Technical Report

Evaluation of the Effects of Climatic Factors on the Occurrence of Diarrheal Diseases and Malaria:

A Pilot Retrospective Study in Jhapa District, Nepal

World Health Organization
Centre for Health Development

World Health Organization
REGIONAL OFFICE FOR South-East Asia

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Thank you

Dr Choplal Bhusal
Executive Chairman
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2. INTRODUCTION

2.1 Background

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and / or the variability of its properties and that persists for an extended period, typically decades or longer". The Earth's average surface temperature has risen by about 0.74 degrees Celsius in the past 100 years and it could even rise by up to 5 degree Celsius by 2080 if the emission of such gases are not decisively reduced (IPCC 2007). It is now universally acknowledged that the climate change we are witnessing will continue for a long time. Clearly Nepal is facing climate change-induced consequences in many spheres of society and development. The data are still scarce and it is difficult to draw clear conclusions for future adaptation measures for Nepal.

Climate change is an emerging risk factor for human health. Human beings are exposed to climate change through changing weather patterns (temperature, precipitation, sea-level rise and more frequent extreme events) and indirectly through changes in water, air and food quality and changes in ecosystems, agriculture, industry and settlements and economy. The IPCC most recent report 2007 which concluded that "Climate change currently contributes to the global burden of disease and premature deaths…At this early stage the effects are small, but are projected to progressively increase in all countries and regions" (IPCC 2007). Human interactions with the natural environment have grown tremendously in the recent centuries. Environmentally significant greenhouse gases are increasing due to both natural and anthropogenic activities and contributing to global warming.

In the early 1990s there was little awareness of the health risks posed by global climate change (IPCC 1990). Nevertheless, the IPCC Second Assessment Report devoted a full chapter to the potential risks of climate change to health (IPCC 1996). In the Third Assessment Report (IPCC 2001) the IPCC concluded that: “Overall, climate change is projected to increase threats to human health, particularly in lower income populations, predominantly within tropical/subtropical countries.”

Climate change has direct and indirect impacts on human health. The Fourth Assessment report (IPCC 2007) has summarized the main health outcomes attributed to climate change as follows:

Human-induced climate change significantly amplifies the likelihood of heat waves, increasing the possibility of heat strokes, cardiovascular and respiratory disorders.

More variable precipitation patterns are likely to compromise the supply of freshwater, increasing risks of water-borne diseases like cholera, and outbreaks of diarrhoeal diseases.

Rising temperatures and variable precipitation are likely to decrease the production of staple foods in many of the poorest regions, increasing risks of malnutrition.

Meeting increasing energy demands by greater use of fossil fuels will add to the number of respiratory disorders, such as asthma.

The increase in frequency and intensity of extreme weather events will translate into loss of life, injuries and disability.

Changes in climate are likely to lengthen the transmission season of important vector-borne diseases (like dengue and malaria) and to alter their geographic range, potentially reaching regions that lack either population immunity or a strong public health infrastructure.

Rising sea levels increase the risk of coastal flooding, and may lead to displacements of population.

Loss of livelihood will increase psychosocial stress in the affected populations.

The health impact of climate change in the context of Nepal is obvious yet more evidence-based data is needed. There is a need of research in national context to understand the actual health problems induced by climate change and formulate the evidenced based adaption strategies. However, there are a lot of research challenges in vulnerable mountainous countries like Nepal to conduct research on climate change and health (Dhimal 2008). The major research challenges are access of information and data, availability of trained human resources, interdepartmental coordination, financial capacity, geographical situation and research methodology.

The first outbreak of dengue occurred in Nepal in 2006. The cross- sectional entomological survey conducted in 2006 identified the presence of *Aedes aegypti* in 5 major urban areas of terai regions bordering with India i.e. Biratnagar, Birgunj, Bharatpur, Tulsipur and Nepalganj. Similarly, entomological survey conducted in Kathmandu valley in 2009 has revealed the presence of *Aedes aegypti* in Kathmandu (Gautam et.al 2009). Previously *A. aegypti* was not recorded in Nepal. The presence of *A. aegypti* in these districts may be attributed to climate change. The outbreak of diarrhoea and cholera in mid-western development region of Nepal in 2009 may be partially blamed for climate change (Bhandari et al 2009). However, everything cannot be blamed on climate change and need in- depth study in our context. The crops plantation and harvesting seasons has been changed due to shifting monsoon season and the frequency of extreme events such as floods and droughts has increased in recent years which may reduce the crop yields and aggravate the problems of hunger and malnutrition. Hotter days (Heat stress) have increased in *terai* regions affecting working hours in agriculture and health.

Vector-borne diseases have been a public health problem in terms of mortality morbidity and the subsequent overall impact on the national economy of Nepal. Vector borne diseases that have important public health implications in the national context include malaria, kala-azar, lymphatic filariasis, Japanese encephalitis and — more recently — dengue. Malaria, once believed to be confined to the forest and forest-fringe areas of the *terai* and inner *terai* regions is now distributed over almost 65 districts of the country. Japanese encephalitis, first identified in 1978, is now present in 24 districts. Kala-azar was not a problem up to 1980 but is now present in 12 districts of eastern and central *terai* regions. One of the reasons for increasing the disease and geographical spread might be the climate change. The increased temperatures due to the climate change may create conducive environment to mosquitoes breeding. More research is certainly needed to discern the attribution of climate change. The following adaptation strategies are recommended for Nepal in order to reduce the health impact of climate change in human health in Nepal (Dhimal and Bhusal 2009).

Strengthening Health System Awareness, capacity building and promotion of local adaptive knowledge

Coordination among the concerned stakeholders and integration of health impact of climate change into broader development plans and related activities and Promoting Research on Climate Change and Health

2.2 Nepal Government Response to Climate Change

Nepal signed the United Nations Framework Convention on Climate Change on 12 June 1992 during the UN conference on Environment and Development in Rio De Jenerio, Brazil. In order to implement the convention effectively, Nepal adopted the Kyoto Protocol (KP) on 11 December 1997. The protocol has entered into force in Nepal on 14 December 2005. Major initiatives taken by the Government of Nepal to address the climate change problems are summarized below:

- Nepal conducted an inventory of GHGs for energy sector based on 1990 data under US Country Studies Program in October 1994.
- The then MoPE (Ministry of Population and Environment) prepared two separate studies on implementation strategy on environment related conventions formulated in 1999, and identified potential linkages between UNCCD, CBD and UNFCCC in 2000.
- The then MoPE organized a workshop on UNFCCC and Institutional Design of the Cooperative Implementation Mechanism of KP in August 2000 in collaboration with UNEP/ROAP and Asian Development Bank (ADB).
- With the assistance of the ADB, the then MoPE implemented Promotion of Renewable Energy, Energy Efficiency and GHG Abatement (PREGA) project which contributed to establish Designated National Authority (DNA) and prepare PINs and PDDs for some CDM projects.
- The then MoPE with the assistance of GEF/UNEP prepared the first initial national communication report with the Parties to UNFCCC and shared with the Parties in 2004. This report has been the building block to initiate climate change activities in Nepal in the spirit of the UNFCCC and KP.
- From 2006 onwards, then the MoEST in collaboration with a number of national NGOs organized public awareness activities including workshops on: (i) capacity building on Clean Development Mechanism (CDM); (ii) capacity building to respond to climate change; (iii) negotiation skills; (iv) pre- and post-Bali conference on climate change; and (v) CDM/DNA.
- In early 2007, the Government of Nepal also prepared a funding proposal for National Adaptation Programme of Action (NAPA) and submitted to GEF/UNDP for funding. The Ministry of Environment has entered into an agreement with UNDP Nepal to implement the Project.
- The Government and Asian Development Bank have entered into an agreement to implement the Strengthening Climate Change and the Environment Project.
- The then MoEST has completed the implementation of the National Capacity Needs Self Assessment (NCSA) Project by December 2008 with the assistance of the GEF/UNDP where climate change is one of the major components.
- The MoEST has also initiated climate change policy formulation process in collaboration with the WWF Nepal program and has completed 6 stakeholder consultations as of April 2009. The fourth meeting of the Climate Change Policy Coordination Committee has decided to conduct studies on: (a) vulnerability and adaptation, (b) GHG emission inventory, (c) carbon sinks and mitigation, and (d) policy and legal provisions.

- The Ministry has constituted a 23-member Climate Change Network (CCN) to coordinate activities and share information. The CCN has been constituted to: (i) identify working areas on climate change amongst the government, NGOs, private and donor organizations; (ii) conduct policy/field level research and studies and implement activities based on the capacity and expertise; (iii) promote CDM related activities, and launch public awareness and capacity building programs; (iv) develop position papers for the Parties meeting and enhance negotiation capacity; and (v) also develop Climate Change Clearing House for easy information sharing. The second meeting of the CCN has identified thematic areas for collaborative works on: (a) carbon financing, (b) adaptation and mitigation, (c) carbon sinks, (d) financial mechanism, (e) knowledge management.
- The MoEST has completed the stocktaking exercise and stakeholder consultations to initiate activities for the preparation of the second national communication (SNC) report. This GEF/UNEP and GoN will shortly enter into an agreement to implement the Project to prepare the Second National Communication under UNFCCC.
- The Government has joined the Pilot Programme Climate Resilience (PPCR) which is under implementation with WB assistance. Nepal has been selected as the eligible country for this PPCR. This program might bring up to USD 50 million to implement climate change program in Nepal.
- The Government has also joined the Japan launched Cool Earth Programme recently. Several projects could be developed under this program.

(Source: www.most.gov.np; accessed on March 2009)

On September 1, 2007 the Health Ministers from 11 Member States of WHO's South East Asia Region 25th Health Ministers Meeting in Thimpu, Bhutan adopted the "Thimpu Declaration on International Health Security in the South-East Asia Region". The Thimpu Declaration recognizes natural and manmade health emergencies, emerging infectious diseases and climate change as threats to international health security. The Declaration calls on countries to develop national mitigation and adaptation plans to address the health impact of global warming and climate change. As a follow up of the declaration, Nepal Health Research Council (NHRC) constituted the 13 members steering committee on Climate Change and Health with wider participation of government sectors, UN organization, International Non-Government Organization and Academic sectors and organized first National Workshop on Climate Change and Human Health: Potential Impact, Vulnerability and Adaptation in Nepal (19-21 December, 2007) with the support of WHO Country office Nepal. From the workshop, it was known that very little knowledge exist on Health impact of Climate Change and fair participation of health sector in climate change issues in Nepal. The workshop identified many uncertainties for health impact of climate change in National Context and identified few research areas for study. NHRC with support of WHO country office Nepal conducted few review studies and retrospective study on climate change and vector borne diseases which show that health impacts of climate change are obvious. There is some degree of association between climatic elements and vector borne and diarrheal diseases in Nepal. On September

9, 2008 the Health Ministers from 11 Member States of WHO's South East Asia Region adopted "New Delhi Declaration on the impacts of climate change on human health" in which members states were committed for accelerating actions to reduce health impacts from climate change in the region. The 27th Health Ministers Meeting of South East Asia Region Member States held in Kathmandu in September 7-9 also prioritized the actions for protecting the health from climate change.

The Ministry of Environment has been preparing the National Adaptation Plan of Action (NAPA) since 2008. NAPA has three components

1. Preparation and dissemination of a NAPA document
2. Development and maintenance of a climate change Knowledge Management and Learning Platform for Nepal and
3. Development of Multi-stakeholder Framework of Action for Climate Change in Nepal

Six thematic working groups (TWG) have been formed and one of them is Public Health Group. The TWGs have been working for preparing the NAPA in Nepal which is expected to be completed by April 2010. Nepal Health Sector Implementation Plan II is under preparation in which climate change component has been tried to be incorporated by Cross Cutting Thematic Working Group.

2.3 Climate Scenario in Nepal

Though Nepal lies near the northern limit of Tropics, a very wide range of climates from subtropical in the southern *terai* to Artic in the northern high Himalayas exists here. The remarkable differences in climatic conditions are primarily related to enormous range of elevation within a short north - south distance. The presence of east west extending Himalayas massifs to the north and monsoonal alteration of wet and dry seasons also greatly contribute to local variations in climate

The country experiences the seasonal summer monsoon rainfall from June to September. Most of the days during June to September are cloudy and rainy. Heavy incessant rain falls and periods of dry spells, however, are not uncommon during these months. About 80% of the annual precipitation in the country falls between June and September under the influence of summer monsoon circulation system. The amount of summer monsoon rainfall generally declines from southwest to northwest. The success of farm and crop production and harvest is dependent on timely summer monsoon; it often causes problems like landslides and large scale floods in the plain areas causing losses of human lives, farmlands and other infrastructures and difficulty in transportation of goods and human beings.

December to February (winter months) in Nepal is relatively dry with clear skies. Occasional spells of rainfall occur during these months. The amount of winter rain fall from northwest to both southwest and eastward direction decreases. Pre-monsoon thunder storms are experienced during the month of April and May, more frequent in hilly areas than in southern plains. October and November is considered post monsoon, a transition from summer to winter.

The annual mean precipitation is around 1600 mm. Owing to great variations in topography, it ranges from more than 5000 mm along southern slopes of Annapurna range in the central Nepal to less than 250 mm in the north central portion near Tibetan plateau.

Maximum temperature of the year occurs in May or early June as onset of monsoon in early June checks the increase in daily temperature over the country. Temperature starts decreasing rapidly from October and reaches maximum December or January. In Nepal there are spatial variations in temperature influenced by topography. Terai belt is the warmest part of country where maximum temperature reaches more than 45^{o}C.

Maximum Temperature observations in Nepal from 1977-1994 showed a general warming trend with significantly greater warming at higher elevations in the northern part of the country than at lower elevations in the south (Shrestha et.al 1999) This finding is reinforced by observations on the other side of the Himalayas on the Tibetan Plateaus (Liu and Chen 2000).

2.4 Jhapa District

Jhapa District, located in Mechi Zone, is one of the seventy-five districts of Nepal. The district, with Chandragadhi as its district headquarters, covers an area of 1,606 km^2 and has a population (2001) of 688,109.

Jhapa is the easternmost district of Nepal and lies in the fertile terai (lowland in southern) plains. It borders Ilam district in the north, Morang district in the west, the Indian state of Bihar in the south and east, and the Indian state of West Bengal in the east.

Its major rivers, like the Mechi River, Kankai Mai, Ratuwa, Biring, Deuniya,(Aduwa), (Bhuteni), (Dhangri), Hadiya and Ninda, Krishne Khola, Gauriya, Ramchandre etc provide water for irrigation. Due to its alluvial soil best suited for agriculture, Jhapa has been the largest producer of rice and is therefore known as the Grain Grocery of Nepal. Besides cereal crops like rice and wheat, it is also one of the largest producers of jute, tea, betel nut, rubber and other cash crops.

Jhapa also has vast areas of forests, such as Deonia, Charali, Charkose Jhaadi, Hadiya, Sukhani, Jalthal, and others. Its name itself is derived from the Rajbanshi (an indigenous ethnic group) word "Jhapa" meaning "canopy", which suggests that the area was a dense forest in the past. It was once such a dense and dangerous forest that it was called Kaalapaani and prisoners were sent here to die of malaria and other diseases in the jungle.

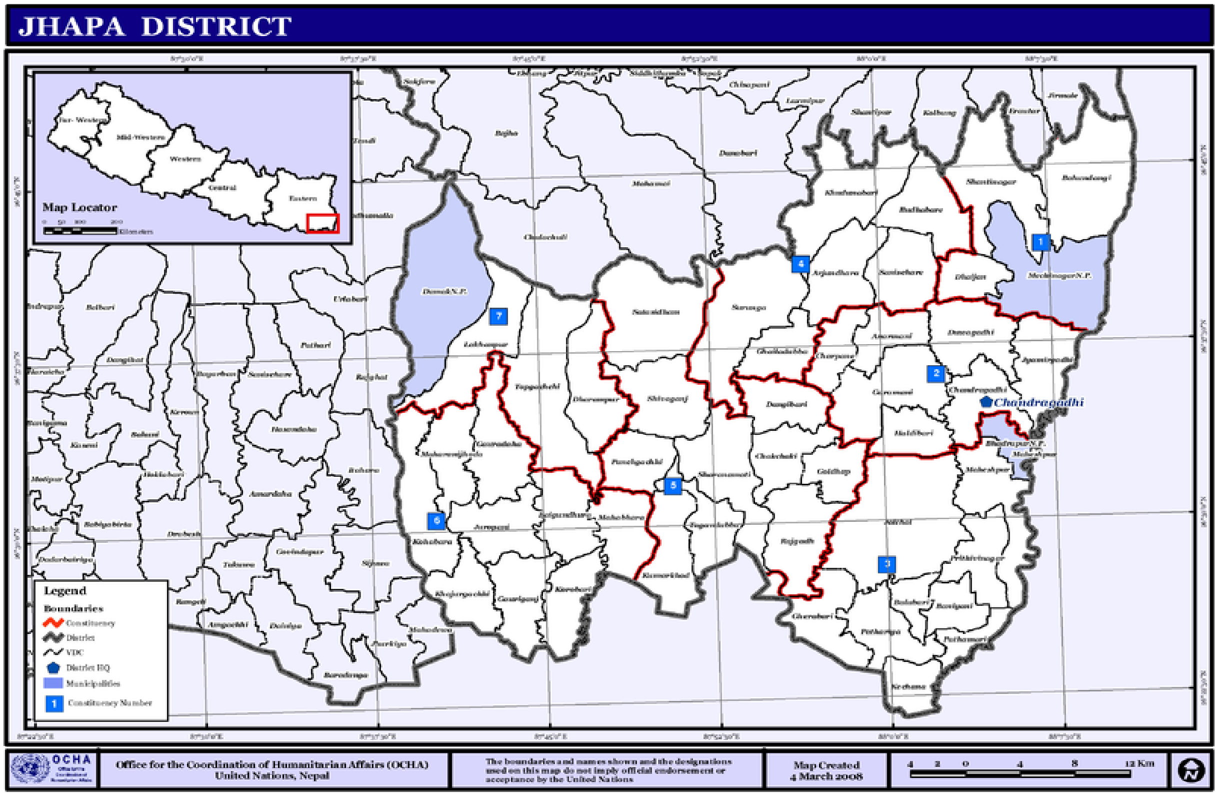

Figure 1 Map of Jhapa District

3. OBJECTIVES

3.1 General

To assess the relationship between climate variability on diarrhoeal diseases and malaria

3.2 Specific

- To assess the relationship between climatic factors (average temperature, rainfall and relative humidity) and diarrhoea
- To assess the relationship between elements of climate change (average temperature, rainfall and relative humidity) and malaria
- To identify and test a range of non-climatic factors that can potentially influence the above

4. METHODOLOGY

4.1 Study design

This was a retrospective study using secondary data analysis. The study design was descriptive longitudinal study from 1999 – 2008 for the period of ten years.

4.2 Study population, sample size and selection criteria

The Jhapa district, eastern region of Nepal, was selected for the study site. The data for other districts were either inaccessible or both the diseases were not prevalent in the same district. Diarrhoeal and vector-borne diseases are prevalent in the Jhapa district. The total population of Jhapa district was 688,109 (CBS Census 2001) with growth rate of 2.1% per year. All cases of malaria and diarrhea were included in the analysis.

4.3 Data collection procedures and instruments

Health related data on malaria and diarrhea were accessed in November 2009 from Management Division of Department of Health Services. The monthly number of cases of diarrheal diseases and malaria were accessed for the period of 10 years from 1999 to 2008. The obtained data were verified by visiting the Jhapa district and accessing the same information from District Public Health Office (DPHO) of Jhapa district. The inconsistent data were then discussed with statistical officer of DPHO and came into consensus after verifying from primary data collection sheet.

Similarly, Climatic element data was accessed in November 2009 from Department of Hydrology and Meteorology (DHM). The data were accessed for the period of ten years from 1999 to 2008. The data obtained from DHM were monthly record on minimum and maximum temperature, total rainfall and morning and evening humidity.

The non-climatic data such as population size and immunization coverage were tried to access from Central Bureau of Statistics and Child Health Division respectively, which later seems difficult to incorporate in the analysis due to its incompleteness. We visited Jhapa district water supply and sanitation division to collect the data, but it was not possible due to lack of recording system.

The data, then, was entered into MS Excel in a standard format and transferred into SPSS 13.0. The analysis was done by calculating correlations and time series analysis (ARIMA) and test of significance was applied accordingly.

5. RESULTS

5.1 Diarrheal diseases

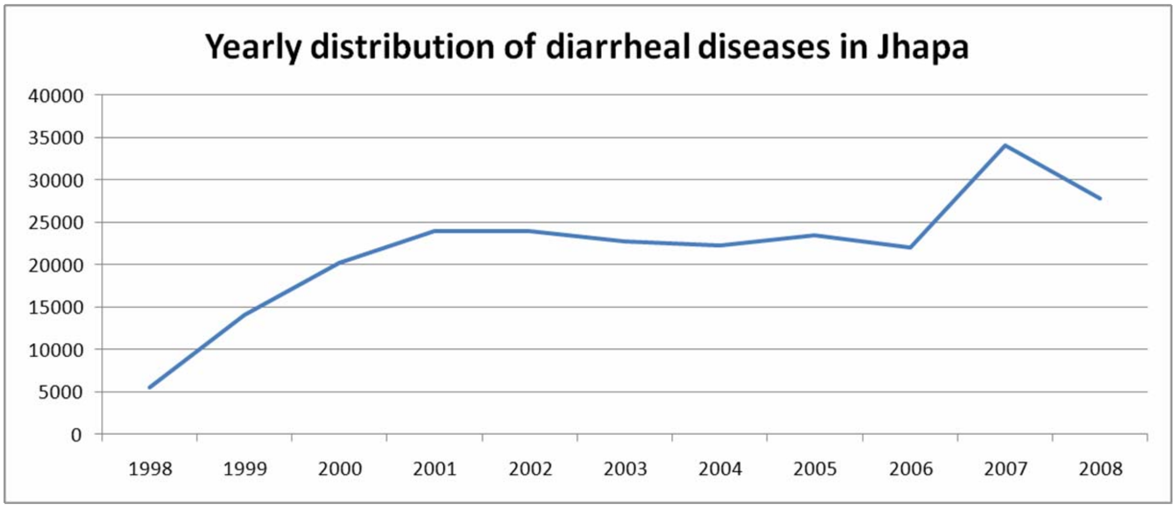

Figure 2 Yearly distribution of diarrheal diseases in Jhapa

Figure 2 shows the yearly distribution of number of cases of diarrheal diseases in Jhapa district from year 1998 to 2008 for the period of ten years. It shows increasing trend from 1998 to 2001 after which the yearly number of cases remain constant till 2006. In the year 2007, the number of cases increases by about 20% from the previous year. The reason for this may be the occurrence of outbreak of diarrheal diseases in Jhapa district in the year 2007 with 900 cases and 6 deaths.

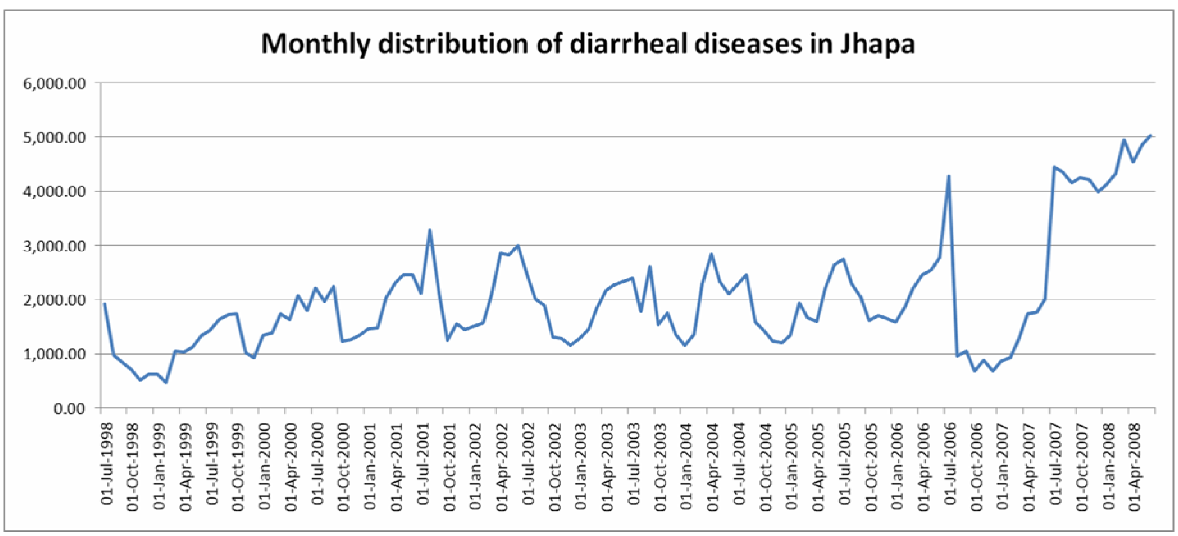

Figure 3 Monthly distribution of diarrheal diseases in Jhapa

Figure 3 shows the monthly distribution of diarrheal diseases in Jhapa district from year 1998 to 2008 for the period of ten years. It shows the disease is endemic in the district and cases appear throughout the year with seasonal rise in diarrheal cases starting from March to November.

5.2 Malaria

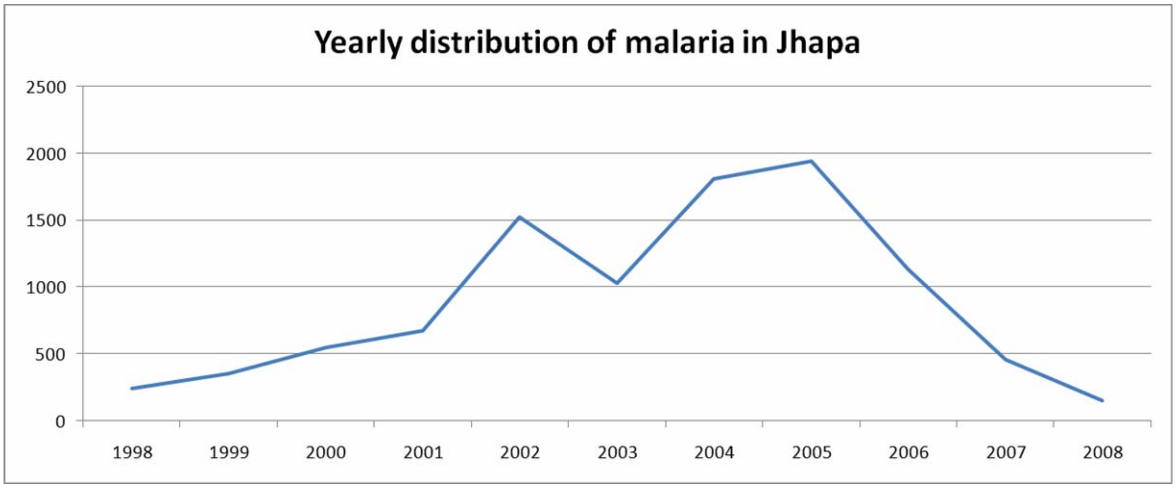

Figure 4 Yearly distribution of Malaria in Jhapa

Figure 4 shows a yearly distribution of number of cases of malaria in Jhapa district from year 1998 to 2008 for the period of ten years. It shows increasing trend from 1998 to 2005 after which the yearly number of cases started declining till 2008. In the year 2005, the number of cases rises up to 2000 which can be explained due to the occurrence of outbreak of malaria in the year 2005. The number of cases in 2008 seems to be fewer because the data for the year 2008 is only up to the month of July.

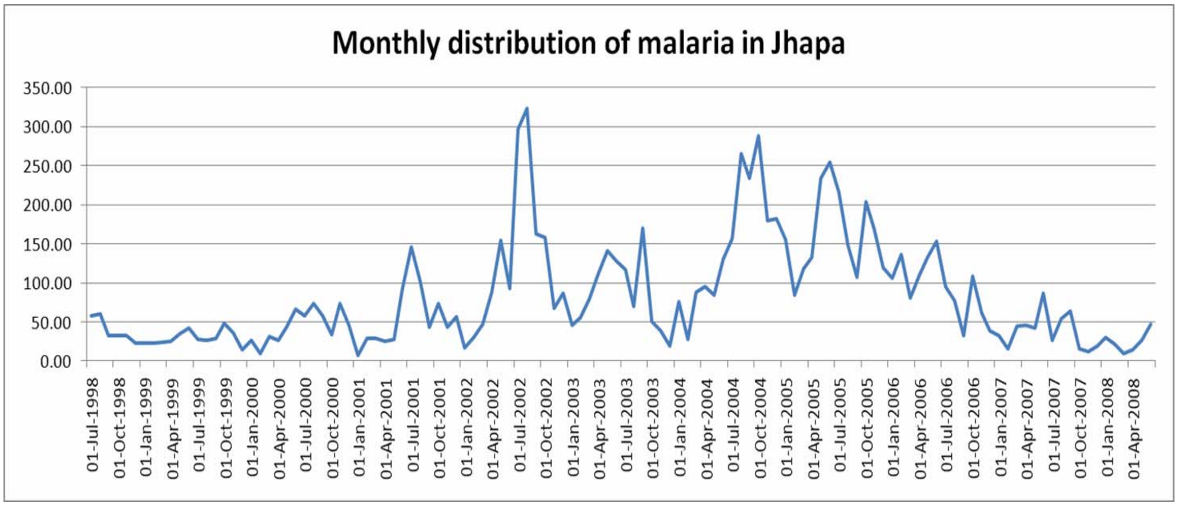

Figure 5 Monthly distribution of malaria in Jhapa

Figure 5 shows monthly distribution of malaria cases in Jhapa district from year 1998 to 2008 for the period of ten years. It shows the occurrence of malaria almost throughout the year with seasonal fluctuations.

5.3 Climate

Climate is the average and variations of weather in a region over long periods of time ranging from months to thousands or millions of years. The standard averaging period is 30 years, as defined by the

World Meteorological Organization (WMO), but other periods may be used depending on the purpose and the data availability. Climate also includes statistics other than the average, such as the extreme values or magnitudes of day-to-day or year-to-year variations. These quantities are most often surface variables such as temperature, precipitation, humidity etc. The climate of a location is often affected by the presence of mountains, ice caps, as well nearby oceans and their associated currents. The main difference between climate and day to day weather is best summarized by the popular phrase "Climate is what you expect, weather is what you get".

5.4 Climate of Jhapa

A study carried out by Department of Hydrology and Meteorology on climatic classification of Nepal by Thornthwaite method shows that the climate types in Jhapa varies from humid to per-humid based on the moisture index and Mega-thermal based on thermal efficiency. For the current study temperature, rainfall and humidity data have been used. The source of these data is Department of Hydrology and Meteorology, which is the only agency in Nepal mandated by the government to monitor all the hydrological and meteorological activities in Nepal. Altogether 5 stations with sufficient number of years of data are available. The description of the stations along with their location is shown in table 1 and figure 6 respectively.

Table 1 Meteorological stations description of Jhapa district

Station	Longitude	Latitude	Elevation (m)	Type
Damak	87.70	26.67	163	Precipitation
Anarmani Birta	87.98	26.63	122	Precipitation
Chandragadhi	88.05	26.57	120	Precipitation
Sanischare	87.97	26.68	168	Precipitation
Gaida (Kankai)	87.90	26.58	143	Agrometeorology

Rainfall is available in all the stations. So, the district monthly, seasonal and annual rainfall has been computed by averaging the rainfall of all the stations from 1984 to 2008. However, temperature and humidity data are available only in Gaida (Kankai) and has been used as a representative of the whole district. Apart from these, since the precipitation stations have a long period of rainfall data, individual station daily and monthly analysis have been done separately. Premonsoon (March-May), Monsoon (June-September), Postmonsoon (October-November) and winter (December previous year – February) are the four categorized seasons used.

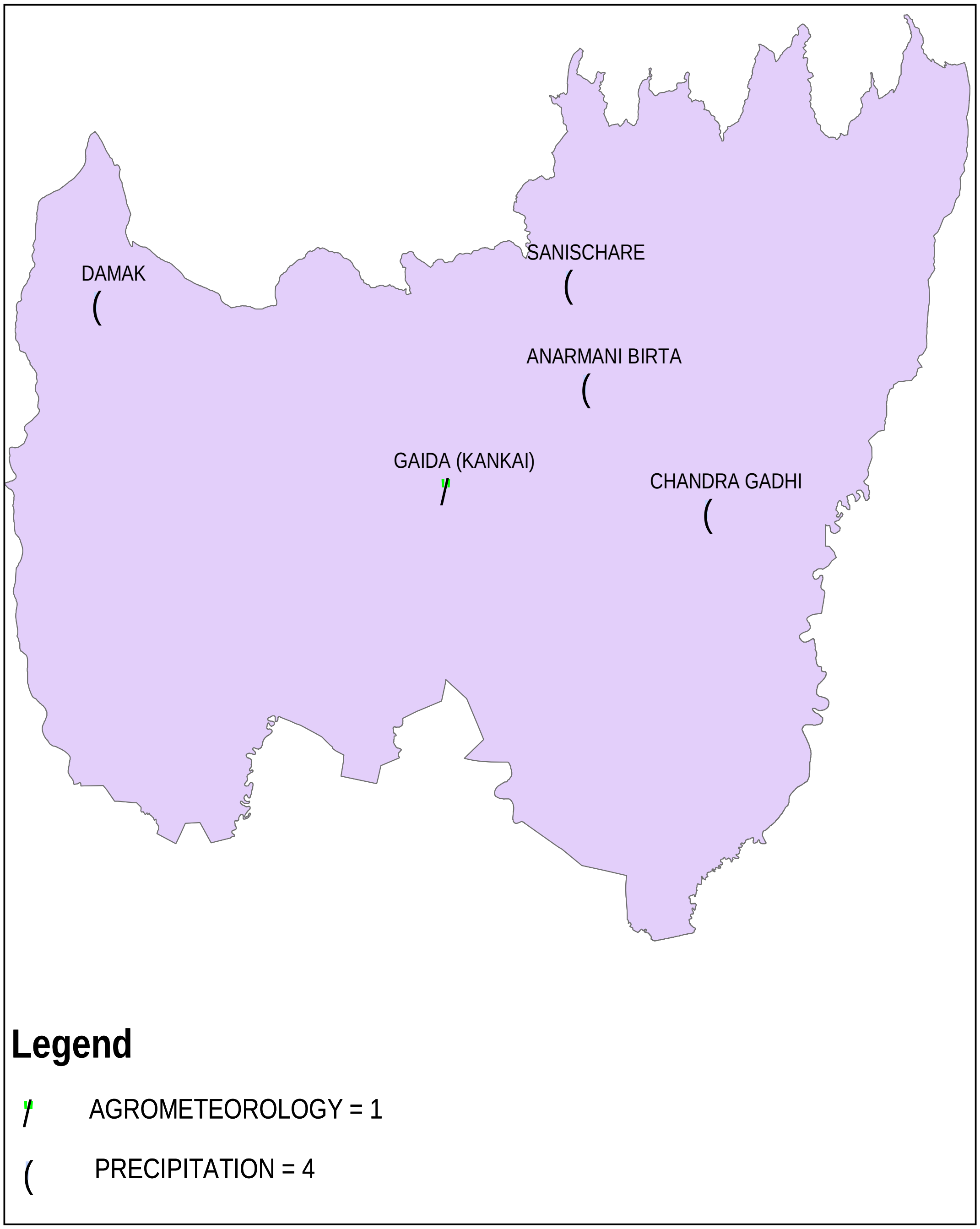

Figure 6 Location of stations in Jhapa district

5.5 Temperature analysis

Jhapa district lies in the Terai belt, the southern plains of Nepal. These southern plains are warmer than rest of the regions of the country. However, even along the east-west Terai belt, the western areas are generally warmer than the eastern areas. Jhapa lies at the south-eastern tip of Nepal. Temperature is lowest during January in the beginning of a year. Temperature then gradually increases as the sun moves from southern to the northern hemisphere and peaks just before the monsoon arrives. Monsoon along with rain and cloudiness checks the increasing scorching temperature. In Jhapa, the maximum temperature is usually over 30 °C from March to October and peaks in April (33.3 °C) during premonsoon season. Minimum temperature on the contrary peaks in August during the monsoon season (Figure 7-8, Table 2).

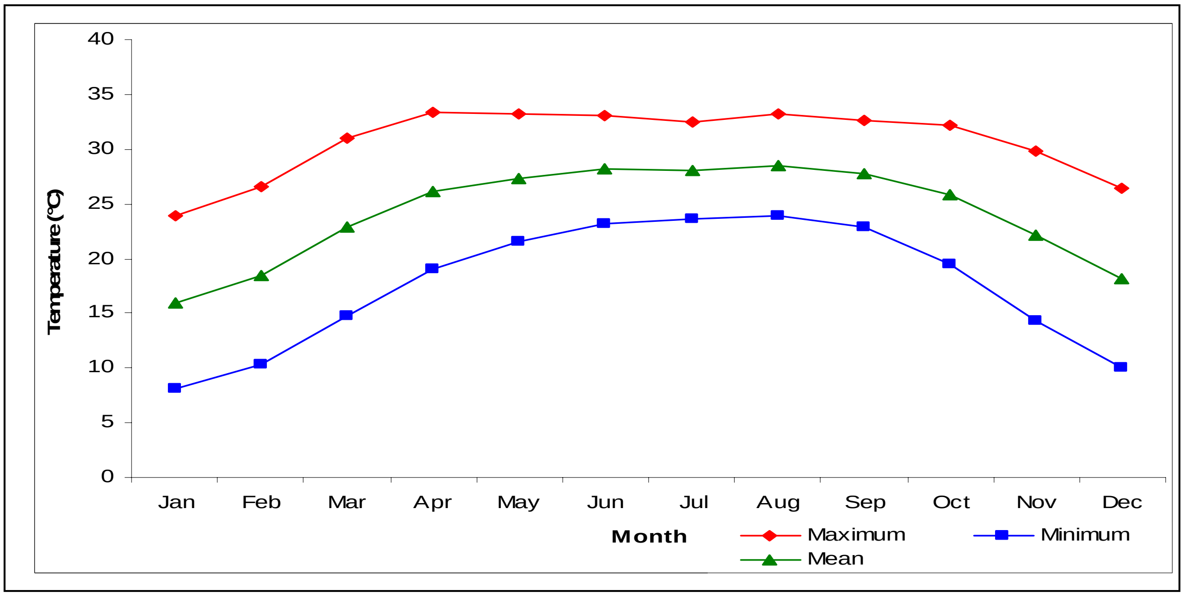

Figure 7 Monthly variation of temperature in Jhapa

Table 2 Monthly mean temperature in Jhapa

Temp (° C)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	23.9	26.5	31.0	33.3	33.2	33.1	32.5	33.1	32.7	32.1	29.8	26.4
Minimum	8.1	10.4	14.8	19.0	21.5	23.2	23.7	24.0	22.9	19.4	14.3	10.0
Mean	16.0	18.5	22.9	26.2	27.4	28.1	28.1	28.6	27.8	25.8	22.1	18.2

The following figure 8 shows the seasonal variation of temperature in Jhapa district.

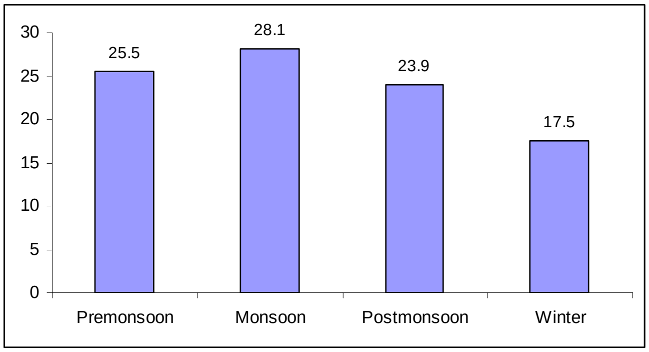

Figure 8 Seasonal temperature variation in Jhapa

During the premonsoon season, the sky becomes clear and the day time temperature reaches at its maximum, but, during the night time, due to the clear sky, longer wave radiation is lost in the space and the minimum temperature drops. However, during the monsoon season the sky remains cloudy most of the time, so the maximum temperature cannot increase further, but, the clouds during the night time absorbs the long wave radiation emitted by the surface and reradiates back towards the surface keeping the night time temperature warm. This is the reason for peaking the maximum and minimum temperature in different months. The mean temperature, the average of the maximum and minimum temperature, in Jhapa is highest during August (28.6 °C).

Season wise, monsoon is the warmest season (28.1 °C), followed by premonsoon (25.5 °C) and postmonsoon (23.9 °C). Winter is the coldest season with 17.5 °C as the mean seasonal temperature.

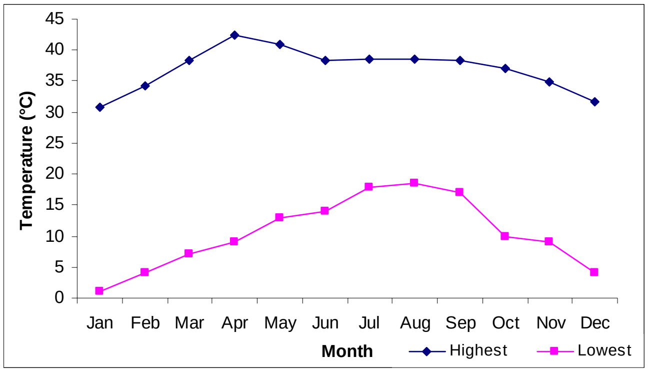

Figure 9 Highest and lowest temperature recorded in Jhapa

Apart from the mean values, the extremes (highest and lowest) also exert significant impacts on human health. Therefore, the highest and the lowest ever recorded temperature have also been computed and depicted in figure 9. The month-wise highest temperature record shows that the highest temperature always exceeds 30 °C, while the lowest temperature remains below 20 °C. The highest ever recorded temperature in Jhapa was 42.5 °C in April 1992 and the lowest temperature was 1 °C in January 1987.

5.6 Rainfall analysis

Rainfall is the most variable meteorological parameter. It has a large month to month, season to season and year to year variation. There are mainly two rain bearing weather systems that affect Nepal, "Monsoon" during the four months of June to September and the "Western disturbances" especially during the winter. Nepal being a mountainous country, the complex topography acts as the controlling factor for the spatial variation of rainfall within the country. Monsoon in Nepal enters from south-east direction and as it gradually moves westward, rainfall also generally decreases from east to west and south to north. During winter, the western disturbances enter Nepal from western parts and therefore rainfall generally decreases from west towards east. During pre and post monsoon seasons rainfall is usually convective type and localized.

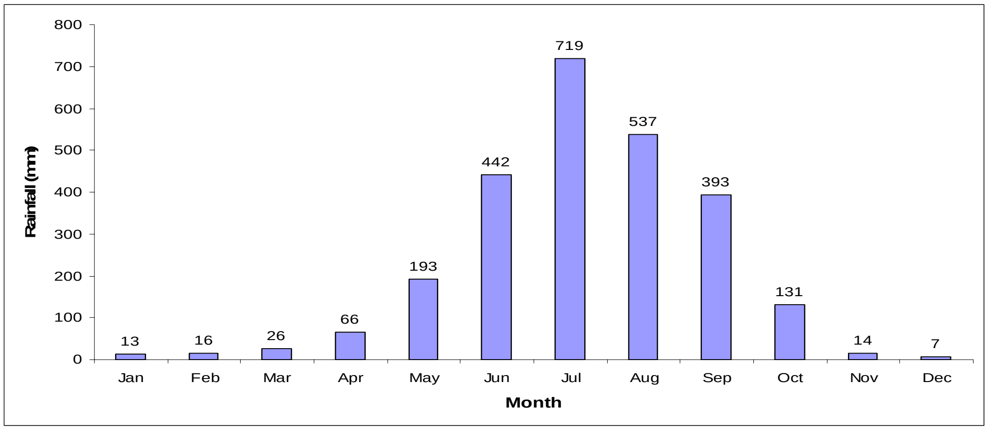

Figure 10 Monthly total rainfall of Jhapa

Monthly total rainfall of Jhapa district (Figure 5) shows that July is the wettest month (719 mm) whereas December is the driest month (7 mm) of the year.

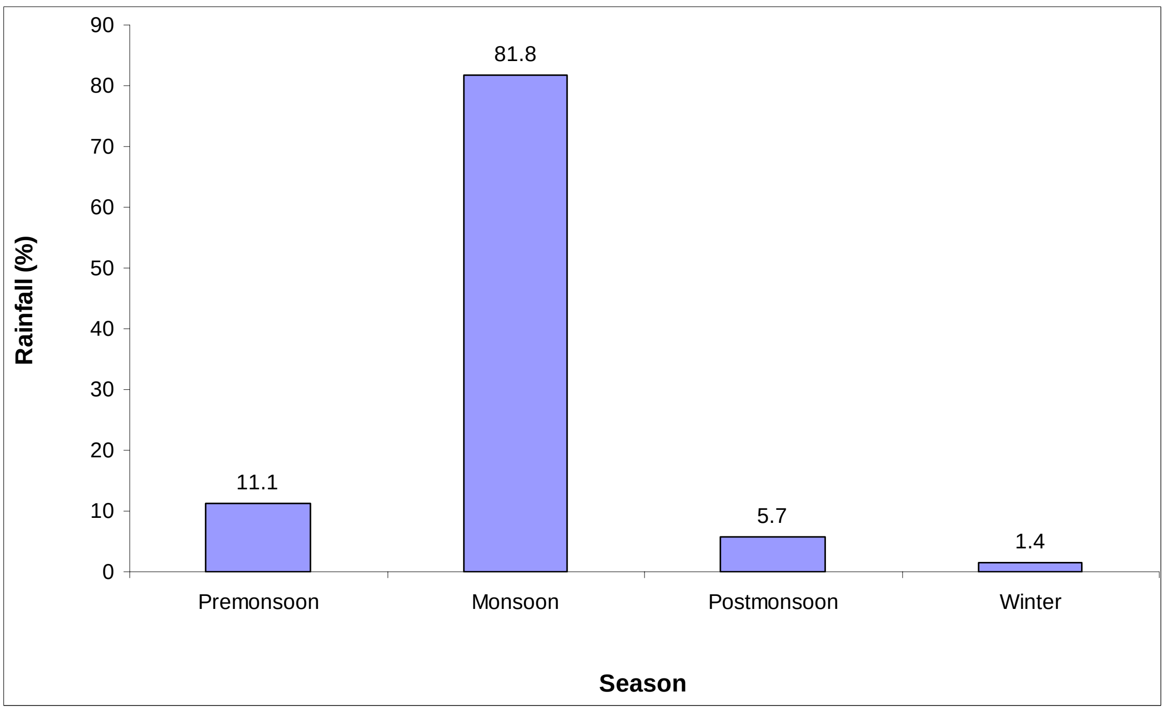

Figure 11 Seasonal contributions in total annual rainfall

The rainy monsoon season contributes (2091.2) mm about 82% of the annual total rainfall (2557.3 mm) followed by premonsoon 11% and postmonsoon 6% (Figure 6). Winter is the driest season which contributes only nearly 1% in the total annual rainfall.

5.7 Relative Humidity

Relative Humidity (RH) is the most commonly used measure of the moisture content in the air. The Relative Humidity is defined as the ratio of the partial vapor pressure to the saturation vapor pressure at a given temperature. By measuring the relative humidity, the actual quantity of water vapor to the maximum quantity of water vapor present in the ambient temperature and pressure is known.

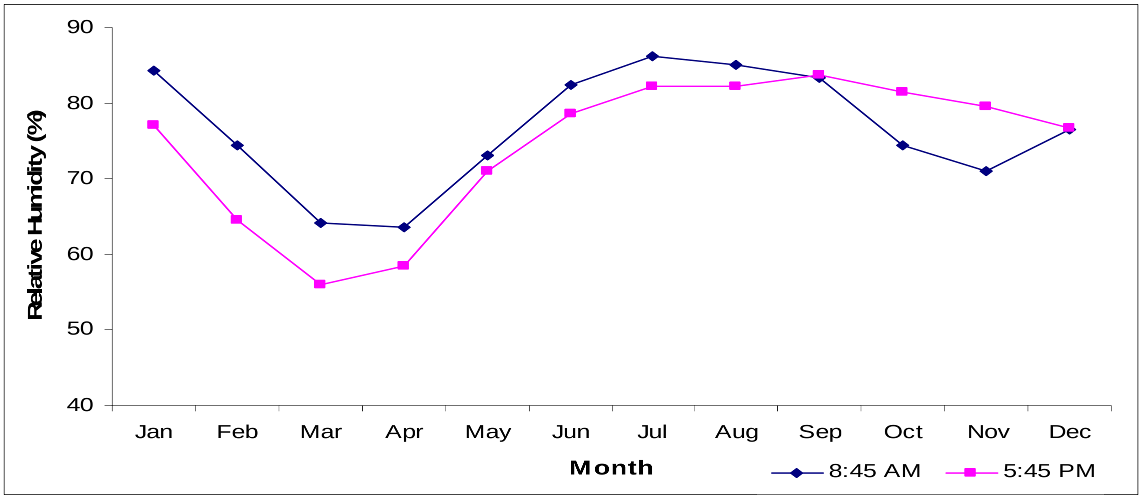

Figure 12 Monthly variation of relative humidity in Jhapa

Relative humidity data is available only twice daily, 8:45 am in the morning and 5:45 pm in the evening. Monthly average relative humidity in Jhapa (Figure 12, Table 3) shows that moisture in the air remains at its lowest during March and April in premonsoon season and highest during the four months of monsoon season. During the January also the relative humidity becomes high, although the water holding capacity in the cold air is less. So the air during the cold days gets saturated even with less moisture content in the air, and the relative humidity gets high, whereas during the rainy and warm monsoon season, the water holding capacity of the air is high and the moisture content in the air is also high. So during the monsoon season both the absolute and relative humidity remains very high.

Table 3 Monthly average relative humidity in Jhapa(1998-2008)

Time	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
08:45 AM	85.0	75.7	64.1	63.9	72.9	82.3	86.0	84.8	83.0	74.9	71.4	77.5
05:45 PM	75.5	64.7	58.3	58.3	70.6	78.1	81.6	81.9	83.0	80.9	78.8	75.7

5.8 Climate change

Climate change refers to changes in the seasonal temperature, precipitation, wind, and humidity for a given area over time. Climate change can involve both cooling and warming. Temperature readings taken around the world in recent decades, and scientific studies of tree rings, corals, and ice cores, show that average global temperatures have raised since the industrial revolution began, with drastic acceleration over the past few decades. The overwhelming consensus among climate scientists is that most of the increase is due to human economic activity, especially the burning of fossil fuels and deforestation. These activities contribute to a build-up in carbon dioxide (CO_2) and other green house gases in Earth's atmosphere increasing the global temperature. Global warming alters the precipitation and wind pattern around the world. The climate change has already been triggered due to the warming of the earth atmosphere system as a recent enhanced greenhouse effect.

Rainfall, temperature and humidity data in the Jhapa district have been analyzed to study the changes in the climate of that region.

5.9 Temperature change

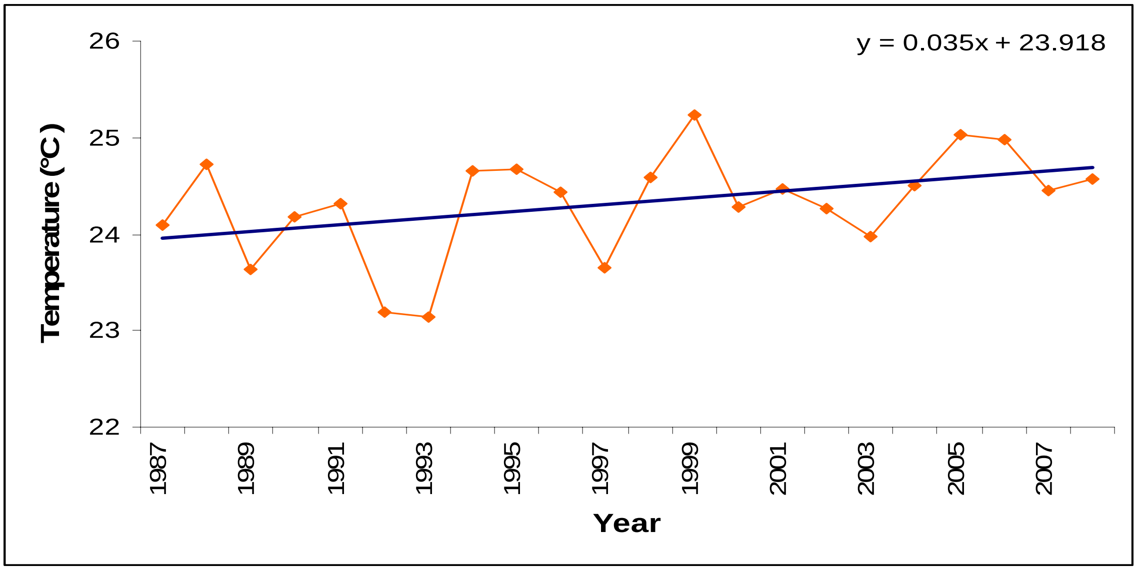

Figure 13 Mean annual temperature trend

A study carried out by Department of Hydrology and Meteorology shows that the mean annual temperature of Nepal is in general in an increasing trend at 0.04 °C/year. But this rate varies from place to place. Generally, the increasing rate is higher at the higher elevation. In Jhapa, the mean annual temperature is increasing in average at 0.04 °C/year (Figure 13, Table 4).

Table 4 Temperature trend in Jhapa

Temperature trend (° C/year)	Premonsoon	Monsoon	Postmonsoon	Winter	Annual
Maximum	0.037	0.072	0.058	0.051	0.060
Minimum	0.002	0.009	0.023	0.058	0.010
Mean	0.018	0.041	0.018	0.054	0.035

This warming trend is equal to the average temperature trend of the country. This increase in the mean temperature is contributed by the increase in both the maximum and minimum temperature (Figure 14 & 15, Table 4). However, the rate of increase in both cases is different. The maximum temperature is warming faster (0.06 °C/year) than the minimum temperature (0.01 °C/year). The maximum temperature during the monsoon (summer) season is increasing quite rapidly at 0.072 °C/year) compared to the rest of the seasons. However, during the winter season the minimum temperature is increasing at faster rate (0.058 °C/year) compared to the other seasons. This is the reason why the day time temperature is getting hotter during the monsoon season and the night time temperature becoming warmer during the winter season. In overall, the mean winter temperature is increasing at higher rate than rest of the seasons.

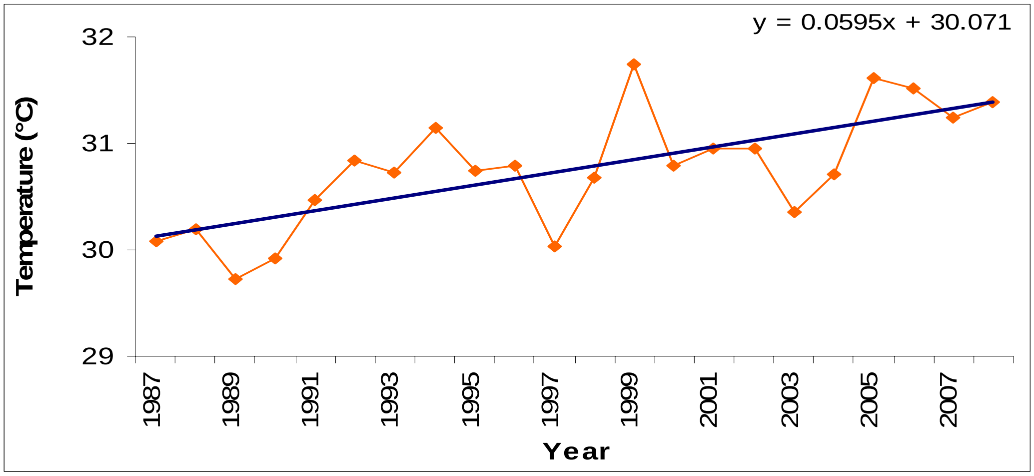

Figure 14 Annual Maximum temperature trend

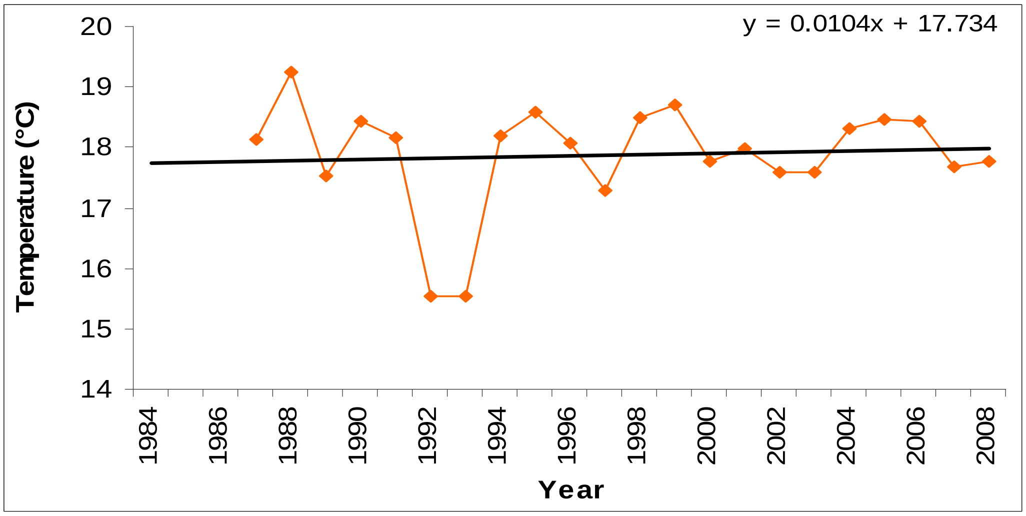

Figure 15 Annual minimum temperature trend

The decadal temperature difference also gives a good idea on the change in temperature taking place from decade to decade. To look at the decadal temperature variation in Jhapa, the average temperature difference between the latest decade (1998-2008) and the previous decade (1987-1997) has been computed and plotted (Figure 16). The figure clearly shows that all the seasons of the recent decade has warmed compared to the previous one. The winter has warmed by 0.69 °C and the premonsoon season has warmed the least by 0.2 °C. Monsoon and premonsoon seasons have warmed by 0.52 °C and 0.47 °C respectively.

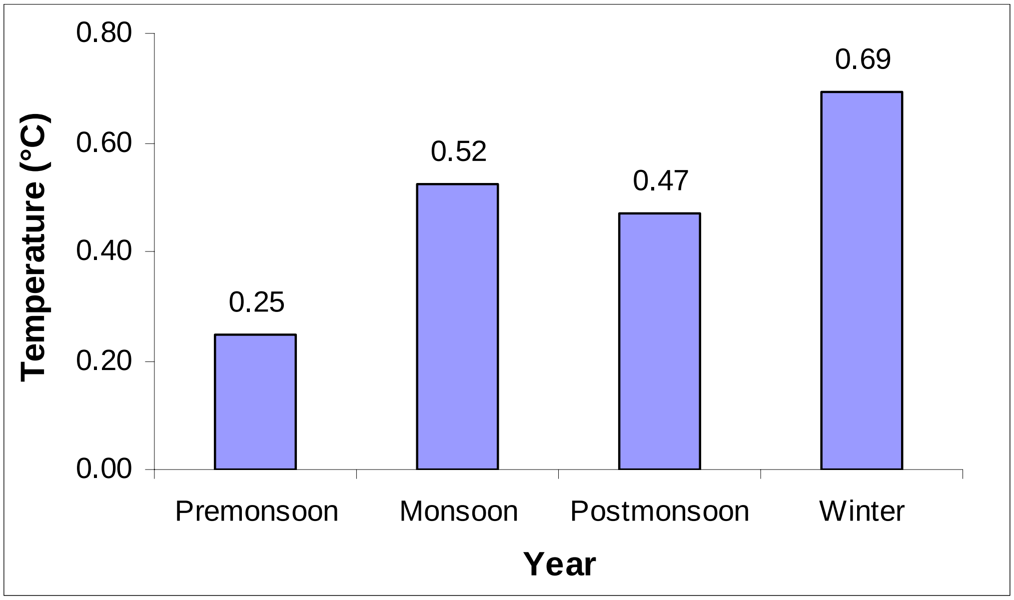

Figure 16 Decadal mean annual temperature difference between (1998-2008) and 1987-1997

5.10 Rainfall change

Due to the global warming, the evapotranspiration increases and thus brings changes in the atmospheric moisture content and the global precipitation pattern. Jhapa district also shows the general increase in both the day time and the night time temperature. But in the contrary, the annual total rainfall is decreasing at an average rate of -7.1 mm/year (Figure 17). Surprisingly, the rainfall in all the seasons is in decreasing trend (Table 5).

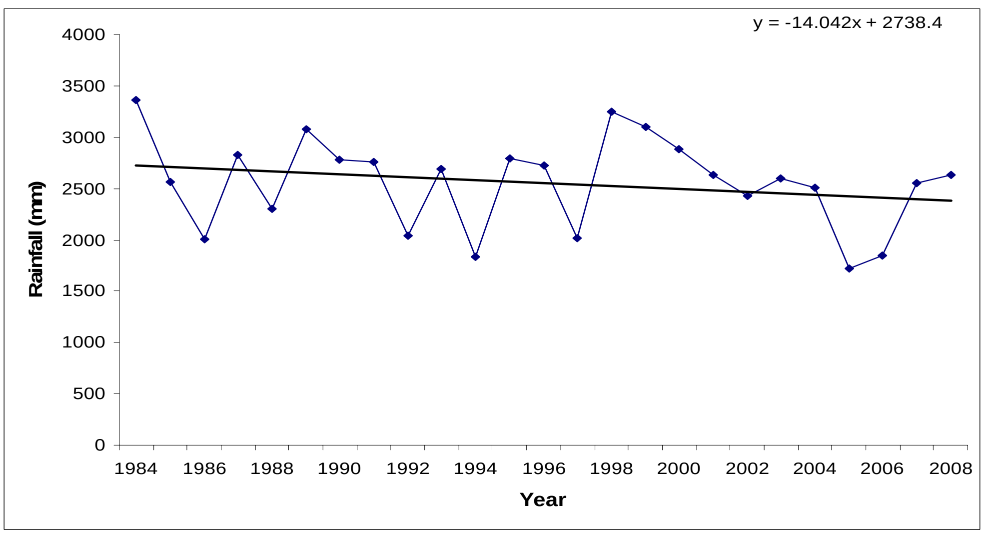

Figure 17 Annual total rainfall trend

Table 5 Seasonal and annual rainfall trend in Jhapa

Rainfall trend (mm/year)	Premonsoon	Monsoon	Postmonsoon	Winter	Annual
	-1.2	-12.6	-0.2	-0.4	-7.1

Even more surprisingly, the monsoon rainfall is decreasing faster (12.6 mm/year) than the rest of the seasons. It seems that the influence of monsoon in the Jhapa district is becoming weaker. To see whether the rainfall is becoming more or less variable, the difference of coefficient of variation (CV) of decadal mean seasonal total rainfall between 1998-2008 and 1987-1997 has been computed and plotted (Figure 18). The result shows that Postmonsoon, winter and premonsoon rainfall have become less variable recently whereas the monsoon rainfall has become more variable. That means the monsoon rainfall is getting unpredictable. This is in consistent with the rapidly decreasing monsoon rainfall compared to the rest of the seasons.

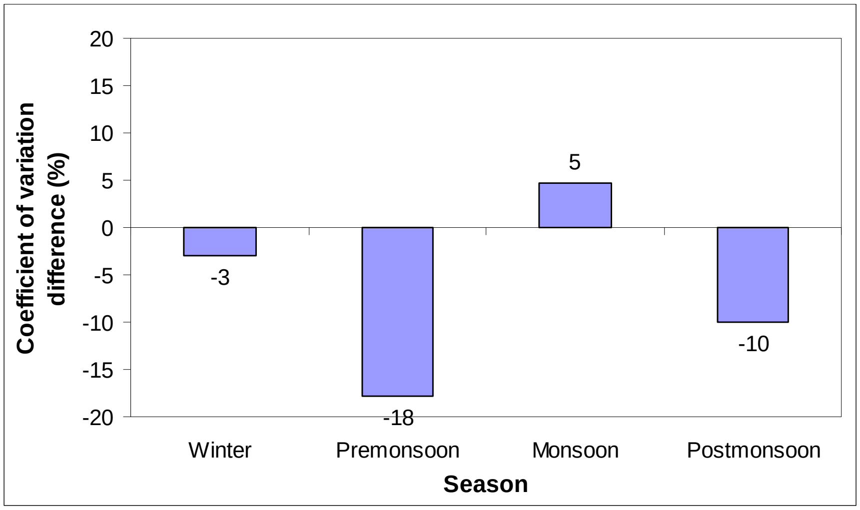

Figure 18 Decadal difference of CV (1998-2008) - (1987-1997)

Rainfall being one of the highly variable of all the meteorological parameters, its year to year variation is large. In total annual rainfall, the variability is often hundreds of millimeters from one year to other. This inter-annual variation in rainfall results in floods and droughts. Figure 19 is the plot of the standardized rainfall anomaly against the year, which depicts the year to year rainfall variation in Jhapa from 1985 to 2008. Rainfall beyond +1 and -1 standard deviation is considered as wet (flood) and dry (drought) years respectively. The record shows that Jhapa experienced more droughts (6 years) than flood (3 years) in the past. 2005 is the year in which the malaria outbreak occurred in Jhapa district happens to be one of the severest driest years on record. The total annual rainfall was less by more than twice the standard deviation.

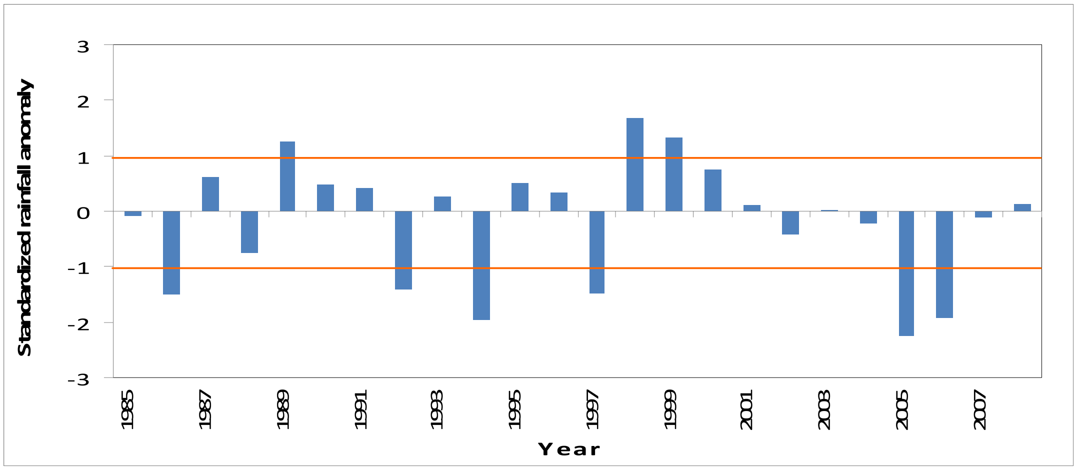

Figure 19 Inter-annual variation of annual total rainfall

5.11 Humidity change

Changes in humidity or the moisture content in the atmosphere depends on the temperature and rainfall change in that area. Relative humidity (RH), by and large has increased in Jhapa district (Figure 19) during the recent decade (1998-2008) compared to the previous one (1987-2007). The changes in the RH in the morning and the evening are not similar. RH at 8:45 am in all the seasons, have increased ranging from 0.2% in the monsoon to 3.8% in the winter season. At 5:45 pm however, RH decreased in winter season by 0.4%, but for rest of the seasons it increased from 0.6% in postmonsoon to 3.2% in premonsoon. The notable fact is that the largest increase in the morning was during the winter season whereas the largest increase in the evening was during the premonsoon season.

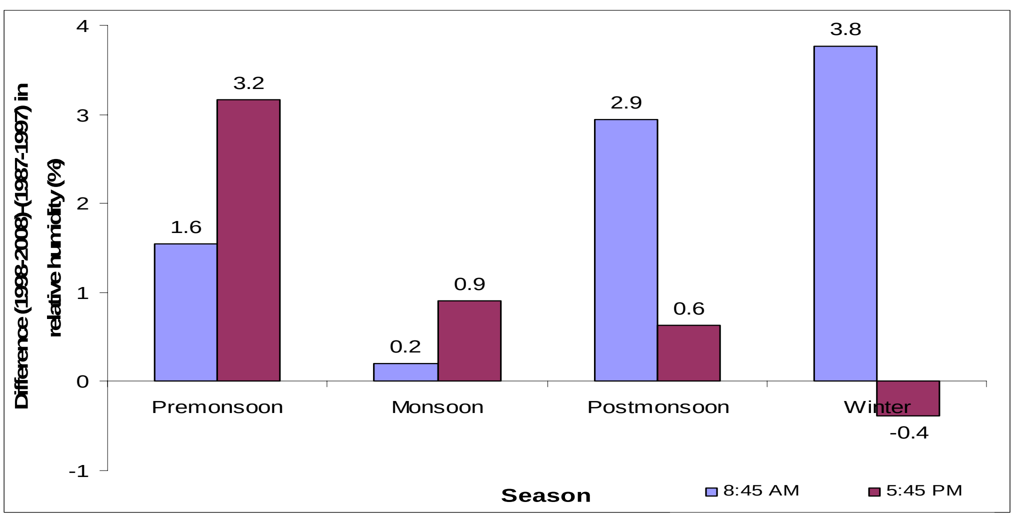

Figure 20 Decadal change in RH (1998-2008) - (1987-1997)

5.12 Relation between climate change and disease

Figure 21 shows the relationship between malaria and maximum temperature in Jhapa district for the period of ten years. The trend of malaria and maximum temperature do not show any increasing or decreasing trend of disease with increase or decrease in the maximum temperature. This can be explained by the fact that the change in temperature is very minimal and difficult to detect in 10 years period.

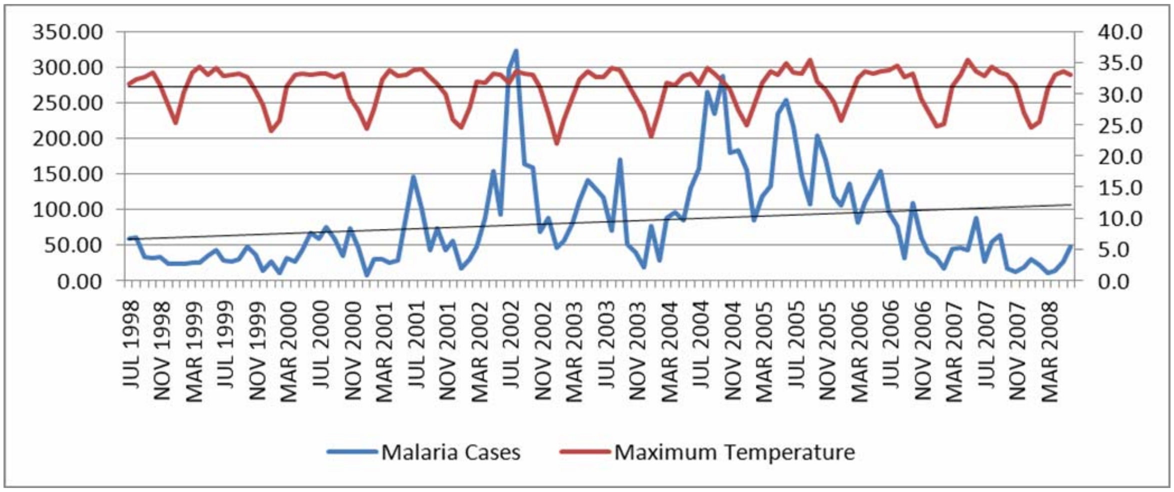

Figure 21 Relationship between Malaria and Maximum Temperature

Figure 22 shows the relationship between malaria and minimum temperature in Jhapa district for the period of ten years. The trend of minimum temperature is decreasing with minimal change whereas the trend of malaria shows increasing which can be explained by the fact that the days in the winter seasons are becoming warmer which may play role positively in the breeding of mosquitoes.

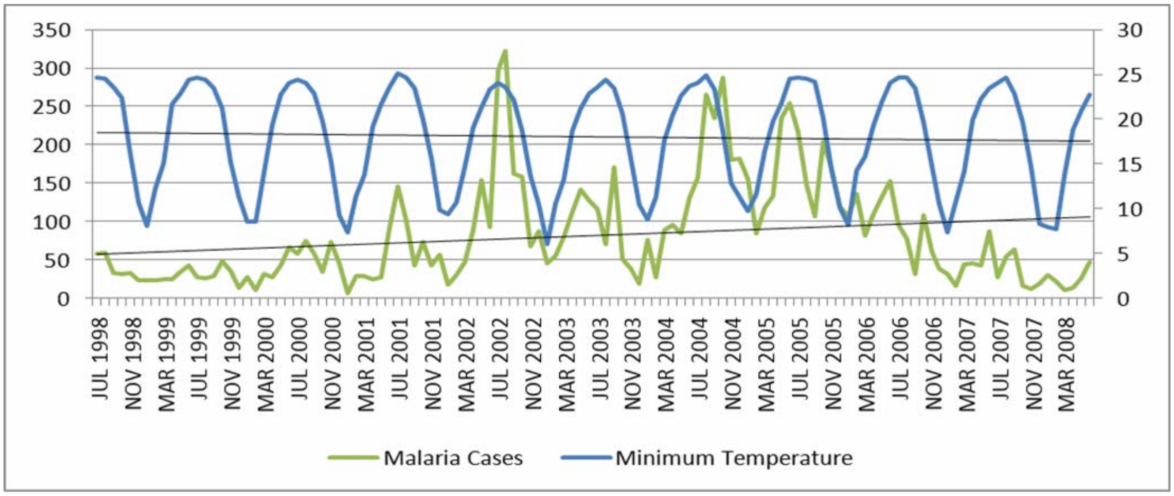

Figure 22 Relationship between Malaria and Minimum Temperature

Figure 23 shows the relationship between malaria and relative humidity at morning in Jhapa district for the period of ten years. Relative humidity shows linear trend without change in 10 years period.

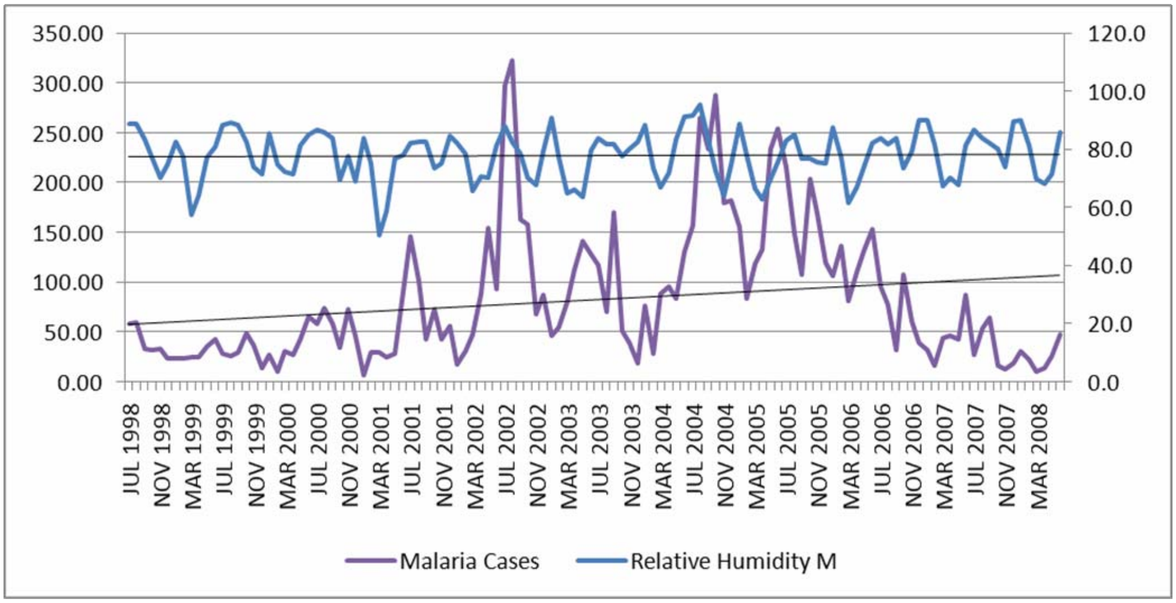

Figure 23 Relationship between malaria and relative humidity of morning

Figure 24 shows the relationship between malaria and relative humidity at evening in Jhapa district for the period of ten years. The trend of malaria shows increasing trend with decrease in the relative humidity at evening.

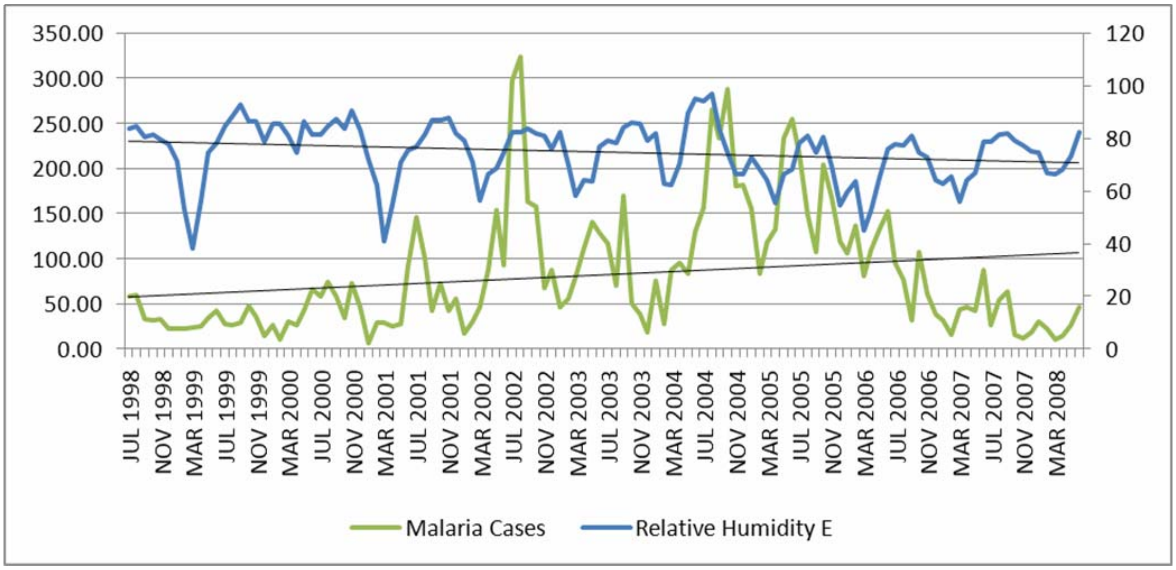

Figure 24 Relationship between malaria and relative humidity of evening

Figure 25 shows the relationship between malaria and total rainfall in Jhapa district for the period of ten years. There is increasing trend of malaria cases with decreasing trend in total rainfall in Jhapa district.

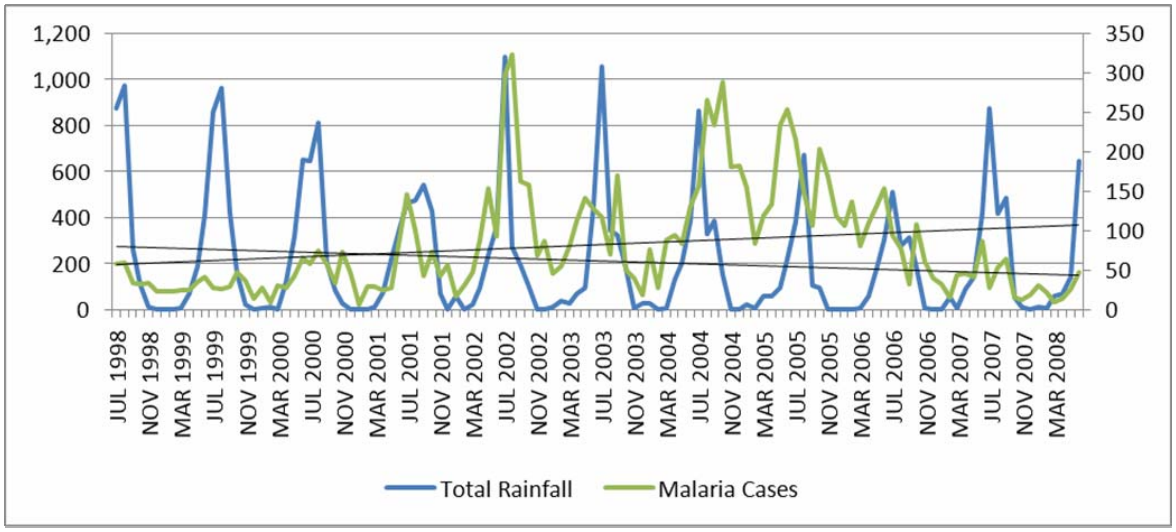

Figure 25 Relationship between malaria and total rainfall

Figure 26 shows the relationship between diarrhea and maximum temperature in Jhapa district for the period of ten years. There is constant increase in the cases of diarrhea with only minimal change in maximum temperature.

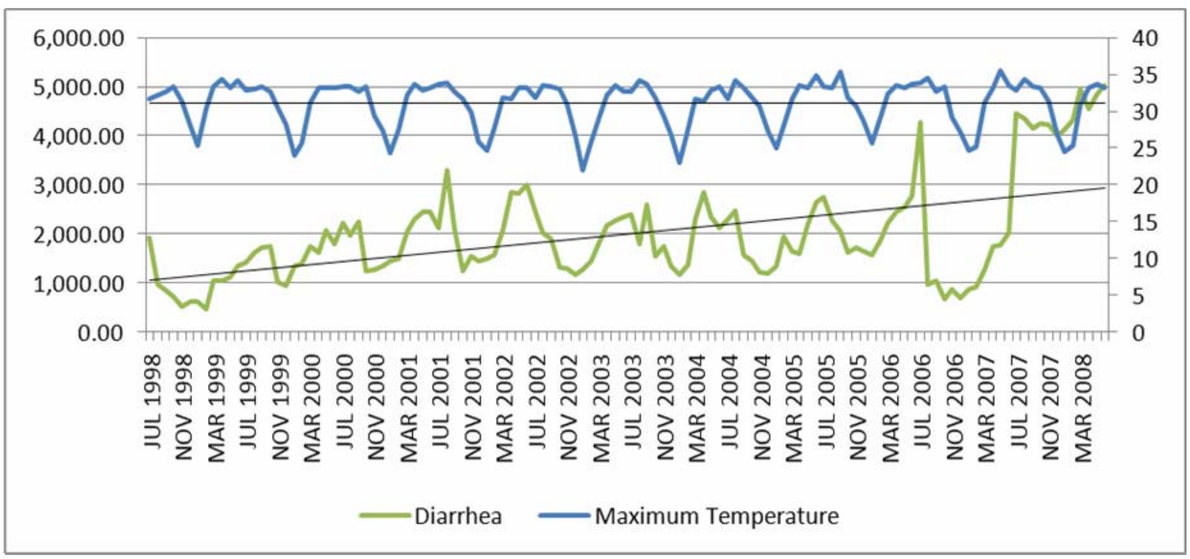

Figure 26 Relationship between diarrhea and maximum temperature

Figure 27 shows the relationship between diarrhea and maximum temperature in Jhapa district for the period of ten years. There is increasing trend of diarrheal diseases with decreasing trend in minimum temperature.

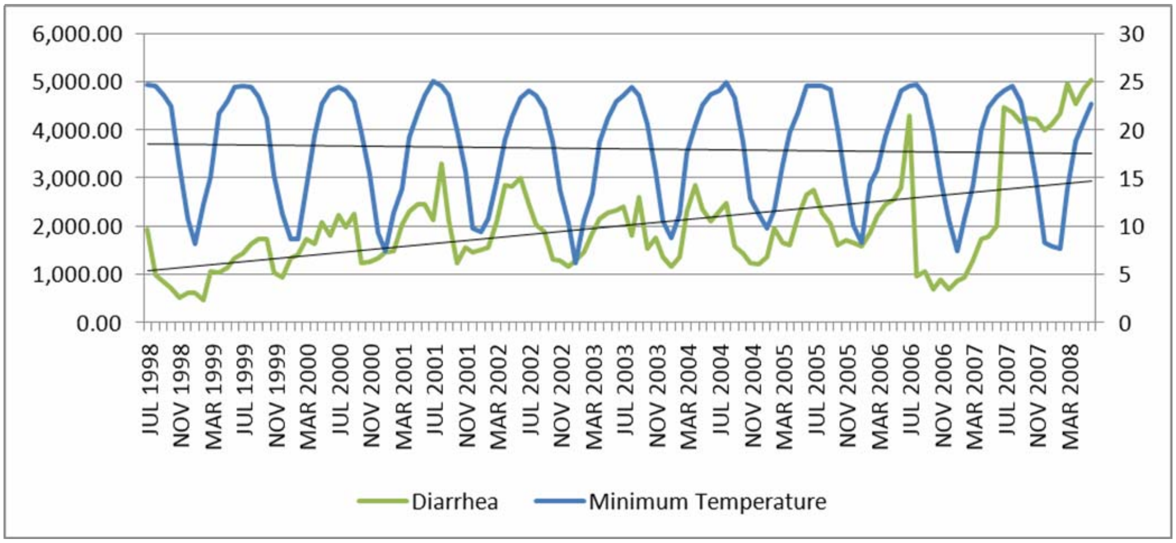

Figure 27 Relationship between diarrhea and minimum temperature

Figure 28 shows the relationship between diarrhea and relative humidity at morning in Jhapa district for the period of ten years. There is no change in morning relative humidity though the diarrheal cases are in increasing trend.

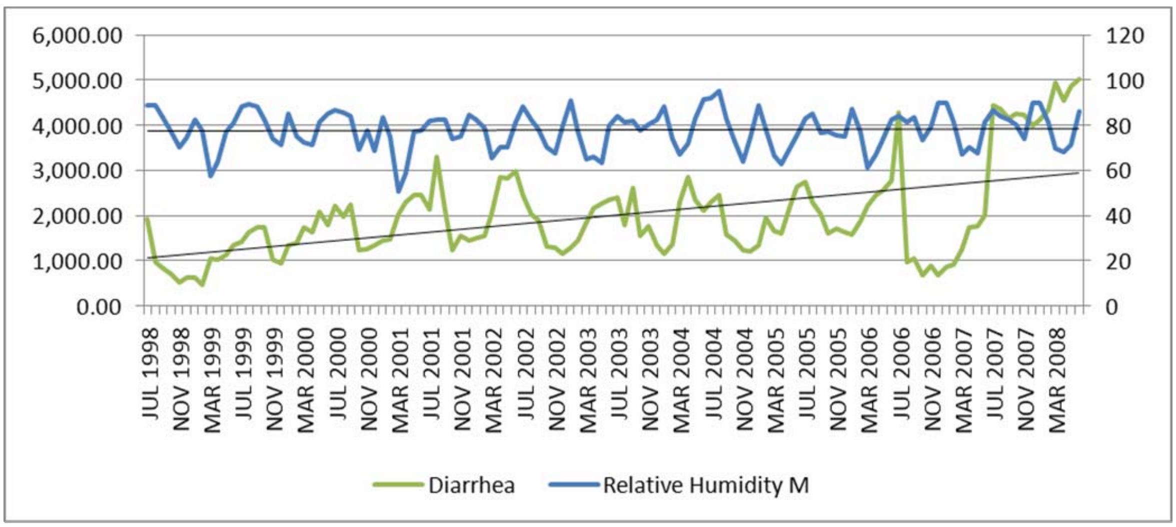

Figure 28 Relationship between diarrhea and morning relative humidity

Figure 29 shows the relationship between diarrhea and relative humidity at evening in Jhapa district for the period of ten years. There is increasing trend of diarrheal diseases with increase in evening relative humidity.

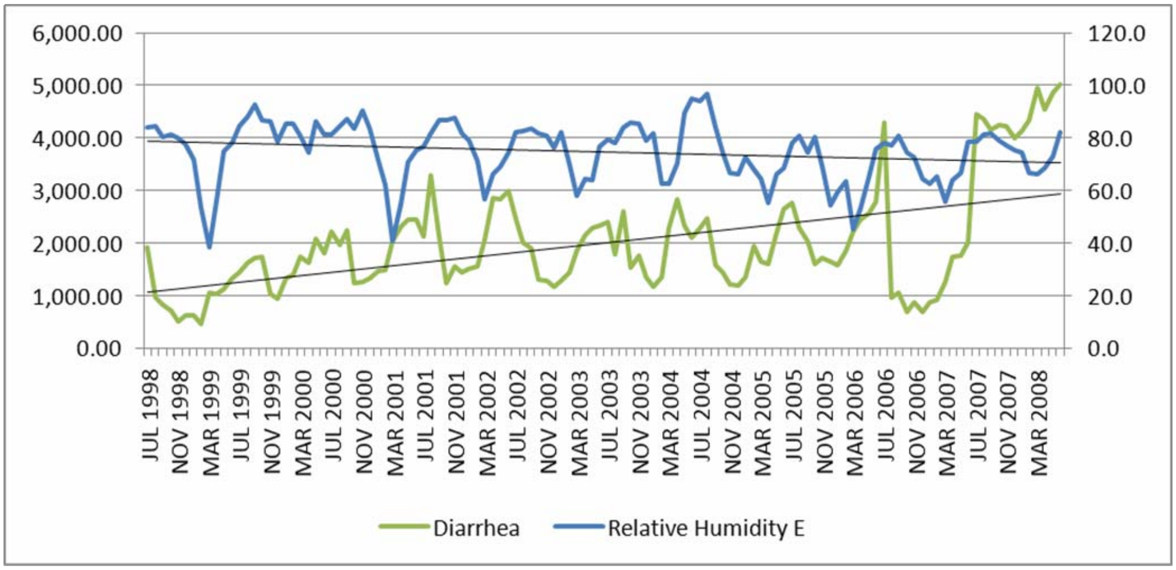

Figure 29 Relationship between diarrhea and evening relative humidity

Figure 30 shows the relationship between diarrhea and total rainfall in Jhapa district for the period of ten years. The number of diarrheal cases has increased with decreasing trend on total rainfall.

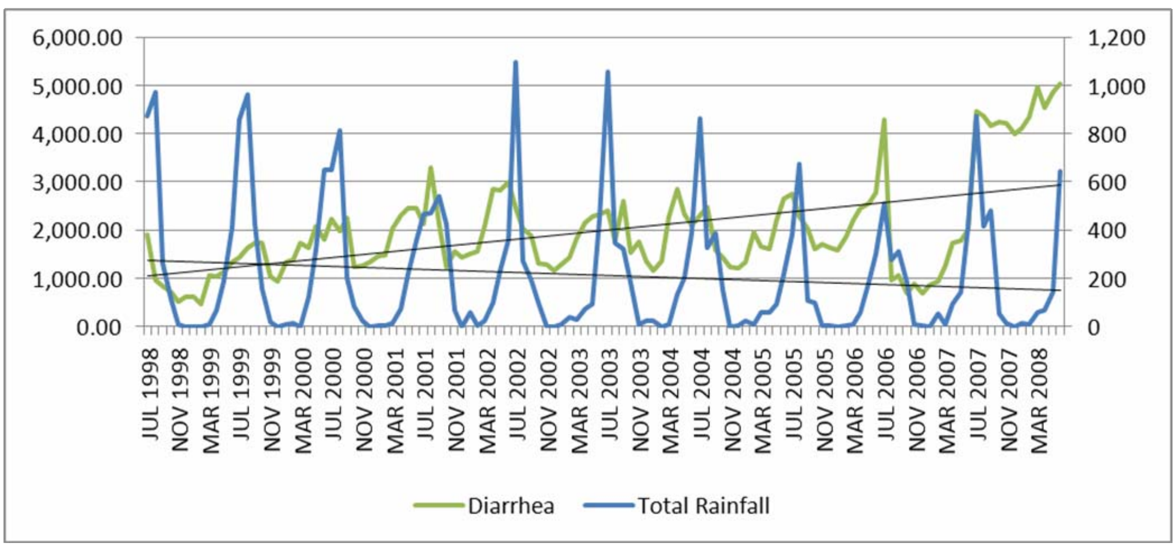

Figure 30 Relationship between diarrhea and total rainfall

5.13 Correlation

Table 6 shows the correlation of climatic variables with malaria. Maximum and minimum temperature and rainfall has positive correlation with malaria which is statistically significance, though the strength of correlation is low. But the relative humidity at morning and evening has not shown positive correlations with malaria.

Table 6 Correlation of Climatic variables with Malaria

	Pearson Correlation	p-value
Maximum Temperature	.284	.002
Minimum Temperature	.338	.000
Relative Humidity (AM)	.065	.481
Relative Humidity (PM)	.076	.408
Rainfall	.202	.027

Similarly table 7 shows the correlation of climatic variables with diarrhoea. Maximum and Minimum Temperature and rainfall has positive correlation with diarrhoea which is statistically significant, though the strength of correlation is low. But the relative humidity at morning and evening has not shown positive correlations with diarrhoea.

Table 7 Correlation of Climatic variables with Diarrhoea

	Pearson Correlation	p-value
Maximum Temperature	.268	.003
Minimum Temperature	.263	.004
Relative Humidity (AM)	.079	.394
Relative Humidity (PM)	.033	.722
Rainfall	.230	.011

5.14 Time Series Analysis

In time series analysis, none of the climatic variables are significant predictors for malaria and diarrhea.

6. NON-CLIMATIC DATA

The non-climatic data such as population size and immunization coverage were accessed with difficulty due to inappropriate reporting and recording system. Though it was accessed, it was difficult to incorporate in the analysis due to its incompleteness. Other non-climatic data like water supply, sanitation and hygiene were also not possible to retrieve due to lack of recording system.

7. SUMMARY

The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and / or the variability of its properties and that persists for an extended period, typically decades or longer". The Earth's average surface temperature has risen by about 0.74 degrees Celsius in the past 100 years and it could even rise by up to 5 degrees Celsius by 2080 if the emission of such gases is not decisively reduced.

The health impact of climate change in the context of Nepal is obvious. There is a need of research in national context to understand the actual health problems induced by climate change and formulate the evidenced based adaptation strategies. However, there are a lot of research challenges in vulnerable mountainous countries like Nepal to conduct research on climate change and health. The major research challenges are access of information and data, availability of trained human resources, interdepartmental coordination, financial capacity, geographical situation and research methodology.

The objective of this study was to assess the relationship between climatic factors with diarrhea and malaria and relate with the non-climatic factors, if possible. This was a retrospective study using secondary data analysis. The study design was descriptive longitudinal study from 1999 – 2008 for the period of ten years. The Jhapa district, eastern region of Nepal, was selected for the study site including all cases of malaria, diarrhea and climatic variables in the analysis. The data for health were accessed from HMIS, Ministry of Health whereas data for climatic variables were accessed from DMH. The data, then, was entered into MS Excel in a standard format and transferred into SPSS 13.0. The analysis was done by calculating correlations and time series analysis (ARIMA) and test of significance was applied accordingly.

The yearly and monthly trend of diarrhea and malaria in Jhapa district is increasing from 1999 to 2008 with seasonal fluctuations. The mean annual temperature is increasing in average at 0.04 °C/year. This warming trend is equal to the average temperature trend of the country. This increase in the mean temperature is contributed by the increase in both the maximum and minimum temperature. However, the rate of increase in both cases is different. The maximum temperature is warming faster (0.06 °C/year) than the minimum temperature (0.01 °C/year). The maximum temperature during the monsoon (summer) season is increasing quite rapidly at 0.072 °C/year) compared to the rest of the seasons. However, during the winter season the minimum temperature is increasing at faster rate (0.058 °C/year) compared to the other seasons. This is the reason why the day time temperature is getting hotter during the monsoon season and the night time temperature becoming warmer during the winter season. Overall, the mean winter temperature is increasing at higher rate than rest of the seasons.

Jhapa district also shows the general increase in both the day time and the night time temperature. But in the contrary, the annual total rainfall is decreasing at an average rate of -7.1 mm/year. Surprisingly, the rainfall in all the seasons is in a decreasing trend.

Relative humidity (RH), by and large has increased in Jhapa district during the recent decade (1998-2008) compared to the previous one (1987-2007). The changes in the RH in the morning and the evening are not similar. RH at 8:45 am in all the seasons, have increased ranging from 0.2% in the monsoon to 3.8% in the winter season. At 5:45 pm however, RH decreased in winter season by 0.4%, but for rest of the seasons it increased from 0.6% in postmonsoon to 3.2% in premonsoon. The notable fact is that the largest increase in the morning was during the winter season whereas the largest increase in the evening was during the premonsoon season.

The trend analyses of climatic and disease data do not show any significant relations. This may be due to the limited number of years (10 years) considered in the analysis. It is known fact that the number of years should be at least 30 years to see the minimum change in climate.

Maximum and minimum temperature and rainfall showed positive correlation with malaria and diarrhea which is statistically significant, though the strength of correlation is low. But the relative humidity at morning and evening do not show positive correlations with malaria and diarrhea.

In time series analysis, none of the climatic variables are significant predictors for malaria and diarrhea.

8. CONCLUSION

Globally, there is direct and indirect impact of climate change on human health. The impact of climate change in human health in Nepal is also obvious. This research was designed and implemented as a pilot project to assess the impact of climate change in human health in one of the district of Eastern Nepal. The finding of this study shows that there is minimum change in climate from 1999 to 2008 and similarly, there is also increase in the number of cases within the same time period. The positive correlation of maximum and minimum temperature and rainfall is detected with both malaria and diarrhea with statistical significance. Whereas, the time series analysis shows that none of the climatic variables are significant predictors for malaria and diarrhea in Jhapa district, Nepal.

9. LIMITATIONS OF THE STUDY

Jhapa is one of the endemic districts for Malaria and Diarrhea where the cases are being reported since 1960. However, there is lack of disaggregated data and even yearly data are not available. The proper reporting and recording of data on diseases was initiated only after the introduction of HMIS reporting system in 1995/1996. Thus, only data of ten years are available for malaria and diarrhea whereas climatic data are available for more than 20 years. This short-duration data cannot give the clear scenario of association between change in climate and diseases. Being a highly endemic district, there are lots of interventions going on such as distribution of Insecticide Treated Nets, insecticide spraying for malaria control, mass media campaign on hygiene and sanitation for diarrheal disease control before the onset of monsoon which have largely helped to reduce the cases of Malaria and diarrhea. Hence, the clear trend on disease cannot be evaluated properly. Similarly, there is Community Based Integrated Management of Childhood Illness Program (CB-IMCI) for control of diarrheal diseases which have helped to control the diarrheal diseases.

10. RECOMMENDATION

There was lack of quality data specifically on health related data in the Ministry of Health, whereas data on climate variables were optimum with good quality. Similarly, data on non-climatic variables were almost impossible to retrieve. So, we strongly recommend conducting a prospective longitudinal study to see the exact impact of climate change on diseases by collecting data ourselves on possible non-climatic factors. This type of prospective longitudinal study with quality data, at least for the period of five years, can be carried out to get the optimum result.

Therefore, there is a need of prospective study to conduct taking three districts from three ecological regions where vector borne diseases including diarrhea are reported after 2000 so as to correlate the association between climate change and communicable diseases.

11. ABBREVIATION

ADB	: Asian Development Bank
CBD	: Convention on Biological Diversity
CBS	: Central Bureau of Statistics
CCN	: Climate Change Network
CDM	: Clean Development Mechanism
DHM	: Department of Health and Meteorology
DNA	: Designated National Authority
DoHS	: Department of Health Services
DHM	: Department of Hydrology and Meteorology
DPHO	: District Public Health Office
GEF	: Global Environmental Facility
GHGs	: Green House Gases
IPCC	: Intergovernmental Panel on Climate Change
KP	: Kyoto protocol
MoEST	: Ministry of Environment Science and Technology
MoH	: Ministry of Health
MoPE	: Ministry of Population and Environment
NAPA	: National Adaptation Programme of Action
NCSA	: National Capacity Needs Self-Assessment
NHRC	: Nepal Health Research Council
NGOs	: Non-Governmental Organizations
PDD	: Pervasive Developmental Disaster
PIN	: Project Idea Note
PPCR	: Pilot Programme Climate Resilience
PREGA	: Promotion of Renewable Energy, Efficiency and GHG Abatement
RH	: Relative Humidity
ROAP	: Regional Office for Asia and the Pacific
SNC	: Second National Communication
TWG	: Thematic working group
UNEP	: United Nations Environment Program
UNCCD	: United Nations Convention to Combat Desertification
UNFCCC	: United Nations Conventions on Climate Change
UN	: United Nations
USD	: United States Dollar
WB	: World Bank
WHO	: World Health Organization
WMO	: World Meteorological Organization
WWF	: World Wildlife Fund

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