CLIMATE CHANGE AND VECTOR-BORNE DISEASES IN BANGLADESH

Institute of Governance Studies

Dissertation submitted in partial fulfillment of the requirements for the degree of Master of Arts in Governance and Development

Submitted by

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MAGD-5, ID-13372001

MA in Governance and Development

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DECLARATION

I do hereby declare that this dissertation entitled "CLIMATE CHANGE AND VECTOR-BORNE DISEASES IN BANGLADESH" is the output of my own research, under the supervision of Dr. Kabirul Bashar, Associate professor, Department of Zoology, Jahangirnagar University, Savar, Dhaka, Bangladesh. The whole dissertation is prepared for academic pursuit and solely aimed for the partial fulfillment for the degree of Masters of Arts in Governance and Development.

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CERTIFICATE

I hereby recommend and certify that this dissertation entitled "CLIMATE CHANGE AND VECTOR-BORNE DISEASES IN BANGLADESH" is a research work conducted by Mohammed Jahedur Rahman, MAGD-5, ID-13372001, under my supervision for partial fulfillment of the requirements for the Degree of MA in Governance and development, BRAC University, Dhaka, Bangladesh.

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Dedicated

To

My Beloved Parents

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Author

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List of Abbreviations and Acronyms

ADB - Asian Development Bank

API - Annual Parasite Index

BIRDEM - Bangladesh Institute of Research & Rehabilitation in Diabetes, Endocrine and Metabolic Disorders

BMD - Bangladesh Meteorological Department

CFR - Case Fatality Rate

DG - Director General

GoB - Government of Bangladesh

ICDDR,B - International Centre for Diarrhoeal Disease Research, Bangladesh

MOEF - Ministry of Environment and Forest

NGO - Non-Governmental Organization

NIPSOM - National Institute of Preventive and Social Medicine

WHO - World Health Organization

ABSTRACT

Background

Climate change is an occurring phenomenon that creates extreme weather patterns and these weather patterns have a direct impact on vector-borne diseases. The relationship between climatic factors and vector-borne diseases is very important to determine parasite activity levels and disease risk. Therefore, the present study was conducted to explore the effect of climatic change on the transmission of vector-borne diseases in Bangladesh.

Methods

Thirty years climatic data (temperature, rainfall, and humidity) were collected from the meteorological department of Bangladesh. Morbidity and mortality data of different vector-borne diseases were collected from the office of Director General of Health (DG Health) of Bangladesh. Data were analyzed using SPSS to find out the association between climatic variables and vector-borne diseases.

Results

From linear regression analysis we found an upward trend of both in mean (r^2=0.402), maximum (r^2=0.225) and minimum (r^2=0.412) temperature. Yearly average humidity failed to show a constant trend (r^2=0.30). We did not found any upward or downward trend of rainfall (r^2= 0.03) in Bangladesh. From Pearson correlation test we found weak association between the climatic variables and the vector-borne diseases. We did not found significant relation with climatic variables and dengue (P>0.05), malaria (P>0.05) and Kala-azar (P>0.05) after generating mathematical model.

Conclusion

Our study demonstrates that the climatic variables do not have significant effect on the transmission of the aforementioned vector borne diseases in Bangladesh. Multiple environmental factors are may be responsible for diseases transmission. This study recommends government authority to cautiously consider complex nature of relationship between diseases and climatic factors. Detail studies of vector bionomics, continuous monitoring and disease transmission dynamics is essential for predicting outbreaks of diseases and if necessary, control of vectors in Bangladesh.

Keywords: Climatic Variables, Vector-borne Diseases, Temperature, Rainfall, Dengue, Kala-azar, Malaria.

Chapter 1

Introduction

Introduction

1.1 General Introduction

There is near undisputed scientific consensus that the rising atmospheric concentration of greenhouse gases owing to human activities will cause warming (and other climatic changes) at Earth's surface. The Intergovernmental Panel on Climate Change (IPCC) revealed an increase in world average temperature by 2100 within the range 1·4–5·8ºC (IPCC, 2001). The increase will be greater at higher latitudes and over land. Global average annual rainfall will increase, although many mid latitude and lower latitude land regions will become drier, whereas elsewhere precipitation events (and flooding) could become more severe. Climate variability is expected to increase in a warmer world (McMichael et al., 2006). WHO estimates that in recent years around 150 000 lives per year have been lost as a result of temperature and rainfall changes (Campbell-Lendrum et al., 2003) and risk from climate change will be more than double by 2030 (WHO, 2002).

Bangladesh is a disaster prone country. A recent study shows that at least 174 natural disasters affected Bangladesh from 1974 to 2003 (Sapir et al., 2004). Almost every year, the country experiences disasters of one kind or another—such as tropical cyclones, storm surges, coastal erosion, floods, and droughts—causing heavy loss of life and property and jeopardizing the development activities. For example, the total death caused by flood in 2004 was about 800 while cyclone of 1991 killed 138,000 people of Bangladesh (BCAS, 1991; ADB, 2004). The country is already overwhelmed with many problems like high population density, shortage of land to accommodate the people, food security, human health, illiteracy, and so forth. The above mentioned types of disasters make the problems all the more complicated. In the projected future, Bangladesh is likely to be one of the most vulnerable countries of the world due to climate change. Climate change related impacts including flood, drought, sea level rise, salinity, temperature and rainfall variations etc. have become major concern due to its long-term implications and undesirable effects on development activities. The developing and underdeveloped countries like Bangladesh are most vulnerable to climate change and climate variability of direct impact on economic, social and development sectors. Almost every sector of socio-economic life in Bangladesh is likely to be affected by climate change (Ali, 1999).

Observational evidence shows that many natural systems are being affected by these changes, and the IPCC AR4 suggests that some changes to the health of the world's population can be attributed to climate change (IPCC, 2007).The consequences of climate change to health are both direct and indirect with some being already experienced and others yet to come. Climate change is likely to have various effects on health, including changes in distribution and seasonal transmission of vector-borne diseases (McMichael and Githeko, 2001).

Vector-borne diseases are infectious diseases spread by intermediate organisms, such as insects and snails that transmit viruses, parasites and bacteria to human .they are most commonly found in tropical areas and places where access to safe drinking-water and sanitation systems is problematic. at the dawn of the 21^{st} century, vector-borne diseases still cause a severe threat to human health. Out of about 11 million annual deaths to infectious diseases (about 19% of total annual deaths), 1.43 million can be attributed to vector-borne diseases (including malaria, trypanosomiasis, chagas disease, leishmaniasis, lymphatic filariasis, onchocerciasis, dengue and Japanese encephalitis). Among these, 1.30 million are caused by mosquito-borne diseases (WHO, 2004). The leader of this deadly procession is malaria, with an annual death levy of 1.27 million (WHO, 2004). Important mortality is also caused by trypanosomiasis (around 51000 deaths per year), leishmaniasis (around 51000 deaths) and dengue (19000 deaths) (WHO, 2004). A study showed that at least 3000 million people of all tropical countries are exposed to the risk of dengue while 2400 million tropics and subtropics are at risk of malaria (IPCC, 2001; Githeko and Woodward, 2003).

One concern to human health in the future is the potential for an increase in the incidence and intensity of the transmission of some vector-borne diseases (Confalonieri et al., 2007). According to IPCC (2001), global warming would cause increase of vector borne and water borne diseases in the tropics (IPCC, 2001). The spread of diseases by insect vectors is influenced both directly and indirectly by a range of environmental variables in a variety of different ways and these effects can be either immediate or act in a cumulative way. Development rates, activity levels and survival of individual insects and timing of emergence, distributions, abundance levels and migrations of populations are determined to differing, but often very significant, extents by weather and climate (Martens et al., 1995; Chan et al., 1999; Sutherst, 2004). The pathogen spread by the vector is itself also regulated by climate, generally reproducing at a faster rate under warmer conditions (Mellor, 2000). The effect of temperature on the duration of the sporogonic cycle of the malaria parasite and vector survival is mostly important (Tanser et al., 2003). Precipitation changes are also known to affect the reproduction, development, behavior, and population dynamics of arthropod vectors, their pathogens, and non-human vertebrate reservoirs (Gage et al., 2008). *As vector-borne diseases are highly susceptible to environmental conditions, it would therefore appear they are likely to respond rapidly to a change in climate* (Confalonieri et al., 2007).

If the public health infrastructure does not anticipate the effects of climate change on infectious diseases, millions of people could die. Climate change is a global issue and must be dealt with before things go irrevocably wrong. There were some researches and studies on climate change and its impacts in Bangladesh at different times by both government and non-government organizations/institutions. *But research on the impacts of climate change on human health in Bangladesh has not gained much focus and is still far from clear*. In part, this uncertainty reflects difficulties in predicting the local effects of global changes in climate on human health. Even if we were certain about future local climates, there is still uncertainty over what impact these climates would have on health. A little research had been done on the impact of climate change on vector-borne disease risk and governance system in Bangladesh to minimize this impact. *The focus of this study is to determine the possible link between climate change and vector borne disease, and to find out possible governance system for the minimization of vector borne diseases due to climate change in Bangladesh*.

1.2 Significance of the Study

Because of rising temperatures and changing rainfall patterns, climate change is expected to have a substantial effect on the burden of infectious diseases that are transmitted by insect vectors and through contaminated water. Insect vectors are likely to be more active at warmer temperatures. For instance, tropical mosquitoes such as *Anopheles* species, which spread malaria, require temperatures above 16°C to complete their life cycles (WHO, 1997). Some vector borne diseases such as malaria are also thought of as water-vectored diseases, since mosquitoes typically flourish in aquatic habitats, where they lay their eggs in water-filled containers. Thus, epidemics of malaria tend to occur during rainy seasons in the tropics. Similarly *Aedes* mosquitoes can bread in fresh rainy in water-filled containers and causes epidemic outbreak in Bangladesh especially Dhaka.

The World Health Organization (WHO) has published a data showing the impact of climate change on human health (WHO, 2009). This data shows that developing regions of the world like Bangladesh have been disproportionately affected by climate change relative to developed regions. The WHO report also includes estimates of the future global burden of disease that will result from climate change.

Although governments must take the lead in tackling climate change, it believes that it is also the responsibility as a government officer to do the own part. Therefore, it must also focus the efforts on mitigating the effects of climate change, including its potential impact on the global burden of vector-borne diseases. Additional research is needed on the ecology and epidemiology of vector-borne diseases that will probably be affected by climate change.

Currently there are few if any published data that provide such information, partly because the science of climate and health is not well developed. The fraction of changes in vector-borne diseases attributable to climate change is therefore still unknown. This is a serious obstacle to evidence-based health policy change. It is therefore an issue that should be rated high among those that affect human health and survival.

1.3 Research Questions

The research will be carried out with a view to answering the following questions;

i. What is the trend of different climate variables in Bangladesh?
ii. What are the relationship among climatic variables and vector-borne diseases?
iii. What are the impacts of climate change on vector-borne diseases?
iv. How the vector-borne diseases have been being managed by health governance and what strategy should adopt to reduce these vector-borne in future by the government?

1.4 Objectives of the Research

Evidence for the past and current impacts of inter-annual and inter-decadal climate variability on vector-borne diseases is assessed on a country basis with the aim of shedding light on possible future trends, particularly in view of the increased likelihood of climate change. The objectives of the study are as follows;

i. Recognize the trend of different climate variables in Bangladesh
ii. Analyze climate and vector-borne disease related data for exploring correlation and regression model.

iii. Assess current knowledge base and understanding on vector-borne diseases due to climate change, and recommend a governance system for the minimization of this impact

1.5 Organization of the Study

The research structure is based on the construction of seven chapters. The first one contains the general information and justification of the topic. At the end, it will outline the objective and aims of this research.

Following on from this introduction, the second chapter will review literature related to climate change in Bangladesh, the health impacts of climate change in general, infectious diseases and specifically in the case of vector-borne diseases. Based on the broader background, health implications of some vector-borne diseases namely malaria, dengue and black fever under changes in climate in Bangladesh will be identified.

In order to achieve the overall objective and specific aims, methodologies employed have been described in detail in the third chapter. This chapter refers to methods to review literature, data collection, data analysis and management.

Furthermore, the fourth one is to present, analyze and discuss results obtained from the analysis data of climatic variables and vector-borne diseases.

Previous outcomes are the basis to generate discussions, which will be incorporated in the fifth chapter of the research.

In addition, conclusion and recommendations to improve the communication of the policy implications of vector-borne diseases due to climate change to the public are also incorporated in the sixth and seven chapters respectively.

Chapter 2

Literature Review

Literature Review

2.1 Weather

Weather is the state of the atmosphere, to the degree that it is hot or cold, wet or dry, calm or stormy, clear or cloudy. Weather generally refers to day-to-day temperature and precipitation activity. Weather, the short-term condition of climate, has a much more direct and tangible impact on daily life. Since earliest times, weather has been fundamental to the success of human activities, from agriculture to seafaring, from warfare to leisure. The universal belief in weather deities, the prominence of weather events in folklore, and the ubiquitous preoccupation with weather signs and portents are evidence that an awareness of weather, particularly a fear of inclement events, has been a major feature of the human psyche throughout history (Reiter, 2001).

The significance of weather has not diminished in modern society. Indeed, in the past few decades, weather awareness, particularly in the global context, has reached unprecedented levels. Weather forecasting has become an important science, fundamental to the success of agriculture, transportation, trade, tourism, and virtually every other aspect of human enterprise. Weather data are collected from every corner of the globe and disseminated in digested form by government and private agencies as an aid to decision making in all walks of life. Continually updated forecasts and other information are available to the public via the popular media. Disastrous weather events from around the world are a major news feature, with detailed descriptions and graphic illustration. With this awareness of weather has come a new realization of the changeability of climate (Reiter, 2001).

2.2 Climate

Climate (from Ancient Greek *klima*, meaning *inclination*) is commonly defined as the weather averaged over a long period. The standard averaging period is 30 years, but other periods may be used depending on the purpose. Climate also includes statistics other than the average, such as the magnitudes of day-to-day or year-to-year variations. The Intergovernmental Panel on Climate Change (IPCC) glossary definition is as follows:

"Climate in a narrow sense is usually defined as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system".

Natural factors that cause climatic variability include fluctuations of the sun's radiant energy, alterations in the transparency of the atmosphere (due to sand, volcanic dust, and other airborne particles), and cyclic changes of the earth's rotation on its axis and its orbit around the sun. In addition, the circulations of the atmosphere and the oceans, which are major components of the climate machine, are subject to internal variations on time scales ranging from weeks to millennia. It is the complex interaction of all these variables that generates the continually changing patterns of climate. As a result, just as the yearly averages of climatic elements— such as temperature, humidity, rainfall, wind, and airborne particles—differ from one another, so too do the averages for decades, centuries, millennia, and millions of years (Reiter, 2001).

Climate is a major parameter in all ecosystems and has always been a fundamental factor in human settlement, economy, and culture. Episodes of second-order climate change, such as the end of the Ice Age, the drying of the Sahara, the waning of the Medieval Warm Period, and the onset of the Little Ice Age, have had an important impact on human history (Lamb, 1995). However, awareness of such change has remained shadowy at best, probably because the inherent time scales are beyond the span of individual human experience.

2.3 Climate Change

Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions (i.e., more or fewer extreme weather events). Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as "global warming".

The earth's climate has always been in a state of change (Lamb, 1995; Chorley and Barry, 1998). For nearly three centuries it has been in a warming phase. This was preceded by a cold period, the Little Ice Age, which was itself preceded by a warmer phase known as the Medieval Warm Period, or Little Climatic Optimum. Such changes are entirely natural, but there is evidence that in recent years a portion of the current warming may be attributable to human activities, particularly the burning of fossil fuels (Houghton et al. 1996; Tett et al. 1999; Wigley and Schimel, 2000). The potential impact of this global warming on human health is a major subject of debate (Longstreth, 1999; Gubler, 1998). Many of the diseases that currently occur in the tropics are mosquito borne (Cook, 1996). It is commonly assumed that their distribution is determined by climate and that warmer global temperatures will increase their incidence and geographic range (McMichael et al. 1996; Watson et al. 1996; Watson et al. 1998). This review explores the validity of both assumptions by examining the history of three mosquito-borne diseases—malaria, yellow fever, and dengue—in the context of past climates and of other factors that can influence their transmission.

2.4 Climate Change and Human Health

Changes in climate variability are projected to have adverse impacts not only on the environment, but also on the society and economy of the city. There would be a wide range of sectors and areas affected by climate change, for instance agriculture, forestry, energy, tourism, water supply, and public health (Tran, 2009).

In the case of public health, scientists foresee a change in global climatic conditions would have a range of health impacts (McMichael et al., 2006, Ebi et al., 2006) because of the climate-society relationship (Frumkin 2002, McMichael 2003, Haines & Patz 2004). Regarding climate change effects, the impacts on human health are identified based on the pathways recommended by McMichael (2003) as in Figure 2.1. The direct factors impacting on health are heat waves (caused by changes in exposure to weather extremes), floods, storm-surges, droughts (due to increases in other extreme weather events), and spores and moulds (due to a rise in production of certain air pollutants and aeroallergens).

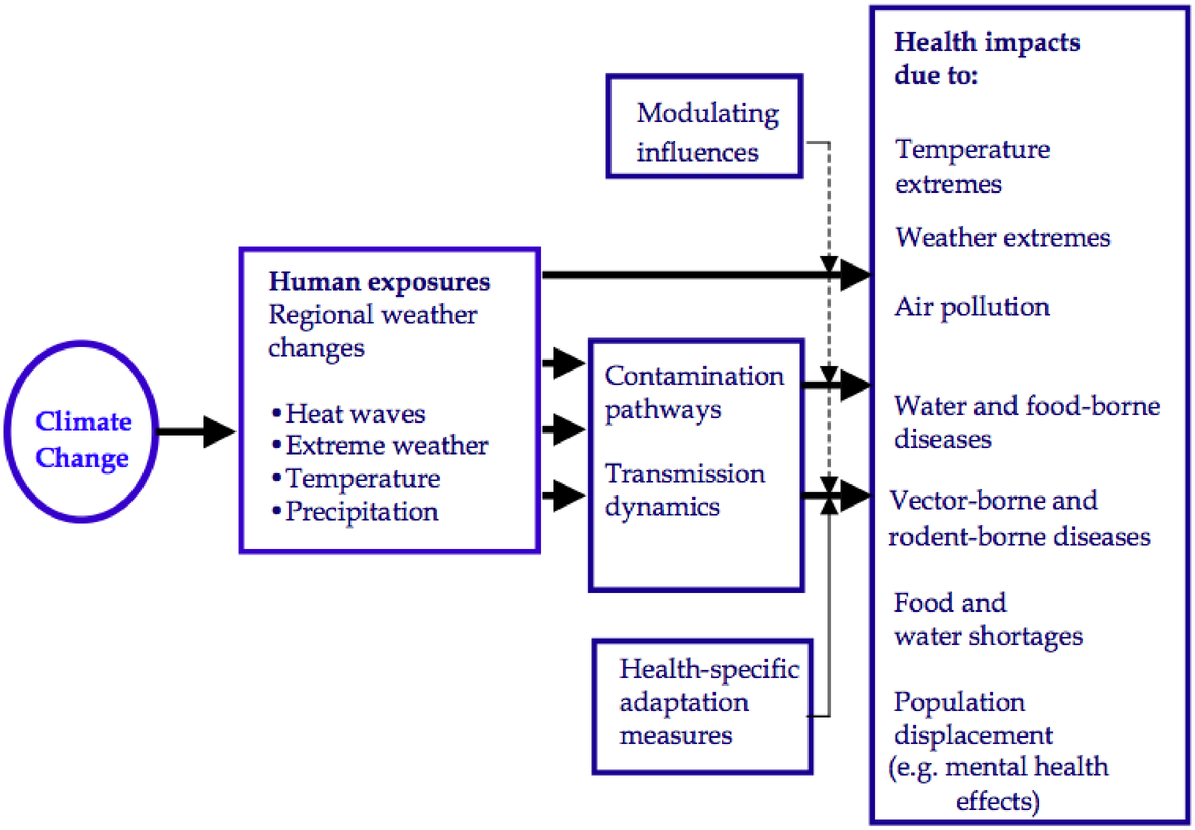

Figure 2.1. Pathways by which climate change affects human health, including local modulating influences and the feedback influence of adaptation measures (based on Patz et al. 2000)

Human health is also affected via less direct mechanisms. These impacts would include changes in the pattern of transmission of many infectious diseases – especially waterborne, food-borne and vector-borne diseases. Further, temperature-related changes in the life-cycle dynamics of both the vector species and the pathogenic organisms would increase the potential transmission of many vector-borne diseases such as malaria and dengue fever – although schistosomiasis may undergo a net decrease in response to climate change (Martens 1998, Patz et al., 1996).

Generally, the main areas of health impact are: heat-related illness and mortality; health effects associated with floods, droughts and storm surges; infectious diseases; allergic and respiratory diseases; and mental health.

2.4.1 Heat Waves

Heat-related deaths are the consequence of prolonged exposure to ambient heat, which results in heat exhaustion, cramps, heart attacks and stroke (McMichael, 2003). Much of the excess mortality from heat waves is concentrated in the elderly and people under intense physical stress, and those with cardiovascular and respiratory disease (McMichael, 2003, Haines et al., 2006, Frumkin et al., 2008). In the case of global warming, there is expected to be an increase in the frequency and intensity of heat waves and warmer dry seasons, hence the mortality accordingly rises in hot weather (Haines et al., 2006). Additionally, the city is often particularly affected because of the urban heat island effect, which can cause the temperatures to be higher than the surrounding suburban and rural areas. Air pollution concentrations, also, may rise during heat waves and may contribute to raise death rates (Haines et al., 2006).

2.4.2 Floods, Droughts, and Storms

The health impacts of natural disasters vary from immediate effects of physical injury, morbidity and mortality through to potentially enduring effects on mental health (in the context of tidal flooding) (Ahern et al., 2005, Haines et al., 2006). Most flood-related deaths can be attributed to rapid rise floods as a result of the increase of drowning. Following floods, there are possible increases in diarrhoea and respiratory diseases (Siddique et al., 1998, Ahern et al., 2005). Furthermore, the impact on the local economy may still be severe and increases in common mental disorders such as anxiety and depression, which result from damage to the home environment and economic losses (Haines et al., 2006). Therefore, there is an increase in vulnerability of populations in low-income areas at high-risk of flooding, with limited presence of public-health infrastructure. On the other side, droughts may have wide-ranging effects on health including on nutrition and infectious diseases, particularly when the country is in the area influenced by the El Niño cycle (Haines et al., 2006).

2.4.3 Infectious Diseases

One of the earliest health impacts of climate change may be altered distribution and incidence of infectious diseases. The movement of people and goods, changes in hosts and pathogens, land use and other environmental factors may influence patterns of diseases (Hales et al., 2003). For example, transmission of many infectious disease agents, namely pathogens and vector-borne agents is sensitive to weather variability including temperature, humidity, rainfall and soil moisture (Gubler, 1997, Haines et al., 2006). Additionally, climate change could affect arthropod vectors in terms of their life cycles and life histories. As a consequence, there would be changes in both vector and pathogen distribution, and in the ability of arthropods to transmit pathogens, resulting in changes in the way pathogens interact with both the arthropod vector and the human or animal host (Patz et al., 2003, Tabachnick, 2010). Therefore, even small increases in disease distributions may cause more serious clinical disease whereas new populations lacking acquired immunity are exposed (Tabachnick, 2010). In general, infectious diseases can be classified according to the natural reservoir of the pathogen (anthroponoses or zoonoses), or according to the mode of transmission of the pathogen (direct or indirect) (Patz et al., 2003).

2.4.4 Respiratory and Allergic Diseases

Certain aspects of air quality known to affect health are highly influenced by weather and climate conditions. Particularly, ozone which is formed in warm, polluted air in the presence of sunlight has well documented human health effects. Ozone causes direct but reversible lung injury and may cause lasting lung damage; increases premature mortality, and worsens respiratory diseases (CDC, 2009a).

Similarly, plant metabolism and pollen production, and possibly fungal growth and spore release, may increase due to rises in ambient temperatures over land and in ground-level carbon dioxide concentrations. Substances like pollen and mould, which produce allergic reaction so-called aeroallergens, can aggravate allergic rhinitis and several respiratory diseases, namely asthma and chronic obstructive pulmonary disease. Furthermore, in the specific case of respiratory diseases, aeroallergens could also worsen these diseases through its interrelation to other harmful air pollution (CDC, 2009b).

2.5 Climate Change and Infectious Diseases

2.5.1. Malaria

The first analyses of the impacts of climate change on vector-borne diseases have been aimed at malaria because of its dominant global and regional impact (Sutherst, 2004; Githeko & Woodward, 2003). Malaria is a life-threatening disease caused by *Plasmodium* parasites that are transmitted exclusively to people through the bites of infected *Anopheles* mosquitoes, called malaria vectors‘. Malaria symptoms are fever, headache, chills and vomiting – may be mild and difficult to recognize as malaria. If not treated within 24 hours, *P. falciparum* malaria, the most severe human malaria type, can progress to severe illness often leading to death (WHO, 2009a).

As regards the transmission of malaria, its intensity depends on factors related to the parasite, the vector, the human host, and the environment (WHO, 2009a). When the parasite has time to complete its development inside the long-lived mosquito, the transmission is more intense. Besides, transmission also depends on climatic conditions such as rainfall patterns, temperature, and humidity that may affect the abundance and survival of mosquitoes (WHO, 2009a). In any case, human immunity reducing the risk that malaria infection will cause severe disease is another important factor, especially in areas of moderate or intense transmission conditions.

2.5.2. Dengue Fever

About two fifths of the world's population is now at risk of dengue, which is a mosquito-borne infection that causes a severe flu-like illness, and sometimes dengue haemorrhagic fever (DHF). Dengue viruses are transmitted to humans through the bites of female Aedes mosquitoes. Mosquitoes generally acquire the virus while feeding on the blood of an infected person, and are capable of transmitting the virus for the rest of their lives. Therefore, infected humans, serving as a source of the virus for uninfected mosquitoes, are the main carriers and multipliers of the virus (WHO, 2009b).

The clinical features of dengue fever vary from fever with rash in infants and young children, to mild or high fever, severe headache, pain behind the eyes, muscle and joint pains, and rash in older children and adults. DHF, a potentially lethal complication, has become a leading cause of hospitalization and death among children in most Asian countries where dengue is found, predominantly in urban and semi-urban areas. Significantly, the disease is now endemic in some countries in South-east Asia, one of the two most seriously affected areas in the world (WHO, 2009b).

2.5.3 Kala-azar

Kala-azar is a neglected tropical disease affecting the marginalized rural population of the society .Though prevalent in about 100 countries that threatens 350 million people of the world and among them 90% of the disease burden belongs 5 countries: India , Bangladesh, Nepal ,Sudan and Brazil .It is estimated that around 147 million people are at risk in three countries – Bangladesh , India and Nepal with about 100000 cases occurring annually .Primary Kala-azar has the manifestations of fever , anemia, weakness and splenomegaly and Post Kala-azar dermal leishmaniasis has skin manifestations of maculo-papulo nodular lesion.

2.5.4. Filariasis

Filariasis is major social and economic burden in the tropics and subtropics of Asia, Africa, Western pacific and parts of Americas, affecting over 120 million people in 73 countries (2011). Filariasis is a global problem .The consequences of filarial infection are many .A large numbers of afflicted persons exhibit physical and mental disabilities, an impaired ability to work, and a compromised quality of life.

2.5.5. Chikungunya

Chikungunya fever is a dengue like disease is emerging alarmingly in the country in the recent years which is an insect borne virus, it the genus Alpha virus vector borne viral disease. In 2011 suspected Chikugunya fever outbreaks was detected in Dohar upazila of Dhaka district and Shibgonj upazila of Chapainawabgonj district during August to October .The disease does not claim mortality but persistent arthralgia may lead to patient’s sufferings.

2.5.6. Water- and Food-borne Diseases

The burden of disease from water- and food-borne pathogens i.e. bacteria, viruses, and parasites is substantial. Several water- and food-borne diseases are subject to environmental changes, which have effects on pathogen replication, survival, and persistent rates; transmission rates; and disease ranges overall (CDC, 2009c). Temperature and precipitation, both of which will increase with climate change, affect the spread of infectious diseases via contaminated water or food (Hales et al., 2003, CDC, 2009c).

In general, increased temperature results in higher pathogen replication, persistence, survival, and transmission for bacterial pathogens. Possibly, it has mixed effects on viral pathogens but often reduces the overall transmission rate (CDC, 2009c).

Overall, increased precipitation is associated with increased burdens of disease for bacteria, viruses, and parasites, particularly where water supplies and sanitation often are inadequate (Hales et al., 2003, CDC, 2009c). Rose et al. (2001) concluded an increase in the frequency and severity of extreme precipitation events attributed to climate change would increase the loading of contamination to waterways. Going into details, outbreaks of cholera and diarrhoeal diseases can occur after flooding due to the contamination of surface water with sewage. Conversely, drought conditions can also lead to hygiene-related diseases, given by decrease in water availability for washing and sanitation, and the increased concentration of pathogens in surface water (Martens et al., 1997, Hales et al., 2003).

2.5.7 Rodent-borne diseases

The uncertain potential effects of climate variability and change on infectious agents transmitted by mammals to humans have received less attention than have vector-borne diseases (Gubler et al., 2001). Rodents act as intermediate infected hosts or as hosts for arthropod vectors such as fleas and ticks to be reservoirs for a number of diseases. Certain rodent-borne diseases, notably plague, Hantavirus and Lyme diseases are associated with flooding while the others are connected with rodents and ticks (Hales et al., 2003).

As rodent-borne diseases do not always involve an arthropod host, they are less directly affected by temperature. Transmission of these infections frequently depends on rodent population density and behaviour that is sensitive to weather conditions (Gubler et al., 2001). Parmenter et al. (1999) found that human plague cases in New Mexico occurred more frequently correlating with above-average precipitation. In addition, McLean (2001) concluded that conditions associated with climate variability and change could increase tick populations and the incidence of Lyme disease. Even though, Gubler et al., (2001) expressed uncertainty about the impacts of climate change on rodent-borne illnesses because of a lack of available research and because of the potentially different impacts resulting from climate change such as population explosions and crashes that could increase disease risk.

2.6 Disease classifications relevant to climate/health relationships

Several different schemes allow specialists to classify infectious diseases. For clinicians who are concerned with treatment of infected patients, the clinical manifestation of the disease is of primary importance. Alternatively, microbiologists tend to classify infectious diseases by the defining characteristics of the microorganisms, such as viral or bacterial. For epidemiologists the two characteristics of foremost importance are the method of transmission of the pathogen and its natural reservoir, since they are concerned primarily with controlling the spread of disease and preventing future outbreaks (Nelson, 2000).

Climate variability's effect on infectious diseases is determined largely by the unique transmission cycle of each pathogen. Transmission cycles that require a vector or non-human host are more susceptible to external environmental influences than those diseases which include only the pathogen and human. Important environmental factors include temperature, precipitation and humidity (discussed in more detail in the following section). Several possible transmission components include pathogen (viral, bacterial, etc.), vector (mosquito, snail, etc.), non-biological physical vehicle (water, soil, etc.), non-human reservoir (mice, deer, etc.) and human host. Epidemiologists classify infectious diseases broadly as anthroponoses or zoonoses, depending on the natural reservoir of the pathogen; and direct or indirect, depending on the mode of transmission of the pathogen.

2.7 Vector-borne diseases

Vector-borne diseases are those diseases that are spread by insect vectors. The insects act as an essential stage in the transmission of the infection from one person to another or from animal hosts to humans. There are a large number of viral, rickettsial, bacterial and parasitic diseases that can be transmitted by insect vectors (Cook, 1996) (Table 2.1). Various vector-borne are amongst some of the major microbial causes of morbidity and mortality in the world today.

Malaria alone causes some one million deaths and 273 million cases worldwide each year (Rogers and Randolf, 2000).

Important properties in the transmission of vector-borne diseases include:

- Survival and reproduction rate of the vector
- Time of year and level of vector activity, specifically the biting rate
- Rate of development and reproduction of the pathogen within the vector (Kovats et al., 2001).

Vectors, pathogens, and hosts each survive and reproduce within certain optimal climatic conditions and changes in these conditions can modify greatly these properties of disease transmission. The most influential climatic factors for vector-borne diseases include temperature and precipitation but sea level elevation, wind, and daylight duration are additional important considerations. Table 2.2 gives an overview of the impact of climatic change on each biological component of both vector and rodent-borne diseases. Vector-borne pathogens spend part of their life-cycle in cold-blooded arthropods that are subject to many environmental factors. Changes in weather and climate that can affect transmission of vector-borne diseases include temperature, rainfall, wind, extreme flooding or drought, and sea level rise. Rodent-borne pathogens can be affected indirectly by ecological determinants of food sources affecting rodent population size; floods can displace and lead them to seek food and refuge.

Table 2.1: Some examples of vector-borne diseases of clinical importance (Hunter, 2003)

Disease	Pathogen	Vector	Geographical distribution	Clinical effects
Viruses				
Dengue	Flavivirus	Mosquito	Africa, Caribbean, Pacific, Far East	Haemorrhagic fever
Japanese Encephalitis	Flavivirus	Mosquito	Japan, Far East	Encephalitis
West Nile	Flavivirus	Mosquito	Africa, India, Europe and North America	Encephalitis
Murray River encephalitis	Flavivirus	Mosquito	Australia, New Guinea	Encephalitis
St Louis encephalitis	Flavivirus	Mosquito	America	Encephalitis
Yellow fever	Flavivirus	Mosquito	Africa, South and Central America	Hepatitis & Haemorrhagic fever
Eastern Equine Encephalitis	Alphavirus	Mosquito	North America	Encephalitis
Crimean-Congo haemorrhagic fever	Nairovirus	Ixodic tick	Europe, Africa, Middle East, Central Asia	Haemorrhagic fever
Tick-borne encephalitis	Flavivirus	Ixodic tick	Former USSR, Europe	Encephalitis
Rift Valley Fever	Phlebovirus	Mosquito	Africa	Haemorrhagic fever
Rickettsia				
Murine typhus	*Rickettsia typhi*	Flea	Tropical countries	Typhus
Rocky Mountain Spotted fever	*R. rickettsii*	Ticks	USA	Spotted fever
Boutonneuse fever	*R. conorii*	Tick	Africa, Mediterranean, Middle East	Spotted fever
Bacteria				
Bartonellosis	*B. bacilliformis*	Sandflies	Western Slopes of the Andes	Oroya fever
Plague	*Yersinia pestis*	Flea	Africa, Asia, South America, USA	Bubonic, pneumonic or septicaemic plague
Lyme disease	*Borrelia burgdorferi*	Ticks	Europe, North America	Arthritis
Relapsing fever	*B. recurrentis*	Lice	Ethiopia, Burundi, Peru, Bolivia, North Africa, India, Asia, China	Severe relapsing fever with high mortality
Relapsing fever	e.g. *B. duttoni*	Ticks	East, Central & South Africa	Less severe relapsing fever
Protozoal parasites				
Malaria	*Plasmodium* spp.	Mosquitos	Widespread in tropics	Febrile illness with high mortality
African trypanosomiasis	*Trypanosoma brucei*	Tsetse flies	Africa	Sleeping sickness
American trypanosomiasis	*T. cruzei*	Triatomine bugs	Central and South America	Chagas disease
Leishmaniasis	*Leishmania* spp.	Sandflies	Africa, Central & South America	Cutaneous and mucosal lesions, visceral disease
Helminths				
Lymphatic filariasis	eg. *Wucheria bancrofti*	Mosquito	Tropics	Elephantiasis
Onchocerciasis	*Onchocerca volvulus*	Blackflies	Africa, Central & South America	Dermatitis, Blindness
Loaiasis	*Loa loa*	Tabanid flies	West & Central Africa	Calabar swellings

Table 2.2: Effects of weather and climate on vector and rodent-borne diseases (Gubler et al. 2001)

Temperature effects on selected vectors and vector-borne pathogens

Vector
- survival can decrease or increase depending on species;
- some vectors have higher survival at higher latitudes and altitudes with higher temperatures;
- changes in the susceptibility of vectors to some pathogens e.g. higher temperatures reduce size of some vectors but reduce activity of others;
- changes in the rate of vector population growth;
- changes in feeding rate and host contact (may alter survival rate);
- changes in seasonality of populations.

Pathogen
- decreased extrinsic incubation period of pathogen in vector at higher temperatures
- changes in transmission season
- changes in distribution
- decreased viral replication.

Effects of changes in precipitation on selected vector-borne pathogens

Vector
- increased rain may increase larval habitat and vector population size by creating new habitat
- excess rain or snowpack can eliminate habitat by flooding, decreasing vector population
- low rainfall can create habitat by causing rivers to dry into pools (dry season malaria)
- decreased rain can increase container-breeding mosquitoes by forcing increased water storage
- epic rainfall events can synchronize vector host-seeking and virus transmission
- increased humidity increases vector survival; decreased humidity decreases vector survival.

Pathogen
Few direct effects but some data on humidity effects on malarial parasite development in the anopheline mosquito host.

Vertebrate host
- increased rain can increase vegetation, food availability, and population size
- increased rain can cause flooding: decreases population size but increases human contact.

Increased sea level effects on selected vector-borne pathogens
Alters estuary flow and changes existing salt marshes and associated mosquito species, decreasing or eliminating selected mosquito breeding-sites (e.g. reduced habitat for *Culiseta melanura*)

2.7.1 Impact of climate on vector-borne disease

The geographical distribution of vector-borne diseases is influenced by the geographical distribution of both vertebrate host (where one exists) and the distribution of the vector.

2.7.1.1 Temperature sensitivity

Temperature can affect both the distribution of the vector and the effectiveness of pathogen transmission through the vector. Gubler et al. (2001) list a range of possible mechanisms whereby changes in temperature impact on the risk of transmission of vector borne disease:

- Increase or decrease in survival of vector
- Changes in rate of vector population growth
- Changes in feeding behavior
- Changes in susceptibility of vector to pathogens
- Changes in incubation period of pathogen
- Changes in seasonality of vector activity
- Changes in seasonality of pathogen transmission

There is also good epidemiological evidence of disease risk in humans linked to climate variability. Extreme temperatures often are lethal to the survival of disease-causing pathogens but incremental changes in temperature may exert varying effects. Where a vector lives in an environment where the mean temperature approaches the limit of physiological tolerance for the pathogen, a small increase in temperature may be lethal to the pathogen. Alternatively, where a vector lives in an environment of low mean temperature, a small increase in temperature may result in increased development, incubation and replication of the pathogen (Lindsay and Birley, 1996; Bradley, 1993). Temperature may modify the growth of disease carrying vectors by altering their biting rates, as well as affect vector population dynamics and alter the rate at which they come into contact with humans. Finally, a shift in temperature regime can alter the length of the transmission season (Gubler et al., 2001).

Disease carrying vectors may adapt to changes in temperature by changing geographical distribution. An emergence of malaria in the cooler climates of the African highlands may be a result of the mosquito vector shifting habitats to cope with increased ambient air temperatures (Cox et al., 1999). Another possibility is that vectors undergo an evolutionary response to adapt to increasing temperatures. There is recent evidence to suggest that the pitcher-plant mosquito (*Wyeomia smithii*) can adapt genetically to survive the longer growing seasons associated with climate change. Bradshaw and Holzapfel (2001) demonstrated this by documenting a change in the photoperiodic response between two different time periods in two populations of pitcher-plant mosquitoes. The change in response was correlated to a marked genetic shift within the mosquito species. A greater degree of micro evolutionary response was associated with mosquito populations inhabiting higher latitudes; the hypothesis is that because these populations have greater selection pressure they have also a greater ability to evolve genetically. Although this study was limited to one specific species of mosquito, it suggests that other mosquitoes, perhaps disease carrying vectors, may undergo an analogous microevolution which would allow adaptation to altered seasonal patterns associated with global climate change (Bradshaw and Holzapfel, 2001).

2.7.1.2 Precipitation sensitivity

Variability in precipitation may have direct consequences on infectious disease outbreaks. Increased precipitation may increase the presence of disease vectors by expanding the size of existent larval habitat and creating new breeding grounds. Gubler et al. (2001) list a range of possible mechanisms whereby rainfall can impact on the risk of transmission of vector-borne disease:

- Increased surface water can provide breeding sites for vectors
- Low rainfall can also increase breeding sites by slowing river flow
- Increased rain can increase vegetation and allow expansion in population of vertebrate host
- Flooding may eliminate habitat for both vectors and vertebrate hosts
- Flooding may force vertebrate hosts into closer contact with humans

In addition, increased precipitation may support a growth in food supplies which in turn support a greater population of vertebrate reservoirs. Unseasonable heavy rainfalls may cause flooding and decrease vector populations by eliminating larval habitats and creating unsuitable environments for vertebrate reservoirs. Alternatively, flooding may force insect or rodent vectors to seek refuge in houses and increase the likelihood of vector-human contact. Epidemics of leptospirosis, a rodent-borne disease, have been documented following severe flooding in Brazil (Ko et al. 1999). In the wet tropics unseasonable drought can cause rivers to slow, creating more stagnant pools that are ideal vector breeding habitats.

2.7.1.3 Humidity sensitivity

Humidity can greatly influence transmission of vector-borne diseases, particularly for insect vectors. Mosquitoes and ticks can desiccate easily and survival decreases under dry conditions. Saturation deficit (similar to relative humidity) has been found to be one of the most critical determinants in climate/disease models, for example, dengue fever (Focks et al., 1995; Hales et al., 2002) and Lyme disease models (Mount et al., 1997).

2.7.1.4 Sea level sensitivity

The projected rise in sea level associated with climate change is likely to decrease or eliminate breeding habitats for salt-marsh mosquitoes. Bird and mammalian hosts that occupy this ecological niche may be threatened by extinction, which would also aid the elimination of viruses endemic to this habitat (Reeves et al., 1994). Alternatively, inland intrusion of salt water may turn former fresh water habitats into salt-marsh areas which could support vector and host species displaced from former salt-marsh habitats (Reeves et al., 1994).

Chapter 3

Methodology

Methodology

3.1 Study Area and collection Data

The study area covers whole Bangladesh. A number of climate change and health related documents were collected from concerned national sources. Time series (30 years) rainfall, temperature and humidity data were collected from Bangladesh Meteorological Department (BMD) and the Ministry of Environment and Forest (MOEF) of the Government of Bangladesh (GoB). Health related documents (malaria, dengue, Filariasis, Chikungunya and Kala-azar) were collected from Director General (DG), Health of the Ministry of Health and Family Welfare of the Government of Bangladesh (GoB). Different journals are also observed.

3.2 Variables to be studied

Independent variables	**Dependent variables**
Maximum temperature	Filariasis
Minimum temperature	Chikungunya
Average temperature	Dengue
Average precipitation (rainfall)	malaria
Average Humidity	Kala-azar

3.3 Statistical analysis

Data obtained from the study were analyzed using SPSS software version 16.0 (Statistical Package for Social Sciences Version 16.0). Microsoft Office Excel 2007 was also used for data analysis.

3.4 Data management

The data entry was started simultaneously along with data collection. Incomplete and inconsistent data were discarded and were not included for final analysis. Data analyses were performed using the available computer software packages of SPSS 16.0. Data were presented in simple measures of frequency (%) and the significance of difference between proportions were tested using P value <0.05 as the level of significance. Linear regression and pearson correlation analysis were used to find the rates of change for rainfall, temperature and humidity data.

Chapter 4

Results

Results

4.1 Trend of climate variables in Bangladesh

Meteorological data of 1981 to 2012 was collected from the meteorological department of Bangladesh. The trend of yearly average temperature, rainfall (mm), Humidity, mean maximum and minimum temperature (degree centigrade) was computed. From linear regression analysis we found fluctuation of mean temperature in the defined time range. Temperature did not follow sequential increase or decrease which is presented in figure 4.1.

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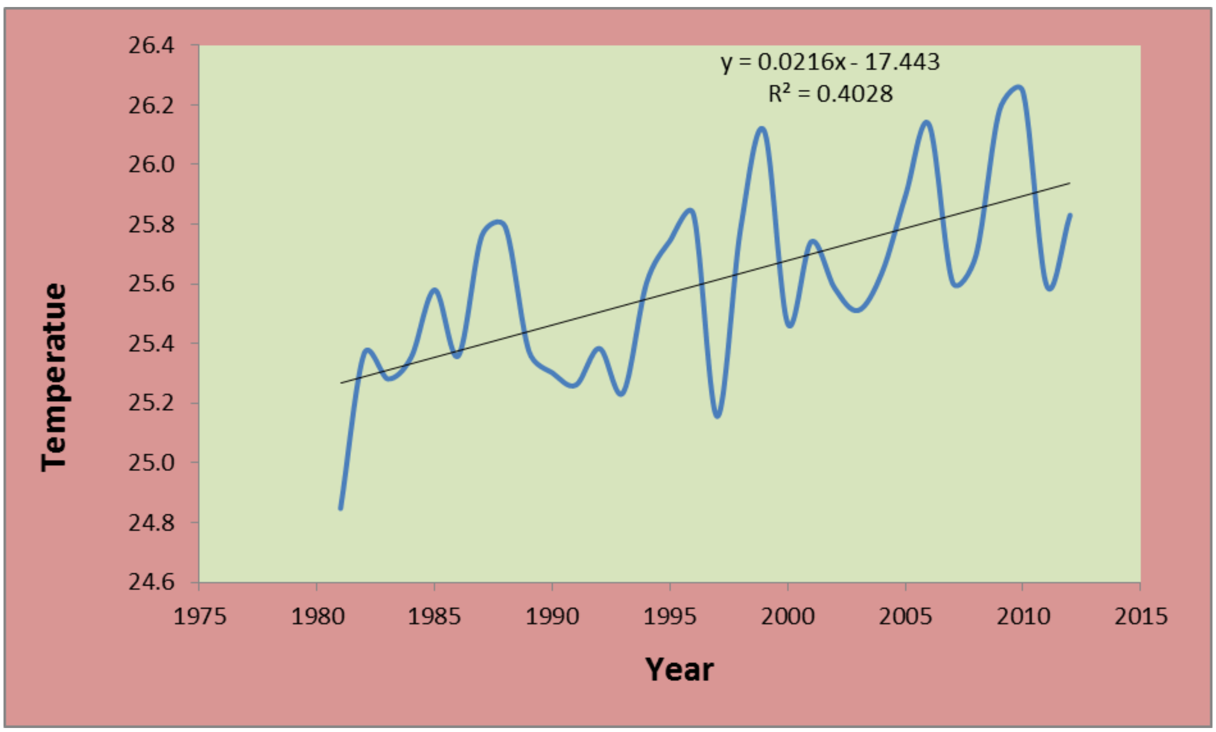

Figure 4.1: Graphical illustration of relationship between year and mean temperature

We found an upward trend of both in mean maximum and minimum temperature (Figure 4.2 and 4.3). These upward trends showed that temperature is increasing day by day.

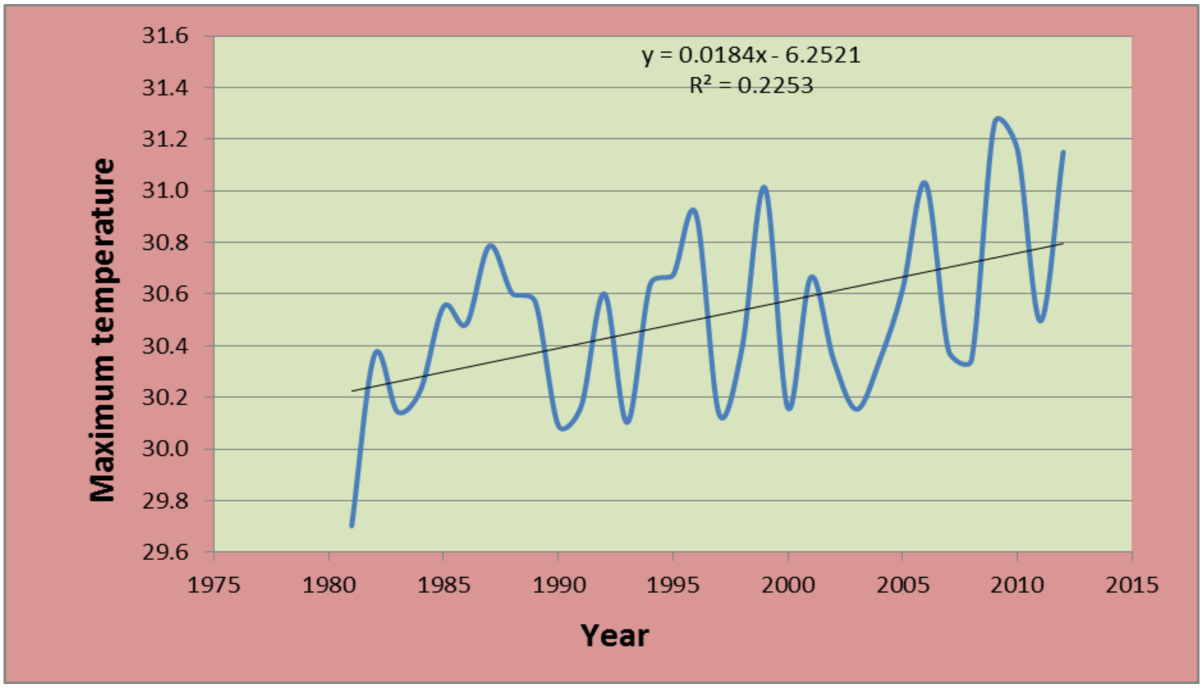

Figure 4.2: Graphical illustration of relationship between year and maximum temperature

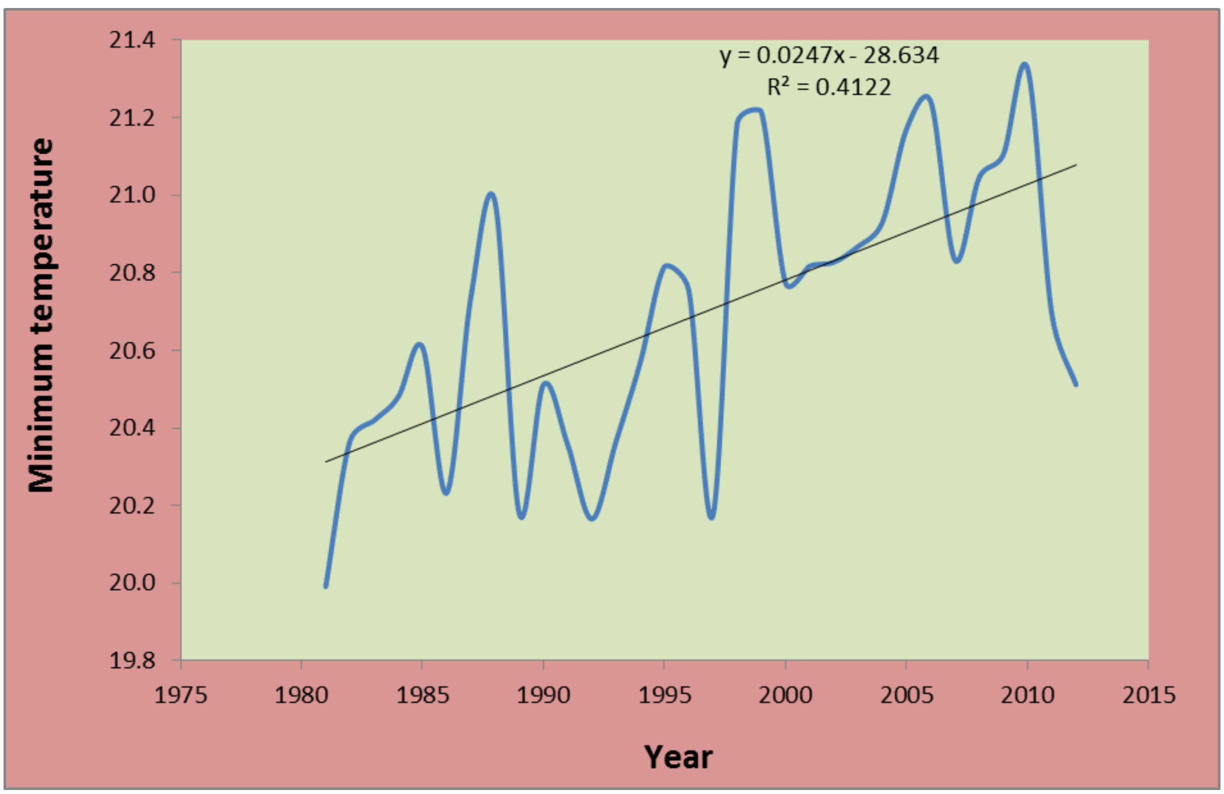

Figure 4.3: Graphical illustration of relationship between year and minimum temperature

Yearly average humidity failed to show a constant trend (increase of decrease) with increase of year (figure 4.4).

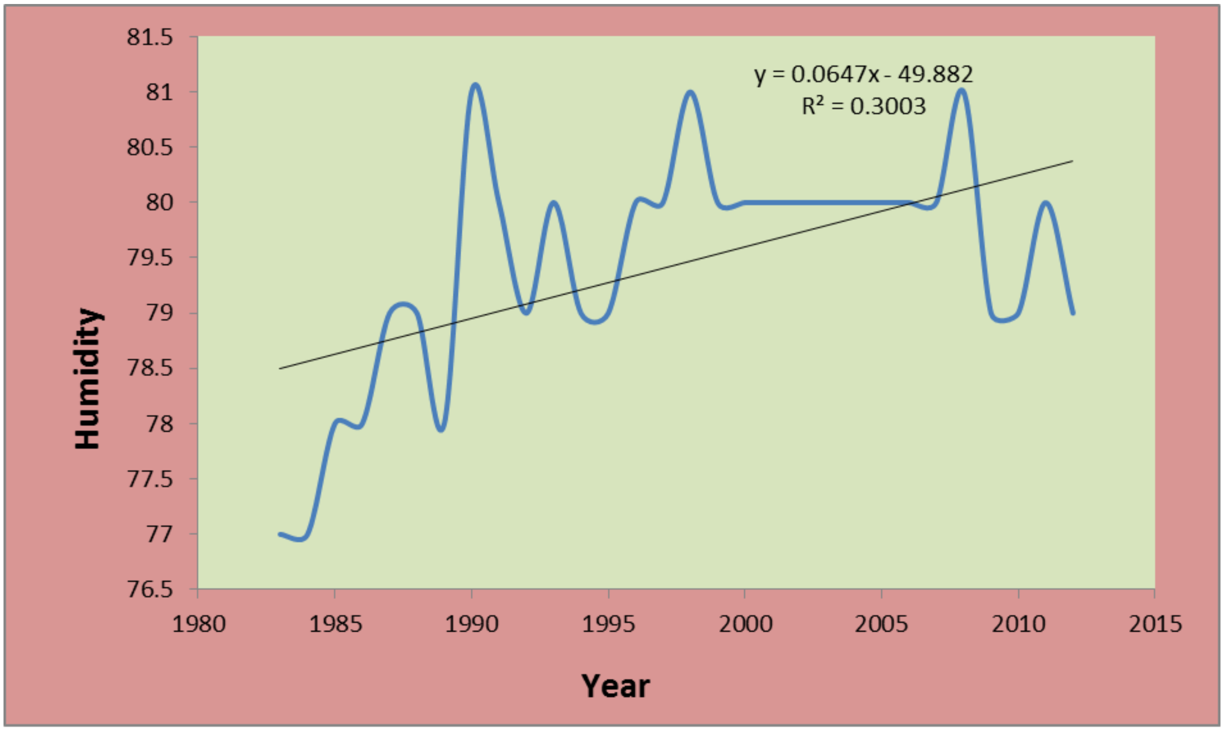

Figure 4.4: Graphical illustration of relationship between year and humidity

Rainfall is an important climatic variable for the breeding of diseases vectors. After analysis of data we did not found any upward or downward trend of rainfall in Bangladesh (figure 4.5).

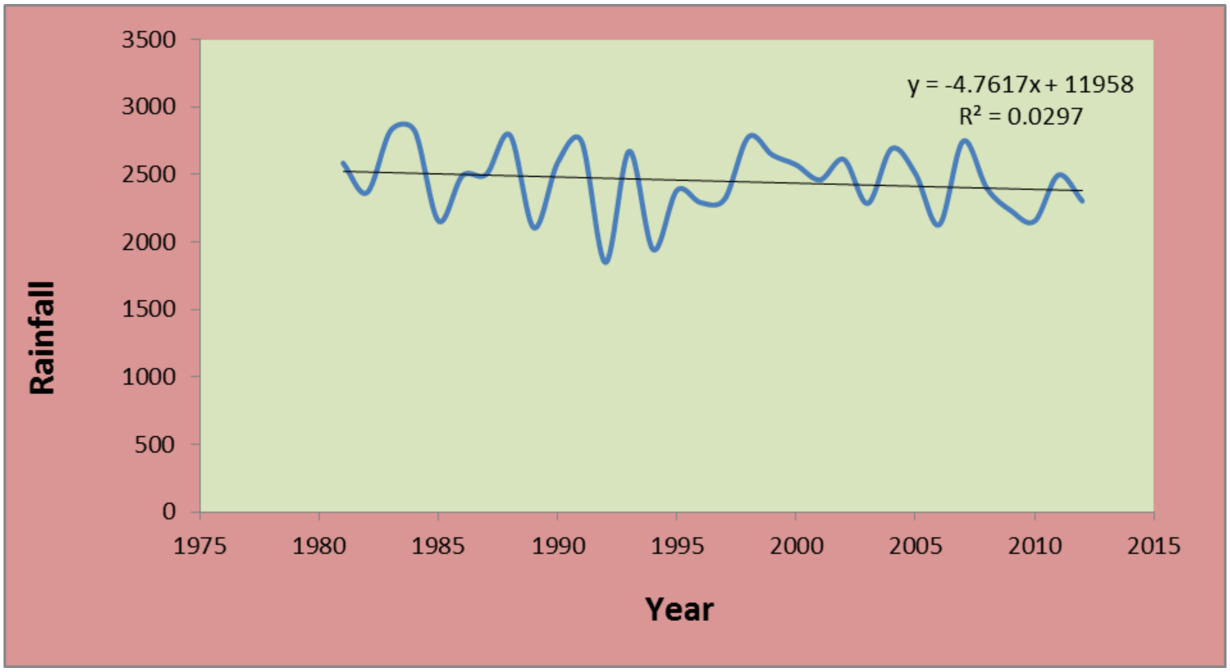

Figure 4.5: Graphical illustration of relationship between year and rainfall

4.2 Dengue Fever

Total patients affected by dengue and death due to dengue each year during 2000 to 2012 were analyzed and try to find out the relation with the climatic variables. Data set are tabulated in table 4.1.

Table 4.1: Report on dengue fever from 2000 to 2012.

Year	Cases	Death	CFR%	Maximum Temperature	Humidity	Rainfall(mm)
2000	5551	93	1.6	30.2	80	2571
2001	2430	44	1.81	30.7	80	2460
2002	6132	58	0.95	30.3	80	2611
2003	486	10	2.05	30.2	80	2285
2004	3934	13	0.33	30.3	80	2690
2005	1048	4	0.38	30.6	80	2506
2006	2200	11	0.5	31.0	80	2127
2007	466	0	0	30.4	80	2746
2008	1153	0	0	30.3	81	2397
2009	474	0	0	31.3	79	2232
2010	409	0	0	31.2	79	2154
2011	1362	6	0.44	30.5	80	2495
2012	671	1	0.1	31.2	79	2303

Table 4.2: Correlation between climatic variables and cases of dengue fever in Bangladesh

		Maximum Temperature	Humidity	Rainfall
Cases	Pearson Correlation	-.486	.277	.479
	Significance value	.092	.359	.098

From the correlation matrix, it was clear that very weak relation was found between number of cases and environmental variables such as maximum temperature, humidity and rainfall (Table 4.2). For better understanding we have tried to establish mathematical model which is discussed below.

Table 4.3: Estimated Coefficients of Dengue (Cases=y) Models

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
	Coefficients (*P*-value)				
Constant	4,474.00 (0.00)	73,117.94 (0.10)	-9,513.52 (0.16)	-76,855.38 (0.37)	-17,681.01 (0.92)
Time (X_1)	-349.96 (0.01)	-	-	-	-336.52 (0.06)
Maximum Temperature (X_2)	-	-2,321.52 (0.11)	-	-	753.06 (0.78)
Mean Rainfall (X_3)	-	-	4.75 (0.098)	-	3.27 (0.37)
Humidity (%) (X_4)	-	-	-	987.90 (0.36)	-111.89 (0.94)
R^2	0.69	0.46	0.48	0.28	0.73
No. of Observations	13	13	13	13	13
F-value (*P*-value)	9.94 (0.01)	3.03 (0.11)	3.27 (0.098)	0.92 (0.36)	2.30 (0.15)

Note: Model 1 includes only one independent variable which is time. Similarly, Model 2, Model 3 and Model 4 include one independent variable which is maximum temperature, mean rainfall and humidity (%) respectively and on the other hand Model 5 includes all the four independent variables.

The estimated model of cases of dengue on time is

$$\hat{y} = 4{,}474 - 349.96X_1 \text{-----------(1)}$$

Where, $\hat{y} =$ the estimated cases of dengue

$\hat{\beta}_0 = 4,474$

$\hat{\beta}_1 = -349.96$

$X_1 = \text{Time}$

The estimated model of cases of dengue on maximum temperature is

$$\hat{y} = 73{,}117.94 - 2{,}321.52 X_2 \text{---------------------------}(2)$$

where, $\hat{y} =$ the estimated cases of dengue

$\hat{\beta}_0 = 73117.94$

$\hat{\beta}_1 = -2321.52$

X2=maximum temperature

The estimated model of cases of dengue on time, maximum temperature, mean rainfall and humidity is

$$\hat{y} = -17681.01 - 336.52 X_1 + 753.06 X_2 + 3.27 X_3 - 111.89 X_4 \text{-----------------}(5)$$

Where, $\hat{y} =$ the estimated cases of dengue

$\hat{\beta}_0 = -17681.01$

$\hat{\beta}_1 = -336.52$

$\hat{\beta}2 = 753.06$

$\hat{\beta}3 = 3.27$

$\hat{\beta}4 = -111.89$

$X4 = \text{Humidity \%}$

In the model -1, independent variable is time and p-value is 0.01, R^2 is 0.69. So there is significance relation between time and dengue cases. On the other hand in the model-5 we incorporated three climatic variables with time and found that R square is 0.73.so the overall effect of (time, maximum temperature, rainfall and humidity) on dengue cases in model-5 is not sufficient significance though there are four independent variables in this model.

4.3 Kala- azar

Total patients affected by kala-azar and death due to this disease in each year during 2000 to 2012 were analyzed and try to find out the relation with the climatic variables. Data set are tabulated in table 4.4**.**

Table 4.4: Report on Kala- azar from 2000 to 2012.

Year	Cases	Death	Maximum Temperature	Mean Temperature	Humidity (%)	Rainfall(mm)
2000	7640.0	24.0	30.7	25.7	80	2571
2001	4283.0	6	30.3	25.6	80	2460
2002	8110.0	36	30.2	25.5	80	2611
2003	6113.0	27	30.3	25.6	80	2285
2004	5920.0	23	30.6	25.9	80	2690
2005	6892.0	16	31.0	26.1	80	2506
2006	9379.0	23	30.4	25.6	80	2127
2007	4932.0	17	30.3	25.7	80	2746
2008	4824.0	17	31.3	26.2	81	2397
2009	4293.0	14	31.2	26.2	79	2232
2010	3806.0	0	30.5	25.6	79	2154
2011	3376.0	2	31.2	25.8	80	2495
2012	1902.0	0	30.7	25.7	79	2303

		Maximum Temperature	**Minimum Temperature**	**Humidity**	**Rainfall**
Cases	Pearson Correlation	-.424	-.086	.449	.130
	Significance value	.149	.779	.124	.673

Table 4.5: Correlation matrix between Kala-azar (cases) and environmental variables

From the correlation matrix above it was clear that the correlation between number of cases with maximum and mean temperature are both negative/weak. The correlation between number of cases with humidity and rainfall are positive/weak (Table 4.5). For better understanding we have tried to establish mathematical model which is discussed below.

Table 4.6: Estimated Coefficients of Kala -azar Models (a)

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
	Coefficients (*P*-value)				
Constant	8,028.11 (0.00)	63,934.69 (0.19)	2,659.81 (0.74)	-120,324.88 (0.18)	-139,985.82 (0.47)
Time	-361.49 (0.01)	-	-	-	-400.00 (0.04)
Maximum Temperature	-	-1,908.22 (0.23)	-	-	1,369.60 (0.63)
Mean Rainfall	-	-	1.17 (0.72)	-	-1.74 (0.64)
Humidity (%)	-	-	-	1,575.81 (0.16)	1,384.81 (0.36)
R^2	0.45	0.13	0.01	0.17	0.54
No. of Observations	13	13	13	13	13
F-value (*P*-value)	8.96 (0.01)	1.64 (0.23)	0.14 (0.72)	2.30 (0.16)	2.33 (0.14)

Note: Model 1 includes only one independent variable which is time. Similarly, Model 2, Model 3 and Model 4 include one independent variable which is maximum temperature, mean rainfall and humidity (%) respectively and on the other hand Model 5 includes all the four independent variables.

In the model -1, (Table 4.6) independent variable is time and co-efficient *P*-value is .01, R square is .45.so there is significance relation with time .on the other hand, in the model-5 we have given time, maximum temperature ,rainfall and humidity as independent variables and find that R square is 0.54. So this model is not so significance though we have incorporated temperature (maximum), rainfall and humidity and time as independent variables.

Table 4.7: Estimated Coefficients of Kala –azar Models (b)

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
	Coefficients (*P*-value)				
Constant	8,028.11 (0.00)	28,299.67 (0.66)	2,659.81 (0.74)	-120,324.88 (0.18)	-195,341.68 (0.19)
Time	-361.49 (0.01)	-	-	-	-398.36 (0.02)
Mean Temperature	-	-884.52 (0.72)	-	-	3,592.28 (0.26)
Mean Rainfall	-	-	1.17 (0.72)	-	-0.20 (0.96)
Humidity (%)	-	-	-	1,575.81 (0.16)	1,396.63 (0.22)
R^2	0.45	0.01	0.01	0.17	0.60
No. of Observations	13	13	13	13	13
F-value (*P*-value)	8.96 (0.01)	0.14 (0.72)	0.14 (0.72)	2.30 (0.16)	2.96 (0.09)

Note: Model 1 includes only one independent variable which is time. Similarly, Model 2, Model 3 and Model 4 include one independent variable which is maximum temperature, mean rainfall and humidity (%) respectively and on the other hand Model 5 includes all the four independent variables.

In the model -1, independent variable is time and co-efficient *P*-value is .01, R square is 0.45. So there is significance relation with time .on the other hand, in the model-5 we considered time, mean temperature, mean rainfall and humidity as independent variables .in model-5 we found that R square is 0.60 . So this model is not so significance with mean temperature, mean rainfall and humidity.

4.4 Malaria

Data about incidences of malaria were collected from 1983 to 2012. All data are tabulated in table 4.8.

Table 4.8: Report on malaria from 2000 to 2012

Year	API	PF(%)	Maximum Temperature	Mean Temperature	Humidity	Rainfall
1983	0.46	41.26	30.1	25.3	77	2827
1984	0.35	45.11	30.2	25.4	77	2823
1985	0.32	52.21	30.6	25.6	78	2155
1986	0.4	53.83	30.5	25.4	78	2490
1987	0.36	57.11	30.8	25.8	79	2500
1988	0.33	63.76	30.6	25.8	79	2791
1989	0.49	70.52	30.6	25.4	78	2104
1990	0.51	63.22	30.1	25.3	81	2588
1991	0.58	47.63	30.2	25.3	80	2745
1992	1.03	44.76	30.6	25.4	79	1848
1993	1.1	43.84	30.1	25.2	80	2672
1994	1.63	48.64	30.6	25.6	79	1943

1995	1.28	49.66	30.7	25.7	79	2382
1996	1	53.84	30.9	25.8	80	2291
1997	0.64	61.78	30.1	25.2	80	2317
1998	0.37	70.34	30.4	25.8	81	2778
1999	0.56	69.51	31.0	26.1	80	2644
2000	0.49	71.1	30.2	25.5	80	2571
2001	0.49	72.4	30.7	25.7	80	2460
2002	0.47	71	30.3	25.6	80	2611
2003	0.47	74	30.2	25.5	80	2285
2004	0.51	78	30.3	25.6	80	2690
2005	0.39	78	30.6	25.9	80	2506
2006	0.27	73	31.0	26.1	80	2127
2007	5.49	78	30.4	25.6	80	2746
2008	7.77	83	30.3	25.7	81	2397
2009	5.86	89	31.3	26.2	79	2232
2010	5.13	93	31.2	26.2	79	2154
2011	3.91	95	30.5	25.6	80	2495
2012	2.23	94	31.2	25.8	79	2303

Table 4.9: Correlation between API and environmental variables in Bangladesh

		Maximum Temperature	**Mean Temperature**	**Humidity**	**Rainfall**
API	Pearson Correlation	0.275	0.344	0.189	-0.159
	Significance value	0.142	0.062	0.317	0.402

From the correlation matrix above it was clear that very weak relation was found between API (Annual Parasite Index) and environmental variables such as maximum and mean temperature, humidity and rainfall (Table 4.9). For better understanding we have tried to establish mathematical model which is discussed below.

Table 4.10: Estimated Coefficients of API (Malaria) Models (a) with independent variables in Bangladesh

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
	Coefficients (*P*-value)				
Constant	-0.62 (0.31)	-47.67 (0.15)	4.42 (0.21)	-27.36 (0.34)	43.90 (0.45)
Time	0.14 (0.00)	-	-	-	0.17 (0.00)
Maximum Temperature	-	1.61 (0.14)	-	-	-0.35 (0.77)
Mean Rainfall	-	-	-0.001 (0.40)	-	0.00 (0.85)
Humidity (%)	-	-	-	0.36 (0.32)	-0.42 (0.30)
R^2	0.36	0.28	0.02	0.04	0.39
No. of Observations	30	30	30	30	30
F-value (*P*-value)	16.00 (0.00)	2.31 (0.14)	0.72 (0.40)	1.04 (0.32)	4.07 (0.01)

Note: Model 1 includes only one independent variable which is time. Similarly, Model 2, Model 3 and Model 4 include one independent variable which is maximum temperature, mean rainfall and humidity (%) respectively and on the other hand Model 5 includes all the four independent variables.

The regression model of API on time is given below

$$y = \beta_0 + \beta_1 X_1 + \varepsilon$$

Where, y = the value of API

β_0 = intercept

β_1 = regression coefficient of time (X_1)

ε = the random error component

The estimated regression model of API on time is given below

$$\hat{y} = -0.62 + 0.14 X_1$$

In the model -1, independent variable is time and co-efficient *P*-value is 0.00, R square is 0.36. So there is significance relation with time. On the other hand, in the model-5 we find that R square is 0.39. So this model is not so significance with temperature (maximum), rainfall(mean),time and humidity.

Table 4.11: Estimated Coefficients of API (Malaria) Models (b)

Variables	Model-1	Model-2	Model-3	Model-4	Model-5
	Coefficients (*P*-value)				
Constant	-0.62 (0.31)	-58.82 (0.07)	4.42 (0.21)	-27.36 (0.34)	38.62 (0.43)
Time(X1)	0.14 (0.00)	-	-	-	0.17 (0.00)
Mean Temperature	-	2.35 (0.06)	-	-	-0.31 (0.82)
Mean Rainfall	-	-	-0.001 (0.40)	-	0.00 (0.92)
Humidity (%)	-	-	-	0.36 (0.32)	-0.40 (0.30)

R^2	0.36	0.12	0.02	0.04	0.39
No. of Observations	30	30	30	30	30
F-value (*P*-value)	16.00 (0.00)	3.79 (0.06)	0.72 (0.40)	1.04 (0.32)	4.06 (0.01)

Note: Model 1 includes only one independent variable which is time. Similarly, Model 2, Model 3 and Model 4 include one independent variable which is maximum temperature, mean rainfall and humidity (%) respectively and on the other hand Model 5 includes all the four independent variables.

In the model -1, independent variable is time and co-efficient *P*-value is 0.00, R square is 0.36. So there is significance relation with time. On the other hand, in the model-5 we find that R square is 0.39. So this model is not so significance with mean temperature, mean rainfall,time and humidity.

3.5 Filariasis

Lymphatic filariasis (LF) is a vector borne disease caused by *Wuchereria bancrofti*. In Bnagladesh. *Culex* mosquitoes are main vectors for transmission. Bangladesh is one of the nine LF endemic countries categorized by WHO. Filariasis elimination programs are in operation in all the nine endemic countries and national plans of action are being implemented in all the countries under the supervision of WHO. Bangladesh has the necessary infrastructure and experience for implementation of the program. Filariasis is to be eliminated by 2020 as per WHA resolution of May 1997. Bangladesh govt. declared to eliminate this disease by 2015. Mass drug administration (MDA) was performed among 5.1 million populations in four district Thakurgaon, Nilphamari, Lalmonirhat and Panchagar.

3.6 Chikungunya

Chikungunya fever, a dengue like disease is emerged alarmingly in recent years. It is an insect borne virus. Two outbreaks have been noticed in Rajshahi and Pabna districts. In 2011 Chikungunya outbreaks was detected in Dohar upazila of Dhaka district and Shibgonj upazila of Chipainawabgonj district. However no case fatality was observed. This disease does not claim mortality but persistent arthralgia may lead to patient's sufferings.

Chapter 5

Discussion

Discussion

Charles Darwin in his classic “On the Origin of Species” (Darwin, 1859) wrote that “Natural Selection has been the main but not exclusive means of modification” and further pointed that “Action of Climate seems at first sight to be quite independent of the struggle for existence”. This article was perhaps the first scientific reference to climate change. Several autonomous observations link climate change to emergence or re-emergence of infectious diseases directly or indirectly. Climate change will affect the seasonal transmission, potential incidence and geographic range of different vector-borne diseases. These diseases include malaria, dengue fever, and yellow fever (all mosquito borne), different types of viral encephalitis, schistosomiasis (water-snails), leishmaniasis (sand-flies: South America and Mediterranean coast), Lyme disease (ticks), and onchocerciasis (West African river blindness, spread by black flies) (McMichael et al., 2003).

Dengue fever is caused by infection with four dengue virus serotypes of the family Flaviviridae. Clinical manifestation of the primary infection (dengue fever, DF) ranges from mild febrile illness to fever, arthralgia, rash, and hemorrhages. In our investigation we found nonsignificant relationship between number of cases of dengue disease and environmental factors temperature, humidity and rainfall. It may be suggested that environmental factors may not produce significant impact on the trend of this disease. Furthermore we explored mathematical model to analyze the data set. Mathematical /statistical modeling is for a better understanding of how the transmission of dengue is affected by climate variables (rainfall, temperature, and humidity) or even time and its variation is an important research subject in public health. Mathematical modeling can help our understanding and assessment of the present and future risk areas on spread of infectious diseases based on climate data. Here we have considered incidences of dengue as a function of time for Bangladesh. Mathematical modeling can help us not only understand and predict the future spread of infectious diseases but also evaluate strategies on combating dengue. If we analyze the mode 5, we find time is the function of dengue cases and according to *P*-value time is significant. For this reason, it should not be wise to think that there is no relation with other climate variables like temperature, rainfall and humidity. Epstein (2001) stated that "diseases carried by mosquito vectors are particularly sensitive to meteorological conditions". So "temperature thresholds limit the geographic range of mosquitoes". An example being that extreme heat kills mosquitoes, but warmer temperatures within their survival range, increases their reproduction rate, biting activity, and the rate at which pathogens mature within them (Epstein, 2001). Epidemiological studies have shown that temperature is one of the major factors in dengue transmission in urban areas (McMichael et al., 1996). It has been reported that increase of temperature from 26-28 to 30^{0}C decreases the extrinsic incubation of the dengue virus (serotype 2 & 4) which may facilitate the transmission of virus (Watts et al., 1987; Raohani et al., 2009). Higher humidity during rainy season facilitates the growth and survival of mosquitoes leading to an increase in the number of infected mosquitoes for successful propagation of virus (Focks et al., 1995; Barbazan et al., 2010). According to Barbazan et al (2010), an increase in mosquito longevity disproportionately enhances the number of potential transmissions by as much as five times when the survival rate rises from 0.80 to 0.9525 (Barbazan et al., 2010). Climate change projections on the basis of humidity for 2085 suggests that dengue transmission is shifting towards latitudinal and altitudinal range of the world (Hales et al., 2002). In temperate locations, climate change could further increase the length of the transmission season (Jetten and Focks, 1997). The decreases in winter rainfall and increases in summer rainfall will have a variety on larvae production, their growth and habitat of mosquito species. A general decrease in winter rain fall will have a deleterious effect on winter and spring mosquitoes through reduction in habitat and the reduced humidity may also impact on overwintering adults of mosquito species. Increased rain fall might actually enhance mosquito populations and increase virus transmission particularly if temperature has a supportive influence (Russell, 1998). Though our study recorded nonsignificant impact of climactic change on dengue fever, a recent study in Bangladesh showed that Climatic factors, *i.e*. rainfall, maximum temperature and relative humidity were significantly correlated with monthly reported dengue cases. The climate had a major effect on the occurrence of dengue infection in Dhaka city (Karim et al., 2012). Our findings differ with this report because the authors of the previous study used seasonal data from 2000 to 2008 only in Dhaka city but we represented yearly average data of whole country from 2000 to 2012. Besides the mathematical we used is based on variation of just a few parameters such as temperature, rainfall and humidity, whereas others key variables such as sea level, wind, land-use changes, sun, poverty etc. excluded from this model. Mean rainfall, temperature and humidity is used. All months have got equal weight in data management. Seasonal fluctuations have important impact on transmission of dengue fever. In this model we did not use seasonal data.

Visceral leishmaniasis (VL), also known as kala-azar, black fever, and Dumdum fever is the most severe form of leishmaniasis. Leishmaniasis is a disease caused by protozoan parasites of the *Leishmania* genus. This disease is the second-largest parasitic killer in the world (after malaria), responsible for an estimated 500,000 infections each year worldwide (Desjeux, 2001). The parasite migrates to the internal organs such as liver, spleen (hence '*visceral*'), and bone marrow, and, if left untreated, will almost always result in the death of the host. Signs and symptoms include fever, weight loss, mucosal ulcers, fatigue, anemia, and substantial swelling of the liver and spleen. Of particular concern, according to the World Health Organization (WHO), it is the emerging problem of HIV/VL co-infection (Karp et al., 1993). Historically, sand fly vectors from the Mediterranean have dispersed northwards in the postglacial period based on morphological samples from France and northeast Spain, and, more recently, sand flies have been reported in northern Germany (Perrotey et al., 2005). Kala-azar first came to the attention of Western doctors in 1824 in Jossore, India (now Bangladesh), where it was initially thought to be a form of malaria. In Bangladesh kala-azar has reemerged since the cessation of dichlorodiphenyl- trichloroethane (DDT) spraying operations. At least 20 million people in more than 27 districts are at risk. The estimated cumulative disease-specific burden is 35000 cases (Rahman, 2008). In our study we did not notice any significant relationship between climatic variables (temperature, humidity and rainfall) and incidence of kalaazar. Moreover, we have set up a mathematical to provide support for our findings. Here we have considered incidences of Kala-azar as a function of time for Bangladesh. Mathematical modeling can help us not only understand and predict the future spread of infectious diseases but also evaluate strategies on combating that disease. If we analysis the mode 5, we find time is the function of Kala-azar cases and according to *P* value time is more significant. For this reason, it should not be wise to think that there is no relation with other climate variables like temperature, rainfall and humidity. Though we found no significant relationship between climatic variables and incidence of kala-azar, the biting activity of sand flies (Leishmaniasis) is strongly seasonal. The survival rate of the vector depends on appropriate climatic condition. The mathematical model we developed for Kala-azar is based on mean data set of environmental variables. Our data set lacks seasonal data and we used mean value of each year. Moreover, we used data of short time range. That's why these limitations may have impact on our mathematical model.

Malaria is one of the most important infectious diseases worldwide. It is caused by attack with any of the four *Plasmodium* species that can infect humans (*P. falciparum, R. vivax, P. ovale,* and *P. malariae).* After successful malaria control in many countries, malaria incidence has been increasing at an alarming rate since the 1970s worldwide and is, therefore, considered to be a re-emerging disease (Gubler, 1998a; Nchinda, 1998). It is one of the most formidable and serious public health problems in Bangladesh (Alam et al., 2010). It is endemic in 13 northern and eastern areas bordering India and Myanmar, with 90% of morbidity and mortality reported from Rangamati, Bandarban and Khagrachari districts (Haque et al., 2010). *Anopheles* mosquitoes are vectors of malaria responsible for human and animal morbidity and mortality worldwide. The malaria situation in Bangladesh is complex due to high species diversity and species complexes with many sibling species presenting different ecological behaviors (Haque et al., 2010; Khan and Talibi, 1972; Elias et al., 1982; Maheswary et al., 1992a, 1993b, 1994c). We did not found any significant correlation with rain fall and incidence of malaria. Like us, Rahman et al (1993) did not found correlation between density and rainfall in Malaysia (Rahman et al, 1993). The observed results may be because Bangladesh has very high vector species diversity and vectors are suited to different breeding habitats. There was mark reduction of mosquito abundance occurs during May to August which may be due to the heavy rainfall, which flushes out breeding sites, larvae, and pupae. It also causes mechanical damage and egg mortality, therefore, reduces the adult abundance (Amusan et al., 2003). Usually, mosquitoes get optimum (22^0 - 30^0C) temperature for rising population after the winter (March and April) (Pratt and Moor, 1993). We did not found any significant association with temperature and malaria incidence (API) from data analysis. Temperature is directly affecting mosquito breeding, survival, and behavior and also malaria transmission (Craig wt al., 1999; Paaijmans et al., 2010; Ye´ et al., 2007; Bi et al., 2003). We were unable to detect a significant relationship with this factor, because the temperature ranges in this region are always suitable for mosquito breeding and development. Moreover, statistical significance alone does not always unclouded the complex biological dynamics of mosquito and temperature. Though we did not found significant correlation between rainfall and humidity with incidence of malaria (API), however, it was negatively correlated with malaria cases in India (Bhattacharya et al., 2006). Haque et al (2010) investigated the relationship between climatic parameters and malaria cases over the last 20 years in the malaria endemic district of Chittagong hill tracts of Bangladesh and showed insignificant relation (Haque et al., 2010). But, Wiwanitkit (2006) reported that malaria cases were positively associated with rainfall in Thailand (Wiwanitkit., 2006). Briet et al (2008) showed that malaria cases increased with lower rainfall and that the region with the highest rainfall had the least malaria (Briet et al., 2008). Malaria incidence and relative humidity were positively associated when not considering the effect of multiple factors. Bhattacharya et al (2006) accounted humidity levels between 55 and 80% were appropriate for both *P. falciparum* and *P. vivax* and this range of humidity are present throughout the year in Bangladesh (Bhattacharya et al., 2006). It was also reported that the malaria risk at 80% humidity was double as that of 60% (Ye et al., 2007; Tian et al., 2008). We explored a mathematical model for this disease which is based on few parameters such as temperature, rainfall and humidity. We did not include seasonal data of the environmental variables. That's why it will not be wise to say that environmental variables do not have impact on transmission of this disease.

However we cannot clearly state that temperature, humidity and rainfall do not have significant relation with dengue, malaria and kala-azar and its transmission in Bangladesh because in our country maximum rainfall happens between May to August, summer happens between March to May and winter happens between November to January. Humidity also fluctuates in these months. If we get seasonal data of these climatic variables then it will be helpful for us to clearly define the impact of these variables on these vector-borne diseases.

Chapter 6

Conclusion and Recommendations

Conclusion and recommendations

The study demonstrates the incidence of three vector borne diseases malaria, dengue and kala-azar and relationship with different climatic variables and its changes (temperature, humidity and rainfall). The outcome of relationship was not significant. Though we found no significant impact of climatic variables on vector borne diseases, we cannot reach a final decision because we used yearly average data for each variable. Besides we used data of short time in dengue and kala-azar. If we can use seasonal data that means monthly data of temperature, humidity and rainfall of each year, it will be possible to find out clear and more specific outcomes. Bangladesh government is determined to combat vector borne diseases, which is reflected through various programs undertaken by the Ministry of Health and Family Planning. WHO plays an important role in this in this programs. Therefore future attempts should be taken to explore a more specific model to predict effect of climate change (temperature, humidity and rainfall) on these vector borne diseases -

— To ensure complete management of the diseases and outbreaks for reducing mortality rate and prevention at national, district and upazilla level

—To implement integrated vector management program

—To develop a strong national public health system able to maintain public health events

For effective vector-borne diseases control we must work together to raise awareness about the threat posed by vector-borne diseases and to formulate evidence based strategies and policies to prevent vector borne diseases. WHO supports developing countries in the confirmation of outbreaks through its collaborating network of laboratories. The collaborating networks in Bangladesh are ICDDR,B, BIRDEM and NIPSOM. Bangladesh government should launch healthcare programs in collaboration with international organizations such as WHO, ADB, Unicef, NGOs etc. to successfully complete the aforementioned tasks.

Chapter 7

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