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Capacity strengthening in the Least Developed Countries (LDCs) for Adaptation to Climate Change (CLACC)

Climate Change and Health in Nepal

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Foreword

LI-BIRD carried out this study on "Human Health and Climate Change" under the Capacity Strengthening of Least Developed Countries (LDCs) for Adaptation to Climate Change (CLACC) network. Primary objective of the study was to create awareness among the health professional in Nepal showing some in-country review and analysis on relationship between human health and climate change including variability and extreme weather events.

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EXECUTIVE SUMMARY

Global climate change has serious implications for Nepal both currently and into the future. The temperature is rising in Nepal and Kathmandu valley and it will continue to rise in the coming years partly due to increases in the human population, vehicles, development activities, and change in agricultural patterns.

Vector and water-borne disease have been found to be increasing within country, along with a strong identified relationship between these diseases and temperature and precipitation. The projected increase of climate disasters under climate change, particularly from floods related to glacier melt, would have a direct impact on health in Nepal. It is already evident that malaria, Kalaazar, Japanese encephalitis, and other water borne diseases such as typhoid and cholera are commonly seen in different parts of the country.

It is mostly the poor and disadvantaged groups who suffer from these climate change consequences, but the health impacts will be experienced across all sectors and regions. In recent years climate change has not been a priority focus of the government. It is recommended here that the government devise clear sectoral policies to tackle the increasing climatic and environmental impacts.

It is necessary to highlight climate change risks and adaptation measures in the government five year plan and poverty reduction strategy. More research and studies are needed to fill the existing information and knowledge gap, and to identify key vulnerable areas, communities, and sector for integrated planning and implementation. The National Adaptation Programme of Action (NAPA) must be initiated soon so that priority sectors and projects can be identified and appropriately funded. Finally, these objectives necessitate an integrated approach for health planning and research in differing climatic regions in the country.

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Section I

1 Introduction

There is now widespread consensus that the Earth is warming at an unprecedented rate and it is likely to accelerate in the decades to come. All aspects of regional weather, climate, and sea level will be altered by climate change. There are risks associated with these changes and there are strategies to minimize such risks. These elements of the problem of climate change are neither accurately quantifiable (scientific uncertainty will remain) nor easily achievable (negotiations over policy will be complex).

The over stresses on the climate system are already causing impacts on Earth's surface. These include not only rising temperatures, but also increasingly frequent floods and droughts, and changes in natural ecosystems. The ecological and socio-economic damage of climate change in the region could have disastrous consequences, causing social unrest and environmental refugees. Sadly, rapidly progressing economic development in the region appears unlikely to benefit over 60% of the population in this region who suffer from poor adaptive capacity. Scientific projections affirm such worries. For example, with each 1°C increase in night time temperature in South Asia, declines in rice yield are projected to be about 6 to 10% on average. Over longer terms, possible warming of about 2.6°C over the 2030-2050 year period could lead to a precipitation reduction of 20%. Yet risks of flooding will also considerably increase in the main river basins of India, Bangladesh and Nepal. In Bangladesh, a rapid shift in extent and depth of flooding will occur with a global mean temperature rise of 2.6°C above pre industrial levels. Sea level rise will also cause severe damages to ecosystems, agriculture, and water resources especially in the coastal regions of Bangladesh and India. Widespread de-glaciation in the Himalayas is likely to adversely impact the hydrological regime of the region (ICIMOD/UNEP, 2002).

With climate change, Nepal itself faces unique and serious challenges. Although Nepal has a negligible share in the global emission of greenhouse gases, Nepal's major natural resources, biodiversity and water, are at the forefront of climate vulnerability. It is expected that increases in temperature will affect the snowline and disturb the discharge routine, leading to extreme flooding and altered water availability. The formation of glacier lakes and the potential for de-glaciation and its impact on downstream communities is particularly severe. For the last 3 years, the rainfall intensify has been very low compared to the last 3 decades. Kathmandu saw only 71 millimetres of rainfall in the first two weeks of August, well below the average of 319.6 millimetres for this month. A weak monsoon has followed one of the driest winter spells faced by the country in some three decades, severely affecting agriculture and power generation (Shrestha, 2003)

There is strong evidence suggesting that such climate changes can affect human health. The effects can be direct, such as through increased heat stress, and loss of life in floods and storms, or indirect through alterations in the ranges of disease vectors such as mosquitoes, water-borne pathogens and water and air quality, as well as food availability and quality. Health authorities have already expressed their concern about climate change and its impact on human health. There have been recent calls for national action by all countries to reduce and prevent these environmental changes, and to limit the exposures of human populations to climate change. In this way seeking to address the likely health risks over the coming decades (WHOSIS 2008),

In Nepal, extreme climate events are expected to become more frequent as a result of climate change. Such climate extremes can have devastating effects on human health and societies. In Nepal, historical information reveals that disasters, famines, and disease outbreaks have been triggered by droughts and floods. Malaria, Kala-azarKalaazar, and arboviral diseases are common in Nepal (DoHS 2005). Scientists and health experts have suggested that these diseases are heavily influenced by climate change.

There are also complex relationships between human health and water quality, water quantity, sanitation and hygiene. Changes in surface water quality and quantity are likely to affect the incidence of diarrhoeal diseases. This group of diseases includes conditions caused by bacteria such as cholera and typhoid, whose infections are dependent on the concentration of the pathogens in water or food. The IPCC concluded that changes in environmental temperature and precipitation could become more frequent in many part of south Asian countries, and as a result could lead to outbreaks of many water borne diseases (Shrestha et al. 2000)

1.1 Climate Change Background

Combusted fossil fuels generate 'greenhouse gases' (GHGs), which have been and are currently building up in the atmosphere. Accumulation of GHGs has caused the earth's temperature to rise, and is continuing to change the climate, with very dangerous consequences. This phenomenon is often termed "Global Warming", but may also lead to cooling in some parts of the globe, and is therefore more accurately termed 'climate change'.

Plants and animals exchange carbon dioxide (CO_2) with the atmosphere in a carbon cycle that has remained in balance for the last 10,000 years. However since the industrial revolution of the mid-eighteenth century, human activities have disturbed this balance. This has occurred through the burning of fossil fuels (oil, coal, gas and wood), which produces CO_2, and the intensive rearing of cattle and high scale plantation of rice which produces methane. Consequently, CO_2 concentration in the atmosphere has increased by about 30% in the last 200 years, from less than 280 parts per million (ppm) to 368 ppm today (Fig. 1). If current trends in fossil fuel burning continue, atmospheric CO_2 will be twice pre-industrial level by 2030, and three times the figure by 2100.

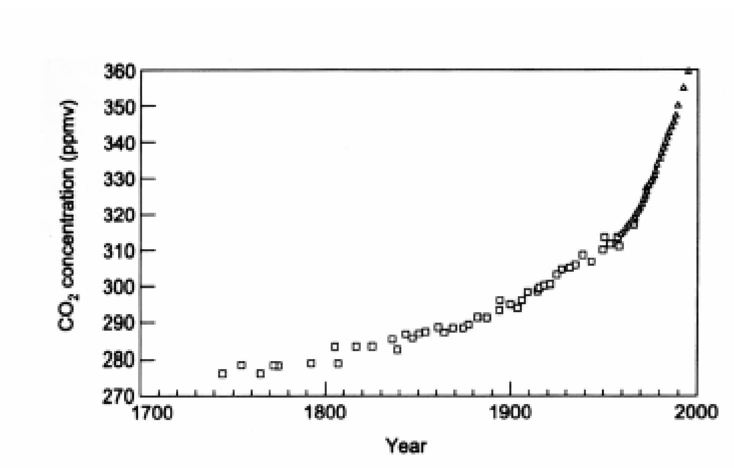

Fig. 1: **Atmospheric CO2 Concentrations since Mid-18th Century** (WHO,2000)

Although the amount of GHG emission in Nepal is insignificant, there are clear indications on the impacts of climate change in the Nepal Himalayas, particularly on snow melting and increases in the size of glacier lakes. For example, no lake was noticed in Barun area in the 1964 topographic survey. A small glacier lake of only 0.0245 square kilometre (km2) was observed in 1995 and that size had increased to 0.78 km2 by 1997. Expansion in the size of Tsho Rolpa Glacier Lake is also obvious. A glacier lake assessment study clearly indicated that its size had increased from only

0.23 km2 in 1957-1959 to 1.02 km2 in 1979 and to 1.65 km2 in 1997 (ICIMOD/UNEP 2002).

Temperature, an important element of climate change, has risen globally in the last few decades. The global average temperature has risen by almost 0.7°C over the last century, very likely as a result of human activity. The 1990s were the warmest decade, and the 1900s the warmest century of the last 1000 years (Fig. 2). According to the Intergovernmental Panel on Climate Change (IPCC), global temperature will rise 1-3.5°C by the year 2100 (IPCC, 1996). Even if greenhouse gas emissions were stabilized today, atmospheric temperature would continue to rise because of the long life time of greenhouse gases.

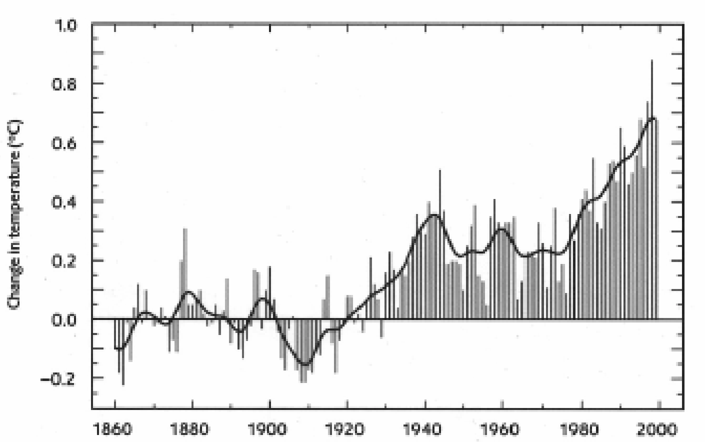

Fig. 2: **Global Temperature, 1860-1999**

1.2 Climate trends

Temperature observations in Nepal from 1977-1994 show a general warming trend (Shrestha et al. 1999). The temperature differences are most pronounced during the dry winter season, and least during the height of the monsoon. There is also significantly greater warming at higher elevations in the northern part of the country than at lower elevations in the south. This finding is reinforced by observations by Liu and Chen (2000) on the other side of the Himalayas on the Tibetan Plateau. Significant glacier retreat as well as significant measurable expansion of several glacial lakes has also been documented in recent decades, with an extremely high likelihood that such impacts are linked to rising temperatures.

The US Country Study of Nepal (USCSP, 1997) used records from 22 stations from the years 1971-1990. Again, the temperature differences are most pronounced during the dry winter season, and least during the height of the monsoon. Regarding spatial variation, temperatures increased faster at higher altitudes than at lower altitudes. The study reported, "Jumla with elevation of 2300m shows the highest value of temperature change whereas the station over the southern plain region like Biratnagar, Janakpur with the altitude of around 80 m shows the lowest value of temperature change." This indicates that, in general, greater warming may be expected in the northern mountainous parts of the country.

The annual average precipitation in Nepal is 1,907 mm, with 80% of it falling during the monsoon season from June to September. Studies project that annual precipitation will increase significantly if CO_2 concentration doubles; it will likely become drier during the dry season, with a significantly wetter monsoon season (as much as three times the current rainfall). It should be noted that the level of certainty for precipitation projections is less than for temperature. The distribution of rainfall throughout the year is a reliable factor in determining the risk of floods. This pattern of precipitation would likely cause droughts during the winter months and floods during the monsoon. There are no definitive trends in aggregate precipitation, although there is some evidence of more intense precipitation events (Yogacharya and Shrestha. 1997). A somewhat clearer picture emerges in stream flow patterns in certain rivers, where there has been an increase in the number of flood days. Some rivers are also exhibiting a trend towards a reduction in dependable flows in the dry season, which has implications both for water supply and energy generation (Shakya 2003). Glacier retreat also contributes significantly to stream flow variability in the spring and summer, while glacial lake outbursts are becoming more likely with rising temperatures, and are an additional source of flooding risk (Agrawala et al. 2003).

There is a significant and consistent increase in temperatures projected for Nepal for the years 2030, 2050, and 2100 across the various climate models (Table 1). The overall temperature is found to be rising at the rate of 0.41% per decade and temperature increases are somewhat larger for the winter months than the summer months. Climate models also project an overall increase in annual precipitation. However given the high standard deviation, the results for annual precipitation should be interpreted with caution. Even more speculative is the slight increase in winter precipitation, while the signal is somewhat more pronounced for the increase in precipitation during the summer monsoon months (June, July, and August). This is attributed to models estimating that air over land will warm more than air over oceans, leading to an amplification of the summer low-pressure system that is responsible for the monsoon. These results are therefore more broadly consistent. They are also more pronounced than the older Country Study for Nepal, which was based on outputs from four older generation GCMs, only two of which simulated the summer monsoon and its intensification under carbon dioxide doubling (Yogacharya and Shrestha 1997).

Table 1: **GCM estimates of temperature and precipitation changes for Nepal** (Agrawala et al., 2003)

Year	Temperature Change (^{0}C) Mean (standard deviation)			Precipitation change (%) Mean (standard deviation)		
	Annual	DJF	JJA	Annual	DJF	JJA
Baseline Average				1433 mm	73 mm	894 mm
2030	1.2 (0.27)	1.3 (0.40)	1.1 (0.20)	5.0 (3.85)	0.8 (9.95)	9.1 (7.11)
2050	1.7 (0.39)	1.8 (0.58)	1.6 (0.29)	7.3 (5.56	1.2 (14.37)	13.1 (10.28)
2100	3.0 (0.67)	3.2 (1.00)	2.9 (0.51)	2.6 (9.67)	2.1 (25.02)	122.9 (17.89)

Thus, based on this analysis there is reasonably high confidence that the warming trend already observed in recent decades will continue through the 21st century. There is also moderate confidence that the summer monsoon might intensify, thereby increasing the risk of flooding and landslides.

2 Climate change and human health

2.1 Impacts on Human Health

Environmental epidemiology involves the comparison of health differences among groups of people, and exposures to environmental conditions, including climate. Figure 3 describes the major components of the climate change process that are related to change in human health.

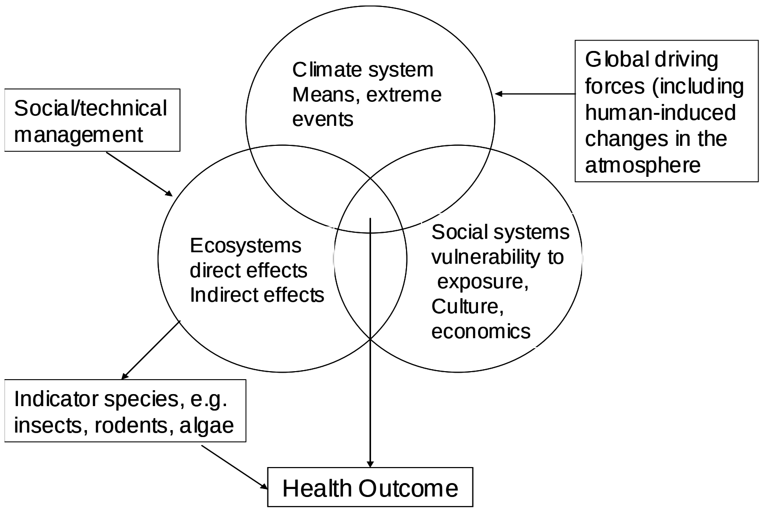

Fig 3: **Impacts of Bio-geophysical Systems on Human Health (WHO, 2000)**

In general, the range of possible impacts of climate change can be categorized into two pathways: direct and indirect. These pathways can be considered in figures 4 and 5 respectively.

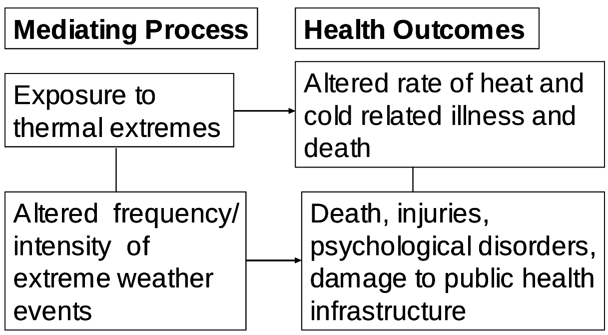

Fig. 4**: Direct pathways for the health impacts of Climatic Change**

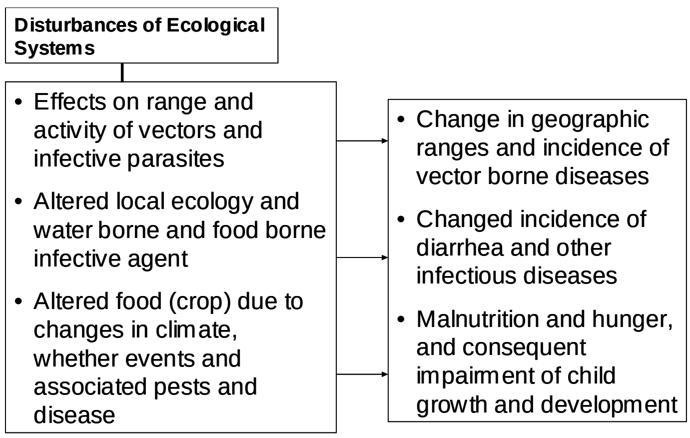

Fig. 5**: Indirect pathways for the health impacts of Climatic Change (WHO 2000)**

2.2 Vulnerability and Adaptation

Vulnerability is a subjective concept that includes three dimensions: exposure, sensitivity, and adaptive capacity of the affected system (Smit et al. 2001). The sensitivity and adaptive capacity of the affected system in particular depend on a range of socio-economic characteristics of the system. Several measures of social well-being such as income and income inequality, nutritional status, access to lifelines such as insurance and social security, and so on, can affect baseline vulnerability to a range of climatic risks. Other factors meanwhile might be risk specific – for example proportion of rainfed (as opposed to irrigated) agriculture might only be relevant for assessing vulnerability to drought. There are no universally accepted, objective means for "measuring" vulnerability (Shardul et al, 2003).

Instead, a score of high, medium, or low for a selection of vulnerability factors can be assigned for each assessed sector. In ranking the risks from climate change, the scoring for four factors was considered, but the most weight was placed on the certainty of impact. Impacts that are most certain, most severe, and most likely to become severe in the first half of the 21st century are ranked the highest. The results of this analysis are summarized in Table 2. Among the sector, health is also one of the most critical area which is mostly likely be affected in the years to come.

Table 2: **Priority ranking of climate change impacts for Nepal:** Source (OECD, 2003)

Resource sector	Ranked importance of resource	Certainty of impact	Timing of impact	Severity of impact (urgency)
Water resources and hydropower	High	High	High	High
Agriculture	Medium-low	Medium-low	Medium	High
Human health	**Low**	**Medium**	**Uncertain**	**High**
Ecosystems/ biodiversity	Low	Uncertain	Uncertain	Medium-high

2.3 Impact of extreme weather events

Extreme climate events are expected to become more frequent as a result of climate change in Nepal. Climate extremes can have devastating effects on human health and societies. In Nepal, historical information reveals that disasters, famines, and disease outbreaks have been triggered by droughts and floods. From 1954 to 2002, floods have affected over a million people in Nepal. As shown in the table below (Table 3), floods killed 5,003 people (24% of deaths from all disasters), left almost 70,000 homeless (45%), and caused damages amounting to US$990,613 (75%).

Table 3: **Damages caused by disasters 1954-2002.**

	Killed	**Injured**	**Homeless**	**Affected**	**Damage US $**
All disasters	20,927	7,794	153,550	7,053,754	1,316,413
Floods	5,003	725	69,350	1,531,125	990,613
Drought	0	0	0	4,400,000	1,000
Extreme Temp	60	210		210	
Windstorms	97	19	0	184	3600
Climate related	5160	954	69,350	5,931,519	1,004,213

Floods, and other climate-related disasters such as drought, extreme temperatures, and windstorms, may occur with greater frequency or intensity in the future (ICIMOD 2004). Heavy rains often trigger devastating landslides, which are another huge concern for Nepal. Disasters severely disrupt livelihoods and community development, whether they are flashfloods or slower onset events, such as drought. In fact, droughts can affect a greater number of people, and the slow onset sadly delays assistance until it is very late. By that point, many families may have sold off their productive assets, and they are left in a precarious state

2.4 Current burden of climate sensitive diseases

Climate change will affect health in countries in ways consistent with existing burdens of disease. Because of this, it is important to understand general demographic, health system, and mortality specifics of a country. Table 4 has shown selected indicators of Nepal, which may be relevant to current and future magnitudes of the health impacts of climate change in the country.

Table 4: **Selected demographic, health system, and mortality indicators for Nepal** (WHOSIS, 2008)

Indicator	Metric
Population total	27 641 000
Population annual growth rate (%)	2
Population living below poverty line (% living on < US$1 per day)	24.1[B]
Population proportion under 15 years (%)	38
Children <5 years of age stunted for age (%)	49.3
Children <5 years of age underweight for age (%)	38.8
Environment and public health workers density (per 10 000 population)	<1.0[B]
General government expenditure on health as percentage of total government expenditure	8.4[A]
Adult mortality rate (probability of dying between 15 to 60 years per 1000 population) both sexes	286
Under-5 mortality rate (probability of dying by age 5 per 1000 live births) both sexes	59
Infant mortality rate (per 1 000 live births) both sexes	46
Deaths among children under five years of age due to diarrhoeal diseases (%)	20.5[C]
Deaths among children under five years of age due to malaria (%)	0.8[C]
Population with sustainable access to improved drinking water sources (%) Total	89
(%) Urban	94
(%) Rural	88
Population with sustainable access to improved sanitation (%) Total	27
(%) Urban	45
(%) Rural	24

All metrics from 2006 unless superscript: A= 2005, B=2004, C=2000

Diarrhoeal diseases are still a major challenge in Nepal because of inadequate safe water supply, poor sanitation, and unhealthy living conditions. A yearly minimum death of 30,000 children and morbidity of 3.3 episodes per child was estimated due to diarrhoea (DoHS 2005). Typhoid fever is estimated to have caused 21.6 million illnesses and 216,500 deaths globally in 2000 affecting all age groups (WHO 2000).

Humans are the only natural hosts and reservoirs for all types of sanitation related communicable disease. It is spread by faecal-oral transmission. The bacterium can survive for days in groundwater, pond water, and seawater and for months in contaminated eggs and frozen oysters. The infectious dose is between 1000 to 1 million bacilli given orally. The infection is transmitted by ingestion of food and water contaminated with faeces. Established risk factors include contaminated water supply, eating ice cream, flavoured iced drinks, food from street vendors, raw fruits, and vegetables grown in fields fertilized with sewage (Pradhan, 2004). Traditionally, typhoid is believed to be the disease of monsoon seasons. The case fatality rate for typhoid without treatment and with treatment is 15% and 1% respectively.

The climate related diseases in the context of Nepal are also vector borne (malaria and leishmaniasis) and non vector borne diseases such as typhoid which is investigated in the case study of Patan Hospital. It is also known that the rate of development of the pathogen in the vector or in the environment also depends on the temperature (Fig. 6).

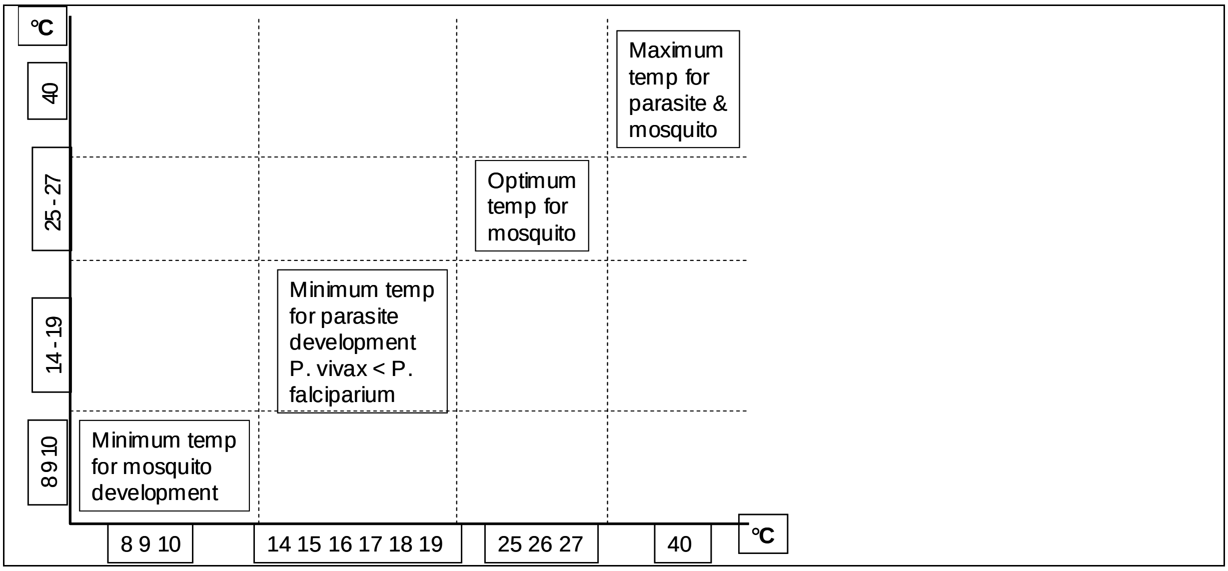

Figure 6: **Critical Temperatures in Malaria Epidemiology (°C)**
Source: WHO(2000)

Mosquito: Malaria Parasite

A mosquito has four distinct stages in its life cycle: egg, larva, pupa, and adult. The common groups of mosquitoes are *Aedes, Anopheles, Culex,* and *Culiseta* An average mosquito's life cycle is between 10-14 days. Poor drainage conditions are known to provide favourable environments for mosquito breeding. Figure 7 shows that Malaria disease is endemic in 65 districts of Nepal (DoHS 2005).

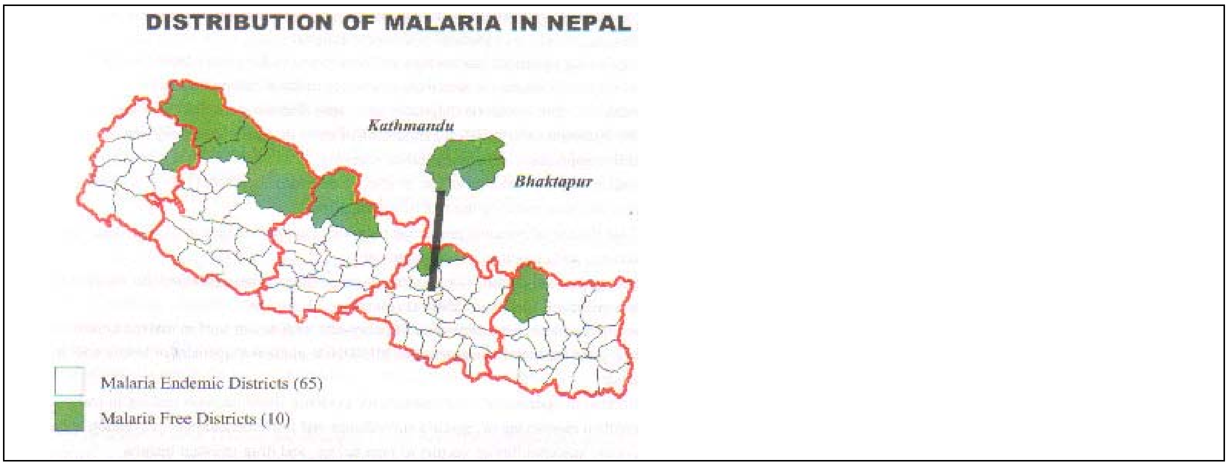

Figure 7: **Distribution of Malaria in Nepal (DoHS 2005)**

The disease decreased abruptly after a 'malaria eradication program' in 1958. In 1978, the name of the program was changed to 'malaria control program'. The most common species of malaria carrying vector occurring in Nepal is *Plasmodium vivax.* Another comparatively more harmful species that is present is *P. falciparum*. The increasing instances of this parasite have been observed, and may be due to the climate change (Fig.8). These observations are supported by the study done in Pakistan (Fig. 9). The common vector (definitive host) for the disease is *Anopheles minimus*.

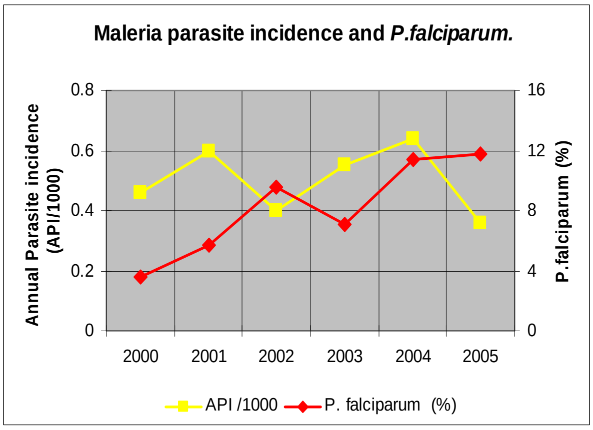

Fig. 8: **Malaria Parasite incidence over time**

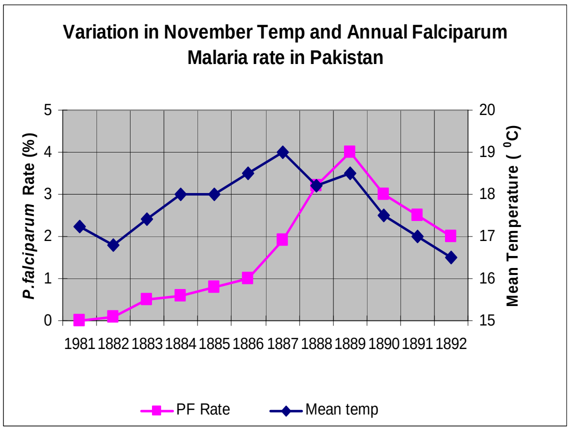

Fig. 9: **Variation in Temperature and Malaria over time in Pakistan**

Housefly

Houseflies have also been identified for their association to human diseases:

- Housefly (*Musca domestica*), Lesser housefly (*Fannia canicularis*), and Stable fly (*Stomoxys calcitrans*) are the most common flies occurring in homes
- Houseflies go through 4 stages of development: egg, larva, pupa and adult
- The entire life cycle can be completed in 7-10 days under ideal conditions; Adult females can lay as many as 2,700 eggs in 30 days but more commonly lay 350-900 in 5 or 6 different batches; adult flies live from 30-60 days during warmer months.
- Generally, the warmer the temperature the faster the flies will develop. In the winter, most of them survive in the larval or pupa stage in some protected warm location.
- They are capable of carrying over 100 pathogens, such as typhoid, cholera, salmonella, bacillary dysentery, tuberculosis, anthrax ophthalmia, and parasitic worms. Some strains have become immune to common insecticides.
- The vector carries bacteria on the outside of its body, and also regurgitates saliva and deposits wastes on human food.

Kala-Azar -Visceral Leishmaniasis

Kala-Azar is an endemic disease in 12 districts of Nepal. The incidence of Kala-Azar is actually decreasing, and may be due to the use of regular pesticide spray of Cypermethrin with 0.025g/m^2 (Table 5). However, the long term consequences of the pesticide are not known. Also interestingly, there has not been much change in case fatality rate.

Table 5: **Trend of Kala-azar**

Year	Incidence/100,000	CFR/100
2002	19.9	1.4
2003	24.6	0.8
2004	11.1	0.9

Source: DoHS (2005)

Yet overall, the common trends of the vector borne diseases in Nepal has been a decreasing one (Figure 10).

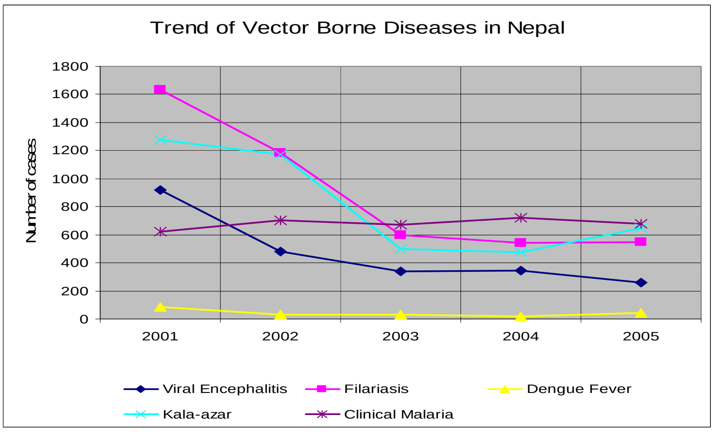

Fig. 10: **Trend of the vector borne diseases in Nepal (DoHS 2005)**

The diseases of people in Nepal can also be indicated in terms of access to drinking water sources and sanitation conditions. Table 6 describes Nepalese households' accessibility pattern to available drinking water sources. Still slightly below 30 percent of households do not have access to a 'safe' piped water source. Such households must depend on other water sources, which are relatively less safe because of lack of protection from contamination during the rainy season (ADB/ICIMOD, 2006).

Table 6: **Households' Accessibility Patterns to Drinking Water Sources**

Ecological Region	Total Households	Percent of Total Households					
		Tap/Pipe	Well	Tube Well	Stone spout	Stream	Others
Mountain	285,217	72.2	6.2	0.0	17.1	3.4	1.0
Hill	1,950,345	72.2	12.0	2.4	10.1	2.0	1.2
Terai	1,938,895	30.8	6.5	58.6	1.1	0.6	2.5

The sanitation conditions can also be explained in terms of households' access to toilets and sewerage. Table 8 shows that about 54 percent households do not have access to toilets, leaving them to defecate in open fields, on river banks, around ponds and lakes or in the jungle. Such locations eventually mix with other water sources such as rivers, ponds, and lakes. Again, this becomes a particularly serious problem during the rainy season. These environmental realities alongside the existing practices of waste water used by farmers in vegetable gardening, leads to many water borne diseases such as typhoid, diarrhoea, dysentery, and hepatitis.

Table 7: **Households' access to Toilets and Sanitation**

Ecological Region	% toilet coverage	% sewerage coverage
Mountain	40.4	1.0
Hill	55.8	18.7
Terai	37.3	7.4
Nepal	46.1	12.1

Source: NLSS (2004)

2.5 Health Related Issues in Context of Nepal

One of the indirect consequences of global warming in mountain regions is increasing risk of infectious diseases. Scientists have reported that the mosquitoes that carry malaria, dengue, and yellow fever are spreading to higher altitudes as temperatures warm. Unfortunately, mountain people are among the world's poorest citizens. With few resources to ward off infectious diseases, they are likely to be among global warning's greatest victims if human activities that contribute to climate change are not soon reversed (Hall et al. 2002).

Human health is arguably the most complex of the major types of global change impacts on societies. WWF has published evidence that correlates climate change with health. In one example, it has been quoted that an increase in malaria is attributable to climate change. Water is the breeding ground for mosquitoes and warmer temperature mean these disease carrying pests will breed in previously cool areas. Outbreaks of Kalaazar and Japanese encephalitis are also linked to climate change in Nepal's subtropical and hot regions. Similarly, flooding and water contamination can lead to heightened risk of water-borne diseases. Contagious outbreaks are more pronounced after flooding disrupts sewage systems.

Because of the existing poor state of health services in Nepal, public health is indeed at higher risks than before from the unfavourable effects of climate change. Malaria and Japanese encephalitis are the two most common vector-borne diseases in the country, both of which are transmitted by the mosquito vector. These vector-borne diseases may increase their impact through expansion to new regions. One area that would be at risk of an increase in disease is the lower flat pain of Nepal, the Terai region, which is warmer than the mountainous regions. The current lack of primary healthcare for large portions of the population also contributes to their vulnerability (Raut, 2004).

2.6 Climates and Diseases

Table 8 indicates that different health outcomes can be uniquely assessed in terms of climate change. In this context, relative impacts are compared and therefore do not take into account existing burdens of disease. With this in mind, vector borne and non vector borne diseases can still be considered very important in Nepal though they have individually shown only medium to small relative effects to climate change.

Table 8: **Likely Relative Impacts on Health of the Climate Change Components**

Health outcome	Aspects of climate change			
	Change in mean temp	Extreme events	Climate change variation	Day night difference
Heat-related deaths and illness		+ + +		+
Physical and psychological trauma		+ + + +		
Vector borne infectious diseases	+ + +	+ +	+	
Non vector borne infectious diseases	+	+	+ +	
Food availability and hunger	+ +	+	+	
Consequences of sea level rise	+ +	+ +		
Respiratory effects – air pollutant	+	+ +		+
Population displacement	+ +	+	+	

Note: Number of + indicates the magnitude of effects; empty cells indicate no known relationship
Source: WHO/WMO (1996): pp 13.

a. Malaria

The general trend of Malaria positive cases was found to increase in Nepal between the period 1963-1985, and then decreased due to the use of mitigation measures (Figure 11.).

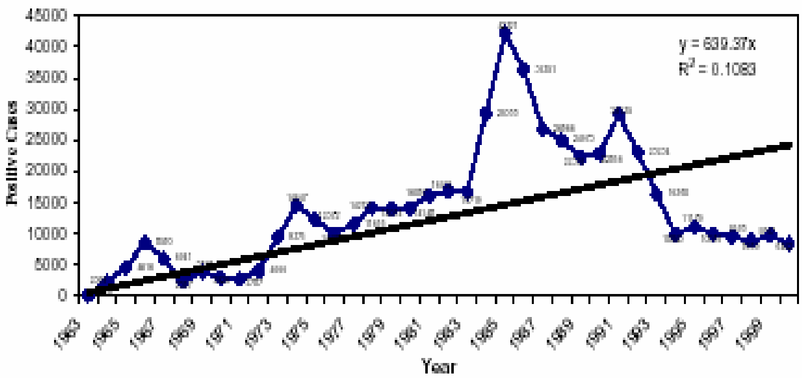

Figure 11: **Trend of Malaria positive cases in Nepal during 1963 to 1999**

Central Nepal recorded the highest number of malaria positive cases, whereas Mid-Western Nepal had the least reported cases. Malaria positive cases are normally found at maximum during wet summers. Malaria positive cases become measurable when the average annual temperature is between 14 and 27° C, with the highest number of cases at 24-25° C in the tropical zone (Figure 12). Malaria cases are also found in the subtropical (18-24° C) and warm temperate (14-18° C) regions of Nepal.

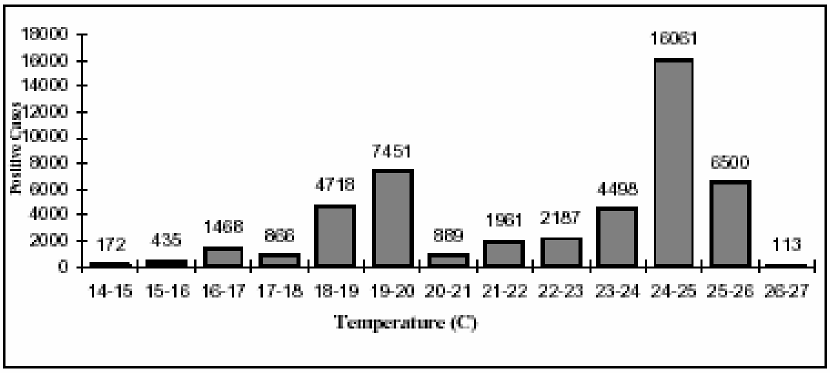

Figure 12: Trend of **Malaria positive cases with respect to temperature**

It is very likely that a rise in temperature due to climate change will increase malaria cases, with the subtropical and warm temperate regions of Nepal being particularly more conducive to the diseases. Temperatures between 22-32ºC are very favourable for malaria parasites to develop and complete their transmission cycle, while temperatures above 32-34ºC could reduce their survival rates substantially. Thus the range of temperatures in Nepal is suitable for the malaria parasites to exist & develop.

b. Kala-azar

Kala-azar (*Visceral leishmaniasis*) cases have also shown increasing trends in the last two decades (Figure 13), and this trend is becoming more pronounced in the recent years.

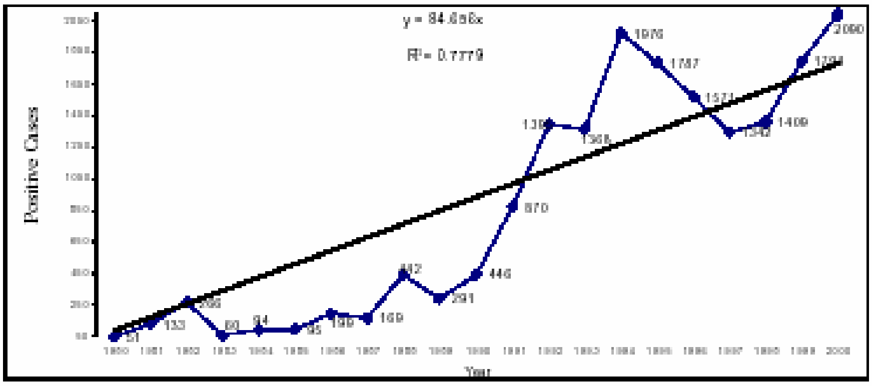

Figure 13: **Trend of Kala-azar cases in Nepal (DoHS 2001)**

Kala-azar has reached epidemic form in eastern and central regions of Nepal, especially in the Terai districts. Most vulnerable are the poor people and rural cattle keepers. This disease occurs mainly in the summer season when the vector is very active and gets optimum environment for breeding. Previously, Kala-azar was found only in the eastern and central Terai regions of the kingdom. But in 1998, cases were recorded in other non-indigenous districts as well.

c. Japanese Encephalitis

Changing climate may be one of the factors for this disease's emergence in new areas. Similar to other vector-borne diseases, Japanese Encephalitis occurs mainly at the average annual temperature range of 23-26ºC. Increases in temperature will therefore make subtropical regions more vulnerable to this disease. Vulnerability is becoming serious in Nepal as the number of patients with this disease is increasing every year. This is most probably due to the rising trend of temperatures (Figure 14 below).

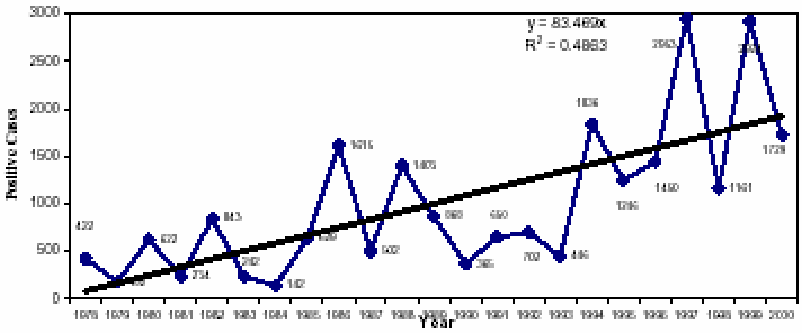

Figure 14: **Trend of Japanese encephalitis cases (DoHS 2001)**

d. Water-borne diseases

There are complex relationships between human health and water quality, water quantity, sanitation and hygiene. It has been noticed that associations between climate and water-borne diseases are based on the indirect evidence of seasonal variations. However, there are studies that provide evidence that water-borne diseases are linked to climatic factors such as temperature and precipitation. Heavy rainfall events transport terrestrial microbiological agents into drinking-water sources, resulting in possible outbreaks of cryptosporidiosis, giardiasis, amoebiasis, typhoid, and other infections. The IPCC (1996) mentioned that water-borne disease such as cholera, and various diarrhoeal diseases such as giardiasis, salmonellosis and cryptosporidiosis, occured commonly with contamination of drinking water in many south Asian countries. These diseases could become more frequent in many parts of south Asia in a warmer climate.

E. Typhoid

Typhoid fever is a systemic infection with the bacterium *Salmonella typhi.* It was an important cause of morbidity and mortality in the overcrowded and unsanitary urban conditions of 19th century in the world. Yet the provision of clean water supply and good sewage systems led to a dramatic decrease in the incidence of typhoid in these countries. Today the vast burden of disease is encountered in the developing world where sanitary conditions remain poor. Incidence rates of 198 per 10^5 persons per year in Vietnam have recently been reported and it is estimated that the incidence in Kathmandu is considerably higher (DoHS, 2001).

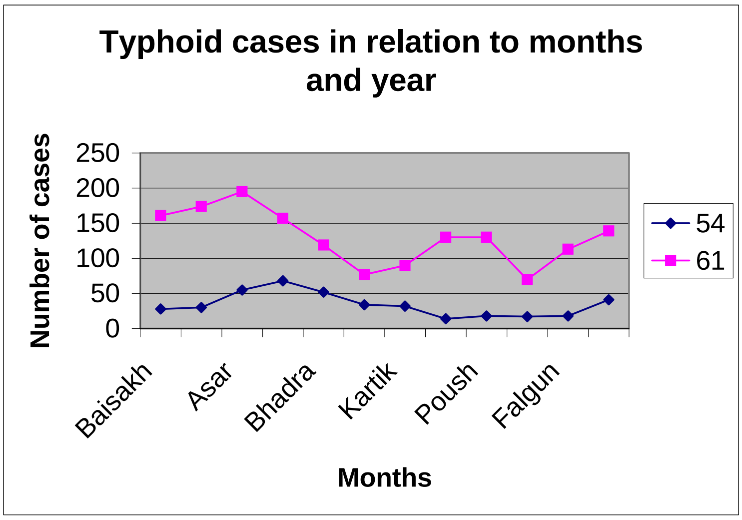

Figure 15: **Typhoid cases in relation to months and year**

Typhoid fever is estimated to have caused 21.6 million illnesses and 216 500 deaths globally in 2000, affecting all age groups. As mentioned, humans are the only natural hosts and reservoirs, and the disease is spread by faecal-oral transmission. Typhoid fever is traditionally considered to occur during summer and monsoon seasons. However, typhoid fever has started occurring in winter more significantly in recent years. This fact is illustrated in Figure 15 (Sinha 1999).

SECTION II

3 Case study: Climate and typhoid in Kathmandu

There are preliminary reports of a re-emergence of vector borne diseases like malaria, visceral leishmaniasis, and encephalitis in areas where they had previously been eradicated. Scientists are concerned that not only antimicrobial resistance but also global warming and climate changes must have contributed to his phenomena. With this view in mind, this case study attempts to explore if recent trends of climatic changes and rising temperature of the Kathmandu valley have any association with increasing number of culture positive typhoid cases in an urban hospital of the valley.

3.1 Objectives of case study

The main objective of this study is to carry out research and analysis on adaptation to climate change for vulnerable communities, with emphasis on health and livelihoods in a selected vulnerable community. Specifically, the study aims to:

- ❖ Describe and quantify the association between climate factors (temperature, rainfall) and reported cases of typhoid in Nepal
- ❖ Describe the impact of an extreme weather event in terms of the burden of climate-sensitive diseases
- ❖ Detect changes in typhoid morbidity due to (any) observed climate warming due to anthropogenic climate change

3.2 Study process

a. *Desk review*

Secondary literature was the principle source of review. Journal articles, published books and papers (seminar/workshop proceedings), institutional reports, papers, articles, books, and other publication materials were reviewed.

b. *Consultation with key stakeholders*

Various stakeholders working in climate change, including government agencies, were consulted through a series of meeting. Government officials including the IPCC national focal point were consulted to inform them about the study.

c. *E-mail and internet based search*

The review used e-mail and Internet as sources of information. Due to time and availability of some key expert persons, e-mail was observed to be the best option.

d. *Stakeholder Workshop*

A one day stakeholder workshop was organized to share the findings of the case study as well as get feedback and suggestions from participants. This workshop was also used as a venue to become aware of the activities carried out by various partner institutions on climate change, and adaptation in particular.

3.3 Data and methods

Typhoid data

Kathmandu (population > 1.5 million), the largest city in Nepal, is situated at an altitude of 1,300 meters. The climate varies from cool, dry winters (December to February), to the hot monsoon season (June to September). Traditionally, the monsoon season is characterized by a heavy burden of enteric infections, while respiratory tract infections are more predominant in winter. Patan Hospital is one of three large general hospitals within the Kathmandu metropolitan area. It has 251 beds and provides inpatient and outpatient medical, surgical, pediatric, obstetrics, and gynecology services, and serves as a primary care facility. Each year Patan Hospital has approximately 250,000 outpatient visits, 30,000 Emergency Department visits, and 15,000 admissions. Bed occupancy for medical wards runs at almost 100%, and approximately 90% of the patients are residents in the immediate Kathmandu Valley area (Bagmati Zone).

We obtained data on cases of laboratory confirmed episodes of Typhoid fever from 1997 to 2005. This includes both inpatient and outpatient data. The data were retrieved from a microbiology laboratory where all the blood cultures from both in-patients and outpatients are collected and cultured.

Weather data

We obtained meteorological data for Kathmandu Valley from the Department of Meteorology and hydrology, Nepal Government, Barbarmahal Kathmandu, Nepal. The data originate from Khumaltaar meteorological station.

3.4 Findings

Typhoid Epidemiology

Typhoid fever is a systemic bacterial infection caused by *Salmonella typhi*. Typhoid is usually acquired through ingestion of water or food contaminated by the urine or faeces of infected carriers, and as such it is a common illness in areas where sanitation is poor. Today, outbreaks of typhoid fever occur most often in developing countries, in refugee camps, and in underserved areas with a high population density. In some areas the annual incidence is as high as 198 cases per 100,000 people. Contrary to a previously held view, the disease causes considerable morbidity in children. Worldwide, at least 17 million new cases and up to 600,000 deaths are reported annually. The case-fatality rate of typhoid fever is 10%, but it can be reduced to 1% with appropriate antibiotic treatment (WHO 1996).

Infections with other *Salmonella* bacteria also occur. Paratyphoid fever is also a systemic disease, caused by *Salmonella paratyphi*. Its presenting symptoms are similar to those of typhoid fever, but they are milder and the case-fatality rate is much lower. The other pattern of *Salmonella* infection is primarily enteric (food poisoning) and can occur with exposure to one of hundreds of different *Salmonella* species.

Clinical management

Although in most cases a transient and mild episode of diarrhoea develops shortly after ingesting *S.* typhi bacteria, most cases are asymptomatic during an incubation period of 7 – 14 days. The disease manifests often a week or so after ingestion and begins with an intermittent fever that becomes high and sustained, with severe headache, poorly localized abdominal discomfort, malaise and anorexia. There may also be a non-productive cough. Although the focus of the infection is the intestine, constipation is more common than diarrhoea in adults. The reverse is true in AIDS patients and children.

Typhoid fever is diagnosed by means of bacterial culture. A blood culture is usually conducted and is most sensitive in the first week of illness. Bone marrow culture is more sensitive for detection than blood culture, regardless of the duration of illness or treatment with antibiotics, but it is technically more difficult to perform. Faecal cultures yield positive results in only one-third of cases. Serologic testing for *Salmonella* antibodies (Widal's test) is also possible but shows cross-reactivity with other *Salmonella* species and has a sensitivity of only 70%.

Prevention and control

Typhoid prevention measures target hand washing, sanitary disposal of human faeces, provision of safe public water supplies, controlling of flies, scrupulous food preparation, and pasteurization of milk and other dairy products. In addition, because many seafood beds are contaminated with sewage, attention is given to limiting the collection and marketing of shellfish to approved sources, and to steaming or boiling shellfish for at least 10 minutes.

Immunity is conferred after infection or through vaccination. In either case, it is only temporary. Typhoid fever vaccine can be given orally or parenterally, and the efficacy and possible adverse reactions to each type differ. Vaccination is often recommended for people travelling to endemic regions, although the cost-effectiveness of this strategy has been questioned. The effectiveness of mass vaccinations in endemic regions are undergoing further study, but such campaigns should be seriously considered in high-risk situations, such as disaster relief sites and refugee camps.

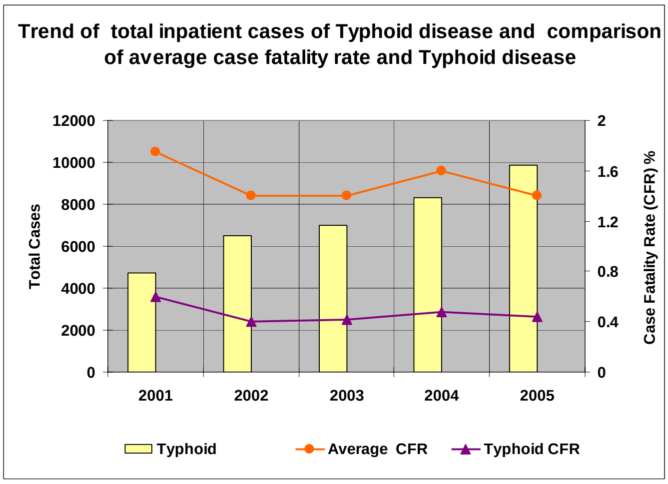

Fig. 16: **Trend of Typhoid cases**

The situation in Nepal appears to follow some general trends. Figure 16 shows that the cases of typhoid in Nepal have been increasing since 2001 but that average case fatality rates appear to be generally decreasing among year to year fluctuations (DoHS 2005).

Location Kathmandu Valley

The climate, water sources, and human health aspects of typhoid are explained based on the data available in the Kathmandu Valley. Briefly, the climatic conditions of the valley are characterized by cool winter days (with recently lessening morning frost) and warmer summer days.

Table 9 indicates that different sources of water consumed by the people of the valley are not free from faecal contamination, though they are safe within WHO guidelines in terms of selected chemical parameters. This is verified by the study of Pradhan (2000, 2004). According to this study no single drinking water source, including dug wells, shallow wells, deep wells, springs, stone spouts, ponds and river, and pipe water, is 100 percent safe from pathogenic bacterial contamination.

Table 9: **Water quality parameters of different sources of Kathmandu valley**

Parameter	Water sources				WHO GV
	Pr_Tap	Pu_Tap	Well	S. spout	
pH	6.5-8.2	6.5-7.5	7.5	7.5	6.5-8.5
Iron (mg/l)	ND-0.2	0.2	0.2	0.3	0.3 -3
Chlorine mg/l	ND	ND	ND	ND	0.2
Chloride mg/l	10-30	22-45	26-27	23-45	250
N-NH4 (mg/l)	ND-0.2	0.2	0.2	0.2	0.04-0.4
PO4 – P (mg/l)	0.1	0.1	0.1	0.1	0.4-5.0
Coliform bacteria (source)	+/-	+	+	+	-
Coliform bacteria (consumption point)	+				-
E. coli cfu/100 ml	10-131	3-20	48-200	58	0

Pr_Tap = private tap; Pr_Tap = public tap; S. spout = stone spout; WHO GV = World Health Organisation Guideline Values (Pradhan, 2004).

In addition to household use, the water of these different sources is used by the farmers to wash fresh vegetables for marketing. The consumption of such vegetables can also be followed by water borne diseases (Pradhan 2001, 2003)

There is data available on the temperature and typhoid cases for the Kathmandu Valley. Figure 16 shows that the cases of typhoid recorded at Patan hospital, Kathamndurise from the month of May onwards; reached a peak in July and declining in the following months. This pattern coincides with the rising temperature. Of particular importance, the months May and June fall in the summer season, during which the monsoon rainfall also occurs.

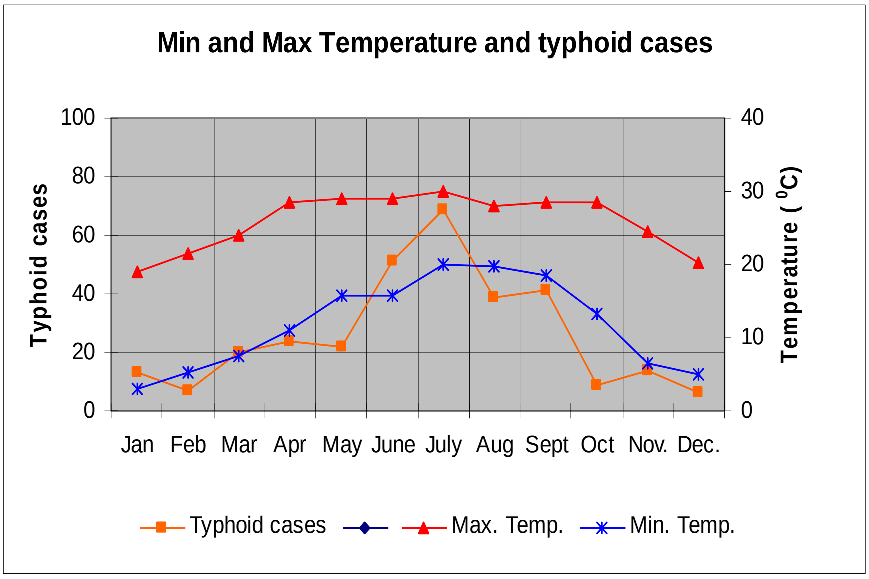

Fig 17: **Distribution of temperature and Typhoid Cases by Month, Kathmandu**

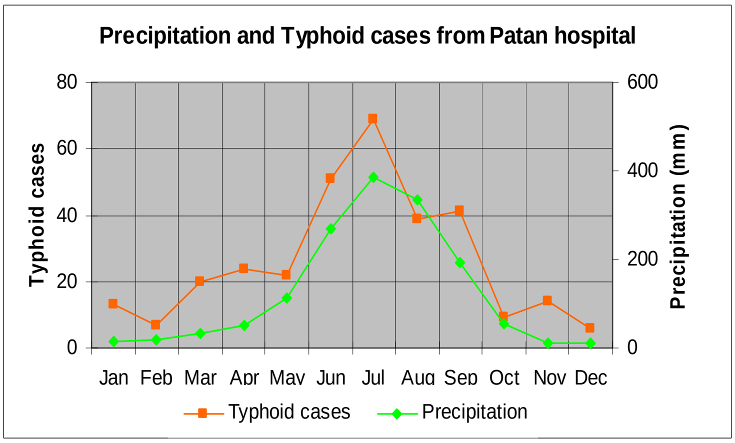

Fig. 18: **Distribution of Rainfall and Typhoid Cases by Month, Kathmandu**

The cases of typhoid can also be linked to the precipitation pattern in the valley (Figure 18 above). The rainfall totals rise from mid-May; reach maximum in July and go down from the month of September. Coincidently, the cases of typhoid rise during the months of June, July, August and September. Though a wealth of information would be required to establish true cause and effect, we can predict from this that drinking water sources are likely contaminated with faecal matter during rainfall periods.

Overall, there is an increasing trend of typhoid cases from 1997 onward (Figure 19 below). The typhoid positive cases have been confirmed by blood culture tests that range from 6 to 19 percent of the total cases cultured.

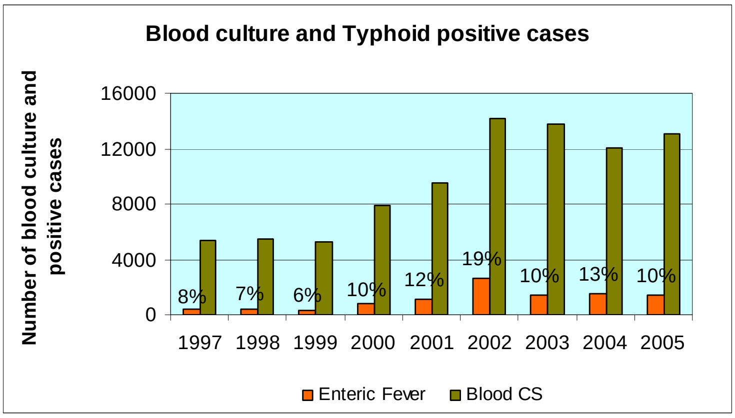

Fig. 19: Pattern of blood culture identified Typhoid case

3.5 Discussion

A number of studies have shown an effect of ambient temperature on the occurrence of certain enteric diseases. A study exploring growth rates of salmonellosis under varying temperatures found that the growth rate increased as the temperature increased (Mackey and Kerridge 1988). It has also been noted that enteric diseases in temperate latitudes have a seasonal pattern, with the highest incidence of illness during the summer months (Isaacs et al. 1998). A study of food borne illness in the United Kingdom found a relationship between the incidence of disease and the temperature in the month preceding the illness (Bentham and Langford 2001). In a study of five cities in Australia, D'Souza et al. (2004) found a significant positive association between mean temperature in the previous month and the number of notifications of cases of Salmonella in the current month. It is therefore believed that the survival and growth of certain enteric pathogens are, within limits, positively correlated with ambient temperature (Hall et al. 2002). We found that weekly counts of typhoid fever generally increased with weekly temperature in Kathmandu, after adjusting for trend, season and 2002 outbreak.

Our results are consistent with research carried out by Bentham and Langford (1995, 2001), D'Souza et al. (2004), Kovats et al. (2004), and Fluery et al (2006). Previous studies have demonstrated the threshold temperature value above which there is linear relationship with occurrence of typhoid fever. However, we didn't find any threshold value, suggesting that the temperature does have effect in the lower end of temperature. No other studies have investigated effects of rainfall on the occurrence of typhoid fever. We found that cases of typhoid fever are positively linked with up to 50mm of weekly rainfall. When temperature, season, trend and 2002 outbreak is included in the model no association was seen. This reflects that temperature has a much stronger relationship with typhoid than rainfall.

In summary, warmer ambient temperature in Kathmandu is associated with an increase in the risk of typhoid fever after controlling for season, disease trends, and a 2002 outbreak. It is known that many pathogens in the environment are sensitive to ambient temperature. Given global climate change and projections for warmer summers and warmer winters, an increase in cases of food-borne illness may be expected. Problems may arise from production to consumption of food during these warmer periods. Although some trends in enteric disease infections are decreasing, public health authorities may need to take present action on such climate-disease relationships. Action could come in the form of public education programs and other polices for particularly vulnerable groups, and to relevant occupational groups in the short term. In the longer term, new policies may be needed in anticipation of additional cases of food borne disease due to climate change.

Section III

4 Key Vulnerabilities

There is an increasing trend of vector and water-borne diseases in the country of Nepal. Coincidently, the occurrence of cases of water borne diseases such as typhoid has increased in the summer months (May-September) when the temperature and the amount of rainfall are also at year maximums. It appears that there is a relationship between temperature and precipitation and vector and water-borne diseases in Nepal. But a cause and effect relationship is not completely certain, and must be continually addressed in further studies.

There have recently been outbreaks of malaria, Kala-azar, and Japanese Encephalitis in the country side of Nepal and all seem to be associated with changes in temperature. Thousands of people die from these vector borne diseases every year. Similarly, severity of water borne diseases is also very high. Typhoid, cholera and other diarrhoeal diseases are becoming common in Nepal due to extreme drought, flooding, and poor sanitation.

The most vulnerable group is poor households who do not have access to good sanitation, regular health check ups, and other facilities. Women, children and aged persons have been the most severely affected groups within the poor households. The cases of malaria, Kala-azar, and Japanese Encephalitis are in increasing trend and their coverage in terms of district are also increasing (DoHS 2006). However, case fatality rate of the diseases has been seen in decreasing trend of all the vector borne diseases. Water borne diseases are more common in the urban areas like Kathmandu and other cities, and most severely affect the poor persons living as squatters and those in poor physical condition (ICIMOD 2007).

Climate variability will increase and some extreme climate events will become more intense and possibly more frequent with climate change. An observed warming trend over the past several decades is already having discernible and generally adverse impacts on many key resources in Nepal – many mountain glaciers are in a general state of retreat, and some are expected to disappear entirely in the coming decades. Glacier retreat and ice melt are also significantly increasing the size and volume of several of Nepal's more than two thousand glacial lakes, making them more prone to glacial lake outburst flooding (GLOF). Climate change scenarios across multiple general circulation models show considerable convergence on continued warming, with country average mean temperature increases of 1.2°C and 3°C projected by 2050 and 2100. Continued glacier retreat can also reduce dry season river flows fed by glacier melt, while there is moderate confidence across climate models that the monsoon might intensify under climate change. This contributes to enhanced variability of river flows. Potential intensification of monsoons combined with enhancement of GLOF risks also contributes to enhanced risk of flooding and landslides, which both have serious impacts on mountain agriculture and rural livelihoods.

There is strong evidence that climate change could affect human health in Nepal. The outbreak of malaria, Kala-azar, and arboviral diseases have all been recently observed in Nepal. Water borne diseases like typhoid are also causing serious problems in the densely populated urban areas of Nepal like Kathmandu. Sadly, there has been almost negligible research and development support from the government and other concerned agencies. It was also discovered that there is limited knowledge, information, and awareness among health sector communities about the potential impact of climate change on human health.

There is an increasing trend of vector and water-borne diseases in the country. Coincidently, the occurrence of cases of water borne diseases such as typhoid has increased in the summer months (May-September) where the temperature and the amount of rainfall are also higher. It appears that there is a relationship between temperature and precipitation and vector and water-borne diseases, but further research is required to establish cause and effect mechanisms.

The case study presented here showed that typhoid has a seasonal trend with peaks in summer months. Ambient temperature has a positive effect on typhoid cases without a discernable threshold value. Without an identified threshold temperature is seen to have an effect even at the lower end of temperatures (in winter). Typhoid cases have a positive association with rainfall up to 50 mm per week, but beyond that there appears to be no clear association.

5 Policy Recommendations

The health sector should have a strategic focus, programme, and policy to combat with negative health impact of climate change. An integrated approach must be adopted for health planning and research in different climatic regions in the country. It is argued that health should not be addressed in isolation from other sectors.

1. The control of typhoid cases in Nepal is not possible solely with a curative approach. Any approach must be supported by preventative and promoting activities such as control of disease reservoirs, disease identification, isolation and treatment, sanitation, and immunization
2. Quarantine program needs to be strengthened, and effective mechanisms for eradication and disease control program should be given more emphasis.
3. Promotion of health education for community awareness to climate-sensitive diseases may be an effective adaptive measure to prevent future occurrences of these diseases.
4. Public awareness regarding the changing climatic situation and its health impact is needed. This can be an important strategy to reduce the vulnerability to climate change and increase the effectiveness of adaptation options.
5. The Government should place great focus on expediting the NAPA formulation process.

6 Research Recommendations

As described above, the data in this case study does not address the cause and effect relationship of typhoid with temperature. It more simply demonstrates the positive relationship between increase in temperature and typhoid cases, as typhoid is usually seen in summer months or during warmer temperatures. We recommend a more detailed epidemiological study to better investigate the possibilities of climate effects on typhoid cases in Nepal.

- Research must be undertaken on healthy thermal environment management and control strategies in work places.
- Studies are needed on epidemiological forecasting and early warming systems using RS/GIS technology applicable in high-risk areas for Malaria, Japanese Encephalitis, diarrhoeal disease and nutritional disorders.
- Prospective and retrospective studies are needed on identified disease patterns relevant to Climatic Change such as eye and skin disorders.
- Studies must be conducted on vector dynamics and change patterns for all relevant vector borne diseases.

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