

ASSESSING THE IMPACT OF CLIMATE CHANGE ON HUMAN HEALTH: STATUS AND TRENDS OF MALARIA AND DIARRHEA WITH RESPECT TO TEMPERATURE AND RAINFALL VARIABILITY IN NEPAL

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ABSTRACT

The study on the status and trends of malarial and diarrheal diseases in the three ecological zones in Nepal viz. the *Terai*, Hills and Mountains shows mixed results in terms of occurrence of the number of incidences with observed rainfall and temperature variability. The total numbers of incidences of malarial cases in the country have significantly declined during the study period of 26 years (1982-2007). However, the occurrence of incidences of the disease increases during the last 6-7 years of the study period, particularly in the Hills and Mountains of Nepal, indicating that malarial incidences are spreading to newer locations at higher altitudes of the country that traditionally were considered malaria-free. Diarrhea, considered to be one of the leading ten diseases in Nepal, shows irregular behavior with temperature and rainfall variability based on the data consideration of 14 years (1994/95-2007/08). Although, in decreasing trend in all three geographic regions, the numbers of diarrheal incidences are highest in the Mountains, followed by the Hills and *Terai*. However, with observed trends of increasing temperature and irregular rainfall patterns across the country during the study period, the diarrheal incidences are predicted to rise in the future, owing to the development of more suitable conditions for the spread of the disease.

Keywords: Climate change, Nepal, human health, diarrhea, malaria.

INTRODUCTION

Change in climatic conditions through altered rainfall and temperature patterns in a place have significant implications to the survival, development and capacity of the agents to cause morbidity or mortality due to effects on the biology, habitats and behaviors of pathogens, hosts and vectors. This is further exacerbated by growing populations, movements and urban activity in previously rural areas. More importantly, the impact due to such alterations has been found and predicted to be more pronounced in societies with low adaptive capacity attributed to their low socioeconomic circumstances.

According to the World Health Organisation (2003), the relationship between climate change and human health is going to be among the most complex issues faced and is expected to have profound implications on overall development and well being of societies [1]. The Intergovernmental Panel on Climate Change (2007) has identified human health as one of the major sectors to be affected due to climate change with more serious stress in the developing parts of the world [2]. Similarly, Organisation for Economic Co-operation and Development (2003) recognizes the impact due to climate change on human health as 'urgent' in terms of severity and therefore demands immediate attention by the authorities around world [3]. In line with global observations, the Government of Nepal ascertains human health in the country is a major aspect to be affected by the global climate change phenomenon and has therefore placed it among six thematic areas of importance to be addressed at policy level through the National Adaptation Plan of Action (NAPA). Yet, the amount of scientific and academic work undertaken

in regards to exploring or understanding the issue is far from adequate despite the fact that above-average changes in climatic conditions have been predicted in Nepal and the region [4].

Based on the state of Human Development Indicators related to life expectancy, literacy rate and per capita income, Nepal is considered to be an underdeveloped country. It is vulnerable to the impacts of Climate Change mainly on the basis of three obvious reasons. Firstly, on the basis of its low socio-economic circumstances as evidenced by the country's per capita GDP of USD 470 with almost 31 % of the population living below the poverty line [5]. Secondly, because of its agriculture-based lifestyle with almost 86 % of the population residing in rural environments. Thirdly, because of the relatively young geology of the region that contains some of the most fragile ecosystems Earth [4].

The status of human health in Nepal remains notably low. Waterborne diseases for instance, are major causes of morbidity and mortality as explained by the fact that one third of the total deaths of children below 5 years are attributed to water borne diseases [6]. Similarly, malaria traditionally has been one of the major causes of morbidity and mortality in Nepal [7].

Malaria, as a vector borne disease, is found to be more influenced by climatic variability than socioeconomic factors [8]. It is caused by Plasmodium species of protozoan parasite transmitted by anopheline mosquitoes, which develop under optimum conditions of 24–26 °C (According to Houghton (2009), it is 15-32 °C [9]) and 60% relative humidity [10]. On the other hand, diarrhea as a water-borne disease, can be caused by a variety of bacterial, viral or parasitic organisms. Diarrheal incidences are related to the quality and quantity of water available as well as rainfall pattern as these factors help in creating breeding habitats [11]. With increasing evidence of alterations in the habitat, distribution, nature and behaviors of the vectors and pathogens of these diseases due to climate change, it is imperative to study the trends of communicable diseases and subsequent impact on human health at academic and scientific level.

This particular study investigates past trends and current status of diarrhea and malaria in relation to the changing patterns of temperature and rainfall in three ecological regions of Nepal viz. the *Terai*, Hills and Mountains, that are characterized by subtropical, temperate and alpine conditions respectively. Future predictions are made about the likely behavior of the diseases' patterns. The outcome of the study will add to the knowledge-base about the relationship between climate change and vector or water-borne diseases that in turn will assist in preparing practical strategies to avoid or mitigate the detrimental impacts of such calamities in the country and the region.

MATERIALS AND METHODS

Nepal is situated between latitudes of 26°22' to 30°27' north and between longitudes of 80°4' to 88°12' east. Climate in Nepal varies greatly from sub-tropical to arctic as evidenced by the unique climatic conditions in the three major geographic regions of the country [12] that also comprise the research area of the study (Figure 1).

1. The *Terai*: This is the southernmost part of Nepal. Climate is tropical to sub-tropical and it is also the hottest part of the country with mean annual temperature ranging between 20-25 °C and rainfall 1100-3000 mm annually (Shaded turquoise in figure 1).

2. The Hills: The region lies to the north of the *Terai*. Average temperature ranges from 10-20°C and total rainfall from 275-2300 mm annually that increases with altitude on the windward side and decreases on the leeward side. (Shaded pink in figure 1).

3. The Mountains: This northernmost region has mostly alpine climate with elevations varying from 2,200 to 8,000m. Mean annual temperature ranges from sub zero to 10 °C and precipitation in the form of snow varies from 150-200 mm annually (Shaded light green in Figure 1)

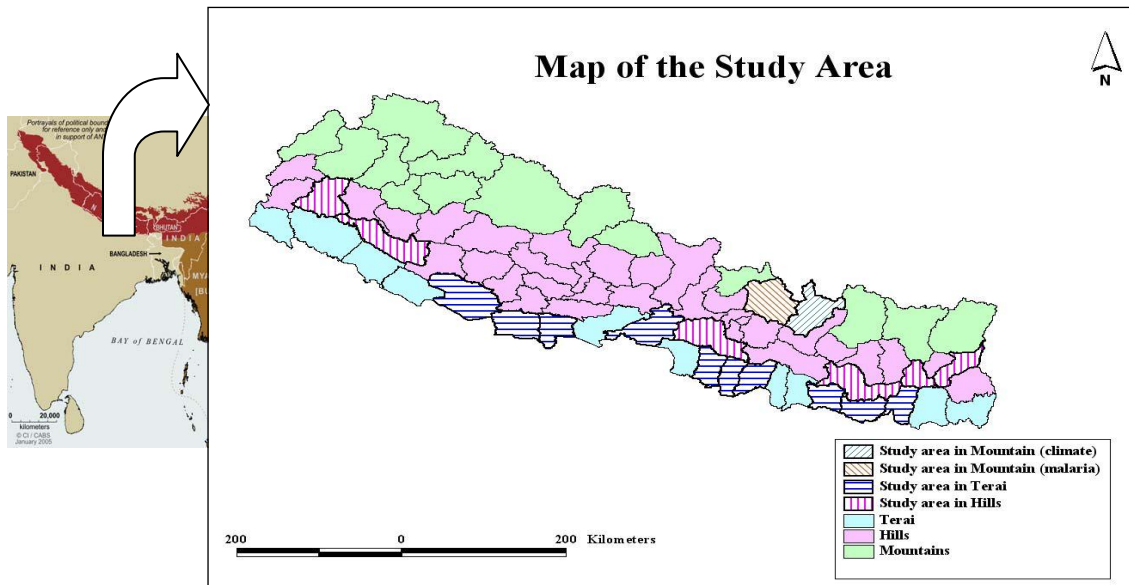


Figure 1: Map of Nepal illustrating the sampled districts and the study area.

In order to study the status and trends of malarial incidences with respect to rainfall and temperature variability, compiled records of malarial incidences from 17 districts across the country have been obtained from Department of Health Services (DoHS) of Nepal for a period of 26 years (1982 to 2007). These districts are organized into three ecological regions with 10 districts (Dang, Rupandehi, Kapilbastu, Chitwan, Bara, Rautahat, Sarlahi, Saptari, Sunsari and Siraha) in *Terai*, 6 districts (Doti, Dhankuta, Surkhet, Makawanpur, Udaypur and Panchthar) in the Hills and one district (Sindhupalchok) in the Mountains. Data on temperature and precipitation from hydrological stations of selected districts were obtained from Climatological records of the Department of Hydrology and Meteorology (DHM). Monthly data on total precipitation and average temperature for each relevant district in the *Terai*, Hills and Mountains are organized such that they represent average annual conditions of rainfall and temperature in respective ecological zones. Data on annual malarial incidences in the *Terai*, Hills and Mountains are presented graphically against the rainfall and temperature data of the three ecological regions to analyze the status and trends of the diseases with respect to observed variability of temperature and rainfall.

The study period for diarrheal diseases is restricted to 14 years because of the constraints to data availability. It is to be noted that, organization and presentation of the data on the incidences of

diarrhea by the DoHS follows more traditional approach in the sense that data are organized to suit the government's fiscal year requirements that begins mid May of the Gregorian calendar. This requires reorganizing the climatological data such that the newly constructed year consists of 7 months from the previous year and 5 months of the following year in order to maintain consistency with the patterns followed by the government-generated diarrheal data. For illustration, the year 1994/95 consists of 7 months (June-December) of the year 1994 and 5 months (January-May) of 1995. Data on diarrheal incidences in the *Terai*, Hills and Mountains following this pattern are presented graphically against the rainfall and temperature data of the newly constructed years for the period of 14 years (1994/95 to 2007/2008) for further analysis.

Admittedly, the status of infectious diseases may not always be attributed to climate change. It can also be influenced by factors related to lifestyle and living conditions such as demography, sanitary provisions and the ambient air or water quality of a particular place. In order to limit the influence of these factors, the study has been conducted in areas that have undergone less drastic changes in living conditions. Similarly, the study incorporates the data obtained from government hospitals only and not from privately owned health institutions. This is of particular significance because the government-run hospitals in Nepal tend to cater to rural populations with lower socioeconomic profiles which is characteristic of Nepal's very large majority of population.

RESULTS AND DISCUSSION

The status and trends of malarial and diarrheal diseases with observed rainfall and temperature variability in Nepal's three ecological zones- the *Terai*, Hills and Mountains are discussed individually below.

The *Terai*

The *Terai*, once considered inhabitable due to the high prevalence of malaria has experienced tremendous success in reducing the prevalence of the disease as evidenced by a subsequent reduction in the number of malarial incidences from above 9000 in the early 80s to a few hundreds in recent years. This can be attributed mostly to the enhanced administrative commitment of the Government to malarial control. Today, with the highest population growth rate nationally (2.62 in 1991-2001), the region is also home to almost half (48.43 % in 2001) of the country's population [5].

The rate of reduction of malarial incidences since 1982 to 2007 in the *Terai* shows abrupt decline in the first decade or so which, however, slows down significantly toward the latter half of the study period, with in fact a rise in the number of incidences towards the end (Figure 2). Coincidentally, the temperature and rainfall patterns both show an increasing trend in the region suggesting that the parasites are capable of surviving outside normal averages of temperature and rainfall conditions.

Incidences of diarrheal diseases on the other hand, show somewhat constant behavior during the study period (1994/95-2007/08) with a slightly decreasing trend in the latter half. Although the diarrheal incidences show no direct relationship to average temperatures of around 25 °C in the *Terai*, they show consistent behavior with irregular rainfall patterns i.e. enhanced activity on number of diarrheal incidences with increased rainfall (Figure 3), in line with observations found in other countries [11].

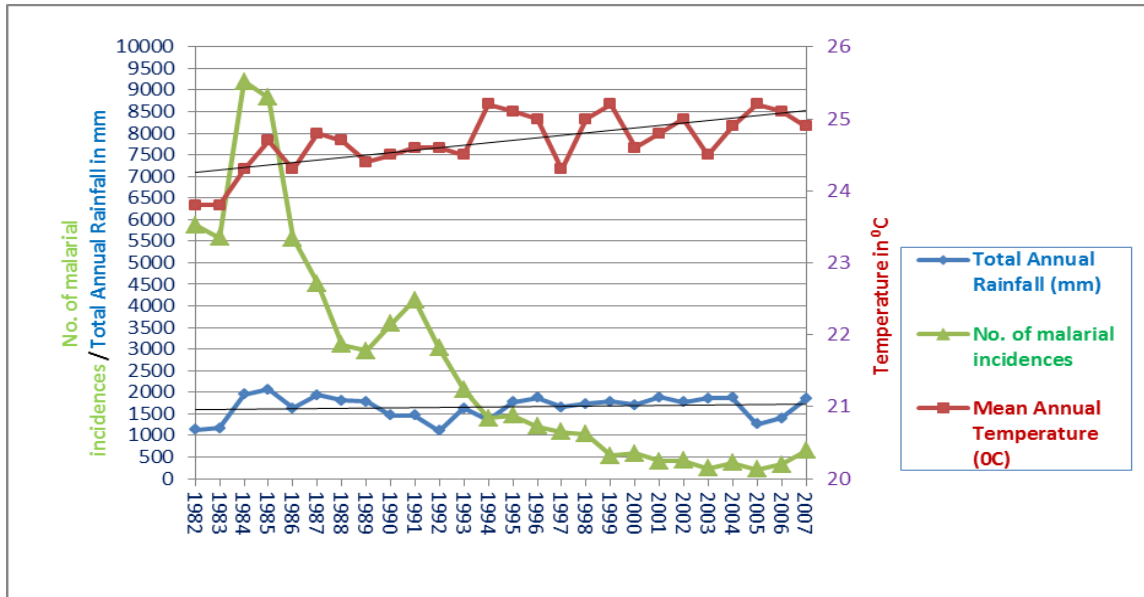


Figure 2: Malarial incidence with temperature and rainfall variability in the Terai (1982-2007)

Given that incidences of diarrheal diseases are influenced significantly by socioeconomic and living conditions of the population such as growth rate, density and sanitary facilities, the *Terai* of Nepal is predicted to undergo a more significant burden of disease due to its population size, growth rate and subsequent rise in urban activities [13].

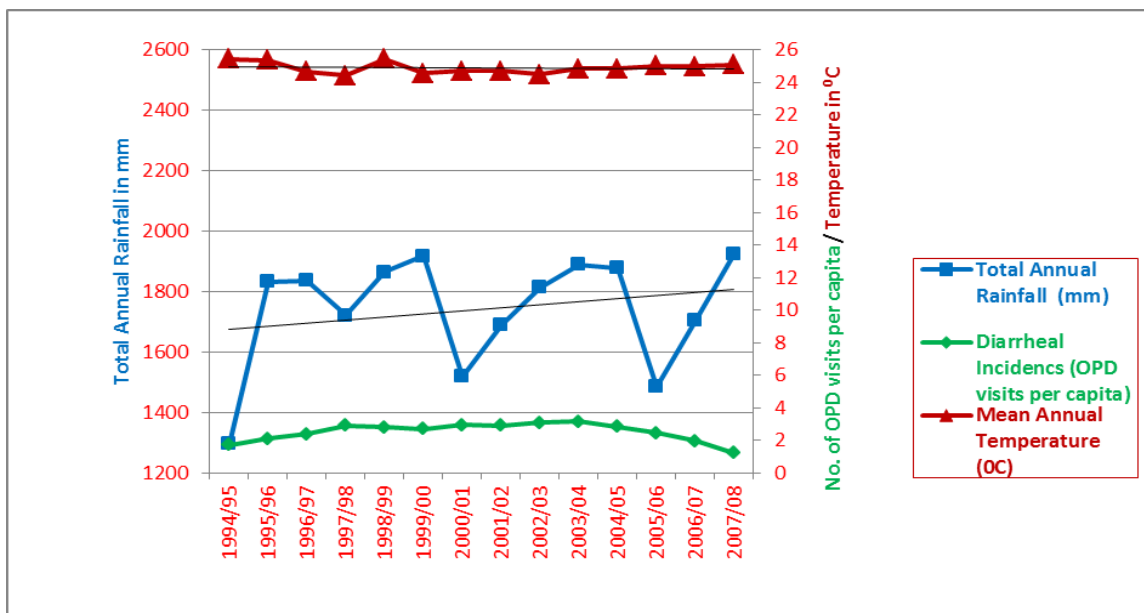


Figure 3: Diarrheal incidences with temperature and rainfall variability in the Terai (1994/95-2007/08)

The Hills

Traditionally, malaria has been prevalent predominantly in the *Terai* region of Nepal [7]. However, based on results of current study (Figure 4) and global observations related to suitable climatic conditions for malarial activity [9], the Hills in Nepal can now be considered a malaria-friendly region. However, not all districts in the Hills are found to have been affected equally by malaria. The districts such as Surkhet, Makwanpur and Udaypur, which exhibit similar climatic conditions to the *Terai* because of their physical vicinity to the region (Figure 1) and geography [5], have experienced more prominent effects of malaria. What is even more vital is that malarial incidences are on the rise in recent years in the region (Figure 4) and undeniably contribute an added complexity to the existing situation. These results are in agreement with the observations made in many parts of the world in recent times such as in India [10], Africa [8] and New Zealand [1]. Furthermore, if predictions about enhanced malarial activity with rising temperature and falling rainfall are to be considered, then the Hills in Nepal can be expected to experience an increased burden of malaria as suggested by observed trends in the region (Figure 4).

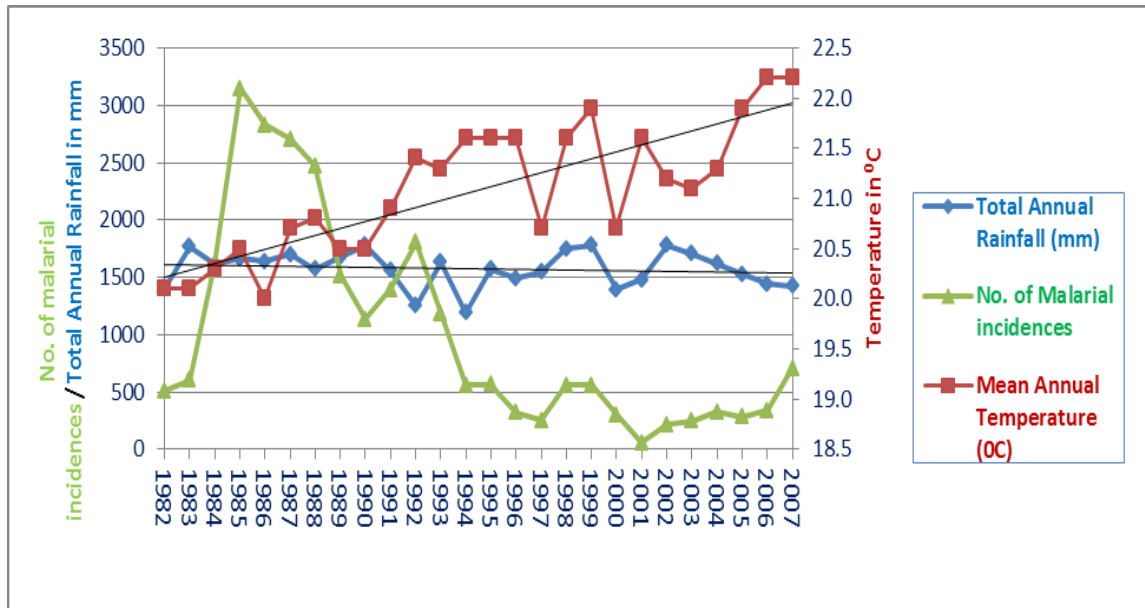


FIGURE 4: Malarial incidences with temperature and rainfall variability in the Hills (1982-2007)

Diarrheal incidences in the Hills show somewhat similar behavior to the trends observed in the *Terai*, i.e. increasing at the beginning and gradually decreasing towards the latter half of the study period (Figure 5). However, the higher number of incidences during the study period in the Hills indicates that the region is more ‘diarrhea-friendly’ than the *Terai* region. Increased temperature and rainfall in the region during the study period also indicates that the Hills will be more susceptible to the impact of water borne diseases because conditions are expected to provide better breeding opportunities for the pathogens as observed in other parts of the world [8, 1].

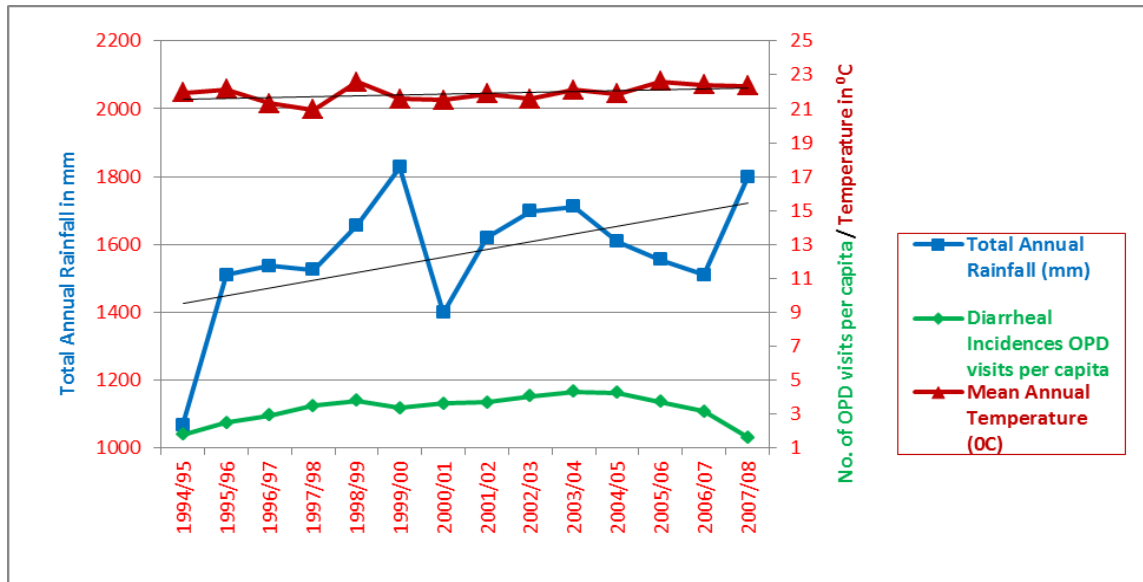


Figure 5: diarrheal incidences with temperature and rainfall variability in the Hills (1994/95-2007/08)

The Mountains:

Traditionally, the Mountains of Nepal have been malaria-free until the year 2002 (Figure 6). This study indicates that malarial activity is spreading to higher altitudes in recent years. This is also in line with the findings of several studies undertaken in sub-Saharan Africa. It is further predicted that previously malaria-free areas, including the Mountains in Nepal, will experience more intense impacts in comparison to the traditionally malaria prevalent areas because activity and transmission rate of the diseases will be enhanced due to lack of immunity on the part of the hosts and enhanced capacity of the agents [8]. In Nepal, incidences of diarrheal disease traditionally have been highest in the mountains. This could be attributed to the rural environment with comparatively poorer sanitary conditions and meager public health facilities in the region [13].

The number of incidences of diarrhea in the region seems to be declining during the last few years of the study period (Figure 7). However, with expected decline in rainfall and increased temperature the diarrheal incidences are expected to rise [8]. Furthermore, observed increase in temperature in the region is also predicted to give rise to escalation of glacial retreat [4] resulting to change in the quality and quantity of water with likely alterations in the behavior of the diarrheal diseases [1].

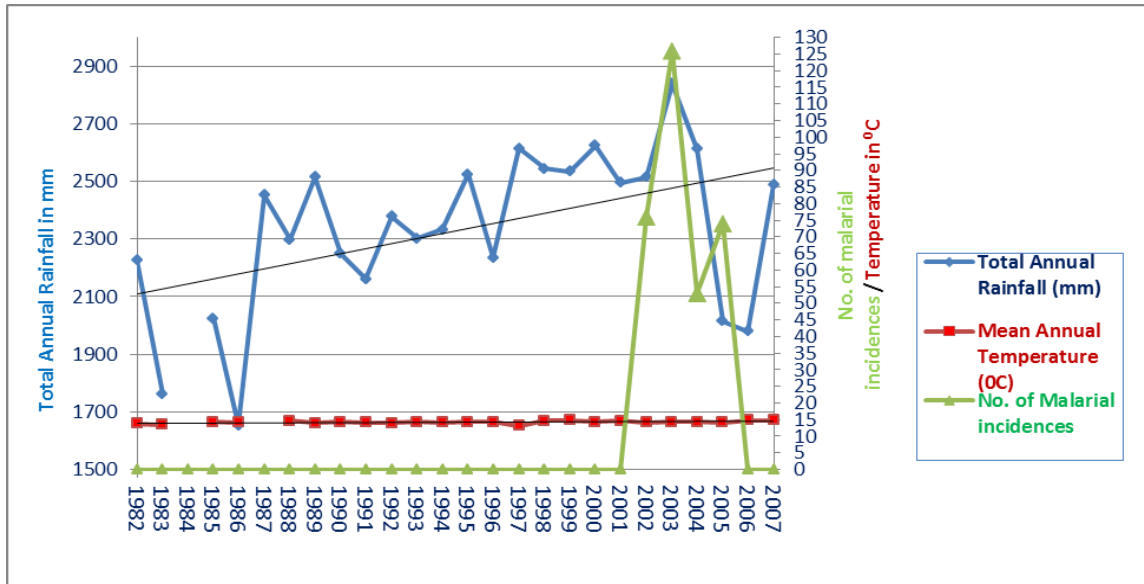


Figure 6: Malarial incidences with temperature and rainfall variability in the Mountains (1982-2007)

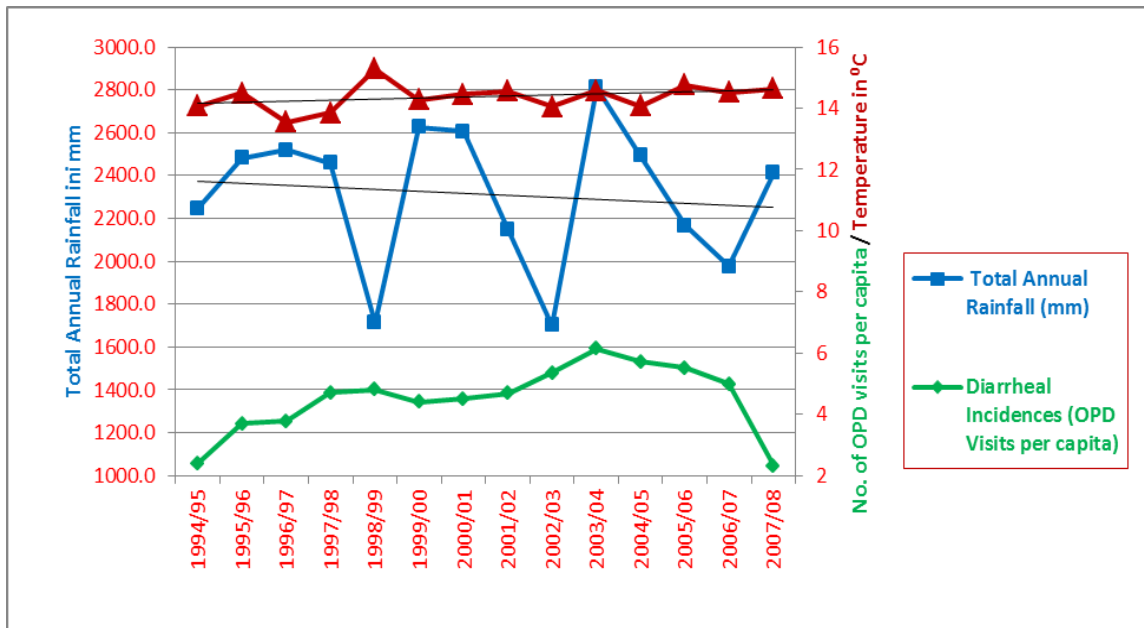


Figure 7: diarrheal incidences with temperature and rainfall variability in the Mountains (1994/95-2007/08)

CONCLUSION

The results of the study indicate that the impact of climate change on the survival and behavior of malarial and diarrheal diseases in the three ecological regions of Nepal is pronounced. In the case of malaria, although the mortality and morbidity due to the disease has decreased

significantly during the study period of 26 years (1972-2007), the incidences are spreading to previously malaria-free regions. Observed expansion of the geographic range of the disease with no effective systems of intervention or health care facilities in place makes the populations living at the margins of malaria such as those in Nepalese mountains, most susceptible. Thus, almost all of Nepal's population can be considered to be at risk of malaria now. Likewise, alterations in the climatic conditions due to an observed rise in temperature and irregular rainfall trends throughout the country are likely to provide more desirable conditions for waterborne diseases, making Nepal equally vulnerable to diarrheal diseases. Despite the observed causal links between climatic factors and transmission dynamics of the water and vector borne diseases, there is still much uncertainty about the potential impact of climate change on malaria and diarrhea at local and global scales because of the lack of detailed historical observations about climate change, the diseases epidemiology and the influence of non-climatic factors on diseases. In the face of these limitations, accurate understanding of the significant health risks of malaria and diarrhea due to climate change requires further research with enhanced commitment to understanding the impact of climate change on human health.

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