Global Climate Change and Infectious Disease

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ABSTRACT

The impact of global climate changes on transmission of infectious diseases will be discussed in this article. The goal of this article is to reveal the relationship between climate and infectious disease with stressing in the importance of multi-disciplinary approach in a global problem including vector-born disease, dengue fever, malaria, rodent-born disease, water and food born disease, cholera. This review has been written based on some research publications and will discuss more detail on their study design, statistical analysis methods, usage of meteorological variables, and results of those studies. The authors found that the limitations of analytical methods exist in the most articles, besides climate variables, few of them have limitation included others factors that can affect infectious disease (e.g. cultural, socio-economic status). In addition, the quantitative relationship between global climate change and infectious disease is consistent. Further research should be conducted among different populations with various climate or ecological regions by using appropriate statistical models.

Key words: *global climate change, dengue fever, malaria, leptospirosis*

INTRODUCTION

Global climate has serious implications for all aspects of human life, including infectious diseases. The impact of global climate change on the infectious diseases, particularly on vector, rodent borne disease and water borne disease, has been studied recently. However, the quantitative relationship between climate variables and the infectious disease is still not clear, and the some researchers demonstrated inconsistent data in their studies, and their inconsistent data may due to many reasons, including the limitations of the research methods and data availability. This article systematically reviews some published research articles, and analyzing the relationship between global climate change variations and dengue fever, malaria, *leptospirosis* and waterborne disease that have attracted the most research attention recently. The objectives of this review are summarize what has been in analyzing the relationship between global climate change and the infectious diseases worldwide and give suggestion for the future research directions by limitations preview published works.

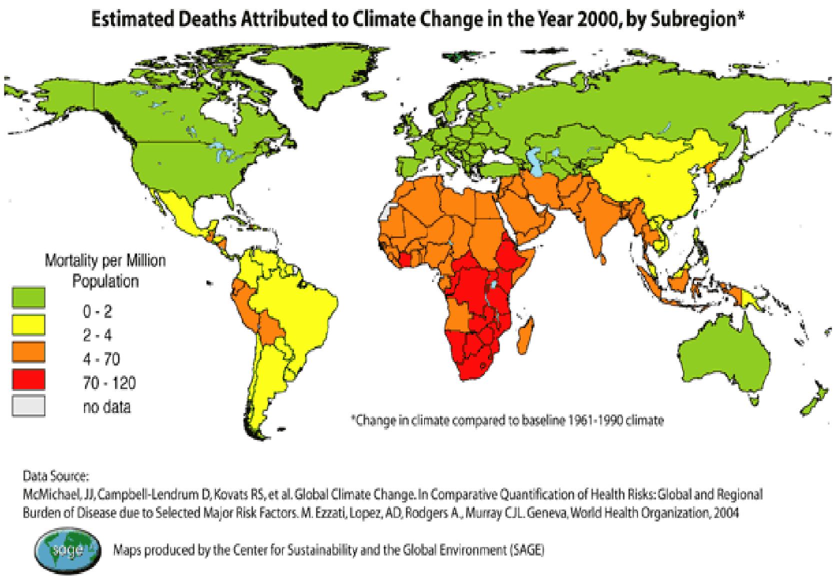


Figure 1. Estimated Over 150.000 Climate Change Related Deaths Each Year

GLOBAL CLIMATE CHANGE

There abundant evidence to illustrate that climate change has occurs at global level, according to the Intergovernmental Panel on Climate Change (IPCC), the global average surface temperature has increased approximately 0.6° C since 1850s when temperature records were first kept. Global land precipitation has increased by approximately 2% since the beginning of the 20th century, showing an increase in middle and high latitudes and decrease in the tropic and sub tropical regions, the rate of the sea level increase during the 20th century in the range 1.0 to 2.0 mm per annum.

According to the projections, there will be can increase in global average temperature in the range of 1.4° C to 5.8° C by 2100, indicating that the rate of warming could be up to 10 times that observed during the past century. Global average precipitation and evaporation are also projected to increase from 1% to 9% during 2nd century, depending on different climate models, and vary by location, with some regions having increased rainfall, whereas others might experince decrease (BP Parton, 2003; UNSEG, 2007.

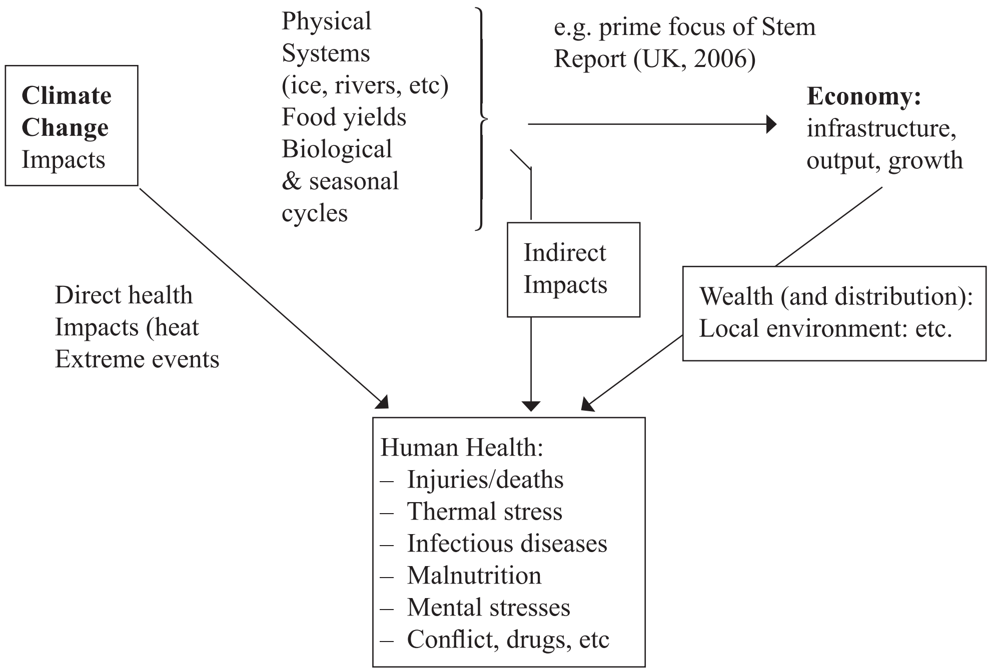


Figure 2. Relationship of Climate Change and Health

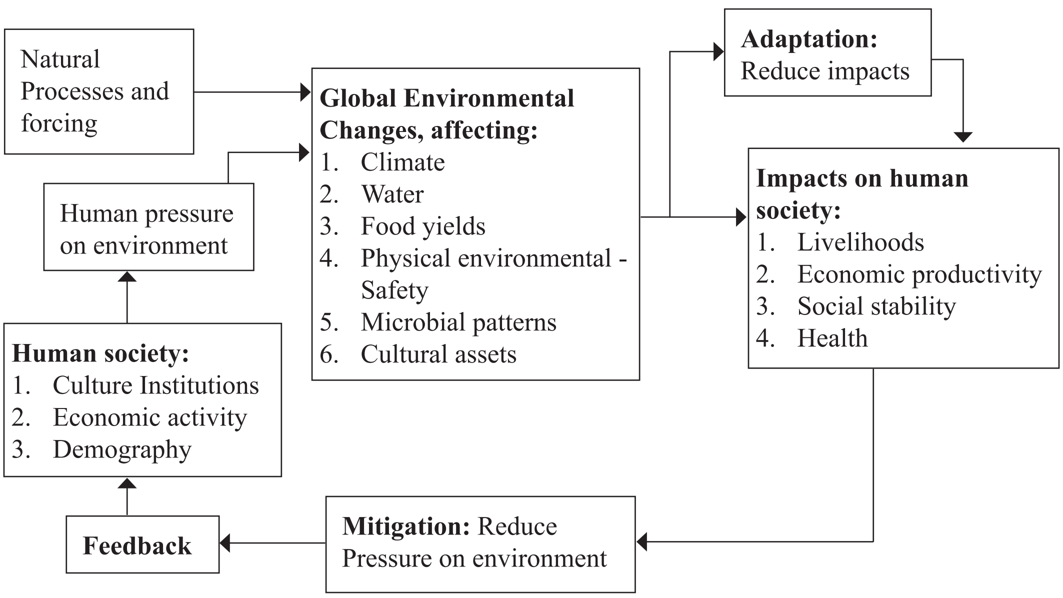


Figure 3. Climate Change, Health Impacts and Policy Responses

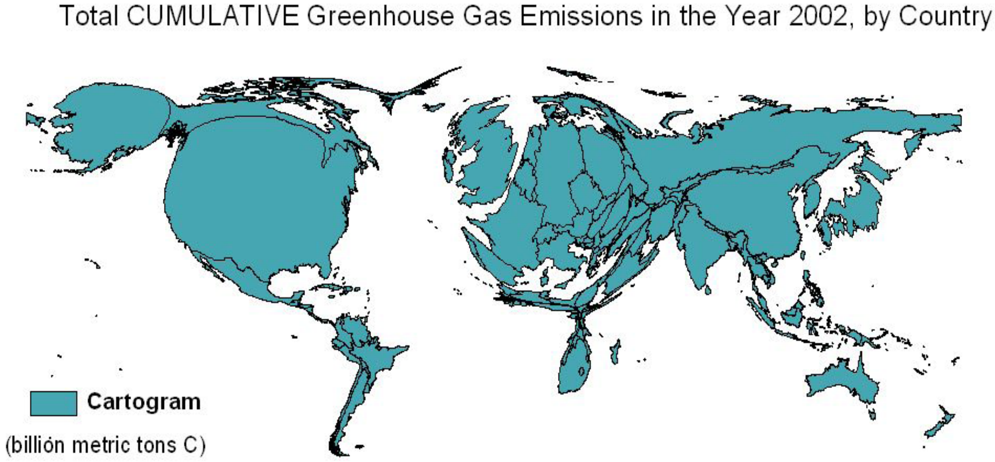


Figure 4. Density-equalling cartogram. Countries scaled according to cumulative emissions in billion tonnes carbon equivalent in 2002. Patz, *et al.*, 2002

POTENTIAL HEALTH EFFECTS OF CLIMATE CHANGE

Many health outcomes and diseases are sensitive to climate including: heat-related mortality or morbidity, extreme climate related disasters (hurricanes), air pollution related illnesses, allergic diseases, infectious disease (water and food born diseases, vector born diseases), climate related crop development (influences world food supply and famine), refugee health issues, linked to forced population migration (IPCC, 2007).

Impact of global climate change on vector borne disease

If we talk about vector born disease, there are three crucial things: the disease (bacteria or virus), the vector and a susceptible host. Global climate change may affect all the three components. Disease vectors, such as arthropods are very sensitive to temperature, because they are cold blooded. This means that their internal temperature is greatly affected by the temperature of their environment. The range of suitable climatic conditions for the survival of vectors and for their reproductive activities is therefore still limited. Temperature effects on selected vectors and vector-borne pathogens

Global climate conditions affect the transmission of vector borne disease by altering the distribution of vector-species and their reproductive cycles, influencing the reproduction of the pathogens within the vector organism, known as the external incubation period (EIP) and affecting human behaviors and activity. Malaria, dengue fever, c*hikungunya* fever, cholera are the most commonly investigated climate related vector borne diseases (Tong and Mc Michael, 2004).

Vector. Global climate change will affect disease vectors, which in turn may alter the current patterns of vector borne diseases. The most common vectors, arthropods, are cold blooded, meaning that their internal temperature is greatly affected by temperature of they environment. The incidence of arthropods borne diseases will depend on both of vector and host factors, survival decrease or increase depending on the species, changes in the susceptibility of vectors to some pathogens, changes in rate of vector population growth, changes in feeding rate and host contact

Pathogen. Climate may affect all of these factors to some extent factors but will have most direct effect on decreasing the extrinsic incubation period of pathogen in vector at higher temperature changes in the transmission season, changes in distribution, decreased viral replication.

Effects of changes in *precipitation* on selected vector-borne pathogens

Vector. Increasing precipitation is not always favorable for mosquitoes. Torrential rains may wash away breeding sites and drought may eliminate the small pools of water favored by the mosquitoes for their eggs. There is a disadvantage relationship between rainfall and the habitat of larva. The effect of increasing change of rain fall associated with the increasing the larva habitat has been well understood. However, sometimes the rain contribute the good environmental condition, because excessive rainfall can eliminate habitat by flooding, but on the other hand, the low rainfall can create habitat by causing rivers to dry into pools. This condition often causing the increase of malaria incident, therefore it is called as dry season malaria. Decreased rain can increase container-breeding of mosquitoes by forcing increased water storage. Epic rainfall events can synchronize vector host-seeking and virus transmission. Increased humidity could increases vector survival and vise versa.

Dengue. Dengue hemorrhage fever (DHF) is an important mosquito-born disease in tropical regions, and about 2.5 billion people at risk worldwide. The *Aedes aegypti* mosquito as the disease's vector is well adapted to the urban environment and thrives well in a warm and humid environment. Furthermore, it is known that at least in the laboratory, viral replication increases with temperature, which will affect viral transmission. Minimal transmission temperature for the dengue virus is 12° C. DHF outbreak in southern Sumatra was accompanied by more extreme weather due to El Nino effects (Nakhapakorn and Tripathi NK, 2005). Linked to future climate change projections, a small rise in temperature in temperate regions will increase the potential for future epidemics, given a susceptible population and introduction of the virus.

CLIMATE VARIABILITY AND DISEASES INCIDENCE

Dengue incidence

Climate variability, particularly for warm climate, may increase the *Aedes aegypti* mosquito breeding (Argentina), highest abundance mean temperature 20° C, increasing accumulated rainfall (150 mm), decline egg laying monthly mean temperature less than 16.5° C, and the eggs can not survive at temperature less than 14.8° C. According to a slight increase in temperatures could result in epidemic of dengue in the world. Recently, a series of papers studying the association between climatic factors and dengue in Indonesia have been published.

Other studies, this mosquito is weak adapted to the urban environment and successfully breeds in containers where water is allowed to accumulate, such as discharge cans, bottles, plastic containers and tires (Nakhapakorn and Tripathi NK, 2005). *Aedes* mosquitoes usually thrive in warmer environments but not in dry environments. Thus, the global climate affect to diseases like dengue depend on both precipitation and temperature.

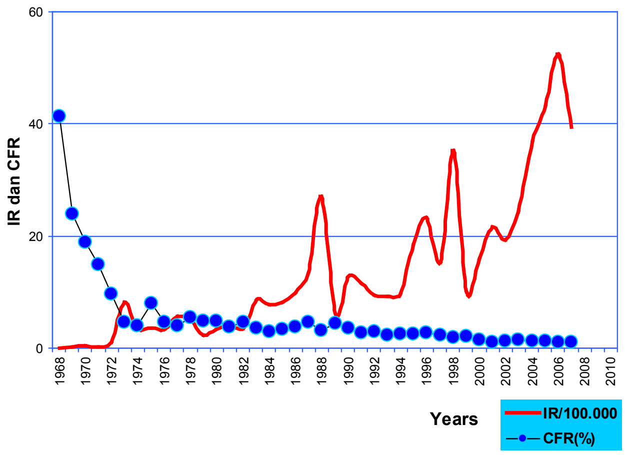


Figure 5. Incident and CFR Dengue in Indonesia, 1968–2007

Malaria

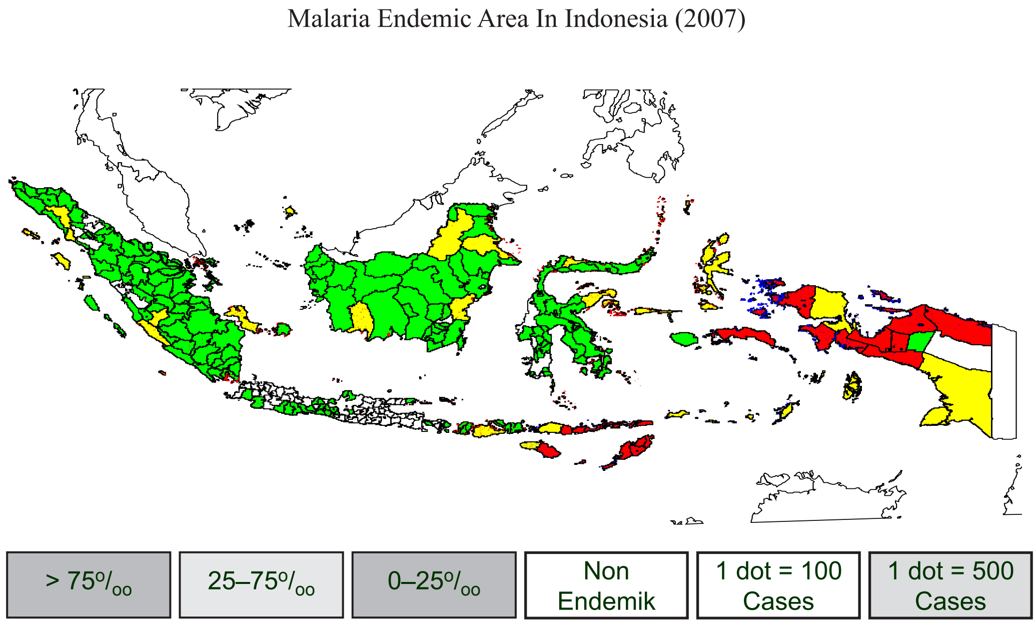
Malaria is considered the most important vector borne diseases, with cases occurring in more than 92 countries in the world. The relationship between malaria and climatic variables have been assessed in many studies, and almost of these studies have been conducted in Africa and indicated that increasing in the incidence of malaria are strongly associated with higher temperatures (Kuhn *et al.*, 2003).

From the standpoint of malaria, the effect of global climate will be felt most in areas that are currently on the edges of the range of infected mosquitoes (Patz JA, and Khalig, 2002). For example, malaria has been shown to march up mountains in response to wetter and warmer weather. Altitudes that were once safe mosquitoes will be at risk for epidemics. This applies for example for many of the densely populated highland regions in Africa that are surrounded by lowland areas where malaria is endemic. Small changes may therefore lead to the exposure of many people to malaria.

Approximately 40% of the world's population lives in areas at risk for malaria. Every year about 500 million people become severely ill from malaria. Between 700 thousands and 2.7 million – mostly children in sub-Saharan Africa- die each year of malaria. Malaria is an extremely climate sensitive disease. Clearly, the transmission does not occur in climates where mosquitoes cannot survive. The optimal larval development occurs at 28° C and optimal adult development between 28° C and 32° C. Transmission cannot occur below 16° C or above 33° C as *sporogony* (the production of *sporozoites*) cannot take place.

From the standpoint of malaria, the effect of global warming will be felt most in areas that are currently on the edges of the range of infected mosquitoes (Patz JA and Kovats, 2002). This applies for example for many of the densely populated highland regions in Africa that are surrounded by lowland areas where malaria is endemic. Small changes may therefore lead to the exposure of many people to malaria.

Many global warming scenarios include an increase in the frequency and intensity of the El Niño phenomenon (Patz JA and Khalig, 2002) such as storms, heavy rain, droughts and warm temperature. El Niño seasons have been associated, although not always, with outbreaks of malaria in many areas (Kuhn *et al.*, 2003). Therefore it seems reasonable to speculate that intensification of El Niño effects due to global warming will facilitate local epidemics of malaria.



Source: Ministry of Health RI, 2007

Figure 6. The Areas of Endemic Malaria in Indonesia

Chikungunya Fever

Chikungunya fever is another viral infectious disease and transmitted by *Aedes albopictus*. It's the most common mosquito borne disease in Indonesia, where approximately 500 cases are notified annually. The transmission of mosquito is influenced by environmental and reservoir factors. Few quantitative estimates have been made study the possible impact of climate variations on the disease transmission.

Other vectors will be affected to different extent. Models to predict tick populations have also shown that arid conditions decrease tick populations. However, epidemic of tick borne diseases such as the lyme diseases have not been associated with climate change. As state above, it is possible that global climate will bring stronger or more frequent El Nino of 1997–1998, there was associated increase in Rifer Valley Fever. The mosquito vector populations increase during times of flooding, because more eggs are immersed in water. Vector may transmit pathogen to-non human mammalian host (Mackenzie *et al.*, 1993).

Rodent Borne Disease

The increasing of rodent breeding will occur during mild weather and will decreases in time of drought or heat. On the other hand drought may drive the rodents to seek indoor sources of water. This may increase the chance that humans will come into contact with rodents and the insects that feed on them, such as lice. The emerge of Hanta virus pulmonary syndrome in the South West US 1993 was attributed to drought followed by El Niño related heavy rainfall resulting in growth in rodent populations and subsequent disease transmission. Extreme flooding and hurricanes can lead to outbreaks of *Leptospirosis*. In 1995, an epidemic of severe *leptospirosis* occurred in Nicaragua after heavy flooding (Mackenzie *et al.*, 1993).

Leptospirosis

Leptospirosis is another emerging bacterial infectious disease and distributed and spread out by rodent as a disease vector. In Indonesia *Leptospirosis* is the most common rodent borne pathogen Hospital based active surveillance study (n = 326). Its habitat is usually warm humid climate, temperature limiting factor. The incidence of the disease is 100 per 100,000 per year. Modelling infected rodent (*Mastomys natalensis*) and *Leptospira* abundance in environment. The risk factors for Leptospirosis1 (*data from large case control studies*). It transmitted by water contact and exposure to carrier animals (*Ratus spp*). The potential outbreaks usually follow the previous heavy rainfall or several weeks after flooding. This situation will left the residue of water as a reservoir for the viral development and increase bacteria of leptospira in stagnant water. Most of cases occur two weeks after large flooding. The transmission of *leptospira* is influenced by environment, occupational and reservoir factors. Few quantitative estimates have been made in some studies about the possible impact of climate variations on the disease transmission. A significant inverse association between the amount of precipitation and the incidence of *Leptospirosis* demonstrated in Indonesia (Ministry of Health Republic of Indonesia, 2007) when the density of rodents and the degree of contact were considered. Heavy rainfall in the lowland areas could reduce the density of mice and thus decrease the incidence of the disease. However, these studies were only conducted in lowland areas. Therefore, further research is needs to be conducted in other ecological situations.

Water and food-born diseases

Worldwide, more then one billion people lack access to safe drinking water. Modeling of impacts of climate change on water stress shows considerable variability between climate scenarios. Increased water stress is likely to occur in countries of southern and west Africa and in the Middle East. It is difficult to relate water stress directly to the attributable risk of water related diseases; however water scarcity may result in the use of more contaminated sources. Epidemics of cholera, typhoid and similar disease can be expected if the quality of water deteriorates.

Warmer seas surface temperatures promote algal blooms that may be associated with cholera outbreaks (Roststayn L, 2004). Algae, and zooplankton that feed upon them, provides a natural refuge for *Vibro Cholerae*, which are normally in a dormant state. An increase in sea surface temperature can activate the bacteria. V. Cholerae also occurs in the Gulf of Mexico and along the east coast of North America. From 1980–2001 the incidence of cholera in Bangladesh was strongly correlated with El Niño events (Patz JA and Kovats, 2002). Outbreak of cryptosporidiosis have been related to heavy rainfall events (Tong and McMichael, 2004). Cryptosporidium causes severe diarrhea in children and may cause death among the immuno compromised patients

Cholera

Global climate change may also bring the increasing of sea surface temperature associated with Cholera outbreaks, because increasing of the sea surface temperature could promotes the algal blooms and activates the *V. Cholerae.* Warmer seas surface temperatures promote algal blooms that may be associated with cholera outbreaks. Algae, and zooplankton that feed upon them, provides a natural refuge for *Vibro Cholerae*, which are normally in a dormant state. An increase in sea surface temperature can activate the bacteria. V. Cholerae also occurs in the Gulf of Mexico and along the east coast of North America. From 1980–2001 the incidence of cholera in Bangladesh was strongly correlated with El Niño events (Patz JA and Khalig, 2002).

Mitigation and Adaptation

Mitigation refers to policies to reduce greenhouse gas emissions such as: promoting energy efficiency and the use of renewable energy sources such as solar and wind energy. Adapting to global warming and the possibility of changing infectious disease epidemiology may include several measures. Disease surveillance programs should play a key role. Hence, epidemiological data should be linked to climate databases. Combining data may provide the information needed to create early warning systems, making use of weather forecasts. Furthermore, physicians need to be aware of how current climate variability can affect health outcomes. They should also recognize that long-term climate change may exacerbate climate sensitive infectious disease. The distribution of those diseases may be altered and should be considered in the diagnosis of patients with unexplained symptoms. Physicians can also educate communities about the potential impact of climate change and the need to improve current public health infrastructure.

CONCLUSION

Most of published studies have only answered the question, "is there association between global climate variability and infectious diseases"?. The few studies have defined human infections are intricately linked to the global environment. By altering this environment, global warming has significant potential to intensity selected infectious diseases. Climate effects are predicted to include crowding, famine, water contamination, human migration and alterations in vector ecology, all of which increase infectious diseases.

Whereas some disease resurgence has been attributed to recent warming trends, some of the long term and complex problems are difficult to predict. We should be aware that future scenarios are based on mathematical models, which are not necessarily true. In addition, the many health impacts of climate change must be examined in the context of other environmental and behavioral determinants of disease.

Human infections are intricately linked to the global environment. Warming of the earth has a significant potential to intensify selected infectious disease, in this presentation I showed some examples. Climate effects are predicted to effect vector ecology, the pathogens, alteration of rodent populations and may influence water-born diseases trough both drought and flooding. There for, we should be aware that climate change has a significant potential to change the epidemiology of vector and rodent diseases.

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