

Social Justice, Climate Change, and Dengue

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Abstract

Climate change should be viewed fundamentally as an issue of global justice. Understanding the complex interplay of climatic and socioeconomic trends is imperative to protect human health and lessen the burden of diseases such as dengue fever. Dengue fever is rapidly expanding globally. Temperature, rainfall, and frequency of natural disasters, as well as non-climatic trends involving population growth and migration, urbanization, and international trade and travel, are expected to increase the prevalence of mosquito breeding sites, mosquito survival, the speed of mosquito reproduction, the speed of viral incubation, the distribution of dengue virus and its vectors, human migration patterns towards urban areas, and displacement after natural disasters. The burden of dengue disproportionately affects the poor due to increased environmental risk and decreased health care. Mobilization of social institutions is needed to improve the structural inequalities of poverty that predispose the poor to increased dengue fever infection and worse outcomes. This paper reviews the link between dengue and climatic factors as a starting point to developing a comprehensive understanding of how climate change affects dengue risk and how institutions can address the issues of social justice and dengue outbreaks that increasingly affect vulnerable urban populations.

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Climate change as an issue of global justice

THROUGH ENHANCED EXPLOITATION and increased burning of fossil fuels, the world's developed nations continue to pursue an unsustainable course of industrial production and development that is changing the planet's climate in ways we are only beginning to understand. The risks posed by climate change will continue to be borne disproportionately by those who are least able to adapt, namely the urban and rural poor in developing countries, who also carry the highest burdens of morbidity and mortality associated with infectious diseases such as dengue. While a survey of the literature indicates a dearth of studies that specifically address climate change, dengue, and social justice, there is a rich and growing literature on climate change and vulnerability that provides a useful lens through which to view the closely intertwined issues of dengue and climate change.¹

In his influential work on health rights, Daniels argues that people tend to attribute special moral importance to health itself as well as the factors that affect health.² The reason, he suggests, is that meeting health needs contributes significantly to normal species functioning and thereby helps to safeguard the "normal opportunity range," i.e., the life plans that citizens can reasonably expect to follow given their talents and skills and the society within which they find themselves.³ Thus, assuming that mitigating the twin impacts of climate change and dengue forms a moral imperative, it can be argued that climate change should be viewed fundamentally as an issue of global justice and that human health be given paramount consideration in the formulation of climate change policies and interventions.⁴

More concretely, both climate change and disease affect human vulnerability, which is conditioned by two main factors: exposure to shocks associated with climates (e.g., El Niño, floods, heat waves, droughts, storms), which can increase disease risk, as well as management of ensuing shocks such as dengue outbreaks following extreme events.⁵ When the livelihoods of the urban poor are threatened

by dengue outbreaks, vulnerable populations often employ a range of coping strategies such as spending savings, selling assets, or diversifying their incomes to reduce risk and mitigate the immediate effects of lost income. When those strategies fail, the urban poor often become even more susceptible to external shocks and stresses, and thus require outside interventions to prevent further erosion of their livelihoods, health, and well-being. Such interventions are driven by policy responses that emanate from institutions operating over a range of spatial scales, from neighborhood associations within urban areas to international agreements such as the UN Framework Convention on Climate Change (UNFCCC) that seek to mitigate climate change globally by improving adaptive responses.⁶

According to some authors, current policies and programs that address climate-induced health risks are more reactive than proactive.⁷ On the surface, this may seem like a failure of policy; however, as Oppenheimer points out, rapid societal learning after climate-related health shocks may lessen the effects of subsequent events.⁸ For example, the devastating heat wave of 2003 in Western Europe was followed by another severe heat wave in France in 2006 when anticipatory responses were apparently much improved and mortality was reduced by two-thirds, thus suggesting rapid learning after the 2003 event.⁹ Further, in South Asia, policy responses to Indian Ocean cyclones illustrate the effects of learning related to extreme events in which a combination of early warning systems, wetland enhancements, provision of shelter, and increased forecasting capacity implemented in response to earlier disastrous cyclone impacts appears to have reduced mortality rates in Bangladesh by more than an order of magnitude compared to both historical experience in Bangladesh and experience in neighboring Myanmar.¹⁰ These recent examples clearly demonstrate the adaptive capacity of institutions to intervene quickly to reduce repeat health impacts of climate-related events. How can these responses inform strategies to address the

needs of those most vulnerable to climate change and dengue?

To effectively address the growing global risks of dengue and climate change, interventions aimed at minimizing climate-related dengue outbreaks must be implemented locally and provide clear mechanisms to reduce contact between dengue vectors and vulnerable populations (source reduction, use of window screens, provision of affordable air conditioning, spraying to reduce adult vector populations, to name a few). But responses to address the needs of the urban poor must also include strategies that anticipate how the risk of dengue is likely to change with rapid and unpredictable climate change. Such strategies may include improved early detection of outbreaks through comprehensive surveillance, development of climate-based dengue early warning systems that produce detailed risk maps that can guide interventions locally within urban settings, complementary research that furthers our understanding of temperature and moisture sensitivities of both dengue viruses and vectors, enhanced understanding of societal-dengue interactions through modeling exercises that explore how human migration and international trade may change as a function of climate change, and improved projections of dengue transmission in temperate areas that are currently free of the disease. When viewed as a comprehensive, multi-scale approach to climate change adaptation, these efforts may go a long way to addressing the needs of the urban poor and reducing the burden of dengue globally.

In this paper, we review the various climate factors that link dengue and climate, such as El Niño, temperature, and precipitation, as a starting point for developing a more comprehensive understanding of how climate change affects dengue risk and how institutions can address the issues of social justice and dengue outbreaks associated with extreme weather events that will continue to affect growing urban populations in vulnerable settings.

Dengue fever trends

Dengue fever, the most common mosquito-borne viral disease in the world, is spreading rapidly.¹¹ In

2009, the World Health Organization (WHO) reported that in the last 50 years, the incidence of dengue fever has increased 30-fold, and the geographic area affected has expanded. At that time, WHO estimated there to be 50 million cases annually, with 2.5 billion people at risk living in endemic countries.¹² A 2013 analysis published in *Nature* predicts a much greater impact, with dengue fever infecting 390 million people annually, and 96 million symptomatic cases.¹³ Geographic spread of dengue fever is influenced by factors that affect mosquito and human habitats, such as rainfall, temperature, and degree of urbanization.¹⁴ Modeling of the effect of climate change on dengue fever using expected change in humidity predicts that 5 to 6 billion people (50-60% of the projected global population) will be at risk for dengue fever in 2085, versus 3.5 billion in the absence of significant climatic changes.¹⁵ Dengue fever disproportionately affects the poor.¹⁶ Therefore, in order to protect vulnerable populations, it is increasingly important to understand how climatic and non-climatic trends affect complex relationships between the vector, pathogen, and host that drive the spread of dengue fever globally.

Background on dengue fever

What is dengue fever?

Dengue fever is a *flavivirus* with four serotypes spread primarily by the *Aedes aegypti* and the *Aedes albopictus* mosquitoes. The virus causes an acute febrile illness characterized by malaise, retro-orbital pain, and bone pain that give it the name “break bone fever.”¹⁷ Approximately 1-5% of symptomatic patients will develop severe dengue, which is characterized by plasma leakage causing shock, pleural effusions, and ascites; severe bleeding; and severe organ impairment.¹⁸ While there is no approved dengue vaccine, there is a vaccine in phase 3 trials.¹⁹ Present treatment is supportive care.

History of dengue fever

The *Ae. aegypti* mosquito originated from Africa and spread during the slave trade, while the *Ae. al-*

bopictus mosquito originated from Southeast Asia. Both vectors have spread throughout the tropics and sub-tropics through trade pathways.²⁰ During World War II, *Ae. aegypti* spread widely through Southeast Asia as people migrated to cities in search of work, which resulted in unplanned urbanization with inadequate housing, sewage, and waste management creating an environment with multiple factors to facilitate transmission.²¹ In the 1950s, dengue was predominantly focused in Southeast Asia, but with increased global travel and trade, it expanded globally by the 1970s.²² Local endemicity in Latin America and Asia was facilitated by crowded cities with poor water infrastructure leading to ideal mosquito breeding sites. Today, with increased global spread of disease, many temperate areas in North America, Europe, Australia, and Japan are reporting travel-associated cases.²³ Within the US, the first locally acquired dengue outbreak since World War II occurred in Hawaii in 2001 and subsequent outbreaks have occurred in Texas in 2005 and 2013, and in Florida in 2009, 2010, 2011, and 2013.²⁴

As illustrated in the past, the spread of dengue has depended largely on socioeconomic factors related to urbanization and migration that affect mosquito populations. Looking forward, the spread of dengue fever will continue to be influenced by socioeconomic factors, as well as climatic factors as discussed below. Furthermore, future dengue morbidity and mortality will be determined by how adeptly social institutions are able to predict and respond to outbreaks.

Appreciating the complexity of dengue modeling

While predictive dengue and climate change models are useful for conceptualizing future trends, transmission of dengue fever cannot be accurately predicted using simple models of temperature variables and mosquito spread.²⁵ Transmission depends upon multiple complex factors, such as the number of female mosquitoes per person, the probability that the infectious mosquito transmits dengue virus while biting a susceptible human, the probability that a mosquito acquires dengue infection while bit-

ing a viraemic human, the number of bites per person per day, the duration of incubation of the virus in the mosquito, and the survival rate of the mosquito.²⁶ These factors are affected directly and indirectly by long-term *climatic changes* in rainfall, temperature, natural disasters, and climatic variability, as well as *non-climatic changes* such as urbanization, travel, and trade patterns. The relationship between these factors is often not linear, further complicating the picture.²⁷ Different models have been developed to predict the role of these trends on dengue incidence and prevalence, but the role of poverty on human behavior, health care access, health-seeking behavior, and provision of social services is not addressed in most models of dengue transmission.²⁸

Statistical models do provide powerful tools to advance prediction of dengue outbreaks. These tools are made more powerful by incorporation of climate and vegetation parameters, and have recently advanced understanding of dengue outbreaks in the Americas.²⁹ Such models are still relatively novel because they subsume the many biological and human parameters considered in mechanistic models, which include parameters related to vector population dynamics, human-vector spatial contacts and networks, vector control measures, and immunological effects such as herd immunity.³⁰ While theoretically elegant, such mechanistic models are difficult to parameterize because they require many data inputs that generally can be obtained only through intensive field work, which is generally limited in spatial and temporal scope. Thus, there is a clear need for relatively simple, statistics-based models that can predict dengue epidemics using climate data and public health data that is publicly available free of charge.

Dengue epidemics in different areas often exhibit wave-like behavior in near synchrony to climate variables. Several studies have analyzed dengue time series using climatic indices that relate to global teleconnections such as the El Niño Southern Oscillation (ENSO).³¹ Climate-based studies have generally revealed strong relationships between dengue outbreaks and climate oscillations using data from meteorological stations and sea-surface temperature (SST) observations. Precipitation and

temperature oscillations over large parts of Latin America and the Caribbean are strongly influenced by changes in Pacific SST, and these in turn can influence vectorial capacity.

While ENSO may play a role in synchronizing epidemics, seasonal vegetation dynamics may also influence vector populations at relatively local scales.³² Often, there is a close association between vegetation canopy development, local moisture supply, and breeding of mosquito vectors. Fully developed tree canopies not only provide shade that can reduce evaporation from containers, but may also decrease sub-canopy wind speed and increase humidity near the ground, factors that tend to increase vectorial capacity.

Macro-scale (ENSO) and micro-climate data can be used to predict the occurrence and spread of vector-borne diseases.³³ Future models for dengue will need to consider this data in the context of long-term environmental and socioeconomic trends.

The relationship of climatic factors with population growth, human migration, urbanization, and poverty

There is near unanimous scientific consensus that global temperatures are increasing, global annual rainfall will likely increase with increased rainfall in some areas and decreased rainfall in mid-latitude and lower latitude regions, flooding will become more severe, and climate variability will increase.³⁴ Humidity refers to the concentration of water vapor in the atmosphere and is dependent on rainfall and temperature. Hales et al. used expected humidity changes and expected population growth to model the increase in area of land with climate suitable for dengue transmission and calculate the population at risk. They concluded that with climate change, the population at risk for dengue would be 4.1 billion people (44% of the total population) by 2055 and 5.2 billion people (52%) by 2085, as compared to 3.2 billion people (34%) by 2055 and 3.5 billion people (35%) by 2085 due to population growth alone.³⁵ Therefore, both climatic and population growth factors are expected to increase the population at risk

for dengue.

Dengue incidence is related to temperature, and this relationship appears to vary by location.³⁶ In Veracruz, Mexico, from 1995 to 2003, 37,005 dengue cases were reported between San Andres Tuxtla and Veracruz municipalities with respective mean annual minimum temperatures of 15.9 degrees centigrade and 18.1 degrees centigrade. Each degree centigrade increase in sea surface temperature shown by ENSO was followed by an increase in the number of dengue cases by 46% in San Andres Tuxtla and 42% in Veracruz.³⁷ Increases in minimal temperature and rainfall also increased dengue cases.³⁸ However, Johansson et al found no association between ENSO, temperature, or precipitation and dengue incidence during the same time period in Mexico as a whole. In Puerto Rico, ENSO was transiently associated with temperature and dengue incidence on multiyear scales.³⁹ In Thailand, there was a weak association between temperature and precipitation.⁴⁰ These differing associations are evidence of the complexity of the relationship between climatic variables and dengue incidence. Variations may be seen in dengue incidence based on factors not accounted for in temperature and precipitation modeling such as human migration patterns and water storage behaviors.⁴¹ For example, decreased rainfall may indirectly increase dengue incidence due to increased storage of water in containers for domestic use that acts as breeding sites.⁴²

The relationship between rainfall/flooding with mosquito breeding is complex. In general, higher rainfall increases standing water that may serve as breeding sites for mosquitoes, while flooding may initially reduce mosquito populations by flushing larvae from pooled water.⁴³ Approximately one week after flooding or heavy rainfall, however, there is often a rebound in vector population present in new breeding sites.⁴⁴ While flooding and increased rainfall have the potential to alter mosquito breeding sites and thus vector abundance, this does not necessarily imply increased dengue transmission that requires virus and host abundance as well.

The effects of flooding on dengue transmission are also complex. Flooding can increase mosquito densities and landing rates, as seen in Louisiana af-

ter Hurricane Andrew, or increase exposure to mosquito populations through housing damage, as seen in Florida after Hurricane Andrew.⁴⁵ These conditions do not necessarily lead to dengue transmission. The theory is that increased vector mosquito populations increase the prevalence of potentially infectious mosquitoes and thus increase the risk for human disease when humans are exposed after a disaster.⁴⁶ Therefore, host, viral, and vector elements must align for transmission to occur. While heavy flooding has been associated with dengue outbreaks in locations without dengue for many years, it is important to consider that in endemic areas increased dengue cases during the rainy season are a part of annual seasonal variation.⁴⁷ For example, flooding in the United States is rarely accompanied by epidemics of mosquito-transmitted disease, but there are accounts of increased mosquito populations and dengue cases after flooding in India and Thailand.⁴⁸ Outbreaks such as these may be the result of disruptions to the basic water supply and use of water storage containers that serve as breeding sites; interruptions of mosquito control programs; crowding of infected and susceptible hosts; and increased exposures to mosquitoes while sleeping outside.⁴⁹ These factors stress the need for adequate public health infrastructure to address potential arboviral threats during both seasonal rainfall variations and floods.

Following natural disasters, human migration leads to areas of unplanned urbanization without proper infrastructure for water supply and waste management that have increased incidence of dengue fever.⁵⁰ With general trends towards urbanization in all countries expected to increase from 45% in 1995 to 61% in 2030, climate change-related flooding, storms, and landslides are projected to displace several hundred million people by 2050. Sea level rise will force some residents of low-lying coastal areas to relocate.⁵¹ Human displacement and poorly planned urbanization increase risks of undernutrition, conflict situations, mental health problems, and exacerbation of infectious and vector-borne diseases such as dengue.⁵²

Likewise, urban poverty contributes to dengue transmission in slums with inadequate

drinking water, garbage collection, and surface water drainage that leads to mosquito breeding sites in areas of high population density.⁵³ These problems cannot be fixed by blanket applications of pesticides, and require community empowerment and mobilization as well as government support to improve infrastructure.⁵⁴

Interestingly, as urban poverty contributes to particular environmental risks as above, affluence contributes to different risks. Living in a house rather than an apartment leads to increased dengue risk, as apartments often have private water wells, while homes commonly have peri-domiciliary water storage containers.⁵⁵ This appears to be related to the presence of ornamental gardens with flowerpots, vases, fountains, rarely-used pools, and birdbaths common in affluent areas that serve as mosquito breeding sites.⁵⁶ Furthermore, residents of affluent communities are more likely to have multiple properties with tenants, and to be away for travel, limiting vector control measures.⁵⁷ Therefore, wealthy populations are also at risk for dengue fever for different environmental reasons than poor populations. However, wealthy populations are more financially empowered to fix these environmental risks than their poor counterparts.

Factors affecting vector biology

Temperature affects adult mosquito survival, reproduction, and biting rate.⁵⁸ *Ae. aegypti* is generally restricted to the 10 degrees centigrade isotherm.⁵⁹ Freezing kills the *Aedes* eggs, larvae, and adults, while warm nights and winters favor survival of the dengue vector.⁶⁰ Mosquito reproduction occurs in gonotrophic cycle, which is the time interval between two consecutive blood meals or two consecutive acts of egg-laying. Blood meals are required for oogenesis to occur. Gonotrophic cycles are repeated during the life of the female mosquito. The length of the gonotrophic cycle is shorter at higher temperature increasing the reproductive capacity of the female mosquito.⁶¹ In addition, warmer temperatures increase biting frequency. Large adult mosquitoes can obtain enough blood in one meal for oogenesis. Warmer temperatures

lead to smaller adult mosquitoes that must feed more than one time during the gonotrophic cycle to obtain enough blood for oogenesis.⁶² Increased biting increases the probability of biting a dengue-infected host in endemic areas. Higher temperature increases mosquito survival, reproductive capacity, and biting frequency.

Increased international trade and travel have also expanded the spread of competent vectors.⁶³ *Ae. aegypti* spread throughout the tropics on sailing vessels, while *Ae. albopictus* spread outside its native range to at least 28 other countries via internationally traded used tires.⁶⁴ Increasing global trade networks will further spread the scope of dengue competent vectors.

Pathogenic factors

As global trade and travel spread the mosquito vector, viraemic human passengers are also spreading the dengue virus across the globe. For example, Florida has had *Aedes* mosquitoes and susceptible people for years, but only recently, in 2009, did an outbreak of endemic dengue occur as the result of introduction from a viraemic traveler coming from a dengue-endemic country.⁶⁵

Temperature affects transmission of the virus by decreasing the extrinsic incubation period, the time period required for the virus to replicate, enter the midgut, permeate the mosquito body, and reach the salivary glands, where it can be transmitted via the following bite.⁶⁶ The average extrinsic incubation period is 15 days at 25 degrees Centigrade, and 6.5 days at 30 degrees Centigrade.⁶⁷ A shorter extrinsic incubation period means that the mosquito is capable of spreading the virus during biting for more days before the end of its approximately two-week lifespan.

Host factors

Poverty impacts human factors that influence dengue transmission through physiologic and behavioral mechanisms. The dengue virus has four serotypes. Physiologic immunity to these different serotypes is complex. Previous infection with the

same serotype provides protective immunity, while secondary infection with a different serotype leads to increased hemorrhagic and shock syndromes due to a process of augmented immune response known as antibody dependent enhancement.⁶⁸ For example, Cuba had an epidemic of DEN-1 in 1997, followed by an outbreak of DEN-2 in 1981. Hemorrhagic and shock syndromes were found in patients with exposure to both of the two serotypes due to altered immune response.⁶⁹

While global spread of the different serotypes plays a role in the severity of immune-mediated response to the infection, individual host factors also play an important role. Poor nutritional status and micronutrient deficiencies among urban poor contribute to vulnerability to increased severity of infection.⁷⁰

While human movement affects the spread of different dengue serotypes, human urban settlements affect local climate through the heat island effect. The heat island effect refers to increasing atmospheric and subsurface temperatures as a result of urban development.⁷¹ As dengue is primarily an urban disease, and the heat island effect accounts for cities being comparably warmer than suburban and rural locations, cities may serve as a natural laboratory for testing hypotheses about climate change and dengue.

Vector-borne disease such as dengue disproportionately affects the poor, who may have limited means to control their environment. For example, a comparison of dengue cases at two cities on the US-Mexico border, Matamoros, Tamaulipas (Mexico) and Brownsville, Texas (US), found a seroprevalence of 32% in Matamoros versus only 4% in Brownsville. This increased seroprevalence of infection in Matamoros was attributed to reduced access to air conditioning, smaller lot size, and decreased use of insect repellents.⁷²

Unfortunately, urban slums often present highly suitable breeding ground for *Aedes* mosquitoes, and these communities often lack the ability to perform adequate vector control.⁷³ For example, the density of mosquitoes in Matamoros was approximately twice that in neighboring Brownsville.⁷⁴

Multiple studies have demonstrated an inverse

relationship between wealth and dengue infection.⁷⁵ For example, a Brazilian seroprevalence study demonstrated that deprived socioeconomic areas have three times the intensity of dengue infection compared to privileged areas. By the age of five, 59% of deprived children in Recife, Brazil, have been exposed to dengue. Deprived areas had the lowest proportion of households with regular water supply (only 12.7%) and in Venezuela, interruptions in water supply were associated with increased dengue cases.⁷⁶ In India, slum areas were associated with higher larval indices than affluent or mixed areas.⁷⁷ Another study from Brazil did not show an association between different socioeconomic levels, but did demonstrate that the locations adjacent to the worst basic sanitary conditions showed the highest larval indices.⁷⁸ However, this relationship is not straightforward. As described, while poverty contributes to environmental risks such as poor access to water and sanitation, lack of air conditioning, window screens, and poor water drainage infrastructure, affluence contributes to environmental risks from lush gardens, flower pots, and rarely used pools. Affluent populations, however, have the ability to avoid exposure, while poor populations generally do not. While integrated vector control programs are needed to educate both poor and affluent citizens, programs to empower disadvantaged populations are imperative to address their environmental risks.

Furthermore, while poor patients are more likely to get dengue fever, they are less likely to seek medical attention in a timely fashion. For example, dengue infection in Texas is associated with very low income (less than \$100/week).⁷⁹ In Cambodia, poor patients come later in the course of the disease and suffer worse outcomes than wealthier patients who present sooner.⁸⁰ Improved access to health services, and awareness of the dengue warning signs of severe disease, are needed among marginalized populations.

Therefore, poverty affects the burden of dengue by malnutrition increasing vulnerability to infection, reduced access to air conditioning and repellent, closer living areas, inadequate vector control, and decreased health-seeking behavior due to decreased access to care.

Potential solutions to mitigate the burden of dengue fever globally

Successful solutions will require an interdisciplinary approach that considers pathogen, vector, host, and environmental elements. Simplistic approaches that fail to recognize larger environmental and socioeconomic trends will fail, given the complexity of factors affecting dengue transmission. The mobilization of social institutions, from neighborhood organizations to international governing bodies, is necessary.

Countries should adopt the integrated vector management (IVM) approach to vector control, as promoted by WHO and defined as a rational decision-making process to optimize the use of resources for vector control.⁸¹ It aims to improve efficacy, cost effectiveness, ecological soundness, and sustainability of vector control interventions. Dengue vector control is most amenable to the implementation of IVM, which ensures the judicious use of insecticides in combination with other prevention and control interventions.

Governments need to support domestic infrastructure for prediction and response to outbreaks, and international cooperation, which is critical given the role of border transmission and international trade and travel. For example, a recent outbreak of local dengue fever occurred in Texas at the Mexico-Texas border after a few months of increased cases in Mexico.⁸² Cooperation in public health measures and vector control is needed internationally to prevent further outbreaks.

Simple measures can be employed at a community level to empower populations to eliminate standing water that may serve as mosquito breeding sites, encourage the use of repellents, and educate families on the importance of seeking medical attention if warning signs of severe dengue arise. Community empowerment has been shown to decrease larval indices through the use of educational meetings, educational materials, outreach visits, involvement of local opinion leaders, involvement of national institutions, and use of education by mass media.⁸³ Sustained community empowerment programs are needed in order to reinforce healthy habits.⁸⁴ Community participation is often high only during

epidemics and non-sustainable without government support.⁸⁵ Therefore, continued government support is needed in communities with funding and evidence-based interventions for control based on local disease patterns.

Despite the efficacy of some simple measures, larger public health issues that contribute to the continued presence and morbidity of dengue infection cannot be ignored.⁸⁶ These include the need for constant access to potable water for domestic use, safe sanitation systems, infrastructure to predict and respond to outbreaks and natural disasters, further efforts to develop vaccines, access to health care, and economic development that provides access for all people to proper nutrition, air conditioning, and window screens.⁸⁷ For example, in China, the provinces with the lowest GDP had the highest disability-adjusted life years lost to vector-borne disease.⁸⁸ Recent evidence suggests that economic development can have a positive impact. For example, some areas of Southeast Asia have experienced declining dengue infection rates due to strong economic growth, improved housing standards, and improved vector control programs.⁸⁹ Unless health and economic standards are improved for all people, dengue transmission will continue.

Conclusion

Climate change is an issue of global justice—and climate change policies and interventions should be tailored to focus on human health. Dengue fever is rapidly expanding globally due to the complex interactions of climatic and socioeconomic factors that influence mosquito breeding sites; mosquito distribution and generation time; viral incubation period and global dissemination; and human immunology, migration, and behavior. Impoverished areas have heightened environmental risk and decreased resources to prevent or manage dengue infection. Community organizations in these areas can and do help to mitigate the impacts of dengue in poor urban neighborhoods. However, large-scale structural improvements in public health are necessary to truly address the global intensification of dengue fever.

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