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ENVR 391

Road construction as a facilitator for dengue fever transmission

INTRODUCTION

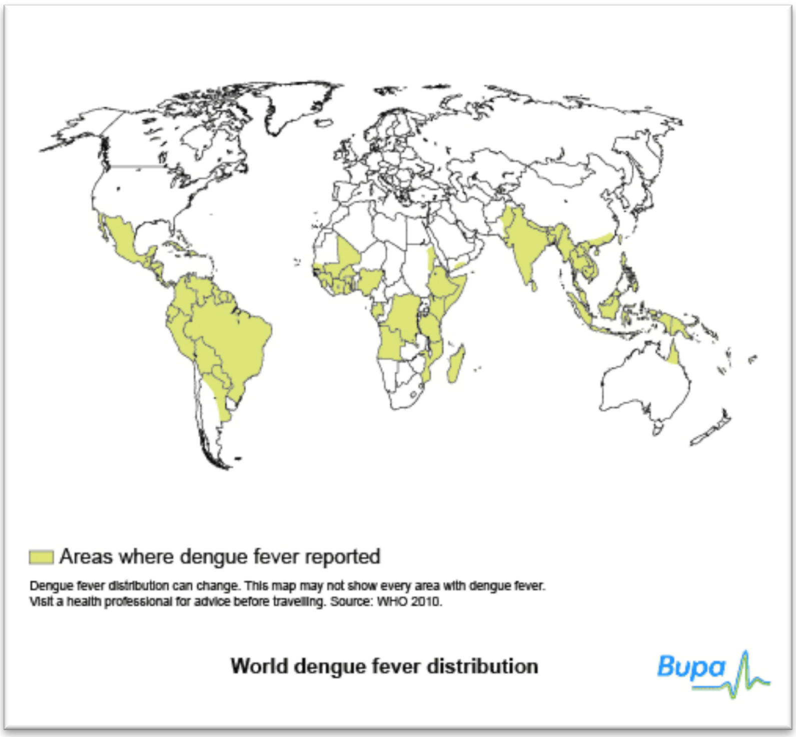

Figure 1. Distribution of Dengue Fever as of 2010 according to WHO data. Source: WHO 2010, Bupa

Human-caused land use changes initiate a gamut of infectious disease epidemics and emergence events and alter the spread of endemic infections. The driving factors include agricultural forces, deforestation, dam building, irrigation management, wetland alteration, mining, the density or growth of urban environments, coastal zone damage, and other activities all of which stem from road construction. Roads lead human populations to expand and push against frontier lands, creating communities prime for the contraction and spread of diseases such as dengue fever (Laurance et al 2009).

Dengue fever (DEN) is a disease carried by mosquitoes with a wide range including asymptomatic infection, mild dengue fever, dengue hemorrhagic fever, and dengue shock syndrome, all of which can result from any of the four serotypes in the genus *Flavivirus*. Even though infections of dengue arise in over 100 countries around the world (**Figure 1**), there has been a dramatic rise in the number of reported cases in the Americas over the last decade, especially South American countries (San Martin 2010).

The patterns of dengue infections in the Region of the Americas, according to research done by San Martín showed significant data that a infection with one serotype of dengue fever can lead to a more deadly infection by a different serotype years later (San Martín 2010). The swing from a low dengue-endemic rate to a hyperendemic state of local transmission within the countries of the Americas has led many to examine possible causes for the rise in dengue fever, which is causing more sickness and fatalities than any other arboviral (disease spread by arthropods) illness (McBride 2000).

Mosquitoes, more specifically the species *Aedes aegypti* (**Figure 2**) and other species of the same genus, are the only vector by which dengue fever spreads. Local vector control is so far considered the best solution to curb the rising incidence in the Americas, but a promising tactic for disease control is the development of competent vaccines to protect against all four serotypes of dengue. Increased incidence of the disease and mosquito population can be credited to the waning since the 1970s of the eradication program for the mosquitoes employed by PAHO (Pan American Health Organization) in the 1940s (Guzmán 2003). Growth in the density of the mosquito vector and disease burden has also been caused by population growth, unplanned urbanization with poor sanitary systems, deterioration of the public health infrastructure, and a decreased access to health care (San Martín 2010).

Figure 2. Aedes Aegypti during blood meal. http://marinedebrisblog.files.wordpress.com/2009/12/aedes_aegypti_during_blood_meal.jpg

Studies have already explored theories that the presence and absence of dengue fever, more colloquially known as breakbone fever, can be attributed largely to environmental and climatic factors, because the mosquitoes carrying the virus prefer wet, tropical biomes (Rogers et al. 2006). However, published studies on dengue fever do not delve deeper into the possible connection between road constructions and the spread of arthropod-borne diseases along them. I would like to further these studies by examining whether the construction of roads deeper into humid, tropical areas exacerbates the spread and contraction of dengue fever. How could roads facilitate an increase in populations of *Aedes aegypti*? Why might cases of dengue fever follow new road construction in the Amazon?

These are important questions for developing countries in tropical and sub-tropical latitudes where road construction is being pushed forward at faster and faster rates while public health services lag behind or are not accessible to the people in those areas where they are desperately needed for a plethora of diseases and ailments. Rainforests fragmented by roads and railways are more likely to attract mosquito populations, who like puddles of standing water and forest edge for breeding grounds (Harrington et al. 2005). The more forest edge created, the larger the size of edge species populations. Not only are there more female mosquitoes born that need to feed, and consequently occasionally spread dengue, but mosquito larvae are more likely to be transported by the movement of humans and vehicles along roads. Because many of the roads are being built further into the remote regions of forest, the healthcare access of the communities that make their lives there is of a lesser quality than larger urban settings, meaning there is more of a chance for the contraction of the more fatal dengue hemorrhagic fever.

More needs to be examined of the effects of roads on the spread of infectious diseases through human-wildlife interactions and lifestyle changes of populations that move along them, especially in developing countries. Deforestation and new road development in the Amazon could lead to many new diseases being transferred to human populations and spreading known diseases quickly in areas with little access to health care. Dengue fever is a good disease to model for how roads affect the disease spread in tropical areas because the genus of mosquito that caries the dengue virus (DENV) also carries many other arboviruses (viruses carried and spread by arthropods), including yellow fever, Chikungunya, and malaria. By better understanding how roads beget roads that then beget the spread of dengue fever, policies to mitigate road expansion and mosquito populations along existing roads can begin to be formulated and enacted. Paying attention to the risks imposed by increased road density with dengue fever and dengue hemorrhagic fever would also help lessen the contraction of the other aforementioned arboviruses.

Patz et al. states that not just change to the environment, but anthropogenic change to the environment, such as deforestation, road construction, and dam erection, drive and modify the transmission of endemic infections, sometimes which are utterly new to an area (Patz et al 2004). Researchers have proclaimed that changes in the physical environment and population movements are the primary devices that appear to impact public health to the greatest degree because they increase the interaction and struggle between humans and wildlife. Daily lifestyles of human populations change with migration, sometimes causing malnutrition and increased non-communicable diseases that weaken the immune system. Migration and urbanization along new roads into the Amazonian rainforests tend to intensify cases of communicable diseases such as sexually transmitted diseases and zoonoses (Cesario 2008).

Connors et al. conducted a case study on the effect of road access on the transmission of dengue fever in a rural area in Ecuador showing a correlation between communities with higher dengue fever contractions and communities near roads as compared to those in more remote areas (Connors et al. 2008). But the authors did not include other factors that may have influenced and biased the study, such as cyclical immunity in populations and the likelihood of communities along roads consisting of homesteaders that may be experiencing malnutrition due to the stress and struggle of life in the frontier lands. Connors paper is only one case study and remains highly focused on a small area in rural Ecuador.

Perz et al. found that the relationships between connectivity and social-ecological resilience are not the same everywhere. These relationships are highly complex and are representative of the quirks of differing study regions. In this way, Perz at al.'s study can be tied to my research; disease is not as indiscriminate as once thought. The differences in community culture and practices can alter the probability of community members contracting certain diseases, both for the better or the worse. The integration of transport geography and resilience could add a new facet to my research that I had not previously thought to include by bringing in factors other than mosquito populations. Connectivity and socio-economic forces can play a part in disease spread by allocating which areas have better access to health care and preventative measures and possible mosquito population movement with agricultural deliveries.

Although I plan to focus on the impact of road construction in tropical and sub-tropical regions on the spread and contraction of dengue fever, I hope to use this focus as a model that could help to create policies that would mitigate other diseases spread through insect contact. In places that road and railway construction have already become a part of the permanent foundation, medical infrastructure should be put into place to ensure that populations at increased risk to contract dengue fever have access to medical care to diminish rates of dengue hemorrhagic fever.

FRAMEWORKS

Dengue fever is a growing problem for the health of communities in the tropical and subtropical latitudes of the Americas (San Martin 2010). Researchers have looked at the issue of dengue fever from numerous perspectives and through the lens of many different frameworks. A large number of these studies have been conducted with their theoretical arguments based in epidemiological and/or public health approaches. Although a very valid piece of the puzzle, to look at the spatial patterns of dengue fever in South America and whether roads facilitate its spread, epidemiology should be flanked by land use land change and road ecology frameworks (San Martin 2007).

For the purposes of my paper, I will be approaching the question of whether the spread of dengue fever in the Americas can be linked to roads within the three contexts of epidemiology, land use land cover change science, and road ecology. Disease contraction relies heavily on these three interrelated contexts. Land use land cover is often caused by road construction, which in turn creates a relationship with the surrounding altered ecosystem known as road ecology. Roads attract and transport animals and people carrying arthropod-borne diseases such as dengue fever and dengue hemorrhagic fever.

EPIDEMIOLOGY

What is it?

Epidemiology is the scientific study of disease distribution and determinants of health related states in populations and use of this study to address health related problems. The information and advancements made by those in the field are essential to public health analysis as they deliver comprehensions for disease transmission within populations, the contraction risk factors, and how to advance approaches to treatment options. Epidemiology cannot exist as a field without the integration of several other disciplines like environmental science, biology, geographic information systems and social science (Hogan 2007). As a cornerstone approach for public health, epidemiology helps to inform not only scientists and health practitioners but also governmental policy decisions dealing with disease and preventative medicine. Although epidemiology can technically refer to animal populations, I am reading it in its usual form as referring to contagions within human populations.

History.

The word *epidemiology* plainly means 'the study of what is upon people.' Credit is usually given to Hippocrates as the father of epidemiology as the first physician to have investigated the links between disease outbreak and environmental stimuli. He even coined the terms for *endemic* (disease visited upon a population) and *epidemic* (disease that resides within a population) to explain the boundaries or lack thereof for the location of different diseases (Hogan 2007). However, Villalba, a Spanish physician, did not introduce the word for the study itself until 1802 in the volume Epidemiología Española (Buck et al. 1998). It began as a description for studying epidemic disease but now is a blanket term for the spatial connections of diseases and even non-disease health conditions. Disease theory has come a long way since the days of Plato, who inferred in *The Republic* that the origin of disease was thought to mainly be the error of human indulgences (Plato 1937). Dr. John Snow is known as the father of modern epidemiology after he identified two water sources as the major cause of the London 19th century cholera epidemic and treated the water with chlorine, ending the epidemic (**Figure 3**)(NPR 2004).

Figure 2. Snow's map of Cholera outbreak in 19th century London identifying the water pumps as the source of infection. Source: Public Domain.

Why is it important?

The mechanisms accountable for an epidemic are recognized and used to target, improve and implement methods to lessen the risk of disease (Gilligan 2002). There is no way to explore the cause of the spatial distribution of dengue fever infections without using the framework of epidemiology. In order to examine why there has been a rise in the incidence of dengue, one must have knowledge about the vector for the disease and what expands or shrinks that vector. It is also necessary to understand the risk factors of transmission and the nature of the pathogen itself to be able to apply any solution to the root cause and decrease the frequency and severity of dengue infections.

This framework is the cornerstone of my explorations of the possible relationship between road construction and dengue fever incidence. Information following it builds onto the general knowledge of the disease, how and by what it is transmitted, and the locations of reported infections. As shown by Dr. John Snow's work, mapping the disease allows the user to identify patterns and possibly lead back to causation. The next two frameworks continue to expand on these themes by explaining human-caused changes in the environment that create routes by which disease, specifically dengue fever and dengue hemorrhagic fever, can flourish and spread more rapidly than in an unchanged environment.

LAND USE AND LAND COVER CHANGE

What is it?

Also referred to as LULC, Land Use and Land Cover Change is the overarching terminology for the anthropogenic alteration of the earth's surface. Land use is defined by natural scientists as the patterns of human activities that alter the land, such as agriculture, construction, and forestry. Land cover includes the physical and biological components on the surface of land, such as water, vegetation, and soil. Even though humans have been changing the land around them to suit their needs for centuries, the rates, extents, and intensity of the current changes are greater than any other moment in history. The alterations this causes to ecosystems and environmental processes are happening at local, regional, and global scales. Some of the environmental processes affected are biogeochemistry, hydrology, and biodiversity (Lambin et al 2001).

Land cover can be studied through direct observation at ground level or by remote sensing technologies such as satellite or aerial imaging, but insights into land use changes necessitate the incorporation of scientific methods from both natural and social studies to identify how human activity changes land cover in different types of landscapes. As a result, scientific investigation of the causes and consequences of LULCC requires an interdisciplinary approach integrating both natural and social scientific methods, which has emerged as the new discipline called land-change science (Ellis 2011).

History.

Land-use land-cover change is an indirect consequence of man's actions towards gathering critical resources. The dawn of agriculture drastically increased the rate of deforestation and alteration of water sources, forest fragmentation, and urbanization. LULLC has had a large hand in climate change and reduction of biodiversity as deforestation has released sequestered carbon and decreased core habitat area. Research has exhibited that disease may occur more readily in areas exposed by LULCC (Ellis 2011). The commonly touted driving forces behind land-use and land-cover change are oversimplifications; neither poverty nor population alone represents the lone and chief underlying causes. How people react to economic opportunities, as mediated by formal factors, motivate land-cover changes (Lambin et al 2001).

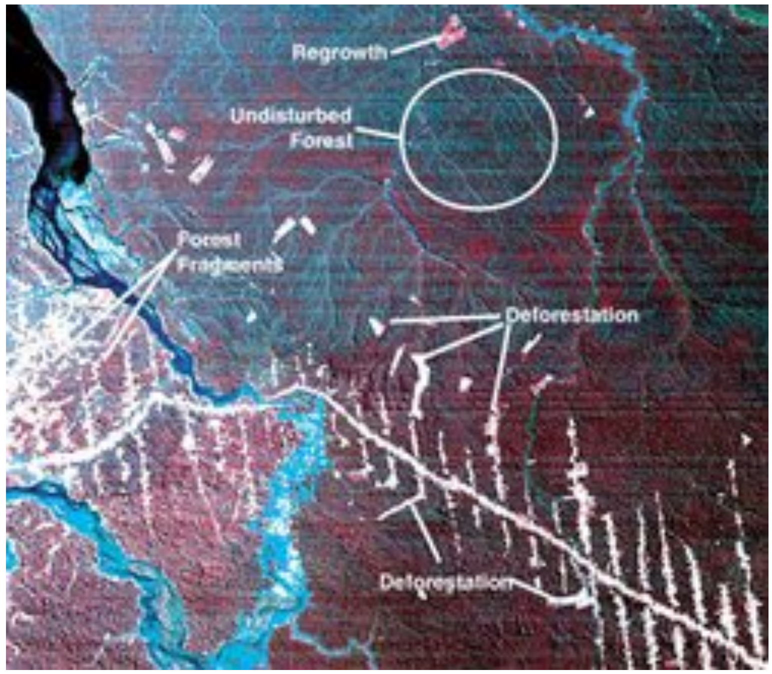

Figure 4. Deforestation in the Amazon region of Para, Brazil. Fishbone pattern of road construction. Source: NASA

Why is it important?

Trails, roads, highways, and other linear infrastructure are spreading rapidly throughout tropical and sub-tropical regions, especially within the Amazon region (**Figure 4**) (Laurance et al. 2009). Land use and land cover change is a substantial science to the topics and concerns at the heart of environmental studies on the global scale (Turner et al. 1995). Road construction, as a major source of land-cover land-use change, raises concerns about the potential ways it could accelerate the spread of disease. Environmental changes via human interference change the ecological equilibrium and setting in which vectors and their parasites breed, develop, and transmit disease. The construction of roads has been escorted by an international rise in illness and fatalities from many emerging parasitic diseases (Patz et al. 2000).

ROAD ECOLOGY

What is it?

Road ecology is a sub-discipline of ecology that strives to define the relationship between road structures and the natural environment. Most of the work done in the field attempts to find ways to mitigate the detrimental effect that road construction can have on plants, animals, ecosystem quality, and human communities. Landscape ecology principles form the theory foundation of road ecology, but conservation, fish, and wildlife biology has contributed heftily (Lloyd 2011). Roads have a wide variety of direct effects on the ecological balance and indirect ecological effects on the settings they pierce. These effects can be quantified in both abiotic and biotic mechanisms of terrestrial and aquatic ecosystems (Coffin 2007). "Few forces have been more influential in modifying the earth than transportation" (Ullman 1956).

History.

The study of road impacts on the environment is not new. Scientists and academics recognized early on the threats of motor vehicles to wildlife. Road construction soared in America from 1920 to 1960, but the effects on other more nuanced ecological processes were not studied in depth until the second half of the century. European scientists moved the sub-discipline forward much more quickly, the early work focused on habitat fragmentation and how to mitigate edge effects and permit animal movements (Lloyd 2011).

Why is it important?

Studies of the relationship between roads and the environment are important to the issue of dengue fever because roads bring vulnerable populations into areas where the risk of infection of the virus is higher and can create breeding grounds for the mosquitoes that make up the vector for the pathogen (Hemme et al. 2010).

The framework of epidemiology cannot be separated from environmental factors as the spread of disease relies so heavily upon the macro factors of climate change, such as global warming and the ENSO phenomenon, that influence the intensity and duration of the rainy and hurricane seasons or facilitate intense flooding and damages to the biodiversity (San Martín 2007). These changes can cause shifts in the ecosystems and create ideal conditions for the expansion and propagation of the mosquitoes that carry the virus (Khasnis 2005). Roads are linked closely with the reemergence of parasitic diseases, as shown by Patz et al. 2000, Laurance et al 2009, and Hemme et al. 2010.

ANALYSIS

Dengue fever and dengue fever hemorrhagic infections have been decidedly rising over the past three decades (**Table 1**)(San Martin 2010). Because there is no functional vaccine, the most reliable method of prevention is still vector control, which entails mosquito (*Aedes aegypti*) population management. Ae. aegypti is extraordinarily prosperous as an invasive species and exists in most of the world's tropical and sub-tropical countries. The objective of vector control is to reduce the populations of adult mosquitoes to the point where dengue transmission is below the point of epidemic threshold. Insecticides are used as an emergency control. Hemme et al. speculates that the increase in dengue incidence can be loosely linked to the greater numbers of people migrating into newly urbanized settings with continued growth. Understanding the factors such as physical barriers that may limit adult dispersal could lead to a more comprehensive control methods, because the adult populations have relatively short travel ranges (<100 meters) (Hemme et al. 2010).

Table 1. DF and DHF cases in the Americas from the last 3 decades. [Data: San Martín 2010]

In the Americas Region	1980s	1990s	2000-2007
Total Dengue Cases	1,033,417 (16.4/100,000)	2,725,405 (35.9/100,000)	4,759,007 (71.5/100,000)
DHF Cases	13,398 (0.2/100,000)	58,419 (0.8/100,000)	111,724 (1.7/100,000)
DHF % of Total	1.3%	2.1%	2.4%

Human land-use changes, especially roads and other linear clearing, are some of the primary factors affecting infectious disease epidemics and changes in disease transmission dynamics (Hemme 2010). Road construction offers access for expanded and new populations of humans, livestock, vectors, and parasites. They allow for rapid expansion of new human settlements, resulting in ecological disturbance. New populations of people without native immunity or preventive knowledge move into these newly expanded areas of tropical forest, creating a bigger population susceptible to infection Roads in forests inaccessible prior to construction often lead to erosion and therefore the creation of stagnant or standing water due to blocked streamflow during the rainy season. These pools of standing water become breeding grounds for arthropods, including the carriers for the dengue fever virus, *Aedes aegypti*. Increased visitors to the area raise the possibility of introducing the vector in an area where it did not exist previously (Patz et al. 2000).

CONCLUSION

Unfortunately, road construction is necessary to many other facets of human life and development and will continue to be a battle between economic development and environmental concerns. Laurance et al. points out that tropical rain forest mainly are located in countries on the periphery of economic status where population growth, economic development, and resource exploitation are continuing (Laurance et al. 2009); therefore, the likelihood of slowing or stopping road construction in these quickly developing areas is slim. In order to keep dengue transmissions at a minimum, it is important to understand the most effective vector control methods and provide a better education to migrants of mosquito biting behaviors and prevention techniques. Governments should focus on road construction methods that mitigate standing water and streamflow blocks to remove possible oviposition sites. After the elimination of yellow fever through the use of an effective vaccine, the hopes for an eventual vaccine for dengue fever are still high. Until then, vector control and prevention education are the main forms of risk alleviation.

References

*Father of epidemiology: John snow*2004. . NPR Talk of the Nation: .

Buck, C., A. Llopis, E. Nájera, and M. Terris. 1998. The challenge of epidemiology: Issues and selected readings. In *Scientific publication.* Vol. 505, 3. Washington, D.C.: Pan American Health Organization.

Cesario, Manuel, and Monica Andrade-Morraye. 2008. Land-use and land-cover changes and the (re)emergence of diseases in brazil bonn: UNU-EHS, 2008. In *Towards sustainable global health.*, ed. Martin Exner, 61-68. Brazil: Bonn: UNU-EHS.

Coffin, A. W. 2007. From roadkill to road ecology: A review of the ecological effects of roads. *Journal of Transport Geography* 15 (5): 396-406.

Connors, K. J., J. Coloma, P. R. Beatty, W. Cevallos, and J. N. Eisenberg. 2008. THE EFFECT OF ROAD ACCESS ON THE TRANSMISSION OF DENGUE FEVER IN RURAL ECUADOR. *AMERICAN JOURNAL OF TROPICAL MEDICINE AND HYGIENE* 79 (6): 35.

Cummings, Derek. 2010. *Temporal and spatial dynamics of dengue virus transmission*. In *Frontiers in dengue virus research.*, eds. Kathryn A. Hanley, Scott C. Weave, 173-182. Norfolk, UK: Caister Academic Press.

Gilligan, C. A. 2002. **An epidemiological framework for disease management**. *Advances in Botanical Research* 38 : 1-64.

Guzmán, M. G. 2003. Dengue and dengue hemorrhagic fever in the americas: Lessons and challenges. *Journal of Clinical Virology* 27 (1): 1-13.

Harrington, L. C., T. W. Scott, K. Lerdthusnee, R. C. Coleman, A. Costero, G. G. Clark, J. J. Jones, et al. 2005. Dispersal of the dengue vector *aedes aegypti* within and between rural communities. *The American Journal of Tropical Medicine and Hygiene* 72 (2): 209-20.

Hemme, R. R., C. L. Thomas, D. D. Chadee, and D. W. Severson. 2010. Influence of urban landscapes on population dynamics in a short-distance migrant mosquito: Evidence for the dengue vector *aedes aegypti*. *PLoS Neglected Tropical Diseases* 4 (3): e634.

Hogan, M. C., and Draggan, S. Encyclopedia of earth: Epidemiology. in Environmental Information Coalition, National Council for Science and the Environment [database online]. Washington, D.C, 20072012].

Khasnis, A., and M. Nettleman. 2005. Global warming and infectious disease. *Archives of Medical Research* 36 (6): 689-96.

Lashley, Felissa R., and Jerry D. Durham. 2007. *Emerging infectious diseases: Trends and issues*. 2nd ed. New York: Springer Pub. Co.

Laurance, W. F., M. Goosem, and S. G. W. Laurance. 2009. Impacts of roads and linear clearings on tropical forests. *Trends in Ecology and Evolution* 24 (12): 659-69.

Lloyd, J. 2011. Road ecology. *The Encyclopaedia of Earth*.

Michael, Jacobs. 2000. Dengue: Emergence as a global public health problem and prospects for control. *Transactions of the Royal Society of Tropical Medicine and Hygiene* 94 (1) (January): 7-8.

Patz, J. A., P. Daszak, G. M. Tabor, A. A. Aguirre, M. Pearl, J. Epstein, N. D. Wolfe, et al. 2004. Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. *Environmental Health Perspectives* 112 (10): 1092-8.

Patz, J. A., T. K. Graczyk, N. Geller, and A. Y. Vittor. 2000. Effects of environmental change on emerging parasitic diseases. *International Journal for Parasitology* 30 : 1395-405.

Plato. 1937.
The republic, ed. Paul Shorey. Cambridge, MA: Harvard University Press.

Rai, Suresh C., and Rakesh C. Sundriyal. 1997. Tourism and biodiversity conservation: The sikkim himalaya. *Ambio* 26 (4) (June): 235-42.

Rogers, D. J., A. J. Wilson, S. I. Hay, and A. J. Graham. 2006. The global distribution of yellow fever and dengue. 62 : 181-220.

San Martín, J. L., and O. Brathwaite-Dick. 2007. La estrategia de gestión integrada para la prevención y el control del dengue en la región de las américas. *Revista Panamericana De Salud Pública* 21 (1): 55-63.

San Martín, J. L., O. Brathwaite, B. Zambrano, J. O. Solórzano, A. Bouckenooghe, G. H. Dayan, and M. G. Guzmán. 2010. The epidemiology of dengue in the americas over the last three decades: A worrisome reality. *The American Society of Tropical Medicine and Hygiene* 82 (1): 128-35.

Tatem, A. J., D. J. Rogers, and S. I. Hay. 2006. Global transport networks and infectious disease spread. *Advances in Parasitology* 62 : 289-343.

Turner, B. L., D. Skole, S. Sanderson, G. Fischer, L. Fresco, and R. Leemans. 1995. *Land-use and land-cover change Science/Research plan.* Stockholm: Royal Swedish Academy of Sciences: International Geosphere-Biosphere Programme and the Human Dimensions of Global Environmental Change Programme, 35,7.

Ullman, E. L. 1956.
The role of transportation and the bases for interaction. In *Man's role in changing the face of the earth.*, ed. W. L. Jr Thomas, 862-880. Chicago: The University of Chicago Press.

Wolfe, Nathan D. 2012. *The viral storm: The dawn of a new pandemic age*. London, UK: Allen Lane.