Impact of climate and land cover/use variability on vector borne diseases: an analysis of epidemic outbreaks of malaria and dengue incidence

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IMPACT OF CLIMATE AND LAND COVER/USE VARIABILITY ON VECTOR BORNE DISEASES: AN ANALYSIS OF EPIDEMIC OUTBREAKS OF MALARIA AND DENGUE INCIDENCE

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ABSTRACT

It has become increasingly clear that global climate is changing, resulting in variations in surface temperature, precipitations and storm activities. Although the patterns of change in specific geographic regions remain uncertain, there are some concerns about the impact of climate variability on the human environment, particularly, the transmission of mosquito borne diseases. Malaria and Dengue Fever incidence have specific geographic regions with climate, land cover and land use being the major determinant factors. Previous studies show that climatic factors have close association with the spatial distribution of vector borne diseases. Accordingly, changes in climate may have a profound impact on the future outbreaks of vector borne diseases. However, our current understandings do not show empirical evidence that indicate the association between climate and disease transmission which will be required in future predictions of disease outbreaks. The purpose of this research is to assess the impact of climate variability on two predominant vector borne diseases; namely Malaria and Dengue Fever. The research will examine epidemiology and environmental data for Sri Lanka and Solomon Islands. The data analysis will be conducted using Geographic Information System techniques, remote sensing and spatial statistics. It is anticipated that the frequency and geographic patterns of disease outbreaks will vary with the changes of climate, land cover and land use. The research will contribute to the current understanding of the association between climate, land cover and diseases and will help in the estimation of future impacts.

1. INTRODUCTION

Climate affects the life cycle of many pathogens and vectors (CDC, 2001; McMichael and Haines, 1997). Environmental and geographical factors, particularly temperature, rainfall, humidity, land use and land cover, each play a role in determining the habitat as well as the distribution of *anopheles* and *Aedes aegypti* mosquitoes. Contribution of these factors as well as the role of climate change in malaria and dengue outbreaks and their spatial distribution have been poorly understood. Current evidence suggests that climate variability has a direct influence on the epidemiology of vector-borne diseases (Githeko *et al*., 2000; Haines *et al*., 2000). Lack of quality data and research tools have limited the understanding of the causes for disease spread and its spatial dimension. This research focuses on the examination of environmental and geographical linkages on mosquito borne diseases using spatial information management techniques. In this research, the preliminary findings will be examined using two study areas from Sri Lanka and Solomon Islands. GIS and remote sensing techniques will be used to create spatial databases and map the spatial distribution of diseases.

1.1 Dengue and environmental attributes

Dengue is an acute infectious viral disease transmitted to humans by the *Aedes aegypti* mosquito. *Aedes aegypti* is also responsible in serving as the most important domestic vector of urban yellow fever. In Asia, the virus is also transmitted, to a lesser extent, by *Aedes Albopictus* (WHO, 2005). Dengue virus (Den-1, Den-2, Den-3 and Den-4) which belongs to the genus Flaviviridae has the potential to cause both Dengue fever (DF) and dengue hemorrhagic fever (DHF) (WHO, 2005). Today, dengue is endemic in many developing countries, mainly in the tropics and subtropics.

The environment plays a major role in transmitting the disease. Out of the four distinct stages of mosquito development (egg, larvae, pupae and adult), the first three stages of *Aedes aegypti* mosquitoes are in water or close proximity to water (Otero, Solari *et al.*, 2005). The eggs are laid on wet surfaces just above the water level. Although hatching of mature eggs may spontaneously occur at any time, it is greatly stimulated by flooding, hence, they are more likely to occur after rainfall (Thammapalo, Chongsuwiwatwong *et al.*, 2005). Temperature affects the development of larvae, decreasing the size of mosquitoes, increasing their range and biting rates and increasing their survival time (Tun-Lin *et al*, 2000).

Dengue incidence pattern in Sri Lanka appears to be closely related to population distribution. Earlier, the disease was mainly restricted to urban and semi-urban areas of the country. However, over the years dengue has spread to rural areas, which may be due to population movement through transport development, economic activities and the changes in climatic factors (Pathirana *et al*., in press).

1.2 Malaria

Malaria remains one of the most serious vector-borne diseases in the world causing over one million deaths a year (WHO, 2005). This also imposes a considerable economic burden costing national income and high morbidity levels within the able adult population. Forty-one percent of the world's population live in areas where malaria is transmitted, while it accounts for about 10.7% of the number of deaths in children in developing countries.

Malaria is an extremely climate-sensitive tropical disease. The mosquitoes are generally found in warm to hot, wet, high humid areas where people are highly vulnerable to the disease due to economic and social factors. Reduction in malaria is likely to associate with a reduction in poverty (Sachs and Malaney, 2002). Global malaria distribution shows that the outbreaks are mainly limited to poor, tropical countries in Asia, Africa and Central and South America.

Malaria is one of the leading causes of morbidity in the Solomon Islands accounting for 60-70% of all confirmed cases (WHO, RBM/Country Profile). After a significant reduction of malaria in the Solomon Islands during the last 2-3 decades, a sharp increase was seen in 2003-2004, specifically in the Guadalcanal and Malaita provinces. WHO has recognized that a national surveillance and response system will help to contain known risk and vector control. This requires an understanding of the factors which contribute to malaria outbreaks and the development of accurate spatial databases and efficient research tools. Lack of quality data and research tools hinder the identification of potentially high risk areas or malaria mosquito habitats.

2. MATERIALS AND METHODS

Examination of environmental characteristics that dominate the distribution of mosquitoes is critical in the monitoring and surveillance of outbreaks. As with many mosquito infected regions in Africa, there is no consistent recording of rainfall, temperature, land cover and land use data available for any part of the Solomon Islands. For the areas where the environmental data are not available, recent advancement of satellite remote sensing will be able to fill in the gaps of data.

2.1 Study Area

This research examines the data from two study areas: Western Province of Sri Lanka and Gudalcanal Island of the Solomon Islands. Solomon Islands form an archipelago in the Southwest Pacific and have a volcanic origin. All islands are characterized by their rainforest covered rugged mountains at the centre. Gudalcanal is the main island in the group where the capital, Honiara with a population of about 55,000 is located on the narrow north-western coastal belt of the island. The Northern coastal area is covered by extensive swamps and mangrove forests. Its equatorial climate is extremely humid throughout the year, with a mean temperature of 27°C. The annual rainfall is about 305 centimetres which is mainly concentrated around the November –April rainy season. The population is distributed as small communities (villages) along the coasts.

The other study area is the Western Province of Sri Lanka which is primarily a tropical region with high humidity and warm temperature through out the year. The mean temperature ranges from a low of 15.8° C in Central Highlands to a high of 29° C in Trincomalee on the northeast coast. The study was conducted in the western province of Sri Lanka where there is a marked increase of dengue incidents evident during the last few years. This is the most urbanized and densely populated region has a number of urban centres including Colombo, the capital.

2.2 Data

Epidemiological, socio-economic and climate data for both study areas were collected from respective health and meteorological departments of Sri Lanka and Solomon governments. Data on, land cover, land use and topography were derived from satellite data.

2.3 Methods

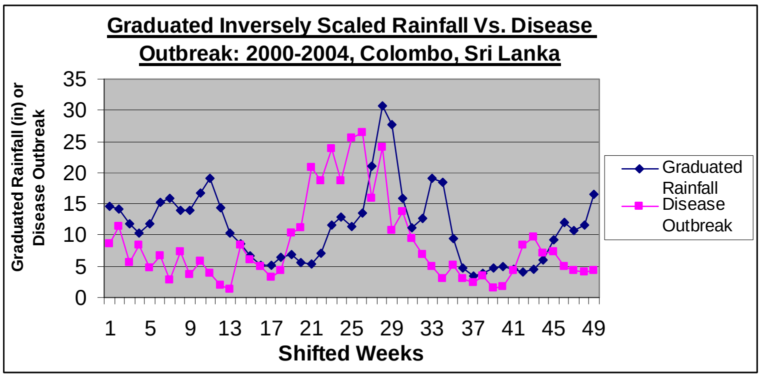
In this research, the weekly rainfall and disease outbreak data for Colombo, Sri Lanka for the years from 2000 to 2004 have been averaged out. They have been statistically analysed to obtain a model for the data. The inverse distance weighted (IDW) interpolation technique in ArcGIS programs was used for producing surfaces such as spatial distribution of dengue and rainfall using interpolation of scatter points such as rainfall point data and mosquito transmission incidents. Landsat ETM satellite data for 2001 was used to produce land cover and land use classes. Population data, land cover, land use, and epidemiological data were analyzed using GIS techniques to identify mosquito habitats.

3. RESULTS

3.1 Association between rainfall and dengue incidence

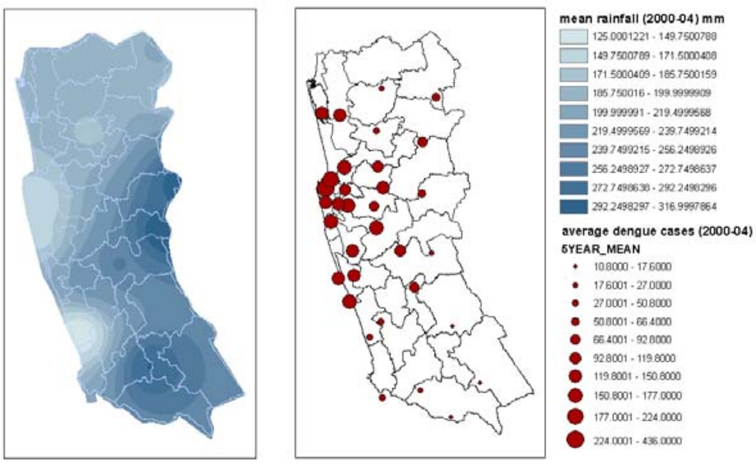
The patterns of annual average rainfall reported for 52 weeks were nearly periodic and compared closely with the periodicity of disease outbreaks. The rainfall data were smoothened to reduce high variability, that is, $R_i^{(j+1)} = \dfrac{R_i^{(j)} + R_{i+1}^{(j)}}{2}$, $j = 1,2,3.$ Finally, they were inversely rescaled using the averages of these data sets, that is, $y = \left(\frac{\sum_i R_i^{(j)}}{\sum_i D_i} \right) \frac{1}{R_i^{(j+1)}}$. This produces the line graph as given in Figure 1.

Figure 1: Graduated inversely related scaled rainfall and disease outbreaks

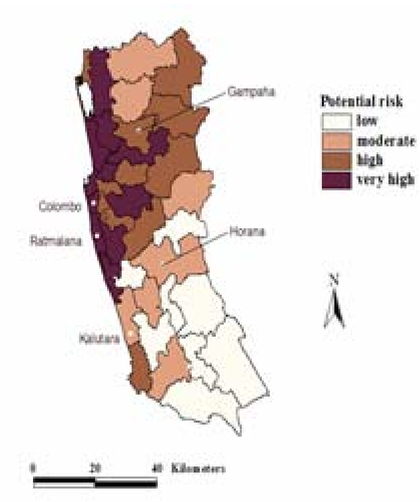


The graduated rainfall data and dengue outbreaks indicate a closer relationship among weekly rainfall and disease outbreak obtained in Colombo, Sri Lanka according to the 2000-2004 data available. This study also shows that high dengue incidence is normally associated with the areas with less rainfall (Figure 2).

Figure 2: Spatial distribution of rainfall and dengue incidence: Western province



Dengue incidence surface maps produced using the IDW interpolation technique shows a number of dengue clusters in the western province over the five-year period. Both dengue and dengue hemorrhagic fever incidence are commonly found among the younger population, generally less than 19 years old. Statistical analysis shows that there is a high correlation between dengue incidence and younger population.



The high risk age category was superimposed over the spatial distributions of dengue incidence to show that the distribution of population clusters are closely associated with dengue incidence clusters (Figure 3).

Figure 3: Spatial distribution of dengue transmission risk (left)

3.2 Environmental Attributes of Malaria

Population distribution in Gudalcanal Island was clearly concentrated to villages mainly located along the coastline. With abundant rainfall and uniform temperature, villages located in lowland coastal areas provide ideal breeding grounds for malaria mosquitoes.

Figure 4: Land cover and land use around Honiara

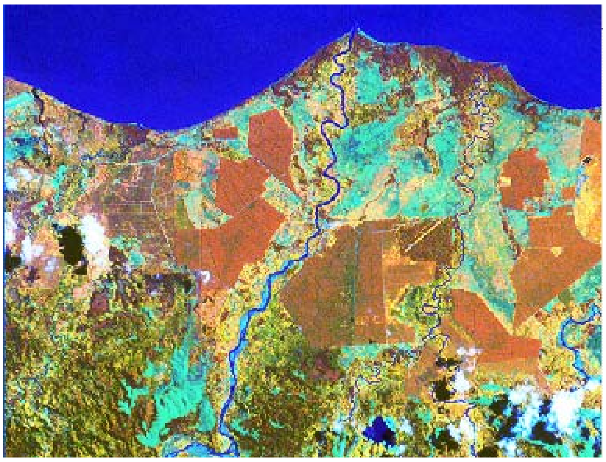
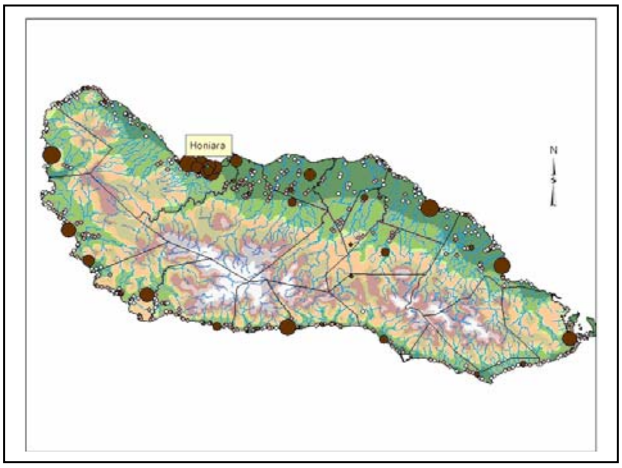


Figure 5: Reported malaria cases, Gudalcanal Island (2000-2004)



The land cover and land use map (Figure 4) is a subset image of the Gudalcanal Island east to Honiara. The cover types show spatial distribution of wetlands, plantations, cleared areas, forest areas and moist areas. The map was produced from Landsat satellite data for 2001. Malaria outbreaks are mainly limited to coastal wetland areas in the lowland along the coast. A comparison of the land cover map (Figure 4) with Figure 5 shows that extensive copra and cocoa processing centres in the region could have been contributed to high malaria incidents through providing breeding grounds for mosquitoes.

4. CONCLUSION

The results show the preliminary findings of the association between dengue and malaria incidents and environmental attributes for two study areas selected from Solomon Islands and Sri Lanka. The research further shows that there is a clear association between dengue and rainfall. We found a temporal and spatial correlation between post rainfall seasons and dengue disease outbreaks for the western province of Sri Lanka based on analysis of climate, population and epidemiology data obtained for the 2000-2004 period. The study found that temporal distribution of dengue incidents were closely associated with the post-rainfall period, showing about three to four weeks lag time between the rainfall and dengue outbreaks. Spatial distribution of dengue outbreaks shows that they were mainly limited to urbanized areas around Colombo.

In contrast, malaria incidents were well distributed along the coastal settlements, with a high concentration of cases around the Honiara, the capital. While there is no large variation of temperature and rainfall within the Gudalcanal Island, spatial distribution of malaria are more likely related to anthropogenic and economic factors. Human settlements are along the lowland river valleys and coastal flood plains. Main economic activities in the region are agricultural crops; namely copra and cocoa. Humid, warm/hot climate at Guadalcanal Islands provide ideal climatic conditions for mosquitoes. Further, wetlands and cleared forest areas in the coastal lowland villages as well as empty coconut and copra shells provide favorable breeding grounds for mosquitoes.

Understanding the spatial and temporal patterns of climate and geography and their impact on human health, particularly outbreaks of vector-borne diseases such as dengue and malaria is important in controlling the transmission of the disease and in treating infected populations.

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6. REFERENCES

Centre for Disease Control (CDC)., 2001. Under the Weather: Climate, Ecosystems, and Infectious Disease. Committee on Climate, Ecosystems, Infectious Disease, and Human health, national Research Council, Washington, DC, USA

Githeko, A.K., Lindsay, S.W, Confalonieri, U.E., and Patz, J.A. 2000. Climate change and vector-borne diseases: A regional analysis. World health Organization, Bulletin of the World Health Organization, Geneva: Vol. 78 (9):1136-1148

Haines, A., McMichael, A.J, Epstein, P.R. 2000. Environment and health: Global climate change and health. Canadian Medical Association Journal, Ottawa. Vol.163 (6) 729-735

IPCC., 2007. Climate change 2007: the Scientific basis.

McMichael, A.J. and A. Haines. 1997. Global Climate Change: The Potential Effects on Health, British Medical Journal 315:805-809

Otero, M., Solari, H. G., and Schweigmann, N., 2005. A stochastic population dynamics model for Aedes aegypti: formulation and application to a city with temperate climate. Elsevier Science.

Pathirana, S., Kawabata, M., and Goonetilake, R., (in press). Study of potential risk of dengue disease outbreak in Sri Lanka using GIS and statistical modelling, The Journal of Rural and Tropical Public Health.

Thammapalo, S., Chongsuwiwatwong, V., McNieil, D., Greater, A., 2005. The climatic factors influencing the occurrence of dengue haemorrhagic fever in Thailand. Southeast Asian Journal of Tropical Medicine and Public Health 36(1), 191-197

Tun-Lin, W., Burkot, TR., Kay, BH., 2000. Effects of temperature and larval diet on development rates and survival of the dengue vector *aedes aegypti* in North Queensland, Australia. Medical & Veterinary Entomology 14(1), 31.

WHO., 2005. Dengue in the Tsunami stricken countries in Asia [accessed 2 Sept 2006]. Available from: http://www.who.int/water_sanitation_health/hygiene/emergencies/tsunami_dengue/en/index.htm

WHO_RBM (http://www.rbm.who.int/cmc_upload/0/000/015/363/RBMInfosheet_10.htm) accessed 16/02/2007