An Examination of the Spatial Factors of Dengue Cases in Quezon City, Philippines: A Geographic Information System (GIS)-based Approach, 2005-2008

Fernando B. Garcia, Jr.[1] and Lilian A. de las Llagas[2]

[1]*Department of Health Policy and Administration, College of Public Health, University of the Philippines Manila*
[2]*Department of Parasitology, College of Public Health, University of the Philippines Manila*

ABSTRACT

Objectives. This paper was undertaken to explore the relationship of a 4-year period dengue incidence and the interplay of selected spatial factors (i.e., build-up structures, existing land use/cover types, and presence of water networks) in Quezon City, Philippines. It attempts to examine why dengue incidences are higher in some areas, looking at factors such as geographical attributes, livelihood activities, and practices in the area. At the end of this paper, dengue risk maps will be produced to guide local health authorities target specific areas for focused interventions to manage future dengue outbreak in the area.

Methods. Reports on dengue cases over the 4-year period (2005-2008) from the City's Health Department Office were encoded and exported in ArcGIS 9.1, a Geographic Information Systems (GIS) mapping software technology. Together with the city's environmental conditions, dengue frequencies were mapped out, overlaid, and examined to determine whether or not these environmental factors affect, contribute and link to the dengue occurrence in an area.

Results. After rendering the dengue risk maps, the highest frequency of dengue is evident in the eastern portion of Quezon City covering District II. Overlaying or superimposing dengue frequency layers with the spatial factors being considered in this study has revealed that these factors affect and contribute to the occurrence of dengue in an area. Areas with a number of river networks and built-up structures experience high dengue incidence. Lands used for residential purposes with neighboring commercial/industrial structures also tend to be dengue susceptible. However, the population density factor alone does not necessarily translate to high dengue frequency. Barangays (the smallest administrative divisions of the city) with high recorded dengue frequency are areas within or near dumpsite facilities primarily because of sanitation concerns as well as the type of livelihood and inherent practices of majority of the residents.

Conclusions. This research provides an understanding of the spatial epidemiology of dengue in Quezon City using GIS as a tool for identifying high risk areas for dengue. Spatial examination has been carried out to determine spatial anomalies (high concentration of incidence) and the spatial makeup of the area that affects or contributes to such anomalies. The role of GIS in public health decision-making is evident in identifying high risk areas and creating dengue risk maps. Local health authorities will be in a better position to target priority areas and decide where to put scarce resources for programs and projects that will address further disease outbreaks.

Key Words: Geographic Information System (GIS), spatial factors, spatial, dengue

Introduction

Dengue, a vector-borne disease, is considered one of the most dreaded health problems worldwide and has become a major international public health concern. This disease is passed on to humans by *Aedes* mosquitoes, the only known vector. Studies have shown that adult female *Aedes* mosquitoes acquire the dengue virus when they bite infected persons during the viremic phase (usually within a 4- to 5-day period, but may last up to 12 days).[1,2] The virus is then transmitted to another person when the infected mosquito bites its next victim.

There has been a dramatic increase in dengue prevalence worldwide in recent decades. Before the 1970s, there were only nine countries that experienced dengue epidemics. The World Health Organization (WHO) reported that the disease is now widespread in more than 100 countries in Africa, the Americas, the Eastern Mediterranean, Southeast Asia and the Western Pacific. Countries in Southeast Asia and the Western Pacific are the most seriously affected.[3,4] Some 2,500 million people or about two-fifths of the world's population are now at risk for this disease. Moreover, WHO estimated that there might be 50 million cases of dengue infection every year worldwide.[5]

In the Philippines, the National Epidemiology Center (NEC) of the Department of Health (DOH) reported that for the period of November 2007 there were at least 40,538 dengue fever cases recorded, an all-time high for the country.[6] Preventive and control interventions have been

Corresponding author: Fernando B. Garcia, Jr., MPA
Department of Health Policy and Administration
College of Public Health
University of the Philippines Manila
625 Pedro Gil St., Ermita, Manila Philippines 1000
Telephone: +632 3024200
Fax no.: +632 5232997
Email: nuj_garcia@yahoo.com

laid down by various sectors to address this public health concern. However, unless concerned authorities can control dengue incidence by preventing the disease, the scarce resources will only go to waste. Thus, understanding the relationship of the disease with environmental factors that contribute to its prevalence and incidence is a prime concern.

Spatial examination involving the use of Geographic Information Systems (GIS) has been identified by several researchers as a significant tool for health to evaluate and model the relationship of environmental factors with the detection and prevalence of diseases.[7,8,9,10] In a dengue bulletin released in 2001 by WHO, environmental factors such as land use/cover types have been identified as important determinants of vector-borne disease transmission. Spatial examination provides important information on the distribution of vector-borne diseases in the physical environment. It has even been considered a potential tool to revolutionize the discipline of epidemiology and its application to human health.[11]

This paper's primary hypothesis is that the relatively high dengue incidence in certain geographic areas can be explained by the interplay of environmental factors (i.e., build-up structures, existing land use/cover types, and the presence of water networks) and, to some extent, the type of livelihood activities and people's practices in the area.

This paper explores the relationship between dengue incidence and selected spatial variables in Quezon City, Philippines. It examines why dengue incidences are higher in some areas, looking at possible explanatory factors such as geographical attributes, livelihood activities, and existing practices in the area. Quezon City has been selected as the study area since among the major urban cities in the country, it constitutes the largest land area and caters to the greatest number of urban poor whose dwelling places are situated in areas that are vulnerable to dengue disease.

Quezon City: Physical characteristics

Quezon City, the study area, is located on the northeast portion of Metro Manila and has an area of 16,112.58 hectares; it is the largest of the cities in the region, almost one-fourth the size of Metro Manila. Considered the most populous city in the country, the city's population (around 2.7 million or 3.0% of the country's total population of 88.57 million[12]) is relatively dispersed but unevenly distributed into four districts. District II has the largest population followed by District IV, District I, and District III, respectively. Based on 1995 NSO figures, Barangay Commonwealth in District II is the most populous barangay with 108,396 persons or 5.45% of the total population of the city. However, in terms of population density, District I has the highest with 195.26 persons per hectare. District IV and II are moderately dense with 169.46 and 131.05 persons per hectare, respectively. District III is the least densely populated.[13] Figure 1 shows the city's district map.

The city's terrain is largely rolling with alternating ridges and lowlands which is conducive for constructing high rise buildings, towers and other huge structures. Land use is predominantly residential with a large area devoted to institutional and commercial uses. The slope is generally manageable with the highest point at 121 meters above sea level and the lowest at 3 meters above sea level.

Numerous rivers and creeks that crisscross the city serve as a network for natural drainage. However, two major concerns that confront the city's natural waterways are pollution and the loss of creek and river easements, primarily because of the garbage being dumped into the waterways that continually clogs these waterways and the proliferation of informal settlers who build shanties in almost any available area, especially along or just within the rivers and creeks. Large colonies of urban poor dwellers, mostly informal settlers, are located in Barangays Payatas, Batasan Hills, Commonwealth and Holy Spirit, in the vicinity of the Payatas dumpsite, in the East and North Triangle Areas, among others.

Methods

Subjects. Reports of dengue incidence in Quezon City, Philippines for a 4-year period (2005-2008) were secured and collected from the city's Health Department Office. The data consisted of the aggregated count of cases per barangay (the smallest administrative division of the city) on an annual basis. No detailed information about the victims such as name, sex, age, and specific address were taken. In addition, the cases collected and recorded by the Health Department Office were not geo-referenced (i.e., no longitude and latitude readings).

The spatial attributes of the study area were all secondary data. The data was already rendered in ArcGIS format. ArcGIS is a group of Geographic Information System (GIS) mapping technology software products produced by the Environmental Systems Research Institute, Inc. (ESRI).

Methods. This research included a review of secondary sources on the city's existing comprehensive development plan and reports from the DOH and the city's Health Department Office. A GIS-based tool was utilized to investigate the influence of spatial factors on dengue occurrence. The role of GIS in public health decision-making can be seen in identifying high risk (vulnerable) areas that need to be prioritized in planning interventions.

The city's environmental conditions such as the build-up structures, the existing land use/cover types, and the presence of water networks were described and mapped-out using ArcGIS 9.1, a GIS mapping software technology. Reports on dengue cases over the 4-year period (2005-2008) from the city's Health Department Office were encoded in Excel spreadsheet format and were then exported in ArcGIS

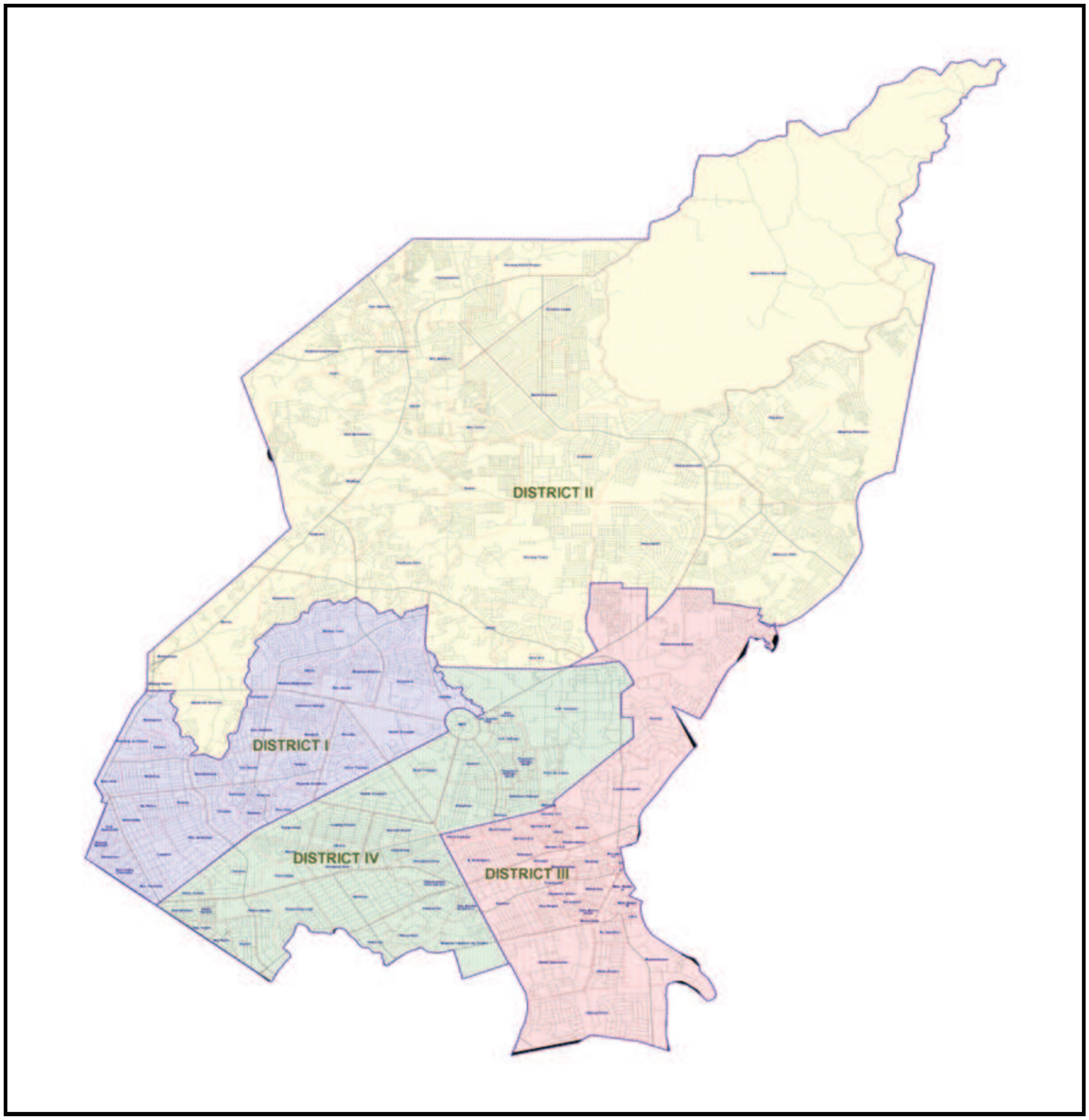

Figure 1. District Map of Quezon City. QC Planning and Development Office. 2008

format. Since cases being collected and recorded by the Health Department Office were not geo-referenced, it is impossible to determine the exact household location of infected individuals. The available data (numbers of dengue cases) was then linked to the respective barangay ID code where the subjects lived. Dengue incidences were then mapped out, overlaid, and examined together with the layers of physical factors present in the area to produce dengue risk maps. The produced dengue risk maps will be used as base maps by local health authorities to target specific areas for focused preventive measures and policy interventions to manage future dengue outbreak in the area.

Results and Discussions

Reported dengue diagnoses

In 2005, the recorded dengue frequency reached 1,178 cases of which 42.4% occurred in barangays located in District II; 23.1% in District I; 18.2% in District III; and 16.3% in District IV.

In 2006, the total dengue cases and deaths increased by 79% from the previous year, distributed as follows: 49.4% still in barangays located in District II; 18.9% in District I; 16.2% in District III; and 15.5% in District IV.

In 2007, the total dengue cases and deaths increased by just 4% from 2,103 of the previous year to 2,188 cases.

District II still had the largest percentage share (47.3) of the cases, followed by District I (22.4%), District III (15.9%) and District IV (14.4%).

During this 4-year period, 2008 had the highest reported dengue cases and deaths reaching as high as 3,343. District II continued to have the largest percentage share (47.7) of the cases, followed by District I (22.2%), and Districts IV and III with near equal share of 15.1% and 15.0%, respectively.

Rendering the dengue risk maps: Overlaying the dengue frequency distribution layer with selected spatial factors

Figure 2 demonstrates the distribution of dengue incidence of each barangay in Quezon City. From the graph, the highest frequency of dengue can be located in the eastern portion of the city covering District II, specifically Barangays Matandang Balara, Batasan Hills, Commonwealth and Payatas. It can be observed that dengue frequency was consistently high for these barangays throughout the 4-year period (2005-2008).

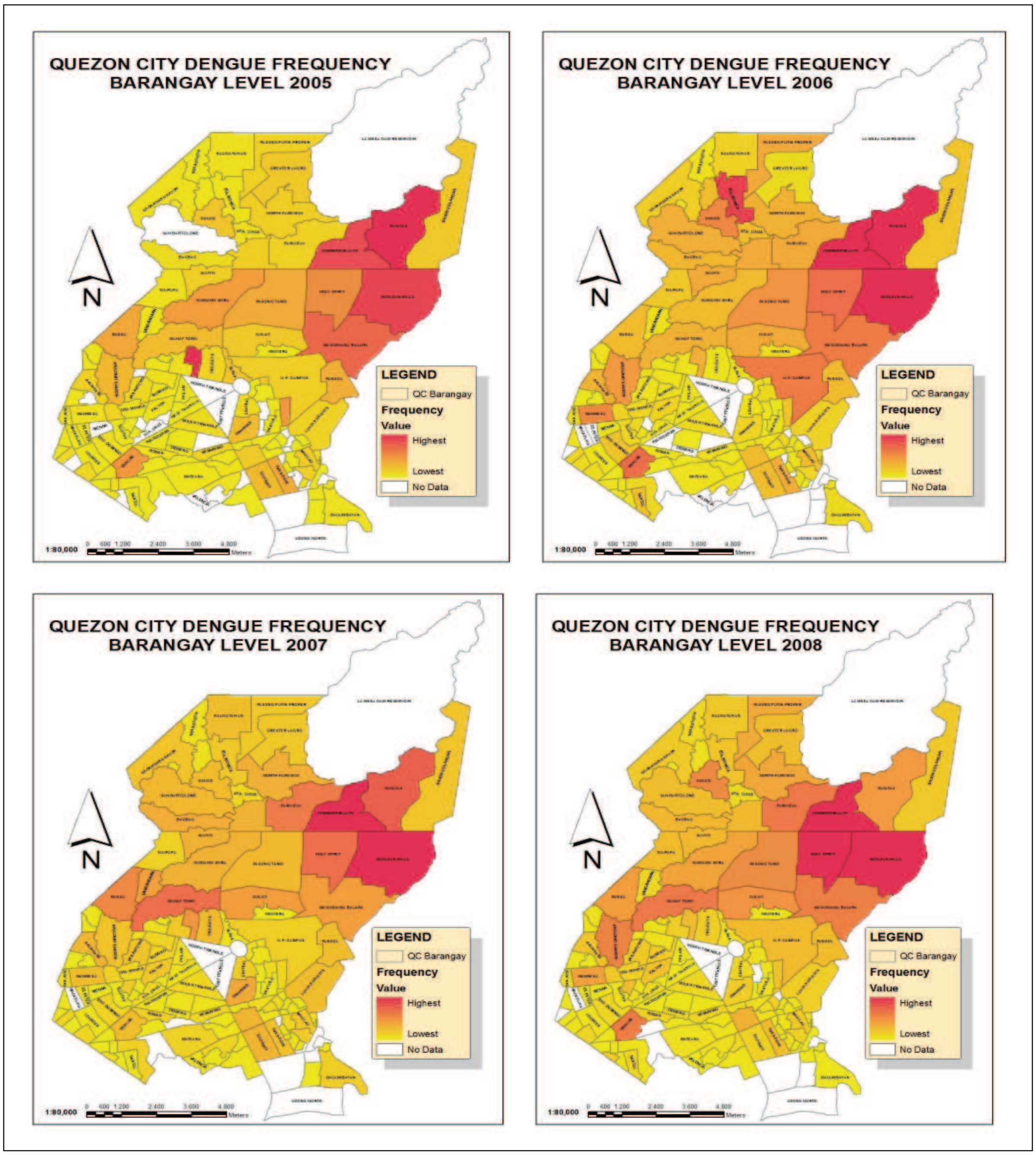

Figure 2. Dengue Frequency Distribution in QC at the Barangay Level, 2005-2008

The subsequent figures give a visual explanation for why certain areas have higher dengue incidences than others. Upon overlaying the dengue frequency map with the selected layers of environmental or spatial characteristics of the city, one can determine whether selected environmental conditions affect or contribute to the frequency of dengue in a locality.

Figure 3 shows the overlaid map layers of dengue frequency and river networks that are present in the city. Adjacent areas of the La Mesa Dam Reservoir have the greatest number of river networks (being represented in the figure as the blue network of lines). These river networks form part of the river basins of neighboring cities and localities such as the San Juan-Pasig, Marikina, Tullahan Tenejeros, and Meycauyan, Bulacan. Quezon City's river network drains into the Pasig River System. As mentioned in the previous section, some of the issues concerning the city's river system are the increasing number of informal settlers living along or just within these waterways and the growing commercial and industrial establishments being located in these areas. These pose a greater problem in managing health issues and the occurrence of disease in these areas. Further worsened by the type of economic or livelihood activities and the inherent practices of people living in these

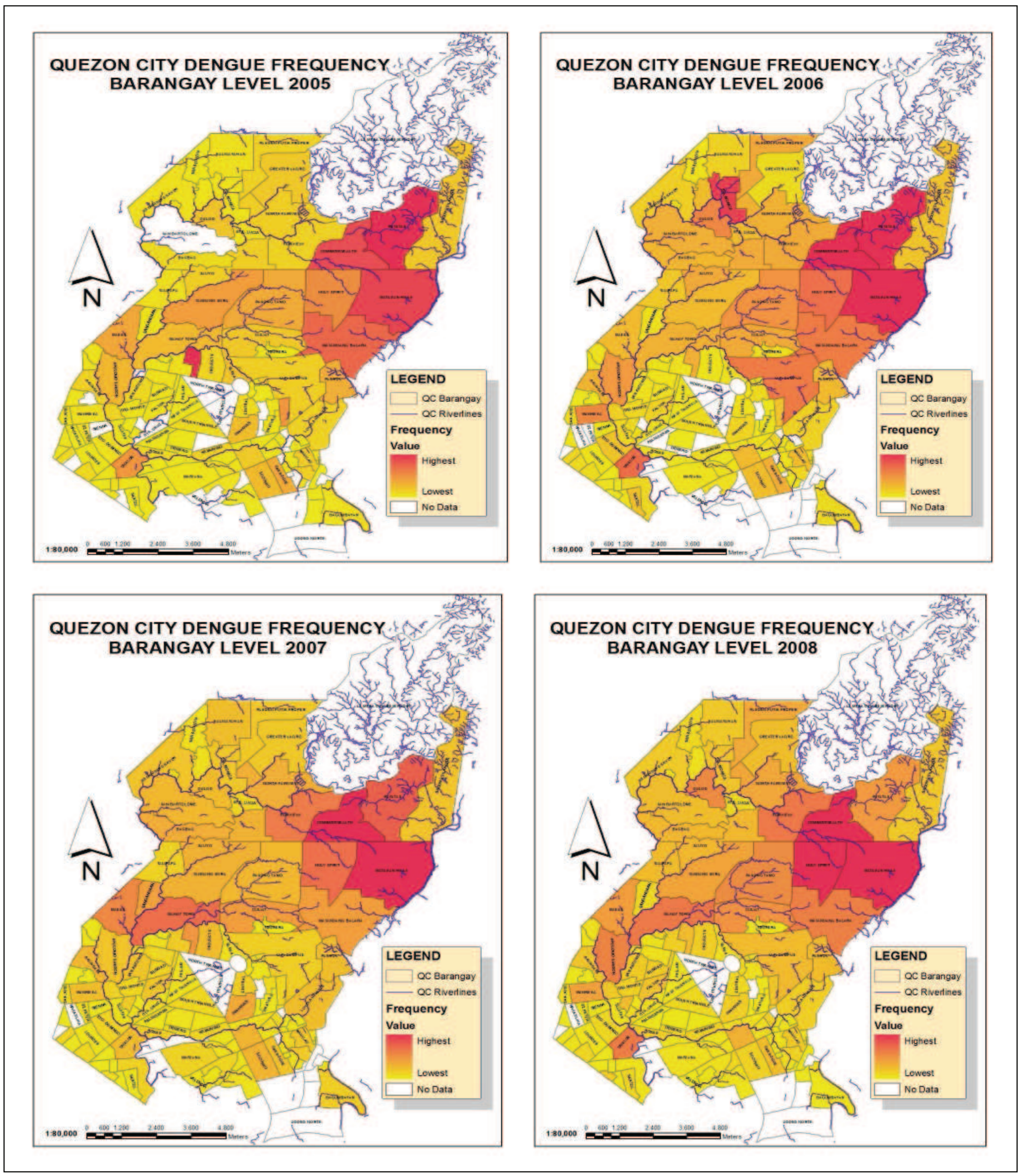

Figure 3. Dengue Frequency Distribution with River Networks, 2005-2008

areas, people living along or within these areas tend to be more vulnerable to the occurrence of diseases such as dengue.

Figure 4 shows the relationship of dengue frequency distribution and population density. The relationship of dengue incidence and a locality's population density is not that significant. It does not follow that the denser an area is, the higher the incidence of dengue or that the less dense an area is, the lower the incidence of dengue (highest incidence = 100; lowest incidence =1). For instance, although the graph shows that dengue frequency is high where barangays are densely populated (e.g., Barangays Bagong Pag-asa and Tatalon), high dengue incidence also occurs in barangays that are less dense (e.g., Barangays Batasan Hills, Holy Spirit, Payatas, Commonwealth, Matandang Balara, and Bahay Toro). Not all low-density barangays have low incidence of dengue. In fact many areas with high dengue incidence were in less dense barangays. An area's

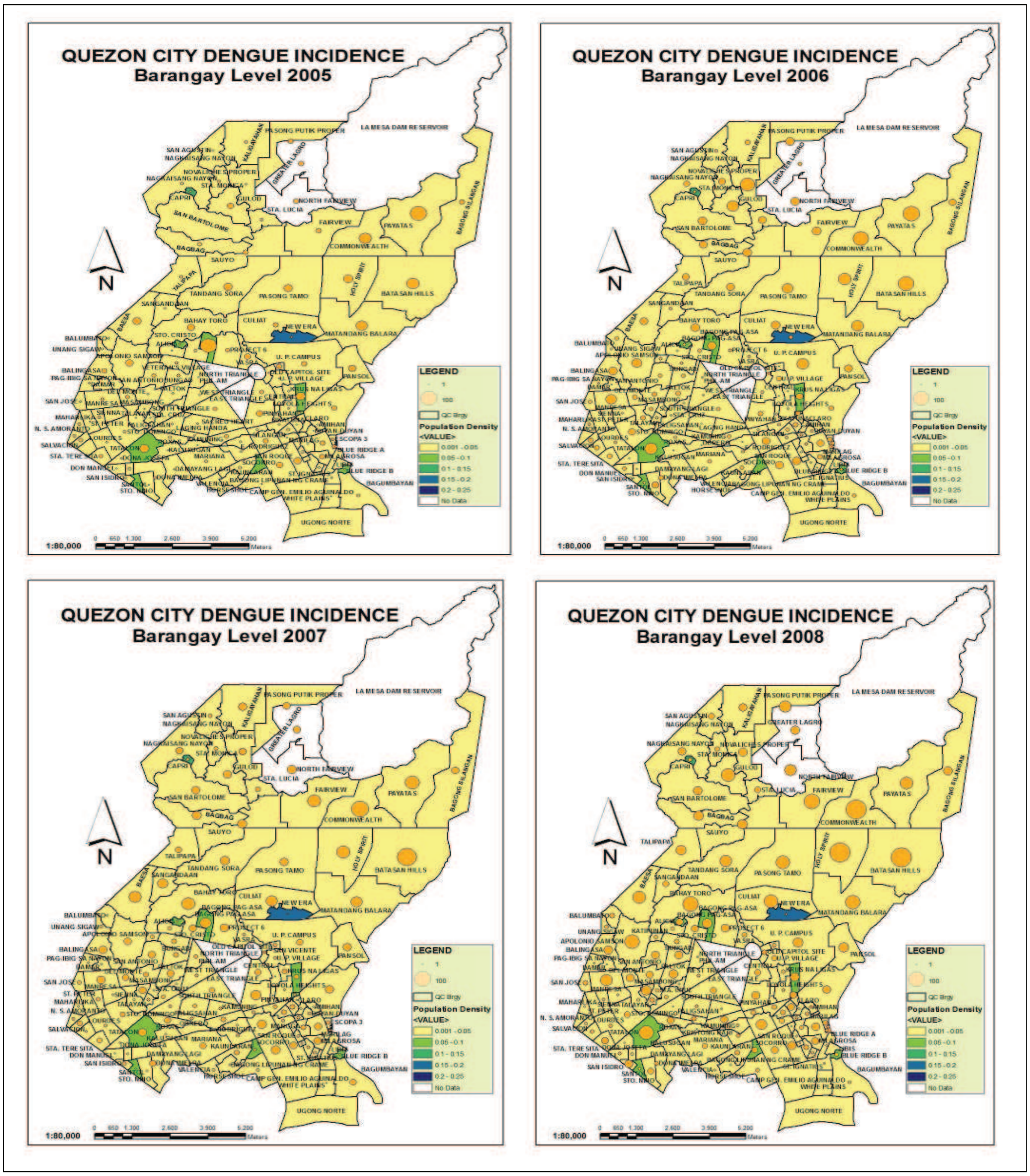

Figure 4. Dengue Incidence with Barangay Population Density, 2005-2008

population density alone does not translate to occurrence of dengue. One has to look at other factors such as the sanitary practices of the locality's residents. This was consistently true throughout the 4-year period.

Figure 5 shows the relationship between dengue frequency and the existing land use of the city. As expected, dengue was more frequent in residential areas. However, dengue incidences are highest (highest incidence=100; lowest incidence=1) and are clustered in residential areas where commercial and industrial establishments are just adjacent. These areas include Barangays Payatas, Commonwealth, Batasan Hills, Sta. Monica, Bagong Pag-asa, and Bahay Toro. Since commercial and industrial establishments are mostly market-oriented, investors tend to situate or build these structures in areas where there are residential concentrations. A study on dengue incidence applying the Information Values (IV) method found that built-up areas or areas with high concentrations of structures have the highest influence and constitute the highest risk zones.[14] The IV method is a conditional analysis which attempts to evaluate the relationship of relevant environmental factors and dengue incidences. The method is based on Baye's theorem

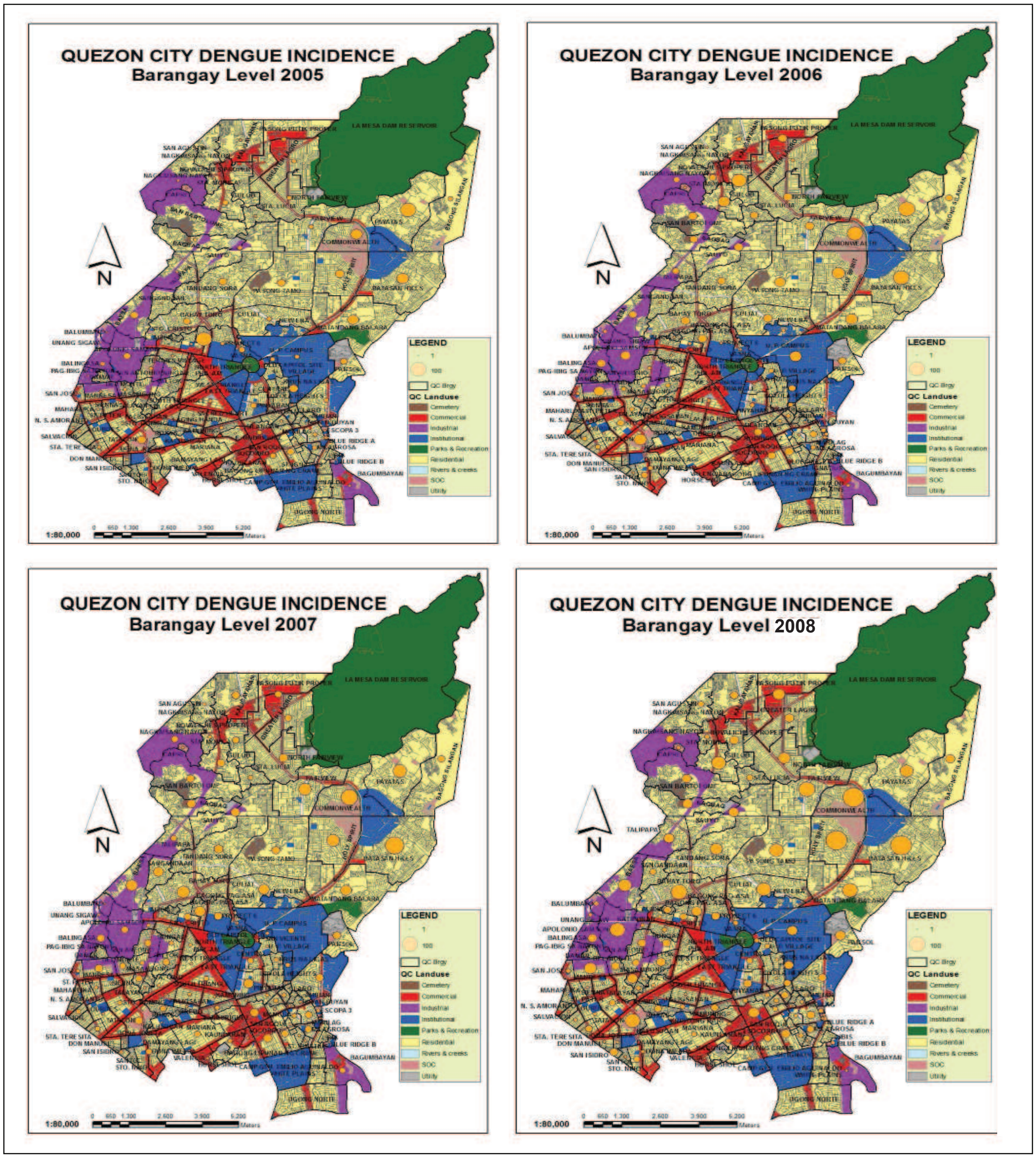

Figure 5. Dengue Incidence with Land Use, 2005-2008

(Bayesian classifier) wherein the frequency data can be used to calculate the probabilities that depend upon the awareness of previous events such as dengue outbreaks.

The incidence of dengue throughout the 4-year period was also higher in areas where Soil Organic Carbon (SOC) was located, particularly Barangays Tatalon, Holy Spirit, Payatas, and Bagong Silangan. SOC or carbon stored within the soil is a diverse combination of materials (usually plants, animals and other decaying materials) that constitute an essential part of the soil. It may be that segregation of waste materials is not properly done in areas where SOC is present, leaving behind some solid waste materials such as containers along with decaying materials, or that segregated recyclable containers are simply stockpiled in one corner of the area. These containers can collect rainwater or spill-over water when residents water their plants or clean the surroundings, creating a breeding ground for dengue-carrying mosquitoes.

There is a constant high frequency of dengue over the 4-year period in areas where informal settlers are located (maroon areas in Figure 6). The phenomenal growth in the population of informal settlers in the city due to migration from rural areas and demolition and relocation activities in

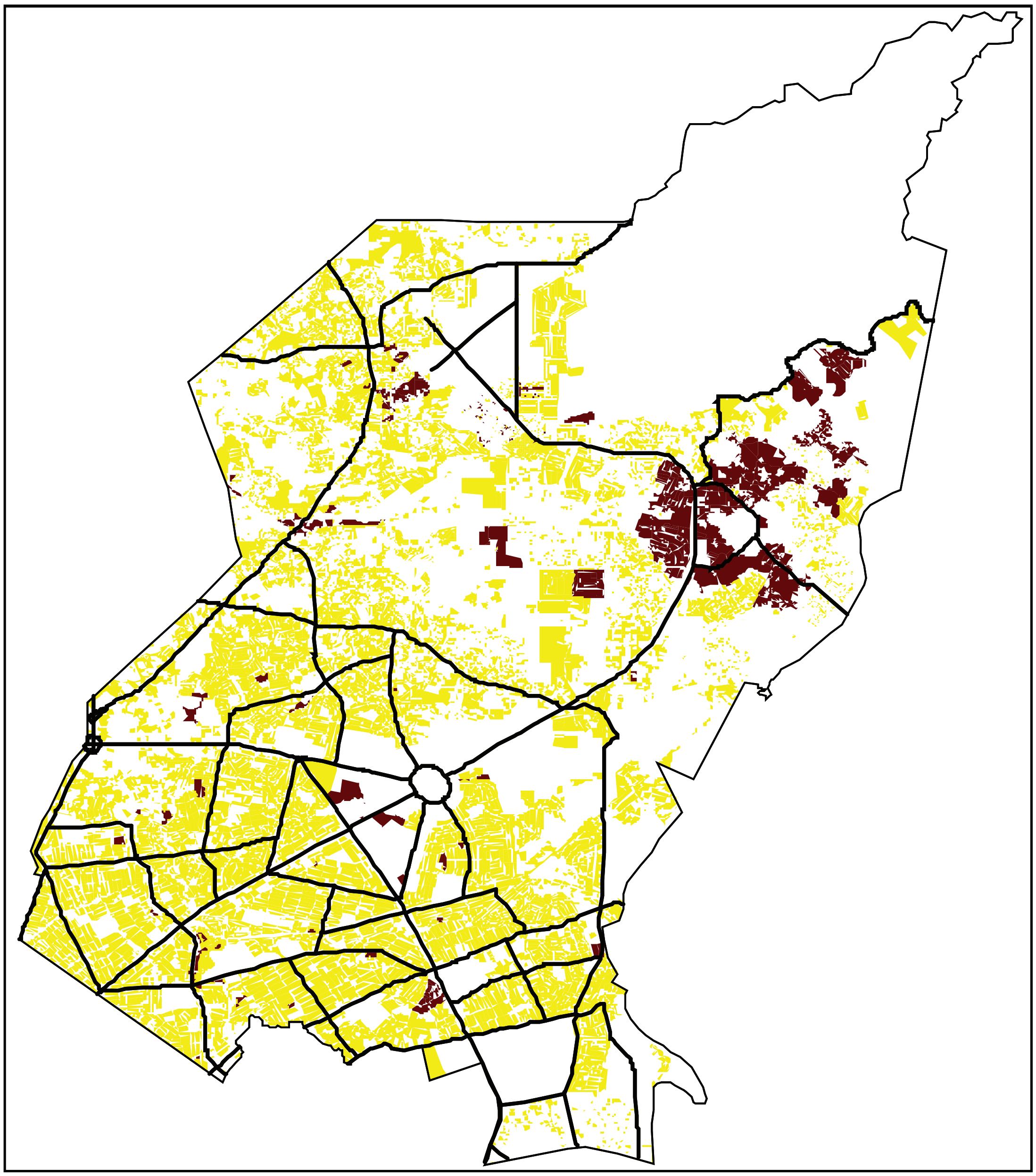

Figure 6. Map of Informal Settlers *(maroon-colored areas)*, QC Planning and Development Office, 2000

other parts of Metro Manila was experienced in areas north of Epifanio De los Santos Avenue (EDSA), largely covering District II. The families of these migrants built their shanties in open lands, riverbanks, creek sides, aqueducts and transmission lines located mostly in Commonwealth and Batasan Hills areas. Although the City Government and concerned National Government Agencies (NGAs) are actively working to contain the growth and resettle existing populations of informal settlers, many are still located in Barangays Payatas, Batasan Hills, Commonwealth and Holy Spirit. Informal settlers are also prevalent in the vicinities of the Payatas Dumpsite, East and North Triangle areas, Bagong Silangan, UP Campus, Escopa, Matandang Balara, Pasong Tamo, Sauyo and in many other places. Overlaying the location of these informal settlers with the dengue frequency distribution map will validate that a high frequency of dengue occurs in areas where informal settlers are located. A WHO study has also revealed that urban poor in the country have a very high disease burden and are prone to outbreaks.[15] The primary reason identified in the study was that they live in crowded makeshift housing with poor environmental sanitation.

Aside from poor environmental sanitation, another reason why informal settlers, especially those living near open dumpsite areas, are more prone to disease is the kind of livelihood and the practices most of them engage in. Solid waste picking, their major source of income, exposes them to diseases. Unlike in higher-income countries, solid waste workers and waste pickers in lower-income countries don't wear protective boots and gloves; instead, they collect or sort waste materials with bare hands, and only have rubber sandals to protect their feet. Occupational diseases such as parasitic and enteric infections, and, to a lesser extent, viral infections are common in this kind of livelihood, putting these people at a relatively higher risk.[16] Aside from dengue and malaria (also spread by bites of disease-infected mosquitoes), parasitic diseases affecting populations living within or near solid waste and open dumpsites include leptospirosis (spread by exposure to rodent urine), bubonic plague (spread by rodent fleas), and hantavirus (spread by contact with rodent droppings or inhaling dust contaminated with rodent urine). Regarding solid waste workers and waste pickers, the usual practice is to keep and stockpile solid waste materials such as used tires and containers (e.g., cans, pots, drums, and plastic bottles and glass jars) in their backyards. It is a common sight to see used tires on top of makeshift houses to add weight to galvanized roof sheets and protect them from being blown away by strong winds, especially when there are storms/typhoons. However, rainwater can collect inside these tires, and similar containers become breeding grounds and continuous habitats for a number of disease vectors such as dengue-carrying mosquitoes.

Studies also revealed that in areas with poor solid waste management, a high correlation exists between dengue incidence and the uncontrolled disposal of solid waste containers.[17,18] However, recognition of the health hazards of a locality's unsanitary practices should extend beyond the subject or host area since vectors can also spread diseases to residents of the neighboring localities. This is evident if one looks at the dengue frequency distribution in the figures provided. Although a solid waste dumpsite is present only in Barangay Payatas, neighboring barangays such as Commonwealth and Batasan Hills have also recorded high dengue incidences.

Conclusion

This research explored the spatial epidemiology of dengue in Quezon City for the period 2005-2008 by looking at the presence of river networks, land use and built-up areas, and population density. GIS was used as a tool to identify areas that are high risk or vulnerable to dengue. Spatial examination was carried out to identify spatial anomalies and the spatial makeup of the area that affects or contributes to such anomalies. After overlaying or superimposing the layer of dengue frequency over a 4-year period on the layers of spatial factors being considered, it can be concluded that dengue incidence can be affected by geographic and environmental conditions of an area. During the study period, areas with a number of river networks and built-up structures experienced high dengue incidence. Land used for residential purposes with neighboring commercial and industrial areas also tended to be dengue-susceptible. However, population density alone did not necessarily translate to high dengue frequency. One has to look at other factors such as the sanitary practices of the area's residents. The highest dengue frequency was experienced over the 4-year period in areas within or near dumpsite facilities probably because of the type of livelihood and practices of the majority of the residents in those areas. Even more worrying is the fact that these disease-prone areas are the same locations where informal settlers or the poor are situated or concentrated making them more at risk to diseases.

The role of GIS in public health decision-making is evident in identifying high risk areas that need to be prioritized in making interventions. Creating these dengue risk maps will guide local health authorities in identifying and targeting priority areas for the allocation of the country's scarce resources for programs and projects for the management and control of future dengue outbreaks.

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