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Identifying urban landscape patterns and influences on Dengue Incidence in Mandaue City, Philippines

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Abstract

Climate change-induced extreme rainfall events have become more frequent inundating large areas in highly urbanized cities in the Philippines. With these potential flood events, it is critical to investigate the potential consequences, such as vector-borne illness epidemics like dengue fever, which have been associated with the monsoon season in the Philippines. In this paper, we study the association of a dengue outbreak in Mandaue city, Philippines with independent variables including climatic variables, drainage infrastructures, urbanization levels and vegetation. We use the Global Moran's I index to measure spatial autocorrelation between the locations of dengue cases while Spearman's rank correlation was used to examine relationships between dengue cases and the chosen landscape variables. The results of this work suggest that inadequate flood control and water disposal facilities can increase the risk of a dengue outbreak especially in densely populated areas.

1. Introduction

Dengue is a mosquito-borne illness that is becoming increasingly common all around the world, especially in tropical and subtropical regions, where it affects one-third of the population. This virus is transmitted through Aedes mosquitos when the temperature is lower than 28°C and is supported by stagnant water that allows them to lay eggs and reproduce. The Philippines has one of the highest age-standardized dengue fever prevalence rates in Southeast Asia, resulting in 170,503 symptomatic cases and 750 deaths annually (Undurraga et al, 2017). In fact, the first known epidemic of the severe form of the virus, dengue haemorrhagic fever, originated in Manila in 1953 and incidences have been on the rise since then (Edillo & Madarieta, 2012). Despite being an epidemic in the country for a long time, no specific treatments or vaccines have been developed to deal with it. Mandaue City, in particular, has reported high numbers of dengue cases and fatalities in recent years, and thus, further research needs to be done to identify the factors that could be contributing to its spread (Quijano et al, 2016; Cotejo, 2022). This study aims to explore the important factors responsible for the spread of dengue and its vectors in Mandaue City, Philippines, and to find variables that could be useful in mapping the potential outbreak of dengue fever.

2. Method

Mandaue City (10.3321° N, 123.9357° E), shown in Figure 1A, is a high-income and urbanized city situated on the Province of Cebu 's central-eastern coast. It is the province's second largest city and a first-class highly urbanized city in the Philippines' Central Visayas region (Mahoney & Klitgaard, 2019). Its population was estimated at 364,116 according to the 2020 census.

Here, we use a spatial statistical approach, the Global Moran's I index, to determine any clustering of dengue incidences in the study's denominator: the barangay-level population data of the city.

2.1. Variables

The dependent variable of the study is the dengue incidence rates (Figure 1A). We collected the dataset through the number of reported dengue cases per barangay in Mandaue City from the Department of Health for the period of January to November 2022. The danger of dengue virus transmission rises as a result of female *Aedes aegypti* or *Aedes albopictus* mosquitoes biting and

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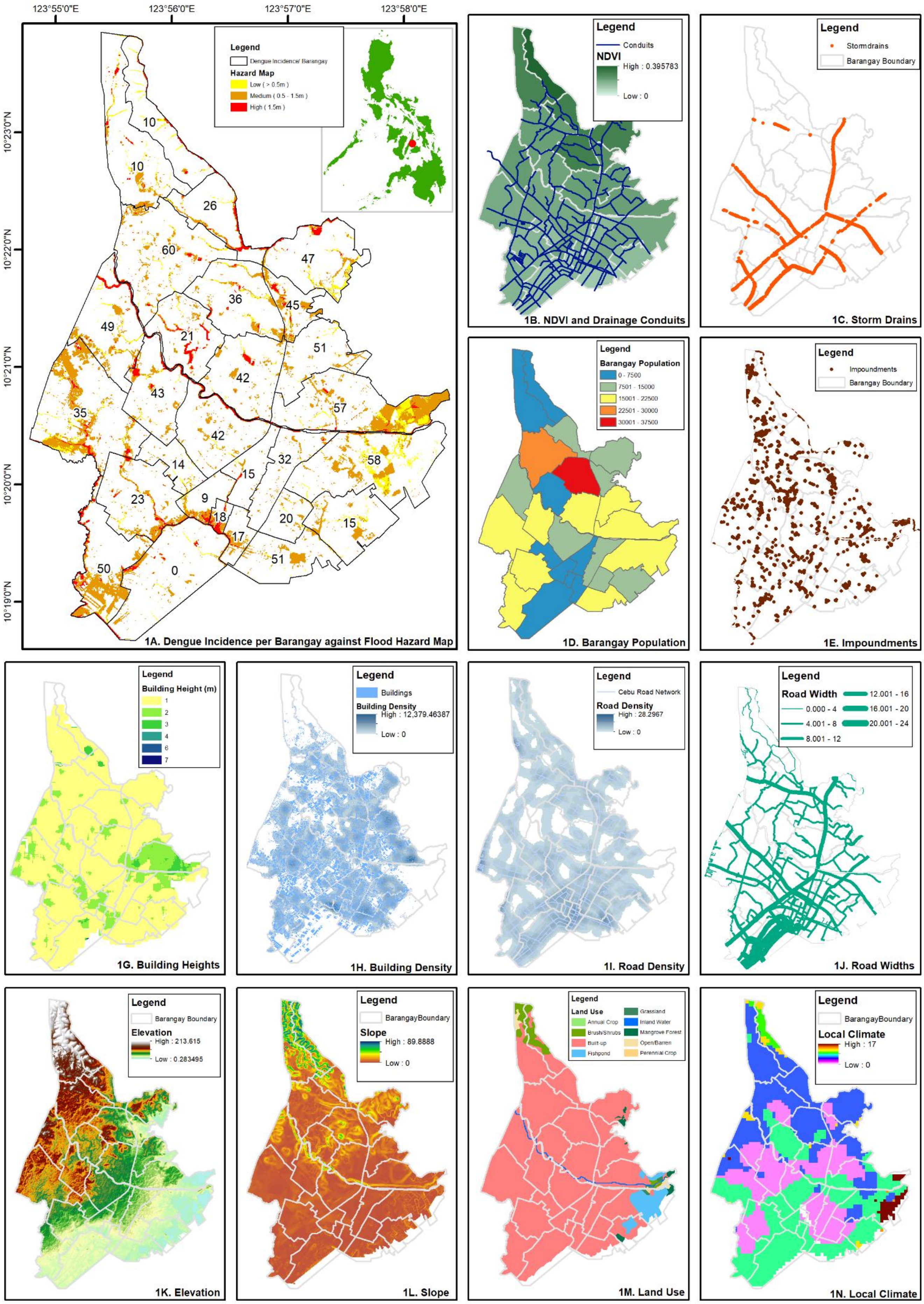

Figure 1. Variables Used as factors for determining dengue incidences in the city

sucking on human blood to get protein and iron minerals. Thirteen independent variables are used and studied to be contributing factors to dengue incidences in the city based on literature review pertaining to *Aedes* dispersal, breeding and nesting factors (Figure 1). The independent variables of the study are categorized into three: infrastructure-linked factors, anthropogenic landscape features and climate-related factors.

The infrastructure-related factors can influence the presence of *Aedes* vector-carrying mosquitoes by enabling or preventing their reproduction and nesting. This includes roof gutters, trash receptacles, sewage, and storm drainage networks in urban areas. For this study, four factors were chosen from this category that could provide *Aedes* sp. with water corridors. The first of these was the flood hazard map, which was used to identify areas that may be inundated with water and could provide a place for mosquitoes to nest in. This data was generated from the Flo-2d software. The second and third factors looked at the city's drainage network and storm drain density, which were obtained from the city's planning office (Hemme et al, 2010; Seidahmed et al, 2018). The last factor studied was the impoundment density, which refers to artificially-created bodies of standing water that could be used by *Aedes* as breeding and nesting sites (Quijano et al, 2016). This data was derived from the digital elevation model through GIS.

This second category, anthropogenic landscape features, focuses on the peridomestic environmental niche of Aedes species. Building density, building height, population density, road width, and road density are the datasets used for this category, which are all related to the dispersal patterns of Aedes species, particularly their tendency to congregate around homes and the potential for habitat fragmentation due to highways to impede their movement (Marti et al, 2020; Seidahmed et al, 2018; Hemme et al, 2010). These datasets were acquired from the city's planning office and further analyzed in a GIS environment.

The last important component of the entomological indices is a set of climate-related factors, including Normalized Difference Vegetation Index (NDVI), local climate zones, land use, elevation and slope datasets (Seidahmed et al, 2018). These datasets were obtained from the city's planning office and were processed using GIS, excluding the climate dataset which was retrieved from the global map of local climate zones and the NDVI dataset which originated from the U.S. Geological Survey's Landsat 8 imagery (Demuzere et al, 2022)..

3. Results

The Global Moran's Index of the dengue cases per barangay was 0.40 with a significant z-score of 2.30 and a p-value of 0.021. This analysis, shown in Figure 2, indicates that dengue incidence was highly spatially autocorrelated with clustering and nonuniformity. These findings imply that a dengue outbreak was experienced in the city among select barangay hotspots and that these areas merit further investigation to scrutinize environmental, anthropogenic or other contributing factors that may have influenced the high incidence of dengue cases in these barangays.

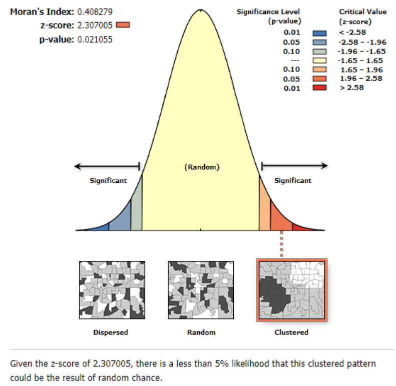

Figure 2. (Global Moran's I) Report

The susceptibility of people becoming ill can be determined by the qualities of their community. Through Spearman's rank correlation analysis, we present a correlation matrix which shows the link between multiple variable datasets (Figure 3). This matrix, when applied to raster layers, shows how the cell values from one layer are related to the cell values from another layer.

The results of our spatial correlation show most of our variables indicating a negative relationship with dengue incidence in the barangays. Unfortunately, our chosen variables for the study presented weak relationships with our dengue incidence rates. Despite this, most notable is the relationship between land use, building height and road density with moderate relationships and population density, flood hazard, building density and NDVI with weak relationships.

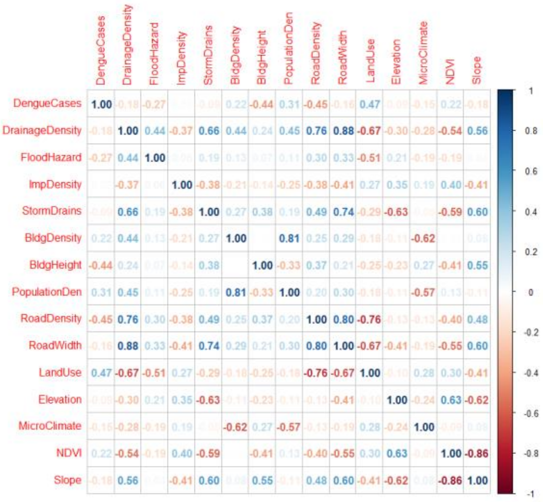

Figure 3. Correlation matrix between all associated variables used for the study and the dengue cases per barangay boundary in Mandaue City.

4. Discussion

All infrastructure-linked variables had a negative association to dengue cases, with flood hazards having the most significant negative relationship (-0.27). The drainage density, flood hazard, and storm drain density all had moderate to strong relationships, which could be due to areas with more drainage channels being connected to storm drains in flood prone areas. Although the drainage network density and storm drain density had values less than 0.2, the direction of the relationship suggests that areas with fewer drainage networks and storm drains had higher dengue incidence rates. This contrasts with a study conducted in Pakistan by Tahir et al (2020) that showed a positive relationship between flooding and dengue incidences. However, this could be due to poor flood management and water disposal facilities, which is supported by this study's results. Further research could be done to explore the influence of standing water after flood events in Mandaue City and how it relates to dengue cases. Studies such as this one, those in Pakistan, and others (Seidahmed et al, 2018; Marti et al, 2020), show that there is a correlation between dengue occurrences and the availability of water management networks, indicating the need for upgraded drainage infrastructures to help control both floods and dengue fever preventive methods.

The most noteworthy result from the anthropogenic factors was that of road density having a negative correlation with dengue cases, meaning that barangays with fewer roads had more dengue cases. Even though the value for road width was not significant, it still demonstrated a negative relationship with dengue cases, implying that narrower roads resulted in more dengue cases. This was further supported by the strong relationship between road density and width, which indicates that more roads connected to highways and major transportation hubs impede *Aedes* migration. This coincides with an Australian study by Hemme et al (2019) showing that Aedes aegypti have difficulty crossing big highways, suggesting that greater roads networks and wider road widths can act as a form of habitat fragmentation and reduce *Aedes* species' mobility.

The study's results regarding building density and building heights are found to also be in line with other literature (Edillo & Madarieta, 2012; Seidahmed et al, 2018; Marti et al, 2020), indicating areas with higher building density and more low building structures to have higher dengue incidences.

Population density has a weak positive influence on dengue incidences, with denser human populations having more incidences. Additionally, the correlation between population density and building density, like road widths and road density, implies that there are more structures in areas with more people. Despite the findings of the study, more research should be conducted to investigate the anthropogenic and socioeconomic connections to dengue outbreaks, due to the restriction of remote sensing and GIS methods in anticipating human behavior, and the lack of consideration of artificial containers for mosquito breeding.

For climate-related factors, land use and NDVI had a positive correlation with the number of dengue cases, meaning that a greater amount of land use in an area and more vegetation can lead to a higher incidence of dengue. Additionally, our research indicated that dengue is more prevalent in lower altitude locations and flatter terrain. Furthermore, the global map of local climate zones suggests that highly urbanized areas have a higher rate of dengue cases. In relation to the climate-related variables, finer scaled dengue incidence rates or population studies of Aedes species could be done to further investigate these relationships.

5. Conclusion

This study found a positive correlation between dengue cases and their locations, indicating clustered outbreaks in some barangays of Mandaue City. Potential factors to dengue outbreaks were identified, showing the need for better flood control, including drainage network conduits and water disposal facilities, to reduce the risk of outbreaks. This study has shown that the complexity of A. aegypti's population structure, which can be impacted by location, environment, and geography, can provide insight into their dispersal patterns, microclimate preferences, and infrastructure issues. It was also observed that inadequate flood control, such as insufficient drainage networks and water disposal systems, can lead to a higher risk of dengue outbreaks.

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