Application of Time Series Analysis and Geographic Information System (GIS) in Forecasting the At-Risk areas of Dengue in Cavite, Philippines

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Abstract: Cavite declared a province-wide dengue outbreak from the year 2015 to 2018. The study helped create maps of the number of cases of dengue in the 16 municipalities and 7 cities of Cavite from 2003 to 2020; determined the predictors of dengue cases in terms of age and sex of the patients; and predicted the dengue cases in the year 2022, 2024, and 2026. The dengue cases and patients' profiles from 2003 to 2020 in Cavite were obtained from the Provincial Epidemiology Surveillance Unit (PESU). The maps of dengue cases from 2003 to 2020 and the predicted cases of dengue in the year 2022, 2024, and 2026 were created using ArcMap 10.4. Time series analysis was used to predict the dengue cases in Cavite in the years 2022, 2024, and 2026. Based on the results, the highest dengue case was recorded in Dasmarinas City, followed by Bacoor City, Imus City, Gen. Trias City, and TreceMartires City. In 2022, the forecasted dengue cases in Dasmarinas City are 1,995; 1,352 in Imus City; and 1,260 in Bacoor City. In 2024, the forecasted dengue cases in Dasmarinas City are 2,228; 1,514 in Imus CIty; and 1,398 in Bacoor City. In 2026, the forecasted dengue cases in Dasmarinas City are 2,460; 1,676 in Imus City, and 1,537 in Bacoor City. Dasmarinas City, Imus City, and Bacoor City in the province of Cavite are at risk of dengue in the years 2022, 2024, and 2026.

Keywords: Outbreak, epidemiology, public health, environmental health

1. Introduction

Cavite declared a province-wide dengue outbreak from the year 2015 to 2018. There were 12,007 dengue cases, of which 48 cases of deaths were reported in 2015; 5,121 cases with 25 deaths in 2016, and 6,129 cases with 27 deaths in the upland and lowland part of the province in 2017. These recorded cases of fatalities and outbreaks post an alarm to the whole province **(Giron.A.2018)**. Provincial Epidemiology Surveillance Unit (PESU) announced that Cavite province has increased dengue cases up to 79 percent from January to June 2017 up to January to June 2018 **(Pino.G.2018)**. Outbreaks were recorded at General Trias City, Bacoor City, Imus City, Dasmarinas City, and TreceMartires City **(Provincial Epidemiology Surveillance Unit.2018)**. The breakdown of these dengue cases are as follows: Bacoor City with 305 cases, Gen. Trias City with 303 cases, Imus City with 278 cases, Naic with 225 cases, Dasmariñas City with 192 cases, Tanza with 176 cases, Rosario with 140 cases, Silang with 137 cases, TreceMartires City with 130 cases and Noveleta with 109 cases **(UNTV News and Rescue.2018)**. The numbers were confirmed by Dr. Nelson Soriano, the provincial epidemiologist.

Furthermore, there were five cases of death and 1,499 dengue cases from January 1 to March 11, 2018; the five cases of fatality aged between 4 to 23 years old **(Cinco.M.2018)**. Dengue cases in the Philippines have been confirmed nationally and occur year-round in the country, with its peak transmission during the rainy season, May to November **(International Association for Medical Assistance to Travellers.2018)**. The World Health Organization (WHO) reported that 20,108 dengue cases had been registered nationwide from January to March 2018, which is 26 percent lower compared to the same period where 27,023 cases have been reported **(WHO.2018)**. In the Philippines, which ranks fourth in the most dengue cases in Southeast Asia, dengue is considered one of the eight pervasive infectious diseases. Dengue can affect the country's economy because of the loss of production caused by illness and premature deaths. The increase in healthcare costs contributes to an additional burden to humans **(Edilllo.F. et al.,2015)**.

2.Significance Of The Study

The prediction and spatial distribution of the epidemiology of dengue in Cavite provides a holistic view of how dengue can spread in the province. This study also provides a warning to the whole province to prevent possible outbreaks of dengue. This can alarm the government officials and make people more aware of what will happen if there is an outbreak. Furthermore, the results of this study can be a basis for the countermeasures on how to prevent such a disaster. The data from this study can also serve as a baseline for future researchers.

3.Review Of Related Studies

A high incidence of dengue has been recorded around the world. 2.5 billion people of the world’s population are now at risk of dengue **(Palaniyandi.M. et al.,2018)**. Dengue has become a major international public health

concern these past few years, and dengue hemorrhagic fever affects Asian countries. This causes hospitalization and death, where most victims are children **(Bhandari.K. at al.,2008)**. According to the World Health Organization, there may be 50 million cases of dengue infection worldwide every year. The global burden of dengue is difficult and represents a growing challenge to public health officials **(Bhatt.S. et al.,2013)**. The virus is transmitted to humans through the bites of an infected female Aedes mosquito, which mainly acquires the virus while feeding on an infected host. The symptoms of dengue fever include severe joint and muscle pain, swollen lymph nodes, headache, fever, exhaustion, and rash. Dengue hemorrhagic fever (DHF) is a specific syndrome that significantly affects children under 10. The complication of dengue causes abdominal pain, hemorrhage, circulatory collapse, and death if not immediately cured **(Cunha.J. & Stoppler.M.2018)**.

Except for the extreme cold, mosquitoes can live in any environment, favoring forests, marshes, tall grasses and weeds, and ground that is wet at least part of the year **(Mosquito World.2018)**. Environmental factors significantly affect the breeding and development of Aedes mosquitoes because they are sensitive to environmental conditions. Temperature, precipitation, and humidity are critical to a mosquito's survival, reproduction, and development and influence its presence and abundance. Climate and environmental factors significantly affect the abundance of mosquitoes in an area, especially in the countries where transmissions routinely occur with short-term changes in weather, temperature, precipitation **(Center for Disease Control and Prevention.2012)**. Mapping the distribution of dengue outbreaks in an area is possible with Geographical Information System (GIS), which can provide visual identification and faster mobilization of resources **(Duncombe.J. et al.,2012)**. GIS and spatial analysis are powerful tools that help describe epidemiological patterns and detect, explain, and predict diseases in space and time **(Adriana.T. et al.,2016)**. A graphical analysis of the area can be provided because GIS can capture spatial distribution and the severity of the distribution of the disease. It can identify the trends and patterns to indicate the affected area **(Ai-leen.G. & Song.R.2000)**. Geographic Information System is recognized as an analytic tool for public health because it can identify the areas where outbreaks originate and effectively target high-risk of different diseases for early prevention **(Er.A. et al.,2010)**.

4.Objectives Of The Study

- Determine the number of cases of dengue in the 16 municipalities and 7 cities of Cavite from 2003 to 2020
- Identify the predictors in the prevalence of dengue in terms of age and sex
- Predict and map the areas at risk of dengue in the years 2022, 2024, and 2026

5.Hypotheses Of The Study

- Age and sex are not predictors of dengue prevalence in Cavite, Philippines

6.Study Area

The study area is the whole province of Cavite. It is located on the southern shores of Manila Bay in Luzon Island.

6.1.Statistical Techniques Used in the Present Study

Dengue Predictors. Multiple linear regression analysis was performed to determine whether the patients' demographic profile (age and sex) can be predictors of dengue prevalence in Cavite. PASW Statistic 18 was used to perform the modeling. The dengue cases from 2003 to 2020 and demographic profile of dengue patients in Cavite were obtained from the Provincial Epidemiology and Surveillance Unit (PESU). The maps of dengue cases per year were generated using ArcMap 10.4.

Time Series Analysis. The researchers employed forecasting to predict the number of cases in the succeeding years, which required dependent (dengue cases from 2003 to 2020). The forecasted data was presented through Expert and ARIMA modelers in PASW Statistic 18 software. The maps of predicted dengue cases will be generated using ArcMap 10.4.

6.2.Data Analysis and Interpretation

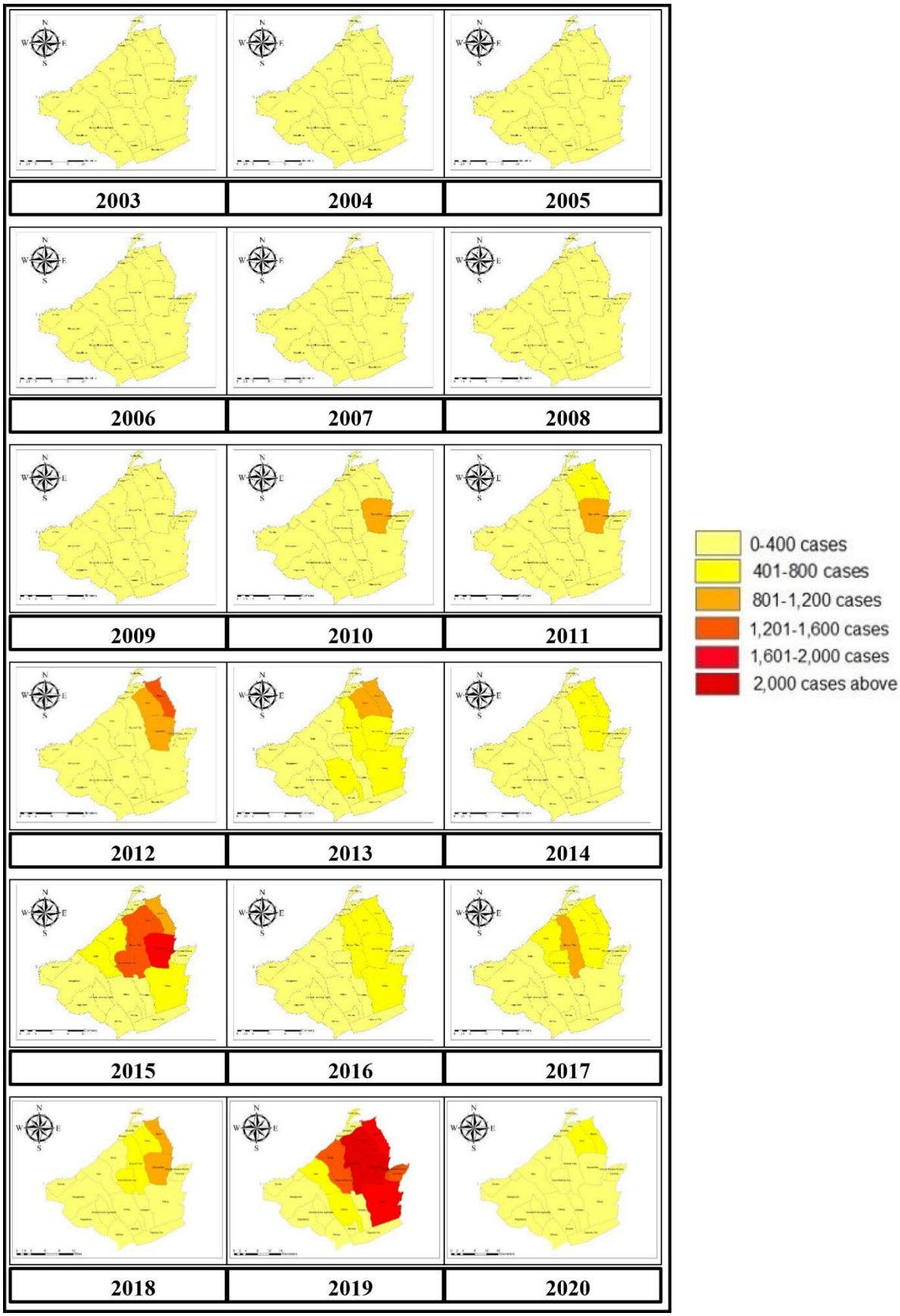


Figure 3. Maps Dengue cases in Cavite from 2003-2020

Number of Dengue Cases in Cavite

The city of Dasmariñas recorded 200 dengue cases in 2009, and the City of Bacoor recorded more than 100 cases in 2008. A low number of dengue cases were recorded in the other cities and municipalities from 2003 to 2009. From 2010 to 2011, dengue cases in Dasmariñas City ballooned to 800 cases. Furthermore, the epidemic increased to more than 1,300 dengue cases in the City of Bacoor in 2012 and more than 1000 cases in 2013. However, the number of cases suddenly fluctuated in 2014 with more than 400 cases recorded each in the cities of Imus, Bacoor, and Dasmariñas.

The increasing number of dengue cases from 2003 to 2020 is seen in the changes of colors on the maps (Figure 1). The dengue cases from 2003 to 2020 have a gradual increase. From 2003, it increased 3.8 times until 2007, and it continued to increase until 2012 with 34 times the number of dengue cases from 2003. Moreover, the gradual increase of dengue cases continued until 2018, and it rose again in 2019 in 12 cities and municipalities in Cavite, having 400 cases above. Furthermore, there is a notable decrease in dengue cases in Cavite in 2020, whereas the people have limited movement due to Covid-19 community quarantine restrictions.

Dengue is considered one of the eight pervasive infectious diseases, and the Philippines ranked fourth in the highest number of cases in Southeast Asia. Moreover, Cavite declared a province-wide dengue outbreak because of the increasing number of dengue cases from the year 2015 to 2018 **(Giron, A. 2018)**.

Table 1. Regression analysis of age and sex as predictors of dengue cases in Cavite

Variable	B	SE	β	t-value	p-value
Age	-0.78	0.462	-0.007	-1.687	0.117
Sex	0.081	0.000	1.002	253.032	0.000

Note: $R^2 = 1.0$

Predictors of Dengue Cases

Table 1 shows that among the age and sex of dengue patients, only the sex is the predictor of dengue cases in Cavite. Most of the dengue patients in Cavite were male. In the case of India, most of the dengue patients were male, and it has been attributed to their frequent outdoor activities compared to females. Thus, males have higher chances of getting bitten by mosquitoes (Antony and Celine, 2014)

Table 2. At-risk areas in Cavite for the spread of dengue in 2022, 2024, and 2026.

Range	2022	2024	2026
0-400	Alfonso, Amadeo, Cavite City, Indang, Mendez, Rosario, Kawit, Naic,General Mariano Alvarez,Tagaytay City, Carmona,General Emilio Aguinaldo,Magallanes, Noveleta, Ternate	Alfonso, Amadeo, Cavite City, Indang, Mendez, Rosario, Kawit,General Mariano Alvarez,Tagaytay City, Carmona,General Emilio Aguinaldo,Magallanes, Noveleta, Ternate	Alfonso, Amadeo, Cavite City, Indang, Mendez, Rosario, Kawit,General Mariano Alvarez,Tagaytay City, Carmona,General Emilio Aguinaldo,Magallanes, Noveleta, Ternate
401-800	Silang, Tanza	Naic,Tanza, TreceMartires City	Naic, Tanza
801-1,200		Silang	Silang, TreceMartires City
1,201-1,600	Bacoor City, Gen. Trias City, Imus City	Bacoor City, Gen. Trias City, Imus City	Bacoor City, Gen. Trias City
1,601-2,000	Dasmariñas City		Imus City
2,001 and above		Dasmariñas City	Dasmariñas City

Forecasted areas of Dengue Prevalence

Table 2 shows the areas at risk for the spread of dengue in Cavite. Based on the outcome of the study, some of the cities and municipalities of the province have an increasing trend of dengue cases from 2022 to 2026. For 2022, 2024, and 2026, there are 15 cities and municipalities predicted to have 0-400 cases from 2020 to 2026. It has also been predicted that Silang, Trece Martires City, Bacoor City, Imus City, Gen. Trias City, and Dasmariñas City will have 800 and above dengue cases from 2020 to 2026. Moreover, Dasmariñas City was on the top, predicted to have more than 2,001 cases of dengue in the years 2024 and 2026.

The continuous development of the province causes these results. The National Competitive Council of the Philippines ranked Cavite as second in economic competencies among all provinces **(Pronove,M.2017)**. Cavite is one of the fastest-growing provinces in the Philippines. It is due to several reasons such as the availability of jobs, proximity to Manila, getaway destination like Tagaytay, Batangas, and other places not as easily accessible if you are not coming from Manila **(Remo,A. 2017).**

Maps of Dengue Prevalence in Cavite

ArcMap 10.4 was used to generate maps of dengue prevalence in the province of Cavite for the succeeding years. There were three points of prediction that were set: 2022, 2024, and 2026. Most of the entry points of the disease in the province were located in lowland areas of Cavite (Figures 2-4).

Figure 2. Predicted dengue prevalence in Cavite in the year 2022

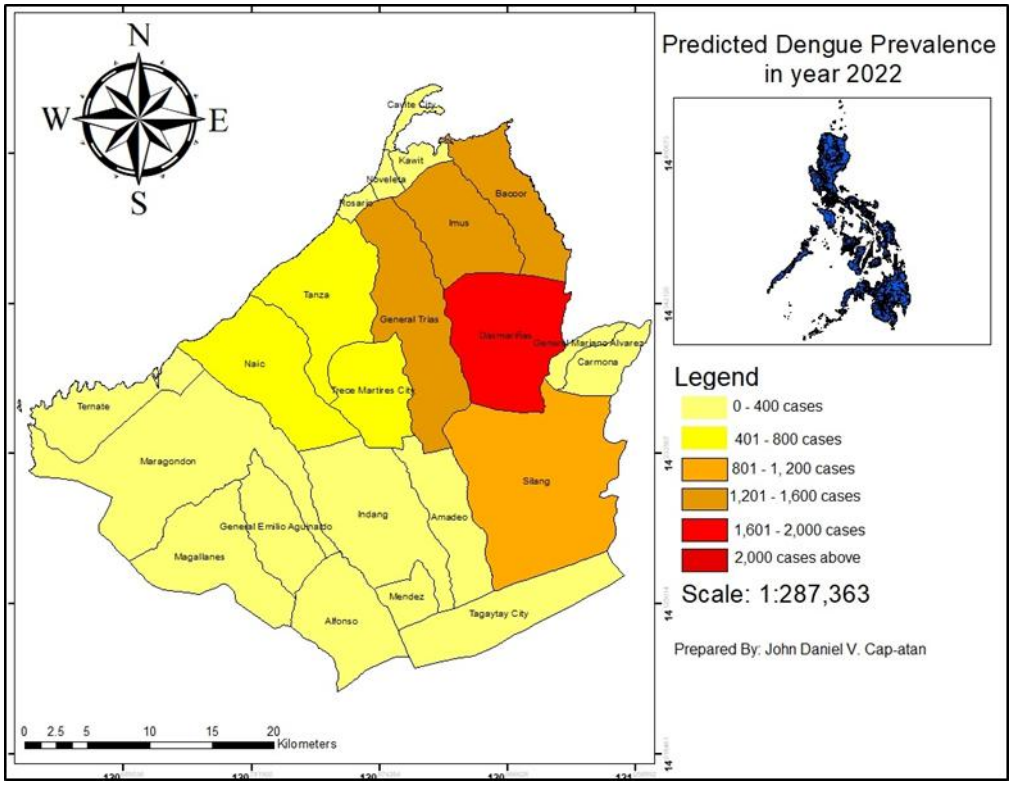


Figure 3. Predicted dengue prevalence in Cavite in the year 2024

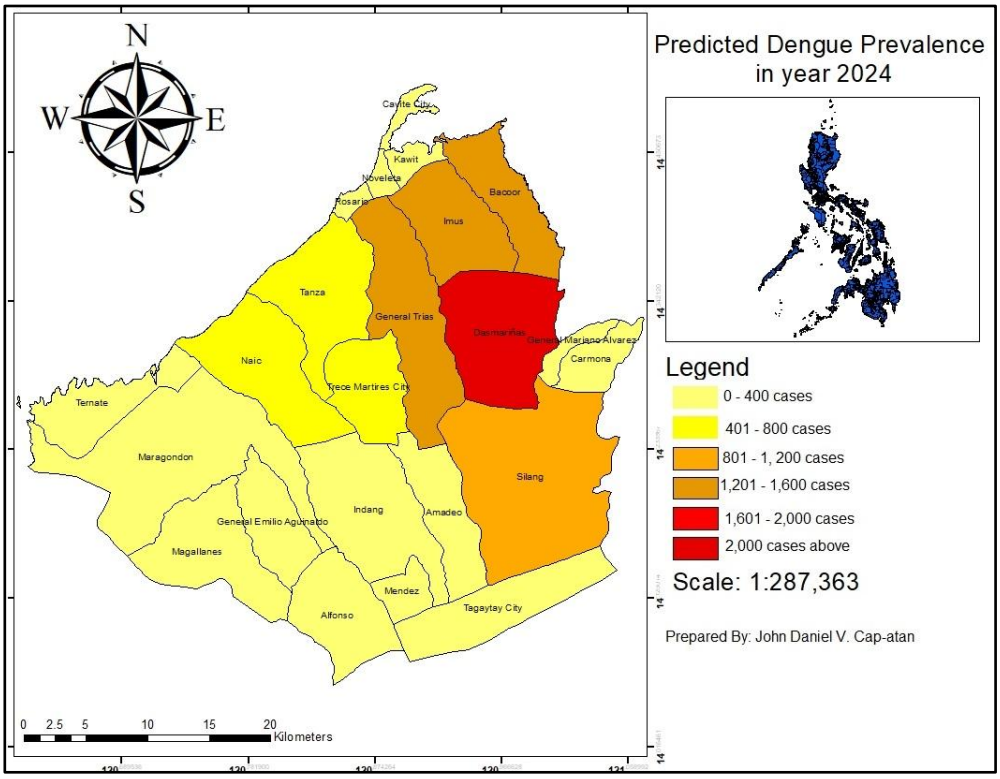
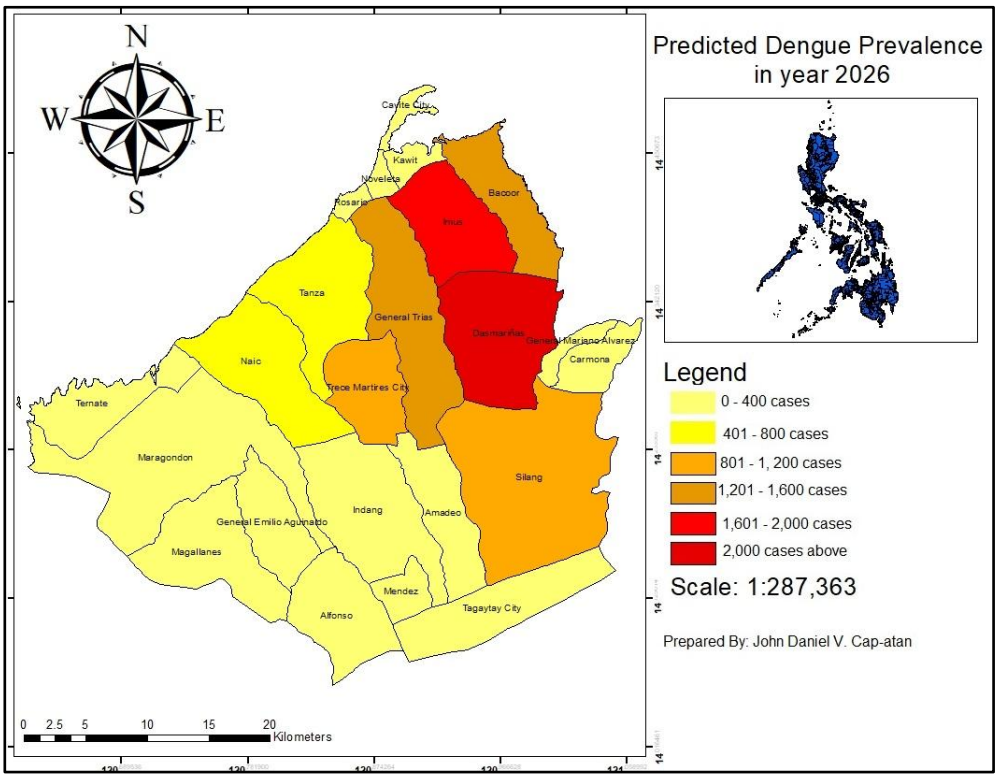


Figure 4. Predicted dengue prevalence in Cavite in the year 2026



7. Recommendations

The predicted number of cases and at-risk areas identified in this study could serve as a basis for further research and decision-making processes by the local government and other concerned institutions. We recommend to:

- Evaluate the surveillance system of the province of Cavite.
- Examine other possible predictors such as climatic factors, population density, and topographic characteristics.
- Create a more comprehensive baseline database that will serve as a basis for formulating policy interventions and health measures to prevent the transmission of the disease.
- Conduct the same study on other mosquito-vectored diseases such as Malaria and Chikungunya.

8. Conclusion

Analysis of the secondary data obtained from the Provincial Epidemiology Surveillance Unit (PESU) of Cavite showed an increasing number of dengue cases since 2010, with the city of Dasmariñas having the highest number of cases that prompted the local government to declare a province-wide dengue outbreak from 2015 to 2018 to address the epidemic. However, the data showed that there had been a decrease in recorded cases during the pandemic, which could impact the quarantine protocols set up by the government. Results of regression analysis showed that sex was the only predictor of dengue cases in Cavite, as confirmed by the higher number of male dengue patients since 2003. Based on these data, the forecast showed a continuous increase of cases in the coming years and high prevalence in specific areas affected mainly by development such as Silang, TreceMartires City, Bacoor City, Imus City, General Trias City, and Dasmariñas City.

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