Development of a localized Web-based GIS Visualization Platform as a tool for Disseminating Habitat Abundance of Aedes Mosquito Vectors in the Philippines

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Abstract

Disseminating up-to-date information on dengue mosquito habitats aided by modern GIS approach would yield benefits to people being informed on the localized developments of the vector and therefore reduce people's risk of being affected by the disease. This paper discusses the development of this monitoring and sensing mechanism through a Web-based GIS mapping and visualization. It utilizes the environmental, WHO dengue indices and weather information for a case of a city in the Philippines to visualize hotspot areas for habitats of dengue vectors. The paper would aid the government in deploying key assets and supporting DOH's 5S drive or Search, Self, Seek, Support and Sustain strategy to curtail the spread of the disease. Through this paper, the author intends to develop a localized web-based platform *Aedes* mosquito vector. Presented in this study provides the data workflow from field observations and the inputs from environmental and meteorological data which has the potential to help enhance the data dissemination as well as the IEC campaign of local health leaders in reducing the mortality and morbidity of people affected by Dengue mosquitoes. This visualization platform includes an easy to set-up system using the available Web-based GIS which can be updated depending on the availability of field data and meteorological observations.

1. Introduction

1.1 The Problem and its Setting

The number of people getting sick from dengue viral infection, a mosquito-borne disease, has been reported to increase locally in urban city centers. In the Philippines, its pathological study was first reported in 1969 by Dr. Vicente Reyes from patients of San Lazaro hospital which distinctly described as the 'Philippine Hemorrhagic Fever'. The disease is characterized by fever, malaise, and petechial hemorrhages (Fresh, Reyes, Clarke, & Uylangco, 1969) as a result of the infection transmitted from mosquito bites mostly from *Aedes* mosquitos. Dengue infections are spread by female *Aedes* mosquitos and is one of the arthropod-transmitted viruses (arboviruses) with the most prevalent and could spread rapidly from person to person (Madewell, 2020).

There have been many reported epidemics of these disease, the first in Southeast Asia happened in Manila in 1953-1954 (Ooi & Gubler, 2008) and followed by many more with the latest national epidemic in 2019 months away from the COVID-19 pandemic. Its fluctuations are highly intertwined with the changes in seasons and, to a greater extent, the warming climate. This is evident locally, as shown in Figure 1. The virus which causes the infection is transmitted to humans when bitten primarily by an infected female Aedes aegypti as well as other genus of *Aedes* (World Health Organization, 2023). WHO (2023) further describes that human-to-mosquito transmission can be from a symptomatic person or even those without the symptoms but has already been infected.

For this proposed sytems, Cagayan de Oro City was selected because of past reported high number cases of dengue from 2016 to 2021. It was observed that the disease worsens as the population grows and the mosquito's natural habitat shrinks, favoring it to thrive in human settlements. Additionally, a global warming and frequent flooding threaten to increase the spread of mosquitoes well beyond their breeding grounds (The Rockefeller Foundation, 2022). As such, the misconception that global warming affects only the weather poorly advocates for monitoring climate and its physical impacts, which could be dangerous as climate and vector-borne diseases are linked.

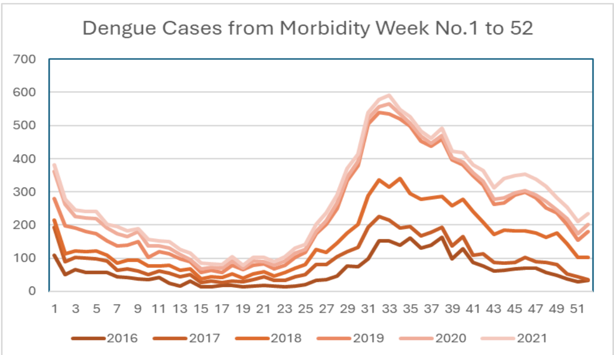

Figure 1. Number of Dengue cases from Morbidity Week no.1 (January) to no. 52 (December) in Cagayan de Oro City Source: City Health Department

Considering the highest baseline emission scenarios (RCP 8.5) for the Philippines, as shown in Figure 2, still point to a wetter climate for 2036-2065, peaking in June-July-August and to even higher rainfall estimates for December-January-February. The locally downscaled climate models for CdeO using moderate emission scenarios (RCP 4.5) points to increase in rainfall manifested by a decrease of wetter than normal years while an increase of drier than normal year for the 2050s (Manila Observatory, 2016). The evident nature of the disease spreading in a space and time prompts for a timely dissemination of information which can be achieved through a visualization platform that is accessible and user friendly.

As shown earlier, these months also coincide with the increase in dengue cases for weeks 27 to 33 and 49 to 51. The cost of recuperating from Dengue and the number of cases leading to deaths necessitates monitoring its habitat and cases, where weather patterns are considered a critical indicator. Since the city is in the tropics, exposure to the virus is high, and children and the elderly are vulnerable to the severe forms of the disease because of their weakened immune system (Undurraga, et al., 2017). Providing this information in a modern GIS approach would yield benefits from people being informed and therefore reduce their risk of being affected by the disease. This would encourage better preparations and improvement of their adaptive capacities.

This paper discusses the development of a monitoring and sensing mechanism through a Web-based GIS mapping and visualization. It utilizes the environmental, dengue indices and weather information in Cagayan de Oro City to visualize hotspot areas for habitats of dengue vectors. The paper would aid the government in deploying key assets and supporting the health department's 5S drive or Search, Self, Seek, Support and Sustain strategy to curtail the spread of the disease. Medical facilities and health providers will benefit from these as there is timely information on the spread of the vectors while considering the developing cases of local transmission. By identifying the locations of at-risk populations, targeted interventions are delivered fast, and decision-making can be achieved with cross-collaboration among stakeholders and decision makers. The visualization platform utilizes a web-based platform in a Geographic Information Systems (GIS) environment to monitor the time and location of vector hotspots and their habitats.

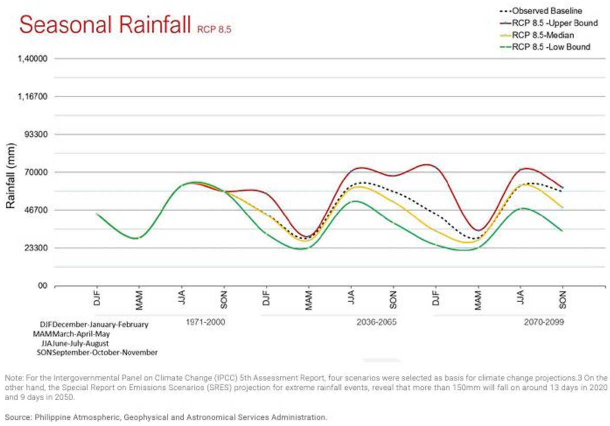

Figure 2. Representative Concentration Pathway (RCP) 8.5 Seasonal Rainfall Projections Source: UN-Habitat

Geography as known today is intertwined with GIS. As a mapping tool, GIS became a popular choice over traditional mapping because digital platforms became accessible with the popularity of personal computers. Since it started developing computer-based systems in the mid-1960s and 1970s (Dempsey, 2012), GIS became a standard visualization and spatial analysis tool. This transition paved the way for digitally created maps, features, and information known today.
From thereon, GIS transitioned from just mapmaking into geo-visualization, spatial data analysis, and Big Data, which is applied to many corners of society - even in the engineering discipline. The first known coined term for GIS was in the 1960s for a research study led by Roger Tomlinson, the well-known "father of GIS" when he worked for Spartan Air Services in Canada (Dempsey, 2012)and later on developed the geographic database for municipalities used for land planning (Dangermond, 2014). His initial work intended to develop a methodology to identify the best sites for tree plantation in Kenya (University Consortium for Geographic Information Science, 2014)

Building GIS databases for local governments as an aid in planning is not new. However, the access to which this database is being stored, retrieved, managed, and visualized is still developing. Its popularity is highlighted in every forum and academic discourse on disaster management, economics, and social development.

While it is true that GIS is not new and even understood as a "modern" way of Geography, its associated technology has evolved. Since the introduction of the World Wide Web in the 1990s, GIS data has been widely used for wayfinding, mapmaking, and information storage. The timeline shown below shows a relatively short but fast-paced history of web mapping, with an impressive evolution related to both the dynamics of science and technology and the increased interests of domain experts and global citizens in consuming UN-Habitat maps created by web mapping services (Veenendaal, Brovelli, M.A., & Li, 2017).

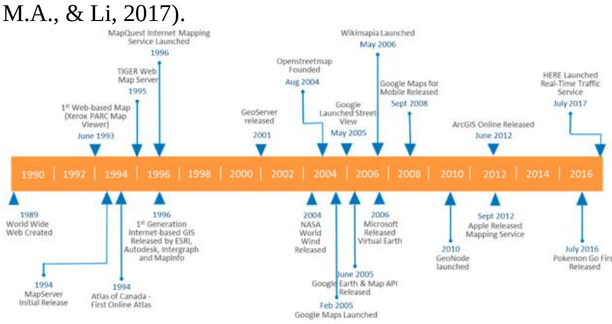

Figure 3. Timeline of some significant web mapping events in GIS (Veenendaal, Brovelli, M.A., & Li, 2017).

With the advent of web mapping, dissemination of real-time and near real-time information through engaging map applications has become popular and provided state-of-the-art visualization not just in the industry but also for disaster response.

With the impending impact of climate, managing risks at the local level has become complex and data-driven. A paper by Yan-xi et al. (2009) explains that information on natural disasters can be better acquired, interpreted, and disseminated using the latest information and geospatial technologies. Further, this benefit can be better achieved in disaster management and control, from preparedness, prevention, and (Yan-xi, Gang-jun, Er-jiang, & Ke-fei, 2009). As GIS technology evolved to what it is known today the requirements for data has transitioned from storing information in shapefiles into data services which are hosted by mapping organizations, government, academe and research institutions. These change in the system prompts for service-based features as opposed to stand-alone data in isolated desktop computers, rather it should be stored in the cloud so client computers and anyone in the web can use the information in creating value-added platforms.

The study intends to develop a localized Web-based GIS mapping and visualization in Cagayan de Oro (CdeO) city that is deployable for Dengue vector applications. This highly urbanized city is located in Northern Mindanao and is its regional and financial center. In terms of population, CdeO posted a total of 728,402 individuals in the latest 2020 population census (Philippine Statistics Authority, 2021), equivalent to 76.12% of the population of Misamis Oriental

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Province. It also presents a doubling population by 2047, placing it as one of the metropolitan areas in the country. The city and neighboring municipalities will be recognized as a metropolitan center by 2040 (National Economic and Development Authority, 2022). With a growing population and metropolitanization, the city faces climate-related issues such as flooding, pollution, and the absence of established evacuation centers (City Government of Cagayan de Oro, 2016)

Through this paper, the author intends to develop a localized web-based platform *Aedes* mosquito vector for its issues in vector-borne diseases. Below is the latest rating per adaptive capacity of the city (City Government of Cagayan de Oro, 2016), which highlights its room for improvement. Technology currently scores highest among other dimensions. While information ranks least, the author believes that this can be improved with the proposed Web-GIS platform as it breaks the barriers of providing local information for the government and the public to use.

1.2 Case studies of Web-GIS platforms

The Mekong case presents a state-of-the-art Geographic Information Science (GIS) technology to model dam construction impacts in the context of the SERVIR-Mekong program which is a joint USAID and NASA collaborative project aimed to provide support to dedicated development and sustainable landscape projects in the Mekong region (Aekakkararungroj, et al., 2020). Further, Aekakkararungroj et al. highlight how the tool computes dam inundation area and reservoir volume with high accuracy compared to ground data. We also give examples of how additional layers of data can be coupled with these outputs to analyze implications on transportation, land use, and protected areas of the environment.

Vranic, Glisˇovic, and Velimirovic (2021) examines the possibilities for the joint use of probabilistic reasoning techniques with multi-criteria decision-making analysis on the selection of the most essential adaptation measures using Bayesian networks, analytical hierarchy processes, and geographic information systems. The created model offers a comprehensive methodological framework that may be utilized at various geographical levels and for various industries. When coupled with platforms to develop a decision support toolset that supports multi-agency decision-making during cross-border emergencies such as S-HELP (Neville, et al., 2016) many lives can be saved in the process.

The case of Gaja in India explored and understood the role of GIS-enabled mobile applications in disaster management in general and in the response to cyclone (Sharma, Misra, & Singh, 2020). The study further shares that the use of GIS-enabled mobile applications in emergency scenarios has not been sufficiently investigated, Sharma, Misra and Singh (2020) concluded that despite the significant impact that mobile applications have on society as a whole. The findings of their study summarized the key takeaways from using a mobile GIS application for disaster management.

1.3 Web-GIS and Visualization Applications in Dengue surveillance and response

Previous studies on Web-based GIS applications in surveillance and response reported various limitations summarized into three categories from i) data collection process, ii) applied techniques and iii) investigation (Mala & Jat, 2019). Using these latest findings, this paper investigates the data collection process by integrating weather information and dengue vector surveillance. In another case, patient information of persons who previously acquired the disease as well as data on climate, socioeconomics, and population were used to generate a similar platform for a province in Pakistan. Their major findings include a 93.97% accuracy using random forest fit model from 6000 data samples used (Javaid, et al., 2023). A recently published similar platform addressing the same concern named PICTUREE is a Aedes web application with spatio-temporal characteristics provides for an estimation of the Aedes mosquito population along with dengue trans-mission quantified as reproduction number Rt , and the dengue risk albeit in a global scale (Yi, Vajdi, Ferdousi, Cohnstaedt, & Scoglio, 2023). This platform utilizes an SQL database where dengue information, weather data, and occurrences which can be viewed on multiple devices for ease of access.

2. Methodology

2.1 Research Design

This study developed a web-based GIS platform to visualize breeding habitats, weather information and elevation which could enable policy makers to anticipate the spread of *Aedes* mosquito vectors. All digitized information used a vector polygon form using the barangay boundaries secured from the City Planning and Development Office (CPDO). This covers all the 80 barangays while the poblacion barangay is clustered into four areas. The GIS overlay method of representing the interplay of different layers utilized, which integrates spatial data and attribute data from pertinent sources. Below is the conceptual framework of the study which illustrates the dependent variable 'Indices of Abundance of *Aaedes* Mosquito Vectors' and its independent variables.

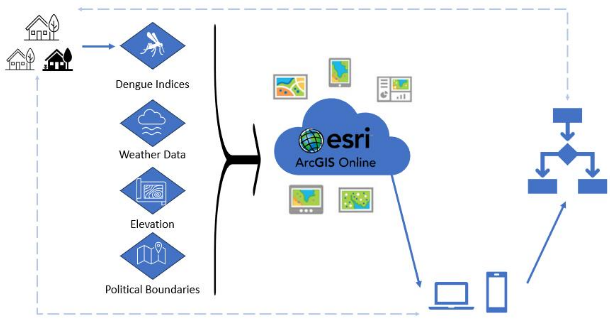

Figure 5. Conceptual Framework of the Study

This paper aims to develop a Web-GIS platform to deliver information, tools, and capabilities in leveraging cloud- and server-based components for visualization at the agency level whether for an LGU or a Health office. It seeks to demonstrate a data-driven monitoring system for dengue vector abundance by way of visualizing the Aedes mosquito vectors and overlaid with other factors that were found to influence the abundance. To provide real-time access the factors and other layers are designed for a local level e.g. LGU that embeds all the relevant information in a Web-GIS platform, so cross-collaboration and communication is better achieved. Specifically, the design was tailored for the LGU of Cagayan de Oro City within its City Disaster Risk Reduction and Management Department.

This study contributes to a sustainable approach to monitoring dengue on top of the surveillance mandate of the city government and the national agencies such the Department of

Health (DOH) and the Department of Science and Technology (DOST). In achieving this the paper also contributes to the United Nations Sustainable Development Goals (UNSDG) no. 3: Good Health and Well-being, no.6: Clean Water & Sanitation, no.11: Sustainable Cities & Communities and no.9: Industry, Innovation & Infrastructure. By providing an accessible and data-drive system UN SDGs 11 and 9 are implemented. Also, improved health and well-being is the direct result of the paper which contributes to UN SDGs 3 and 6.

The paper developed a database for information and dissemination platform in Web-GIS environment for visualization of the abundance of *Aedes* mosquito vectors. Whereby, the abundance of *Aedes* dengue vectors as the mapping goal. The independent variables include habitat parameters, dengue indices, and meteorological variables which used to represent dengue hotspots in a continuous spatial domain.

The research carried out ensuring the flow chart of the methodology shown in Figure 6. Flow chart showing the methodology of the influence of habitat and climate variables on Describes the details of each step is discussed in the paper. Firstly, the raw data from household locations were mapped using the manually collected GPS information. For each household breeding habitats were collected and computed for their dengue indices i.e. House Index, Container Index and finally Breteau Index. Second, the weather information on temperature, rainfall, and humidity were sourced from 9 Automatic Weather Stations (AWS) installed all over in the city. The locations of the AWS were interpolated to produce geostatistical maps using Inverse Distance Weighting (IDW) approach so areas beyond the optimal proximity of the AWS can still be mapped following their natural distance and weather information. Third, information on the elevation of all the households were extracted from a DEM model sourced from the DOST-Lidar project which utilized the lidar technology to measure the accurate elevation of the land. This DEM was collected in 2013 but is still relevant as it covers a wider scope and a pixel scale of 0.1m x 0.1m. An elevation map can be generated from these information which covers the entire boundary of the city. Household data were then joined along with the dengue indices, weather information and the elevation to produce the layers for the Web-GIS visualization. To sift through similarity within space, a clustering analysis using Moran's I was used to check for spatial autocorrelation. It is test done where the z-scores indicate the distribution as either dispersed, random or clustered,

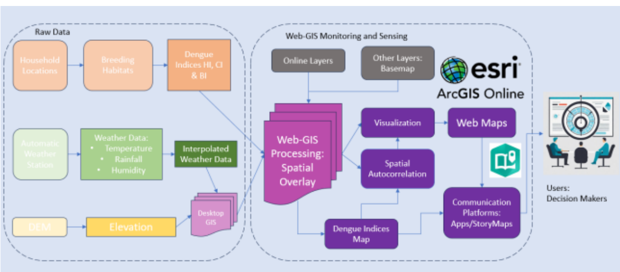

Figure 6. Flow chart showing the methodology of the influence of habitat and climate variables on Dengue Vectors in Cagayan de Oro City

2.1.1 Research Locale

The paper was conducted in Cagayan de Oro City located in the province of Misamis Oriental. It is located in the northern coast of Northern Mindanao facing Macajalar bay with Opol as the boundary in the west and Tagoloan in the east.

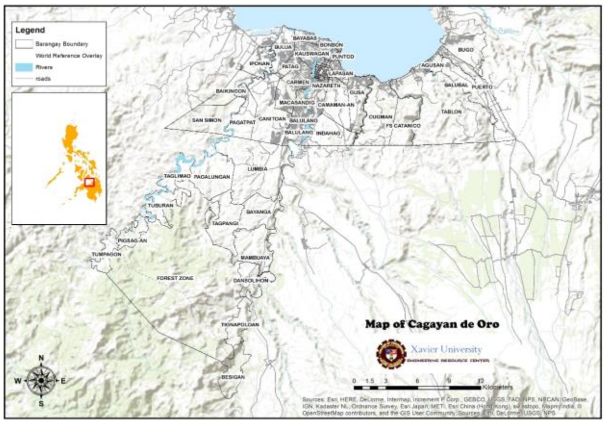

Figure 7. Barangay Boundary Map of Cagayan de Oro City

2.1.2 Determination of sampling sites

The unit of analysis in this paper is the sampling sites carried in a two-stage selection process.

In the first stage, sample sites were divided into two groups, the dengue "hotspot zones" and the non-dengue "hotspot zones". The grouping for dengue "hotspot zones" is based on the report of the Department of health in August 2016 in which five barangays were identified namely: Bugo, Bulua, Cugman, Iponan and Kauswagan. The non-dengue "hotspot zones" were purposively chosen based on areas in the city that are not identified by DOH, these are the following barangays: Bayabas, Carmen, Indahag, Canitoan and Lapasan.

In the second stage, each barangay were subdivided according to quadrants based on coordinates namely north-east (NE), north-west (NW), south-east (SE), and south-west (SW). In each quadrant, two sampling sites were randomly chosen based on X and Y coordinates per field survey. The GIS-aided selection of sites were based on 100-800 meters flight ranges of the dengue vectors (Mcdonald, 1977; Honorio et al., 2003). Table 1 shows the total number of sampling sites for the entire paper using the two-stage selection process of determining the sampling sites.

Sampling Site Selection	**n**	**# of field surveys in a year**	**Total # of sampling sites**	
First Stage			HZs	NHZs
Dengue HZs	5			
Non-dengue HZs	5	10	400	400
Second Stage				
Dengue HZs NE, NW, SE, SW	8			
Non-dengue HZs NW, NW, SE, SW	8			

Table 1. Determination of sampling sites using two-stage selection

Note: for HZ, 5 barangays X eight sampling sites X 10 field surveys = 400. For NHZ, 5 barangays X eight sampling sites X 10 field surveys = 400

2.1.3 Frequency and conditions of field sampling

Climate variables such as temperature and precipitation were the basis of field sampling. There were ten field surveys for this research and sampling were done at least once a month. If there are flooding occurrences in the city, the team conducted field sampling until such time that the ten field surveys are completed. The field sampling data was conducted by the DOST-PCHRD DenVec team which the author is part of.

2.1.4 Data Gathering Procedure

2.1.4.1 Collection of samples

Collection of larval and adult mosquitoes is based on WHO (1995) guidelines and other standard protocols (Wu et al., 2009; Mendoca et al., 2014; Getachew et al., 2015; Dom et al., 2016). Samples were collected in both indoor and outdoor premises of human habitation. Larval samples were collected from all potential habitats of dengue vectors such as domestic containers, flower vases/pots, ornamental containers, plants, toilet bowls, discarded receptacles, drains, tires, barrels, and buckets. Collection of adult mosquitoes were done using pack aspirator between 6:30-8:00 AM or 4:30-6:00 PM while the larvae were suctioned in the sampling sites between 9:00AM-3:00PM. The collection of samples was conducted by the DOST-PCHRD DenVec team which the author is part of prior to submission of this paper.

2.1.5 Laboratory Analyses

Adult mosquitoes collected in the capture chamber were examined for morphological features as basis for taxonomic identification (Stojonovich & Magennis, 1964; WHO, 1995; Farajollahi & Price, 2013; WHO, 2016; Mohamed et al., 2017). The adults of *Aedes aegyti* and *Aedes albopictus* is differentiated by the patterns of white scales on the dorsal side of the thorax (WHO, 1995). The thorax of Aedes aegypti has two straight lines surrounded by curved lyre-shaped lines on the side while that of Aedes albopictus has only a single broad line of white scales situated in the middle of the thorax (Savage & Smith, 1994; WHO, 2016)

Larval samples collected by the DOST-PCHRD DenVec Team were from different sites and habitats were allowed to develop separately in rearing bottles. Identification at the larval stages were based on the shape of the comb scales on the eighth segment of the abdomen and the shape of the pecten teeth on the siphon (WHO, 1995). *Aedes aegypti* have well developed lateral denticles in the comb teeth and the pecten teeth have less defined denticles while *Aedes albpictus* have no lateral denticles in the comb teeth and three well defined pointed denticles in the pecten teeth (WHO, 1995). The resulting analyses from this part of the study was made available to this paper to develop the Web-GIS part of the project.

2.1.6 Data Gathering Instruments

2.1.6.1 Geotagging of sampling sites and Unit of Analysis

This paper utilized a GIS method of pre-identifying the sampled households within each barangay. Coding of coordinates using spreadsheet were done prior to the field survey based on the existing map of the city. This is to ensure randomness in the selection of sampling sites. The households were mapped as point data and were the basis for the unit of analysis for the study. Each households were represented as thematic maps using choropleth method in showing the different layers collected for each household.

2.1.7 Physico-environmental variables

In the initial phase of this study about nine (9) weather stations were in operation and were considered for the physico-environmental information of the study. However, due to maintenance issues and change in ownership of the hosting institutions during the pandemic, only three (3) stations remained to record consistent weather data. From the month of January 2019 to March 2020 weather data such as temperature, humidity, rainfall amount, rainfall duration (hours per month), and rainfall frequency (number of days per month) were collected, as shown below the fluctuations in each data can be clearly seen. In terms of temperature, as shown in the minimum monthly average temperature was observed at 24.17 degrees Celsius while the maximum monthly average temperature was at 30.54 degrees Celsius. The lowest temperature was observed during December 2019 while the maximum was observed for February.

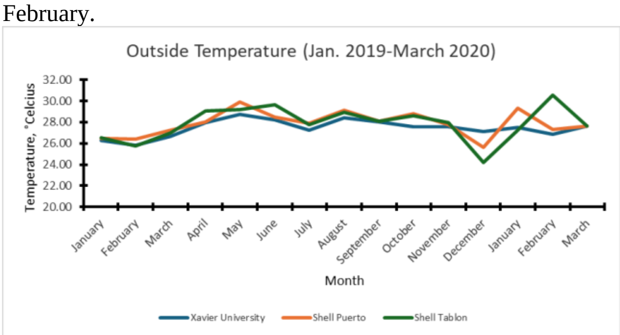

Figure 8. Outside Temperature (Jan. 2019-March 2020)

In order to supply the monthly temperature data for each barangay per month, a geostatistical analysis using Inverse Distance Waiting (IDW) was employed to predict temperature values for barangays that did not have weather stations.

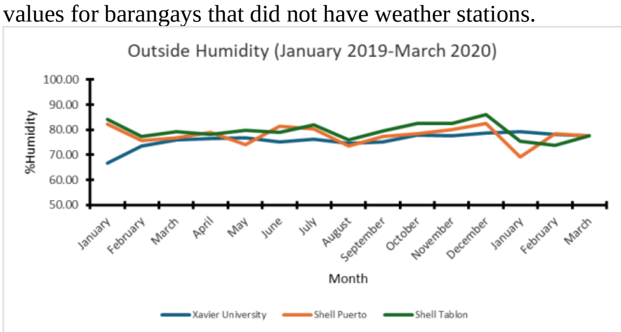

Figure 9. Outside Humidity (Jan. 2019-March 2020)

In terms of rainfall amount, duration, and frequency, as shown in Figure 10, Figure 11, and Figure 12, low rainfall values were observed for the months of February to May which is the usual dry months of the year. While the June to August months are shown with higher values compared to the rest of the months.

With the same procedure with temperature data, the rainfall geostatistical results were used to supply the rainfall values for each barangay per month, an Inverse Distance Waiting (IDW) method was employed to predict rainfall values for barangays that did not have weather stations. Starting from point layers of the weather station locations, the meteorological data were extrapolated to fill-in the data for the other barangays without a weather station. The procedure can be measured for its errors and some of the data shows discouraging results but in the absence of stations in the ground most studies have lean on this approach as the variances are tolerable although some of the errors are evident.

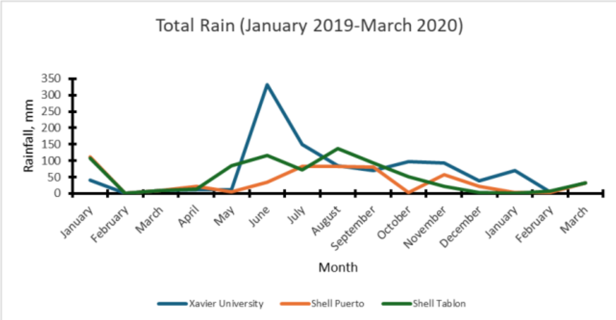

Figure 10. Total Rain (Jan. 2019-March 2020)

It can be observed that rainfall was measured in three different variables namely total rainfall, rainfall duration and rainfall frequency. The decision to have these three were based on recent studies that point to the spread of dengue vector following a recent rainfall.

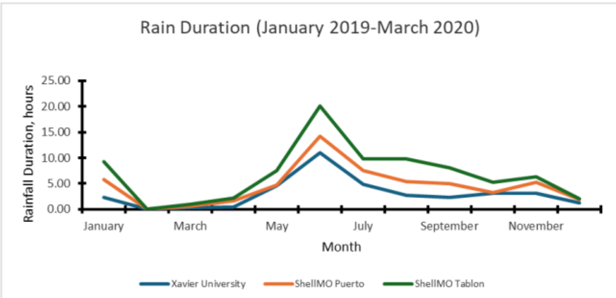

Figure 11. Rain Duration (Jan. 2019-March 2020)

The prevailing temperatures and humidity after these rain events which are usually warm and humid favors for the habitat of dengue mosquitoes and coupled with the actions of the households to stock up water in containers as often these are still a major source of water for household needs in the city.

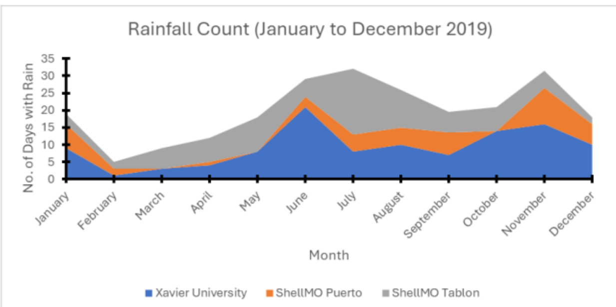

Figure 12. Rain Frequency (Jan. 2019-March 2020)

All the physico-environmental layers were mapped with an monthly interval and were converted into Web Map Services (WMS) in the ArcGIS online environment. As shown in Figure 13 below, the elevation map as well as Dengue Cases were mapped per barangay. The dengue cases map utilized the City Health Office data from https://www.foi.gov.ph/ website. From the interpolated weather data i.e. temperature, humidity, and rainfall data a Root-Mean-Square-Error was computed as shown in table 4.1, this was computed from the difference between the measured and predicted values of the Inverse-Distance-Weighting Model of a geostatistical approach.

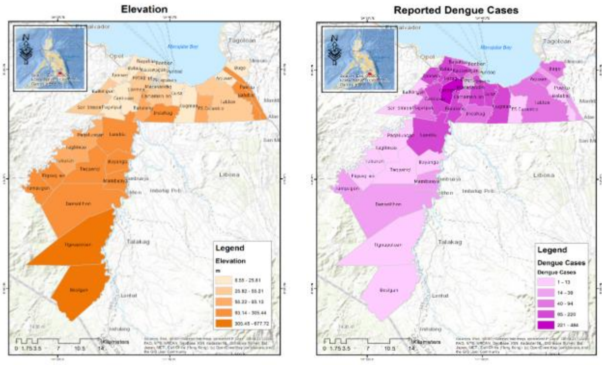

Figure 13. (Left) Elevation Map and (Right) Reported Dengue Cases Map

The resulting lowest RMSE was for temperature was for month of September, for rainfall for the month of March and for humidity for the month of March. While the highest was observed for the temperature was for the month of December, for rainfall for the month of June, and for humidity for the month of January. The high RMSE’s were observed to be due to missing data in some of the months when the stations were offline as a result of the travel restrictions imposed during the COVID-19 pandemic which resulted in the absence of maintenance of the stations. It is also noted that the year 2019 was particularly affected by a Weak El Niño. As a result of this phenomena, the eastern side of Cagayan de Oro was generally wetter than the western side of the city. Notably XU station sits in the middle of the city while the remaining two stations i.e. Shell Puerto and Shell Tablon are situated in the eastern part. This spatial and climatological variables have greatly influenced the variability of the physico-environmental data.

Month	RMSE – Temperature	RMSE – Rainfall	RMSE – Humidity
January	0.146	41.718	10.57
February	0.44	0.494	2.506
March	0.27	0.172	2.44
April	0.913	0.494	1.248
May	0.606	65.629	4.212
June	1.119	153.308	3.178
July	0.344	47.477	3.608
August	0.359	46.957	1.688
September	0.033	14.246	2.916
October	0.678	47.999	3.738
November	0.261	47.224	3.363
December	1.962	23.876	4.988

Table 2. Root-Mean-Square-Error calculation from 3 weather stations.

2.1.8 Web-GIS Mapping

All the spatial layers as independent and dependent variables were mapped in a Web-GIS platform and presented through a web map application. The information, findings, maps, and the auto-correlation results were visualized in the application. Since the maps were generated in a web-based platform it shows an interactive and real-time data which can be updated by any user. In the overlay process, the spatial unit used was the barangay level. Although this creates a statistical bias when point data is

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aggregated into an areal unit. This means that although many households were used to collect the entomological indices it does not fully represent or could even be an exaggeration of the dengue vector indices in a barangay. This only shows that the attempt of the paper to develop a visualization platform is achieved but it may take some rethinking of the spatial strategy to reduce if not remove the bias in mapping. This dilemma in geography is known as the Modifiable Areal Unit Problem (MAUP) which was later found to be significant factor in the overlay visualizations of this practicum paper. As shown in Figure 14 the system is operational but the interpretation of the indices can be biased.

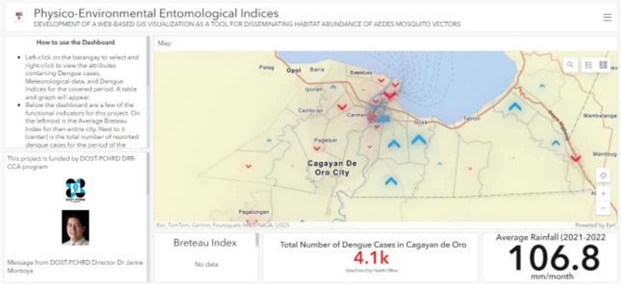

Figure 14. Overlaid entomological (dengue) indices in a Web GIS Platform.

As of this writing more weather stations were operational compared to when the data was used to build the platform. Utilizing these stations would yield better results for disseminating dengue and meteorological observations. To access this dashboard, one may use a QR code or access this hyperlink. In accessing it there is no registration needed. The site is also hosted through Xavier University – Ateneo de Cagayan's Laboratory Software License through ESRI's ArcGIS Dashboard online platform. For the sustainability of the platform the author recommends that there should be a working Academe-LGU linkage such that the LGU focuses on updating the dengue indices through its surveillance efforts while XU maintains the dashboard, weather stations and the interpretation of the data.

In terms of the Moran's I result, for the Dengue Cases, House Index, and Breteau Index all the Moran's I is positive so there is some clustering of like values (high or low) present in the data. It is also interpreted that when high values repel other high values, and tend to be near low values, the Index will be negative. This case is not present in the dataset. All p-values are less than 0.01, meaning the statistics are very highly significant to show the clustering of values. This could mean further that for the dengue indices the high values indicate a similarity between space which could potentially lead to mean that a hotspot is identified. As negative values are not present, high values do not repel each other so some independence can be seen in each barangay. Further the indices have been shown to be independent from each barangays an indication that the surveillance for each barangay is essential in the early detection of the spread of the dengue vector.

3. Conclusion

As reported in the paper, the physical-environmental, dengue indices, and geographical layers can be shown effectively in a Web-GIS platform. Due to the limitation of the analysis, the layers are visualized in web-based environment so the user accessing the application brings some benefits in interaction and the ability to visualize the nearness of events in the spatial environment. The way the system was built also encourages a faster relay of warnings and information dissemination – as stepping stone for a Decision Support System for Dengue 4S drive at the local level. The choice of areal units meaning the barangay boundaries has been chosen due to the possible interventions to be made which when deployed to the local level the barangays are the frontliners. With the consideration of the validity of the weather data, the RMSE's for the meteorological variables were computed which highlights the variability of temperature and Rainfall to be important in developing the influence of meteorological factors to the habitat of dengue vectors. These platform in effect allows for a better understanding of the outcomes of the dengue vector if left unmitigated and the causalities brought by physico-environmental factors e.g. humidity and rainfall. This work aims to contribute to the United Nations Sustainable Development Goals (UNSDG) no. 3, no.6, no.1, and no.9 in providing an accessible and data-drive systems. Also, the paper contributes a significant contribution to an improved health and well-being using state-of-the-art technologies in Geomatics.

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