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Analysis of climate variability and dengue occurrence in social-ecological systems: the case of Bay, Los Baños and Calamba in Laguna, the Philippines

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Abstract

Dengue has been recognized as a global hazard by the public health community as millions of people are at risk of dengue infection and a tetravalent vaccine for cure is to be developed [1].

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Given the disease's impact to the social-ecological systems, the influence of climate variability to the occurrence of dengue was analyzed in three areas within Laguna – the municipalities of Bay and Los Baños and the city of Calamba. In all areas, the increase in dengue cases is generally observed starting June, and the rise in number usually extend up to two months. Results show that disease-climate variability (rainfall, relative humidity and maximum temperature) is statistically significant; the occurrence of dengue is associated with climatic variables.

Specifically, it was observed that dengue is strongly to very strongly associate with rainfall in all the areas for the month of August. The months of April and October yielded strong to very strong significant association in Bay, strong and very strong association for June and March in Calamba. A very strong association was observed in April for Los Baños. In addition, dengue is very strongly associated with relative humidity and has strong and negative relationship with maximum temperature during April for Los Baños. The disease-October correlation for Calamba City is negatively significant. It was also noted that the association of dengue to maximum temperature is an important finding as the general public usually relates this disease to rainfall only.

The variations in the time and strength of association among the study areas show that the occurrence of dengue maybe influenced by multiple climate variables. This implies that the preventive measures should take into account climate services, and dengue surveillance, and allocation of resources on capacitation of human resources. These measures can facilitate better mainstreaming of climate change adaptation at the local level.

Keywords: climate; social-ecological systems; vector-borne disease

1. Introduction

Dengue fever, a vector-borne disease, has re-emerged and has been considered as a global public health hazard [2,3]. In the 2005 World Health Assembly resolution WHA58.3, dengue is considered as one of the diseases that may "constitute a public health emergency of international concern with implications for health security due to disruption and rapid epidemic spread beyond national borders" [4]. The World Health Organization [5], in 2009, reported that approximately of 50,000 dengue infections were recorded annually and an estimate of 2.5 billion people reside in areas that are considered as dengue endemic areas. The report added that majority of them are found to be locals who are residing in WHO South East Asian Region countries and WHO Asia Pacific Region states. Cambodia, Malaysia, Philippines and Vietnam are the countries with the most number of the disease from 2001 to 2008 [5].

Reference [1] stated that the control of this disease remained difficult and challenging as there has been no developed tetravalent vaccine that can provide immunity against the four dengue virus' serotypes. Furthermore, dengue has posed a health hazard, as the dengue virus can affect an individual at any stage of his/her life and the individual's immunity to one serotype does not correspond to immunity for the remaining serotypes [1]. Also, it is considered as a health hazard as it can progress into more severe forms: dengue hemorrhagic fever and dengue shock syndrome. Empirical data conclude that these conditions were proven to be fatal [5,6]. Moreover, it is predicted with low confidence that the recorded cases of dengue will increase and there will be more people who will be at risk of this disease, as climate variability and climatic changes will have an effect to the pathogen and the vector organism [7]. But Cummings [8] as cited in IPCC report [9] emphasized that the associations of dengue to either spatial, temporal and/or spatiotemporal patterns "are not entirely consistent, possibly reflecting the complexity of climatic effects on transmission, and/or the presence of competing factors."

The Philippines is not exempt from the burden of this disease. Statistics show that dengue ranked tenth as the major cause of mortality in the country in 2010. A report from the Department of Health (DOH) in 2010 identified dengue hotspots (areas that have clustered cases with increasing number in two consecutive weeks) of which Calamba, a city in Laguna, Philippines, is included [10]. Moreover data from the Laguna Provincial Health Office from 2001 to 2009 show the increasing cases of dengue, in each municipality and city of an important microwatershed in Laguna.

A dearth of literatures in the Philippines indicate that the increasing trend of dengue is due to the changing climate. Su [11] attributed the increase in reported cases in Metro Manila for the period of ten years (1996 to 2005) to rainfall only. Lorenzo and his colleagues [12], in Strengthening the Philippines' Institutional Capacity to Adapt to Climate Change in the Health Sector Report, analyzed the causality of other climatic factors such as temperature, relative humidity, and environmental factors in Rizal, Palawan and Pangasinan using health and weather data from 1992 to 2009. Their team also developed a dengue impact model: Dengue cases = -1267.347 – 0.615* monthly rainfall – 21.398* maximum temperature + 31.442* relative humidity [12]. They further projected that dengue cases due to climate change variables in the National Capital Region (NCR) will be about 1, 735 in 2020 and 2,128 in 2050. With this scenario, the total estimated cost of dengue is at 13.99 million PhP in 2020 and 43.6 million PhP in 2050 [12].

Furthermore, reference [12] estimated that planned adaptation which includes preventive measures prior 2020 and 2050 will incur cost estimates of 2.8 million PhP and 8.11 million PhP, respectively. In terms of net savings, the researchers reported that local government units that adapt to climate change may save 11.19 million PhP in 2020 and 35.51 million PhP in 2050 [12]. In a nutshell, changes in climate involve costs and damages to various social-ecological systems. Hence, it is imperative to analyze the effects of climatic factors on the occurrence of dengue at various scales including national and local.

In this study, the municipalities of Bay and Los Baños and the city of Calamba, all in Laguna province were studied (Figure 1). Calamba city is an important industrial center; Los Baños is considered as both as a repository of genetic resources of indigenous flora and fauna species in the main site of the Makiling Forest Reserve and an important area for research and biodiversity conservation [13]; and Bay is an agricultural area, with people mainly involved in farming and fisheries. Bay, Los Baños and a portion of Calamba comprise the Los Baños Makiling Microwatershed (LBMM). The LBMM has provided the communities various ecosystem services - provisioning, regulating and supporting.

This research analyzed the relationship of climate variability and the occurrence of dengue in each locality using the following factors: rainfall, minimum temperature, maximum temperature and relative humidity. Specifically, it sought to characterize the occurrence of dengue in each locality and to determine the strength of association of each climate variable against the occurrence of dengue within each area. Other climatic factors and drivers such as land use and urban growth, which may have an effect on the presence of dengue in the province were not considered in this study.

In collaboration with local stakeholders and policymakers, the implications of these findings may serve as baseline for mainstreaming climate change adaptation in development plans of these localities, persuant with Republic Act 9729 or “Climate Change Act of 2009”. Moreover, public health administrators and policy-makers could consider the results of the study as basis for planning in terms of provision and allocation of scarce resources.

2. Materials and Methods

2.1. Study Area

The Los Baños Makiling Microwatershed provides water for various sectors: (i) agriculture including irrigation waters; (ii) domestic and (iii) commercial lines including potable water for households and water for business establishment.

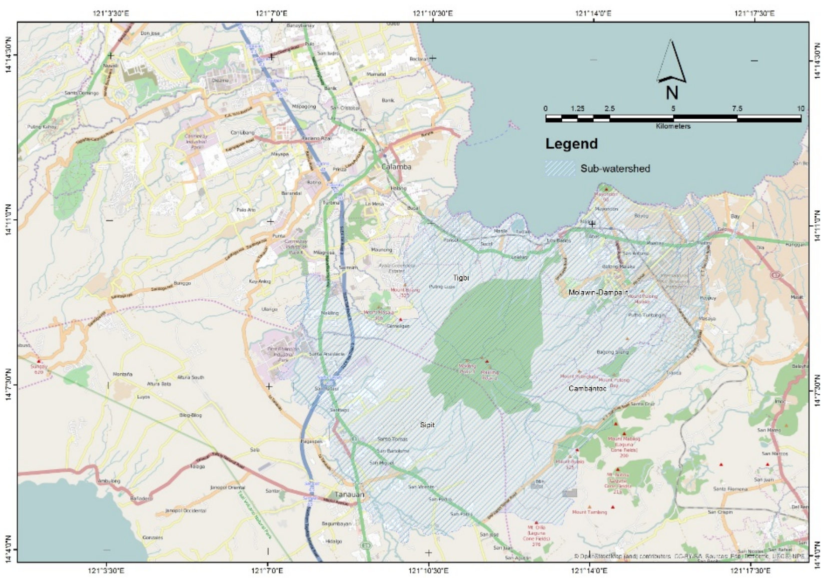

Figure 1: Location map of the study area.

Also, the water from Mt. Makiling plays an important role in boosting the tourism revenue in the area as tourist usually visits Dampalit Falls in Los Baños and the hot springs in Calamba city [13]. In addition, the provisioning, regulating and supporting services from the LBMM can enable human systems to secure conditions that will help them achieve a better state of living and a more positive well-being. Specifically, some biophysical and socio-economic characteristics of the municipalities and city are presented in Table 1.

Table 1: Biophysical and socio-economic characteristics of Bay, Calamba city and Los Baños, Laguna

Characteristics	Bay	Calamba	Los Baños	Data Source
Urbanization	2nd class municipality	1st class city	1st class urban municipality	[14]
Land area (ha.)	4,266	14,950	5,422	[14]
Land use	residential (6.73%),	residential (48%),	agricultural	[15]
	commercial (0.05%)	industrial (44%),	commercial	
	institutional (1.11%),	commercial (5%) and	forestry conservation area	[16]
	agricultural (68.43%)	other land uses (5%)	institutional, parks	
	forest (21.91% and		open spaces and	
	industrial (0.09%)		residential	
	geothermal plant and other special uses (3.49%)			
Susceptibility to flooding	high	medium	low	[17]
Total population	50,756	360,281	98,631	[18]
Population growth rate (%)	2.07	3.48	2.58	[19]

2.2 Data Collection

The monthly recorded cases of dengue for each study area in LBMM from January 2001 to December 2009 were collected from the Provincial Health Office of Laguna. The health data sets are aggregate, based on the respective reports of the Municipal and City Health Offices [20]. The daily data for rainfall, temperature (minimum and maximum) and relative humidity were gathered from Philippine Atmospheric Geophysical and Astronomical Services Administration- National Agrometeorological Station (PAGASA-NAS) [20] in UPLB. The daily rainfall data is the total 24 hour rainfall collected in the rain gauge.

2.3 Data Processing and Analysis

Databases were constructed for the daily data for rainfall, relative humidity, minimum temperature, and maximum temperature for the period 2001-2009 using spreadsheet program. The monthly total rainfall, monthly average minimum and maximum temperatures and average relative humidity for each year were generated from daily values. Data transformation was done to facilitate compatibility of the weather variables with the available monthly health data on dengue cases [21]. Only one set of meteorological data was used for the areas within LBMM, as all of the sites fall under the acceptable radial distance from the weather station.

The relationship and strength of association between climatic factors (monthly total rainfall, monthly average minimum and maximum temperature and monthly average relative humidity) and the recorded cases of dengue fever were both determined using Pearson product moment correlation analysis. Correlation coefficient was interpreted based on the following scale:

0.0	No association
0.01 – 0.20	Very weak
0.21 – 0.40	Weak
0.41 – 0.60	Moderate
0.61 – 0.80	Strong
0.81 – 0.99	Very Strong
1.0	Perfect association

3. Results and Discussion

3.1. Characterizing dengue in Los Baños Makiling Microwatershed (LBMM) and surrounding areas

Dengue fever in the LBMM is observed to be present annually from 2001 to 2009 (Figure 2). Initially, the annual count of dengue cases declined from 2001 to 2002. But it was later followed with a continuous increase for five consecutive years starting 2002. A decreased followed from 2007 to 2008; the next spike in the graph was observed in 2009. Within the nine-year study period, the lowest annual total count of dengue cases was recorded in 2002, with 37 cases while the highest was in 2007, with 879. The distinct increase in dengue in 2007 was not exclusive in these areas. Mia and his colleagues [21] reported that Malaysia also faced the burden of this disease in 2007 when an average of 48,500 cases was diagnosed. The Pan American Health Organization (PAHO) as cited by Barclay [22] declared 2007 as the one of the worst years for the region, with 918, 495 people who experienced dengue hemorrhagic fever [22].

More than half (54.05%) of the dengue cases in 2002 is reported in Calamba City followed by Los Baños (24.32%). The same observation applies for the dengue cases in 2007 (60.52% and 35.04% in Calamba City and Los Baños, respectively). This finding is applicable for the rest of the years under study except in 2008. Thus in this microwatershed, most of the recorded dengue cases are reported in urban areas (Calamba and Los Baños). Literature poses that the occurrence of dengue is supported by conditions of an urban environment [23,24,25] [6]. Conditions include presence of human-made containers such as tires, domestic water storage and stagnant pool of water [24,23,6].

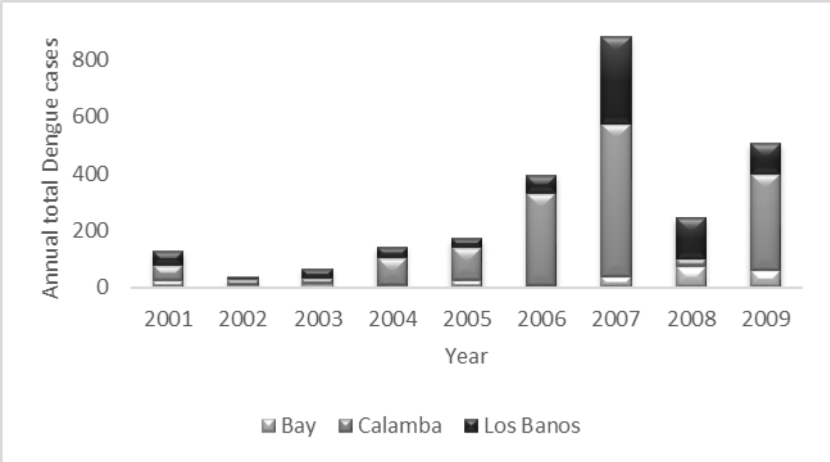

Figure 2: Reported dengue cases in Bay, Calamba city and Los Baños, Laguna (2001-2009).

Looking closely at the months of occurrence, dengue cases were not observed in April, May and December 2001; February, March, May and June 2002; and May 2003 in LBMM. But starting 2004, dengue cases were recorded at a monthly basis (Figure 3). Dengue cases, based on monthly total count for the all the study areas, were at its peak in October (17.25%), then in September and in August (16.25% and 15.3%, respectively). The observation was supported as the highest spike in dengue cases at a single point in time occurred in October 2007, corresponding to 8.22% of the monthly total recorded cases. This observation is not aligned with the study of Wongkoon and his colleagues [26] as the peak rate of dengue transmission in Thailand occurs in June. However, it corroborates the findings of Coelho and his colleagues, [27] wherein the peak months of dengue in Brazil are within the rainy season, starting October. Philippine data shows that dengue occurrence are mostly observed and are correlated during rainy season [11].

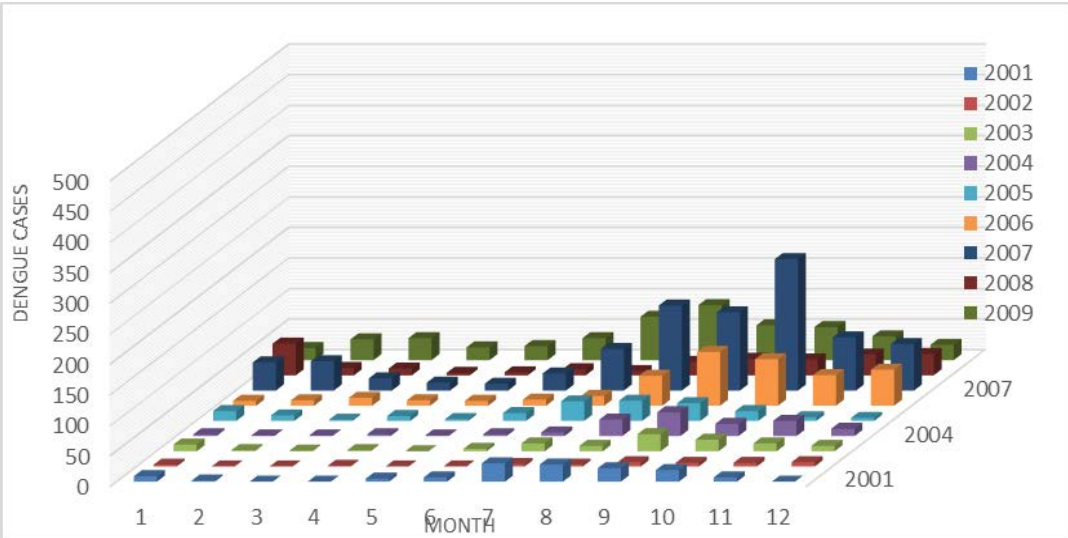

Figure 3: Monthly distribution of reported dengue cases in Bay, Calamba city and Los Baños, Laguna (2001-2009).

In the three areas considered, the cases of dengue usually increases starting June (except in 2008). The increase in the monthly number of dengue cases continue from one to four months as shown in Table 2. The most common period of increase is up to two months, specifically from June to August. In the study of Coelho and his colleagues [27], the period of increase usually last for a period of three months.

Table 2: Periodicity of increase in the recorded cases of dengue in Bay, Calamba and Los Baños, Laguna, in the Philippines from 2001 to 2009.

Number of months showing increase in number of dengue cases	Duration (months within a year)	Year
▪ One	June to July	2002, 2003
	August to September	2002, 2003
	September to October	2007
	November to December	2002, 2006
▪ Two	June to August	2001, 2005, 2007, 2009
	October to December	2008
▪ Three	June to September	2004
▪ Four	June to October	2006

In addition, it was observed that the cases of dengue decreased either in August, September or October. Interestingly, there were years wherein a continuous decline in the cases extended up to three months or more, from September to December and August to December, respectively (Table 3). In several observations (2003, 2006, 2007, 2008), the decline extended until January of the succeeding year.

Dengue cases are observed to be relatively low in the following months: January (except in 2001, 2006 and 2009), February (except in 2002 and 2004), March (except in 2006, 2008 and 2009), April (except in 2005) and May. In the case of the three areas, the occurrence of dengue is prominent during the rainy to cool dry season and recedes during hot dry season. This finding further supports the claims of Rosa-Freitas and his colleagues [28] and Thu, Aye and Thein [29]. In the study of Thu, Aye and Thein [29], a laboratory set-up simulating a rainy season condition (23-30 °C, 90% moisture) led to 82% emergence of well-developed adult mosquitoes, which had shorter developmental period. Based on their study, the temperature and relative humidity during the rainy season facilitated faster development from larvae to adult stage. Regis and his colleagues [30] as cited in Costa and his colleagues [31] marked that there are more eggs per trap-cycle during January to August.

Table 3: Periodicity of decrease in the recorded cases of dengue in Bay, Calamba and Los Baños, Laguna, in the Philippines from 2001 to 2009.

Number of months showing decrease in number of dengue cases	Duration (months within a year)	Year
▪ One	June to July	2008
	July to August	2002, 2003
	August to September	2007
	September to October	2002
	October to November	2006, 2008
▪ Two	October to December	2007
▪ Three	September to December	2004, 2003, 2004
▪ Four	August to December	2001, 2005, 2009

3.2 Climate variability and dengue in Bay, Calamba and Los Baños, Laguna

3.2.1. Rainfall

Bay. The occurrence of dengue is found to be significantly associated to rainfall in three months – April, August and October (Table 4). Dengue exhibited very strong correlation to rainfall during the months of April and August and strong correlation in October. It is observed that the sine curve of the months showing significant association increased from a lower range one month prior. On the other hand, the occurrence of dengue has a very weak relationship with rainfall during the cool dry season (DJF) and in some months of the wet season (July and September). The months of November, December and July even exhibited an inverse correlation.

Calamba. The occurrence of dengue is strongly to very strongly correlate to rainfall during the months of March, June and August in Calamba city (Table 4). Like in Bay, the sine curve of these significantly associated months rose prior then declined afterwards. Among the areas considered, it is only in Calamba city wherein a positive relationship of dengue and rainfall is exhibited all-throughout the year.

Los Baños. The strength of association between the months and disease in Los Baños is the same with the two areas. Dengue is observed to be very strongly and significantly associated to rainfall in April and August, respectively (Table 4). The month-disease association for both months is also observed to be significant in Bay.

There are months in Los Baños wherein a negative and not significant relationship are present. This finding is similarly observed in Bay.

Overall, there were two commonalities observed for the areas studied: (i) the rainfall in August was found to be significantly associated to dengue at certain months and (ii) the sine curve of months that were significantly associated with dengue follows the same pattern in Bay, Calamba city and Los Baños. The mean monthly rainfall for August ranges from 180.10 to 469.10 mm.

Table 4: Summary of total monthly rainfall (mm.) and monthly dengue cases' correlation in the study areas.

Total Monthly Rainfall (mm)	Bay	Calamba	Los Baños
January	0.002	0.064	0.425
February	0.044	0.231	-0.183
March	0.267	0.913**	0.617
April	0.857**	0.142	0.949**
May	0.346	0.564	0.402
June	0.364	0.693*	-0.077
July	-0.013	0.217	0.043
August	0.903**	0.732**	0.951**
September	0.052	0.644	-0.339
October	0.722*	0.104	-0.13
November	-0.134	0.666	0.579
December	-0.123	0.188	0.222

*correlation is significant at the 0.05 level (2-tailed)

** correlation is significant at the 0.01 level (2-tailed)

Rainfall affects the occurrence of dengue in a specific area by increasing the quantity of mosquito habitats and maintaining the water level in the newly-created habitats [11,32], which is important for the larvae' survival and for reproduction of adult mosquitoes. This claim is supported by the findings that there is a wider distribution of mosquito during periods of high precipitation, including La Niña season [33].

3.2.2. Relative Humidity

Bay. There is a very weak to weak positive and not significant association between dengue occurrence and relative humidity, except for the month of April, in the municipality of Bay (Table 5).The same pattern was observed during the rainy season. Also, the month-disease occurrence has negative and not significant correlation coefficients in June, July, November and December. All these months fall under the rainy season.

Calamba. In contrast, an inverse and not significant relationship between dengue incidence and relative humidity was noted during the months of February, March, April, July and August in this area (Table 5).

Though a positive yet not significant relationship was observed for the rest of the year, the strength of the correlation coefficients among months range from very weak to weak, except in July (r=-0.573 ns).

Los Baños. On the other hand, a positive association is present in Los Baños for half a year (January, April, May, September, October, and November), indicating that the percent moisture is related to dengue. Moreover, this site has the most number of months with inverse relationship. The exhibited strength of relationship between dengue and relative humidity is similar with Bay and Calamba City except for the months of January and April. The correlation between April-disease occurrence and relative humidity in Los Baños is the only value that showed very strong significant association (r =0.845 at 99% confidence level). The percent mean relative humidity in April ranges from 75.73 to 83.33.

Table 5: Summary of monthly average relative humidity (%) and dengue cases' correlation in the study areas.

Relative humidity (%)	Bay	Calamba	Los Baños
January	0.337	0.014	0.492
February	0.233	-0.163	-0.324
March	0.149	-0.023	-0.155
April	0.635	-0.063	0.845**
May	0.232	0.094	0.133
June	-0.294	0.096	-0.122
July	-0.301	-0.573	-0.532
August	0.019	-0.363	-0.007
September	0.062	0.317	0.236
October	0.203	0.197	0.381
November	-0.376	0.122	0.177
December	-0.277	0.137	-0.272

*correlation is significant at the 0.05 level (2-tailed)

** correlation is significant at the 0.01 level (2-tailed)

A study in the Amazonian State of Roraira, Brazil reported that higher relative humidity has been associated with increasing dengue case numbers [28] during January to April only. In another study by Costa and his colleagues [31], this climate variable can affect the life span of mosquito, as this arthropod lives longer in humid conditions and lower temperature (80% and 25°C).

3.3.3. Minimum Temperature

Bay, Calamba and Los Baños. A significant correlation between the month-disease occurrences for Bay, Calamba city and Los Baños was not observed (Table 6). And majority of the values show a very weak to weak association between minimum temperature and dengue occurrence. The results are consistent with the findings of Lorenzo and her colleagues [12] which states that minimum temperature is not a determinant of dengue in areas of the Philippines where they had studied.

Table 6: Summary of monthly average minimum temperature (°C) and dengue cases' correlation in the study areas.

Minimum temperature (°C)	Bay	Calamba	Los Baños
January	0.096	0.140	0.240
February	0.028	0.186	-0.221
March	0.382	0.196	0.123
April	-0.011	-0.057	0.377
May	-0.552	-0.223	-0.334
June	0.303	0.143	0.301
July	0.461	0.327	0.041
August	-0.054	0.251	-0.126
September	0.464	0.108	0.316
October	0.293	-0.01	0.196
November	0.413	-0.396	0.039
December	-0.127	0.464	0.343

*correlation is significant at the 0.05 level (2-tailed)

** correlation is significant at the 0.01 level (2-tailed)

3.3.4. Maximum Temperature

Bay. An inverse relationship between maximum temperature and dengue was observed during cool dry months (December to February) to hot months (March to May) until the first month of the rainy season (June). Moreso, the month of April yielded a significant and very strong association (Table 7). The maximum temperature in April ranged from 32.1 – 34.9 °C.

Calamba. Like Bay, there were months in Calamba city wherein the month-disease association had a negative relationship (April, May, August, September and October). It was only during the month of October yielded a significant and strong association with dengue (Table 7). The range in maximum temperature in October is 31.1 – 32.2 °C.

Los Baños. A negative relationship between temperature and dengue was observed in this area similar to Bay and Calamba. In contrast, the frequency of months exhibiting positive relationship with the disease is higher in Los Baños than the two other areas. The month of April also showed a significant and strong association to dengue.

Furthermore, it was observed that there was an inverse relationship among all the months wherein the month-disease association is significant for Bay, Calamba city and Los Baños. This means that as temperature increases up to a certain threshold, it can be associated with dengue. However, mosquitoes cannot thrive beyond ambient temperatures. According to Lorenzo and his colleagues [12], areas that are near Laguna de Bay are highly vulnerable to dengue. This is attributed to the faster evaporation rate and decrease in water level to a stagnant height, which can create habitats for the growth and development of immature mosquitoes and for reproduction [12]. The difference in the associated months is determined by the physical environment, human activities and the health of the ecosystems in the three study areas. Aside from its effect on the mosquito's habitat, temperature influences both the (i) development, survival and reproduction of the vector [34,32,35,36] and (ii) the replication and transmission of the dengue viruses [32,35,6].

Table 7: Summary of monthly average maximum temperature (°C) and dengue cases' correlation in the study areas.

Maximum temperature (°C)	Bay	Calamba	Los Baños
January	-0.029	-0.205	-0.118
February	-0.342	0.141	0.061
March	-0.177	0.222	0.217
April	-0.804**	-0.095	-0.796*
May	-0.419	-0.467	-0.463
June	-0.007	-0.289	0.097
July	0.493	0.241	0.528
August	0.316	-0.122	0.154
September	0.182	-0.019	0.104
October	0.169	-0.679*	-0.551
November	0.044	-0.067	-0.301
December	-0.456	0.351	0.01

*correlation is significant at the 0.05 level (2-tailed)

** correlation is significant at the 0.01 level (2-tailed)

Mosquitoes reach their mature stage at a faster period in ambient warm temperature compared to cooler temperature [37] (as cited in) [35]. Epstein and his colleagues, [38] notes that survival rates of mosquitoes depend on an acceptable temperature range (a maximum threshold) that would allow mosquitoes to survive. In addition, adult mosquitoes that thrived in warm temperature have faster metabolism amidst the smallness of their body size, thus these organisms need more food (blood meal) from host organisms [39]. An increase rate of contact with host organisms leads to (i) better development of mosquitoes' eggs from the protein in the blood [6,32] and (ii) higher chance of viral transmission from the vector arthropod to the human host [6,32].

Moreover, temperature was found to have an effect on virus' extrinsic incubation period (EIP) which is, *"the time taken for the pathogen to develop in the mosquito until the insect becomes infective"* [6]. Watts and his colleagues [34] concluded that high temperature (32-35°C), though it can lead to higher mortality of mosquitoes at day 25 compared with mosquitoes reared in the laboratory at 30 °C, hastens the EIP to seven days. The dengue virus' EIP at 30°C took 12 days and longer [34]. Since IPCC [7] reported that there has been a significant warming across the globe, this condition will become more favorable for the viruses as a higher temperature at a certain threshold would result to a shorter EIP. Consequently, this can lead to a higher chance of transmission from the vector to the host organism [6]. A mean temperature of more than 35 °C can lead to death of mosquitoes and alongside relative humidity, can result to a decrease in the insect's population densities [31].

4. Conclusions and Recommendations

Climate variability and health is recognized as a global international concern yet its direct and indirect impacts to the ecosystems and in situ communities differ, as shown by the varying correlation among the month-disease occurrence and a specific climate variable. Among the climatic variables, rainfall, relative humidity and maximum temperature were found to be strongly to very strongly correlated (at 95 and/or 99% level of significance) with the occurrence of dengue in the Los Baños Makiling microwatershed at specific time period (from March, April, August and October). There are differences in the period and strength of association among the municipalities of Bay and Los Baños and the city of Calamba, in Laguna, the Philippines. These findings show that the occurrence of dengue maybe influenced by multiple climate variables, their interaction with each other and the microclimate [40]. Likewise, it should be noted that anthropogenic activities and the health of ecosystem in each locality affects the microclimate.

Generally, the public usually link the occurrence of dengue to rainfall but not to temperature. It is deemed necessary that citizens, including the industrial sector, in these areas be informed so that they can become more concerned about their activities as well as the effects of these to the earth's atmospheric concentration and global temperature [7].This piece of information on the relationship of human activities and the growth of vectors and viruses can aid various stakeholders, institutions, and organizations in the planning on adaptation. Capacitation can also facilitate better management of perceived and actual future climate risks [38,40].

It is suggested that the public health community in Bay, Calamba City and Los Baños may also opt to revisit the health systems in placed in relation to dengue surveillance per area to (i) track of dengue cases and transmission trends especially during the associated months, (ii) estimate future cost of the disease in the locality and (iii) facilitate optimization of resources through cost-effective preventive measures/ prevention programs [3,42] and will consider the varying association of climate variables over the seasons of a year.

As this is a preliminary exploratory study, it is also recommended that prediction models be developed for each site, to serve as input for a local early warning system. This system can be used as a basis for epidemic contingency plans. The model generated by [12] can also be tested. Should it fit, it can then be considered for possible adoption so that climate science and climate services can be recognized as important resources in the development plans of these social-ecological systems.

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