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A Systematic Review on the Association Between the Climatic Factors and the Prevalence of Disease in the Philippines with Respect to the Trends in Other Southeast Asian Countries

Kyle Gregorio[1] and Ysabelle Guzman [2] and Zeba F. Alam [1, *]
[1] *De La Salle University Manila*
[2] *De La Salle University Manila*
**Department of Biology, Head EBRU, CENSER De La Salle University: zeba.alam@dlsu.edu.ph*

Abstract: A systematic review approach was used to investigate the prevalence of five climate-induced diseases and their correlation with temperature and precipitation in the Philippines and compare it with the trends in other Southeast Asian countries. Using the databases (PLOS NTDs and PubMed), a systematic review was conducted under PRISMA guidelines. Studies from 1990 to 2020 on five diseases in Southeast Asia were included, screened, and ranked by three independent authors through JBI checklist. Data from Philippines was analyzed and correlated with temperature and precipitation. 22 studies were included in the review, with all having a score of at least 7 in the JBI checklist. Dengue showed increasing trend for the past 30 years throughout Southeast Asia, while malaria, malnutrition, leptospirosis, and cholera cases decreased. Correlation's analysis showed that temperature increase affects malaria and dengue cases, while precipitation affects stunting, cholera, and leptospirosis. The findings presented show the relevance and feasibility of doing systematic review on climate change and human health and disease prevalence trends specific to a particular location and region. The systematic review found that all diseases included in the study are correlated with a climatic factor while one negatively affects people's lifestyle. Since the Philippines is at a high risk for effects brought by climate change, the improvement of the health care system is needed to tend to possible disease surges. To the best of our knowledge, this is one of the first studies on the compilation of data related to climate change induced diseases in the Philippines.

Key Words: Climate change; Southeast Asia; Philippines; Diseases

1. INTRODUCTION

Climate change is the change in the normal weather experienced by certain place at a certain time with respect to the amount of annual precipitation or the usual temperature in each season or month (NASA, 2015). While the Earth's climate has naturally changed in the past thousands of years, the climate change that scientists of today refers to is far from being natural and poses a great threat to all the life on the planet. The current trend in climate change would put many countries at risk particularly those that belong to the Southeast Asian region. The Philippines is the most vulnerable country against climate change. In the near future, the greater threat of rising sea-levels would be felt in the country if the trend in the climate continues. It is estimated that

much of the capital city Manila, could be submerged underwater by 2100 (Amnesty International, 2018).

1.1 Purpose and Rationale

Numerous studies on different climate-induced diseases around the world are recorded, though only a few focused on their prevalence in Southeast Asia. Providing trend reports for climate change and disease prevalence in health databases can provide awareness to their citizens, especially in countries with endemic hotspots for these climate-induced diseases. Dengue, malaria, cholera, leptospirosis, and malnutrition are few of the most susceptible to changes in the environment and thus are expected to pose a great threat to human health since climate change is also projected to continue in the future (CDC, 2021; NASA, 2021). Hence, the present study was conducted to prepare a systematic review by collecting and analyzing the data on the trends and prevalence of these climate-induced diseases in the Philippines and other Southeast Asian countries.

2. METHODOLOGY

2.1 Search strategy

In accordance with the PRISMA guidelines, literature search was conducted using PubMed and PLOS NTDs. After article collection, duplicates were removed. Title and abstracts of the articles were then independently screened (K.J.R.G., Y.M.M.G., Z.F.A.). Supplementary manual search was also conducted by scanning the reference list of the included articles.

2.2 Eligibility criteria

Articles were considered eligible if they are: (1) Primary literature, (2) peer-reviewed, (3) published between 1990-2021, (4) in English, (5) discussed one or more included disease, (6) discussed cases in Southeast Asia, (7) discussed climate change or other related concepts, (8) discussed disease trends or projections and its association with climate change, and (9) discussed precipitation or temperature as a factor for the disease.

2.3 Quality assessment

Included studies were appraised independently (K.J.R.G., Y.M.M.G., Z.F.A.) using the JBI appraisal checklist for studies reporting prevalence data. It was composed of 9 questions all of which were answerable by either: yes, no, unclear, or not applicable.

2.4 Data extraction

Identification of climate trends were collected using articles from publishing platforms (e.g., PubMed and PLOS NTDs) and government agencies such as PAG-ASA. Meanwhile, disease prevalence was collected from secondary sources such as websites handled by universities and government agencies (e.g. Department of Health). Lastly, data from the included articles were extracted. Collected data included (1) Title, author, and publication year of the article. (2) Trends or projections of the included disease/s. (3) Its association with climate change or precipitation and temperature.

2.5 Data analysis/ Statistical tools

Microsoft Excel was used to compile and create a visual representation for the collected data. Multiple regression analysis using *Statistica* software was conducted to determine whether the relationship and correlation between temperature and precipitation with disease trends were significant. Multiple regression was used since two independent variables (Temperature & Precipitation) and one dependent variable (Disease prevalence) were present.

3. RESULTS AND DISCUSSION

3.1 Search Results

Identified records from both PubMed and PLOS NTDs yielded 12632 records. After duplicates and those that did not meet the eligibility criteria were removed, 22 records remained and were included in the systematic review. Meanwhile, the JBI appraisal checklist showed that 20 out of 22 of the eligible studies garnered a score of 8 out of 9 while the other 2 scored a 7 out of 9. At least 7 points must be garnered by a study for it to be considered a good quality study (George et al., 2014).

3.2 Leptospirosis

The Gram-negative bacteria *Leptospira interrogans* is known to be the leading cause of

leptospirosis. The standing water due to floods gives the breeding environment for the bacteria to be able to stay viable and remain in water and soil for weeks even after the floods have receded (Johnson, 1996).

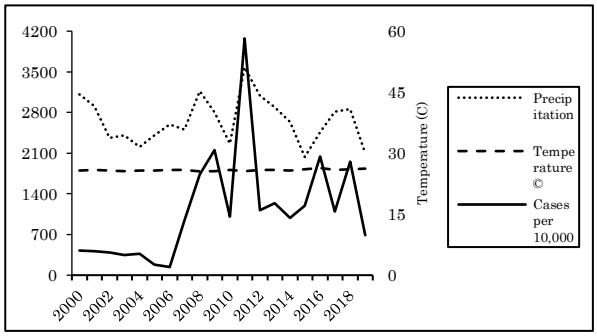

Fig 1. Relationship of climatic factors with leptospirosis cases per 10,000 population in the Philippines

Fig 1 shows the annual cases of leptospirosis in the Philippines and its relationship with local precipitation records and temperature. Based on the statistics and graph, no significant association between leptospirosis cases and temperature was found ($p = 0.40$). However, precipitation and the cases showed a very distinct correlation based on the graph, as well as a significant statistical result ($p = 0.0079$). It is worth noting that outbreaks of the disease were shown to occur after very strong typhoons and heavy rainfall. Leptospirosis cases experience a lag, ranging from 1 week to 4 after exposure to the contaminated waters. Matsushita et al. (2018) saw these 2-week onset patterns after a reported flood in other studies covering other parts of the world such as Hawaii and India. A pattern called "harvesting" explains this phenomenon, where a lag occurs between exposure and onset of symptoms (Schwartz et al., 2004).

In terms of Southeast Asia, fluctuating trends per country were observed, the majority of which are caused by immense flash floods and heavy rains. Increased cases of leptospirosis were observed in Thailand from 1995 to 1999, while cases from Malaysia spiked up in the 2010s. Cases from Singapore were minimal, as it is not an endemic disease in the country. Indonesia also has little to no cases despite experiencing intense typhoons and rainfall, most likely due to inconsistencies in reporting these cases (Appendix 1).

3.3 Cholera

Cholera is a known waterborne disease that would mainly be transmitted through waters and food contaminated by the bacteria *Vibrio cholerae* (Mahon & Lehman, 2019). Flooding is the main cause of transmission of the already-present bacteria in the environment. These bacteria, along with other carriers of the bacteria, can be carried along by the floods and contaminate livestock and waters that are necessary for people in different communities (Brown & Murray, 2013).

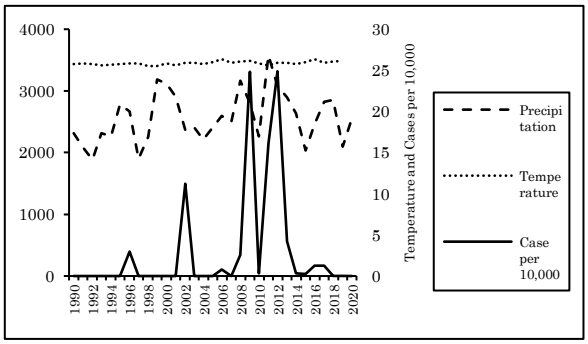

Fig 2. Relationship of climatic factors with cholera cases per 10,000 population in the Philippines

Fig 2 shows the graphical representation of the relationship of cholera cases with the annual precipitation and temperature in the Philippines. No particular spikes in the cases coincided with the temperature, and no significant statistical relationship was observed ($p = 0.160$). However, opposite results and statistical significance was seen when compared with precipitation ($p = 0.04$). Though temperature is part of the viability of *V. cholerae,* other factors such as the presence of water, salinity (15%), and pH (8.5) should have been also taken into consideration (Christaki et al., 2020). The correlation between rainfall and the rise of cholera cases is direct, with the reasoning that the amount of precipitation determines the gene expression of the two *V. cholerae* strains that are known to cause the disease, O1 and O139 (Christaki et al., 2020).

In Southeast Asia, cholera trends are also fluctuating, with some countries having cases above 200 per 10,000 population like Myanmar and Laos, while the rest are below such. Countries like Indonesia have recorded cholera cases as nonspecific diarrhea, which is a main reason for the low number. Singapore, Vietnam, and Malaysia are observed to

have the same trend, with majority being local transmissions rather than international (Appendix 2).

3.4 Malnutrition

Malnutrition is defined as the deficiency or imbalanced intake of nutrients of a person particularly in children. Undernutrition can then further be divided into two. The first one would be wasting which is low weight for height and stunting which refers to low height for age.

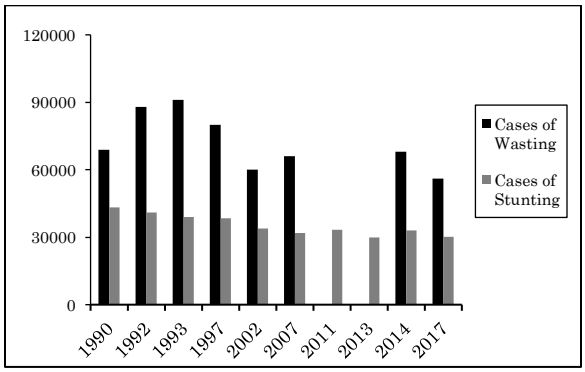

Fig 3. Number of children below 5 years of age experiencing stunting and wasting in the Philippines

Fig 3 shows the cases of malnutrition in the Philippines from 1990-2017. Along with other Southeast Asian countries, cases are steadily decreasing, however the overall numbers are still high. It is worth noting that nutrition is heavily dependent on food production and can be influenced by temperature and precipitation. Since temperatures above 40° C are detrimental to the growth of rice plants, an increase in temperature would decrease rice yield and will have the potential to threaten food security in the Southeast Asian region (Nguyen, 2002). However, using multiple regression, it was found that in the Philippines, both wasting and stunting did not have a significant relationship with temperature with both having a p-value of 0.3. This is because while temperature is increasing, it is still within the range in which crops can grow which explains why its effects might not still be felt for now. Error bars are not applicable for this data since all were obtained from the government or published journal articles. Meanwhile, it is also found out that that wasting does not have a significant relationship with precipitation (p= 0.3) while stunting does (p= 0.02). The significant relationship between precipitation and stunting might be attributed to the effects of precipitation on crop growth. Seasonal weather could change flowering and fruiting timing of plants and its relationship with pollinators (Harrington et al., 1999). The lack of significance between wasting and precipitation can be attributed to the fact that wasting is a greater degree of malnutrition and thus, other factors such as poverty, and food quality might have a more significant relationship with it compared to environmental factors (Jones, 2018).

Overall, the Southeast Asian region is experiencing a decrease in cases in both stunting and wasting. However, the numbers are still high and actions against it must still continue (Appendix 3).

3.5 Malaria

Malaria is a disease that is caused by the parasite *Plasmodium spp.* It is vectored by the mosquito *Anopheles spp.* It is a life-threatening disease; however, it is preventable and curable thanks to current advances in technology.

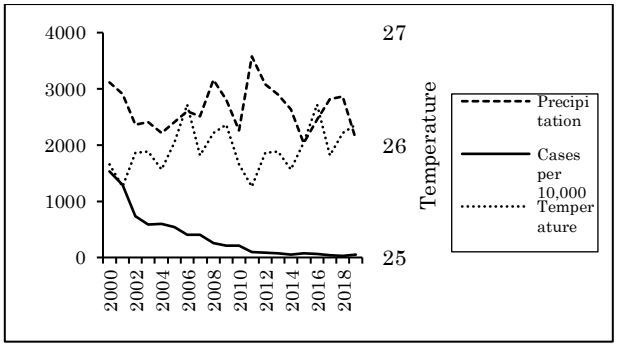

Fig 4. Relationship of precipitation and temperature with malaria cases per 10,000 in the Philippines.

Fig 4 shows the relationship between temperature and precipitation with malaria, with decreasing trend in the malaria cases observed in the Philippines. Using multiple regression, it was found out that temperature has a significant relationship with malaria (p = 0.01) while precipitation does not (p = 0.2). The significant relationship with temperature can be attributed to the fact that it plays a critical role in the parasite's development. Even small fluctuations in temperature reduces the parasite's ability to develop thereby cutting its life cycle (Singhaboot et al., 2019). Also, temperatures above 40° are detrimental to its mosquito vector which contributes to the decrease in cases of malaria. Meanwhile, the non-significant relationship with precipitation could be

attributed to varying effects of it to mosquitoes as it can increase or decrease the cases depending on the situation. An increase in precipitation would provide a breeding site for the mosquitoes however, it could also flush existing breeding grounds and kill existing larvae. Conversely, a decrease in precipitation would reduce breeding ground however, increased water storing behavior have shown to increase when precipitation levels are expected to decrease.

Overall, malaria cases in the Southeast Asian region are decreasing due to improved efforts of governments to combat the disease. However, it is also a fact that the cases still affect thousands of lives in the region and efforts must strengthened to eradicate the disease permanently (Appendix 4).

3.6 Dengue

Dengue is viral disease that is caused by the dengue virus. The virus is then further subdivided on 4 different serotypes. It is vectored by the mosquito *Aedes spp.* and predominantly affects countries in the with tropical and sub-tropical climates.

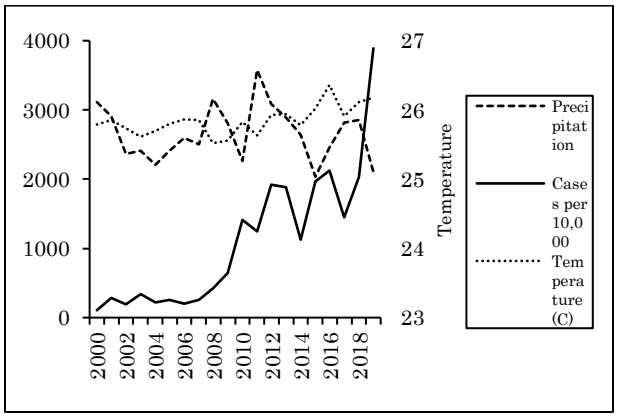

Fig 5. Temperature and precipitation rate relationship with dengue cases per 10,000 population in the Philippines

Generally, the trend of dengue cases in the Philippines is increasing. Through multiple regression, it was found that temperature has a significant relationship with dengue ($p = 0.0007$) while precipitation does not ($p = 0.7$). The significant relationship with temperature can be attributed to the effects of temperature to the mosquito vector of the disease. This is because an increase in temperature would result in the increase in mobility of mosquitoes. This would mean that they would feed more and consequently develop faster and proliferate faster. This increase in mosquito population would contribute to the increase of dengue cases in the Philippines. Meanwhile, the non-significant relationship between precipitation and dengue cases could be attributed to the varying effects of rainfall to the number of mosquitoes. As with malaria, the same rainfall that would create stagnant water for mosquitoes to breed can also destroy other existing breeding ground. Conversely, a decrease in rainfall would not provide mosquitoes a breeding site but would encourage people to store water thereby creating an artificial breeding site for them.

Overall, dengue cases show an increasing trend in Southeast Asian region for the past 20 years. This increase can be attributed to rising temperatures since it has been found that dengue cases have a direct relationship with temperature (Langkulsen et al., 2020). Thus, an increasing global temperature would be dangerous for the Southeast Asian region as it will increase the prevalence of dengue in the region (Appendix 5).

4. CONCLUSIONS

The results in the study showed the essence of conducting systematic review on the trends of climate change and human health region wise. Multiple regression analysis established a significant relationship between temperature with dengue and malaria and between precipitation and cholera, leptospirosis, and stunting. The prevalence of these five diseases in the Southeast Asian region had similar trends, where all except dengue had been decreasing in the past 30 years. Overall, the results showed that climate change negatively affects these diseases and will put human health at risk especially in a worse climate change scenario. The data analysis using systematic reviews can serve as baseline information for governments and other stakeholders to come up with effective strategies to address the effects of climate change on human health.

5. ACKNOWLEDGMENTS

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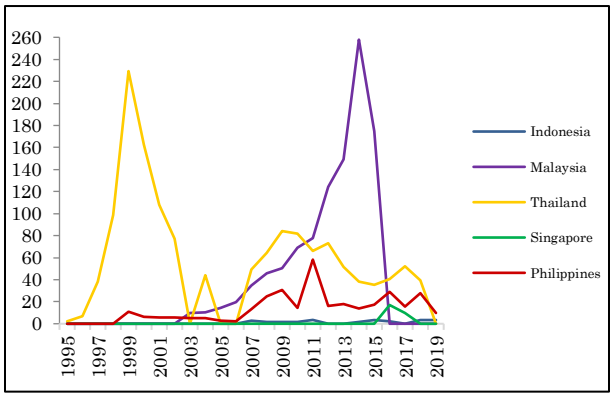
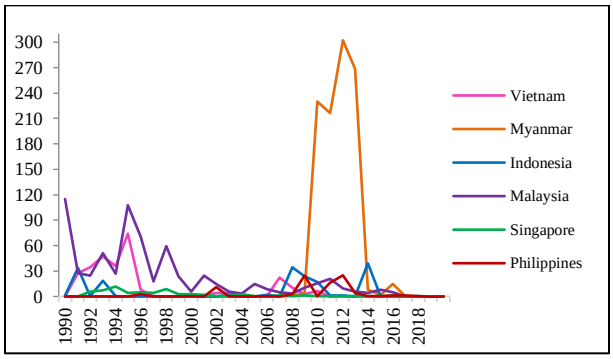
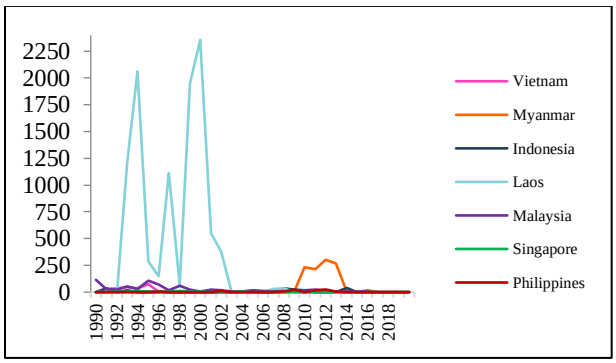
7. APPENDIX

Appendix 1: Leptospirosis in Southeast Asia



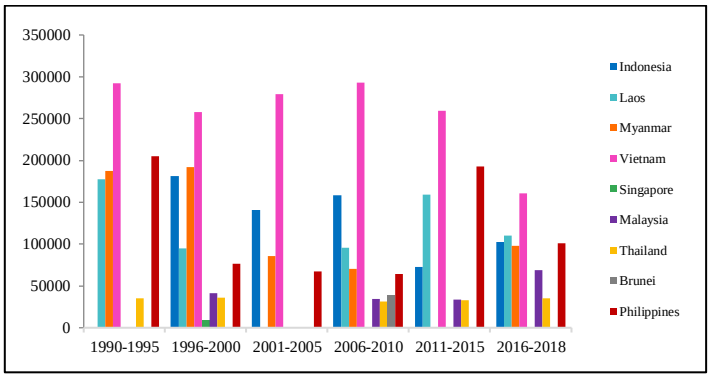
Appendix 2: Cholera in Southeast Asia



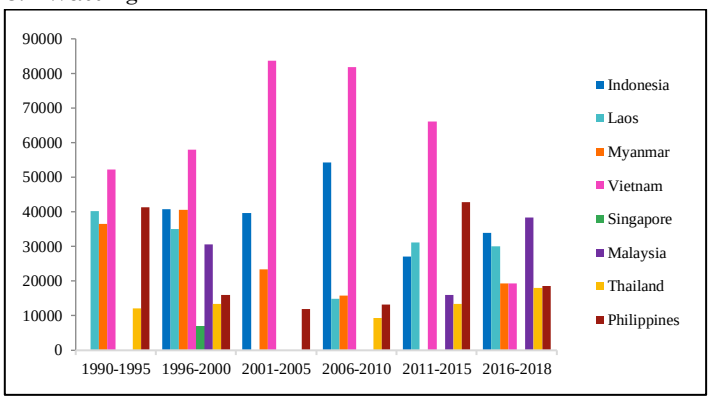


Appendix 3: Malnutrition in Southeast Asia

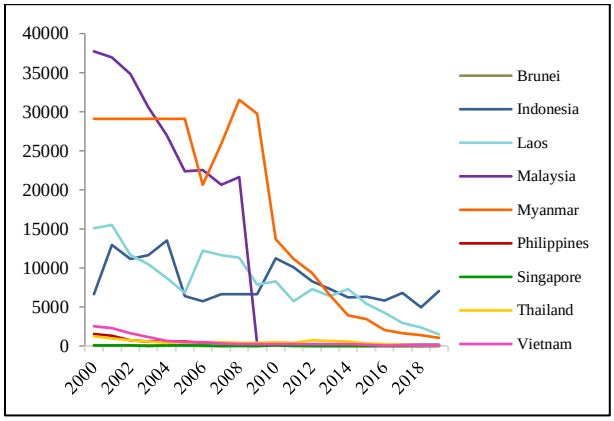
3.1 Stunting

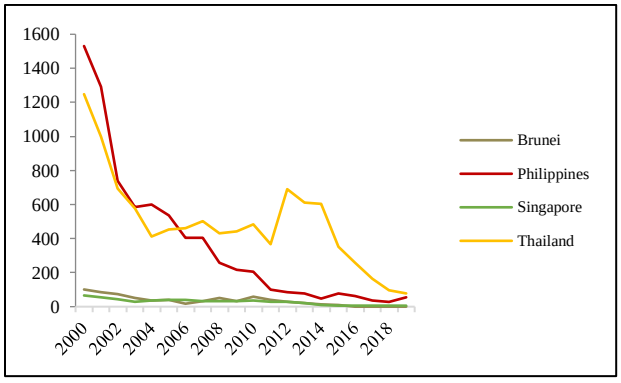


3.2 Wasting



Appendix 4: Malaria in Southeast Asia





Appendix 5: Dengue in Southeast Asia