Geospatial Analysis of DHF Surveillance Model in Si Sa Ket Province, Thailand using Geographic Information System

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Abstract
Dengue Hemorrhagic Fever (DHF) is an enormous global health problem due to its morbidity and mortality across the world and Thailand. The Dengue virus presents four serotypes that contacted patients three or four times. The repeated outbreaks of DHF reported from every part of the world. The issue, we found is lacking proper surveillance. This requires a well-developed surveillance system to be developed by a surveillance organization. The purpose of this study was to investigate the issues and develop a surveillance system or model for DHF with the help of community participation and Geographic Information Systems (GIS). This study aimed to analyze the relationship between constituents that anticipated to the case of the disease. The methods are done with techniques, statistics, frequencies, percentage average, SD, odds ratio (OR), and logistic regression. Three parameters considered were House Index (HI), Container index (CI) and Breteau Index (BI). It was found that the selected villages associated with the higher levels of risk factors in the villages with HI≥5 (OR_{adj} = 5.02; 95% CI = 2.84-8.89), BI>50 (OR_{adj} = 4.84; 95% CI = 1.28-18.37), The flooded area (OR_{adj} = 2.47; 95% CI = 1.39-4.39), Patients with dengue 2013 (OR_{adj} = 2.31; 95% CI = 1.36-3.92), Patients with dengue 2014 (OR_{adj} = 1.81; 95% CI = 1.01-3.23) and area of housing> 100 rai (OR_{adj} = 1.73; 95% CI = 1.03-2.91). The logistic regression equation of the environments to estimate the risk of DHF was $P(risk\ area) = {}^{1}\!/_{1+e^{-z}}$. Using the proposed method, the study could find the number of infected people in 11 experimental villages and also infected with DHF outside the area. The index of mosquito larvae was reduced in short, middle and long-term periods while the levels of distance from the forest, and the number of the patient was increased. The outcome already showed GIS associated with vector index and DHF infection can map out the expected infected population. Therefore, the proposed method may be encouraged to support the system design of disease surveillance for DHF and may be applied in other areas.

1. Introduction

DHF is a major public health concern for many tropical and subtropical regions of the globe. It is one of the important vectors borne disease that is the leading cause of illness and death (Dickinson et al., 2019). There are about three billion people who are at risk in dengue infection particularly people who live in more than 100 areas in countries that find in tropical and subtropical areas of Asia-Pacific, Americas, Middle East and Africa (WHO, 2011). Every year, about 20,000 cases to more than 100,000 cases reported as cases of DHF in Thailand. Besides, the site is another subject area reported from 128 countries risk area and have calculated DF prevalence about 3.9 billion (Brady et al., 2012). The reports of case-fatality rates of dengue fever have decreased since the 20th centuries from early patient screening and patient management. Also, the results showed that there were many factors that affect the occurrence of DHF and DF. The main variants include the swamp and forest areas, riverbank areas, public infrastructure areas and population density. This study used environmental and demographic factors to study the risk of DF and DHF. The development DHF risk prediction model in Penang Island (Shafie, 2011).

The first epidemic dengue fever in Thailand was reported in 1958 (Bureau of Vector-Borne Diseases, Department of Disease Control, Ministry of Public Health, 2010). In 2015, dengue virus infection situation in Thailand reported that the total cumulative of infected cases was 142,925 cases, with the incidence rate at 219.46 per 100,000 populations. Several reports showed that dengue fever patients increased by 247.28% (3.47 times) when compared to the year 2014 at the same time. They also reported that there were 141 deaths with mortality rates of 0.10%. In 2013, the highest prevalence rate was 322.48 per100,000 populations, followed the rate of 251.64 per 100,000 populations in the year 2015, and the year 2012 the fatality rate of 0.06%. The fatality rate in 2013 was 0.02% while the fatality rate in 2015 was 0.05% (Bureau of Vector-Borne Diseases, Department of Disease Control, Ministry of Public Health, 2015). These rates were higher than the value reported by the Ministry of Public Health. DHF control that focused on the control the spread of mosquito-borne and without analysis of factors related to deploying of DHF controlling that was not successful. So, it was necessary to integrate GIS in DHF surveillance. It would be a useful tool to make a comprehensive approach to the prevention and control of DHF. There were many areas in Thailand needed in the pursuit of the methods towards prevention and control of diseases. On an urgent basis, it requires the application of GIS that can use for planning and precisely decision-making to solve the problem. All monitoring and review of the literature of academic papers and research studies that involved both domestically and abroad revealed that the problem of DHF in Thailand need to study.

Literature review related factors found that cause of DHF such as the environment, the forest density, distance from reservoirs, the drainage in the village, the trash in the village and DHF prevalence. The vectors also should study including, prevalence survey of mosquito larvae (HI; House index, CI; Container index, BI; Breteau index) by identifying the types of mosquito larvae. GIS databases have been recently used to check factors affecting disease transmission (Sithiprasasna et al., 1997 and 2003(a) and (b)). The purpose of this study was to prove a surveillance model of DHF in Thailand and the same regions.

2. Material and Method

This mixed methods research to study and check the relationship between factors expected to the cause of DHF. That establishing of the DHF surveillance model at-risk areas. Public participation and integration using GIS. The scope of the research contributed by establishing the model. That related to DHF prevalence in the selected area at Si Sa Ket province. The data used for the model established in this study was derived from a survey study earlier to the process of the model established. The collected data for the model established were the risk factors of the DHF relating to environmental factors which were the variables included the flooded area. According to studies in situations and preparations from climate change for DHF in Thailand, it is an important variable most especially in a flooded area that affects the epidemic of DHF (Nakaphakorn, 2013). Housing area was also a variable in this study. According to studies using GIS application for studying the spread of DHF outbreak within Tamai District, Chanthaburi (Buafueang, 2013), the predictive models of the disease epidemic in eight provinces in northern Thailand is influenced by the drainage channel and trash in the villages (Khantikul and Suwonkerd, 2012). Distance from reservoirs and the forest density were variables in this study. According to studies using GIS application for studying the spread of DHF outbreak within Tamai District, Chanthaburi (Buafueang, 2013), the demographic factors were also influencing, including age, sex, education and ethnic. Moreover, the vector of DHF which was the mosquito larvae identified using entomological indices: (HI, CI, and BI). The entomological indices:

$$House\ Index\ (HI) = \frac{Positive\ Houses}{House\ Inspected} \times 10$$

Equation 1

$$Container\ index\ (CI) = \frac{Containers\ positive}{Containers\ inspected} \times 100$$

Equation 2

$$Breteau\ Index\ (BI) = \frac{Total\ containers\ positive}{House\ inspected} \times 100$$

Equation 3

This study had variables on vector included HI BI and CI. According to studies of Tuladhar et al., (2019) and Ponpetch, (2008) that used the variables on vector indices (HI, BI and CI), disease statistic variables in these study included Dengue patients. According to studies in Surveillance of Dengue Fever Virus: A Review of Epidemiological Models and Early Warning Systems (Racloz et al., 2012). Development of a Participation Model for Prevention and Control of DHF in Koksak SubDistrict Bangkeaw District Phatthalung (Polpong et al., 2017). The geographical factors include the distance from villages to forest and water resource included for data collections. According to studies in a study of the application of GIS for studying the spread of the DHF outbreak within Tamai District, Chanthaburi (Buafueang, 2013).

The established model based on all the derived survey data and the established model applied used for data analysis found DHF patients by DHF risk map with GIS and help real-time and saving money. The data were collected using questionnaires that were answered by the people who are living in the selected study areas. DHF risk map was developed with the use of applied GIS to get the factors that are related to the disease and the causes of infection. The result of data analysis used the logistic regression equation for the contribution of a model that represented the risk of DHF in the study area. The obtained geographical information and all risk factors used for the analysis of the spatial relationship which showed the relationship between the find to villages or homes and geographical distribution that related to health information. The DHF surveillance model used in eleven experimental villages. The eleven control villages use the regular pattern. Population in this research was 2,443 villages. Research areas at Si Sa Ket province, Thailand is shown in Figure 1. The risk areas of dengue specified by the criteria of the Bureau of Communicable Disease Control Department related to insects, diseases, and the current situation of dengue fever that compared to the median values of the five year-retrospective data. These data consisted of the detail as follows; risk level 5; the current prevalence rate that reached to -50% of the median of the five year-retrospective. Risk level 4; the current prevalence rate attached to -10% to -49% of the median of the five year-retrospective. Risk level 3; the current prevalence rate was +9.9% to -10%. The risk level 2; the current prevalence rate was higher than the median of the five year-retrospective data (+10% to 50%) and risk level 1; the current prevalence rate was higher than the median of five year-retrospective data (+50%), the risk specified shows that Figure 2. This study used stratified sampling by dividing the village into a 6-level risk group. And takes a simple random sample from each risk group by Systematic sampling method. The number of samples risks classified by risk levels is shown in Table 1.

3. Result

The results of this study consist of the ratio of the female per male about 1:1. The Majority of the age group show in the age group of 35-59 was 35.67 %. The highest per cent of occupation was 48.58 with Agriculture occupation shows in Table 2. GIS application showed that the risk area that reached at level 1 were found in 891 villages, level 2 was found in 281 villages, level 3 was found in 546 villages, level 4 were found in 466 villages and level 5 were 442 villages respectively shown in Figure 1.

Table 1: The number of sample risks classified by risk level

Risk level	Sample Village	Sample Person
No risk (2112)	145	870
1 (219)	15	90
2 (14)	14	84
3 (70)	40	240
4 (6)	6	36
5 (22)	22	132
total	242	1,452

Table 2: Demographic information of Population in 2017

sex, age, and socio-economic status	number	Proportion(%) of each category
Sex	1,052,472	
Male	515,141	48.95
Female	537,331	51.05
Age	1,052,472	
0-14 years	233,810	22.22
15-34 years	272,973	25.94
35-59 years	375,397	35.67
>59 years	170,292	16.18
Education	549,970	
Unschooled	191,210	34.77
Elementary	148,137	26.94
Secondary	144,098	26.20
Diploma	9,905	1.80
Bachelor degree and Post-Graduate	56,619	10.29
Occupation	549,970	
Laborer	77,867	14.16
Business	4,403	0.80
Government employee	47,135	8.57
Agriculture	269,185	48.95
Others	151,379	27.53

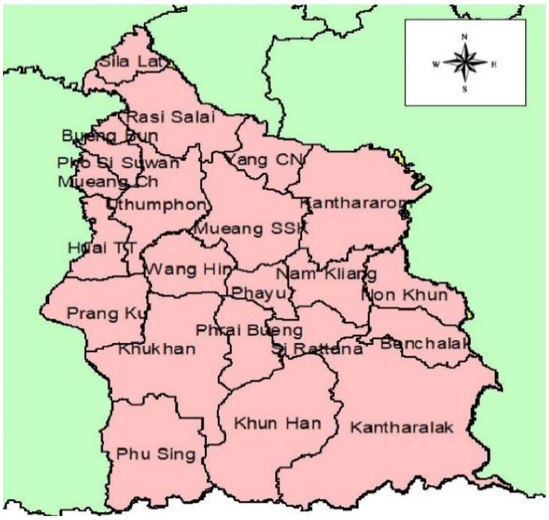

Figure 1: Map of Si Sa Ket

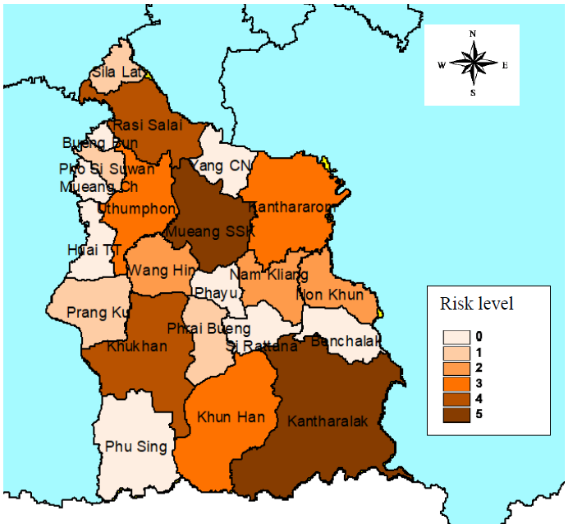

Figure 2: Risk Area in Si Sa Ket

Figure 3: The results of the vector index, Si Sa Ket Province in 2013-2015

Table 3: The relationship between the variables in the village and the risk level of the village

Variable	OR	95%CI for CI	*p*-value
House index (HI)	5.02	2.84 – 8.89	0.001**
Breteau index (BI)	4.84	1.28 – 18.37	0.015*
The area had been flooded	2.47	1.39 – 4.39	0.002**
Patients with dengue 2013	2.31	1.36 – 3.92	0.002**
Patients with dengue 2014	1.81	1.01 – 3.23	0.044*
Housing area	1.73	1.03 – 2.91	0.049*

* $p < 0.05$, * $p < 0.01$ **

Our result showed that the highest BI at 157% was found in Phu sing district in 2013. The district that showed the highest BI at 97% was Sila Lat district in 2014. And the district that had the highest HI was Phayu district with 68% in 2015 respectively. Figure 3 shows the variables in different villages associated with the levels of risk. The villages were HI≥5 (OR_{adj}=5.02; 95% CI=2.84-8.89), BI>50 (OR_{adj} = 4.84; 95% CI= 1.28-18.37), the flooded area (OR_{adj}=2.47; 95% CI=1.39-4.39). Dengue patients in 2013 (OR_{adj}=2.31; 95% CI = 1.36-3.92). Dengue patients in 2014 (OR_{adj}=1.81; 95% CI=1.01-3.23) and housing area > 100 rai (OR_{adj}=1.73; 95% CI=1.03-2.91) shows that Table 3.

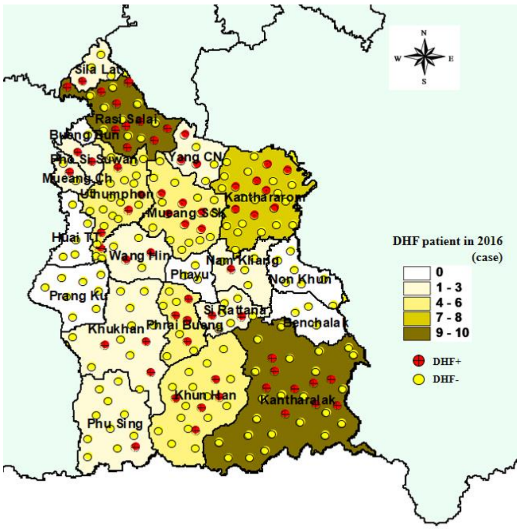

Figure 4: Show DHF patient in 2016

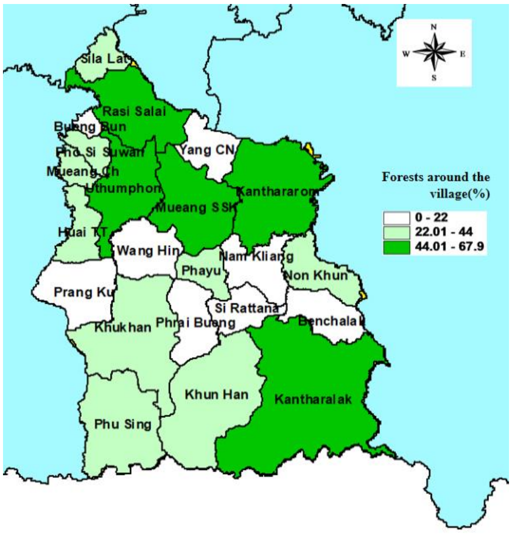

Figure 5: Show the forest map of forest density

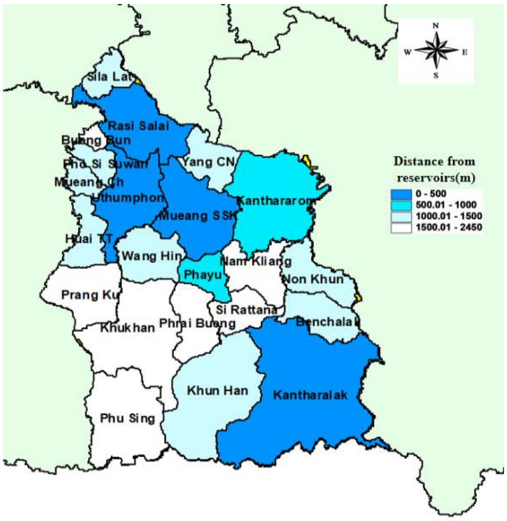

Figure 6: Show the distance from reservoirs

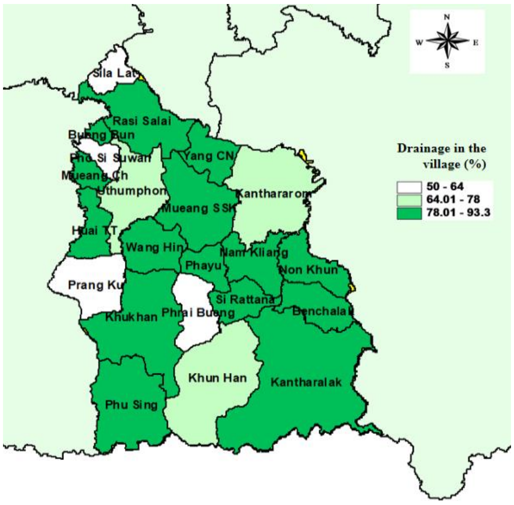

Figure 7: Show the drainage in the village

Table 4: Comparisons of the environment and the risk level of village

Variable	No Risk n=145	Risk Level1 n=15	Risk Level2 n=14	Risk Level3 n=40	Risk Level4 n=6	Risk Level5 n=22	Test Statistics	p-value
environment	number (%)	number (%)	number (%)	number (%)	number (%)	number (%)		
Drainage channel	126 (86.90)	14 (93.3)	11 (78.60)	30 (75.00)	3 (50.00)	18 (81.80)	X^2=9.53	0.045*
trash in the villages	90 (62.10)	12 (80.00)	14 (100.00)	23 (57.50)	3 (50.00)	15 (68.20)	X^2=11.23	0.024*

In comparison with the environment and the risk level of the village (no risk, risk level 1, 2, 3, 4, 5), it was found that drainage channel and trash in the villages would make significant difference ($p<0.05$) as shown in Table 4. By comparison with the vector-borne factor into six groups (no risk, risk level 1, 2, 3, 4, 5), HI BI and CI would make a significant difference ($p<0.001$) as shown in Table 5. The highest positive of DHF already shown 10 cases in Rasi Salai district. It is followed by Kantharalak, Kanthararom and Muang district shown the positive cases of 9, 8 and 6 as shown in Figure 4. The forest density was divided into three categories (0-22.00% low, 22.01-44.00% middle and 44.01-67.90% high). The highest of the forest density already shown 67.90% (high) in Kanthararom district. Followed by Uthumphon Phisai, Kantharalak and Muang district have shown the forest density was 62.20%, 56.30% and 55.00% shows that Figure 5.

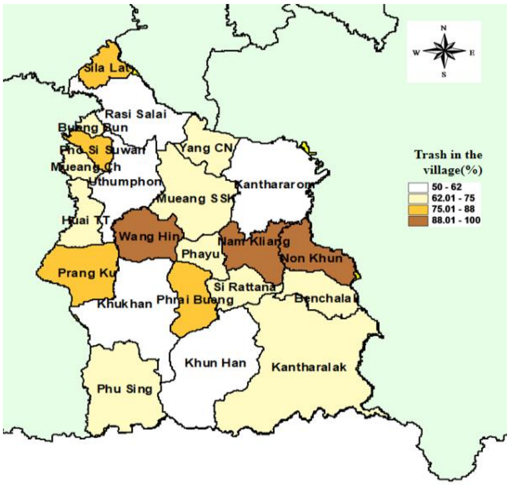

Figure 8: Percentage of trash in the village

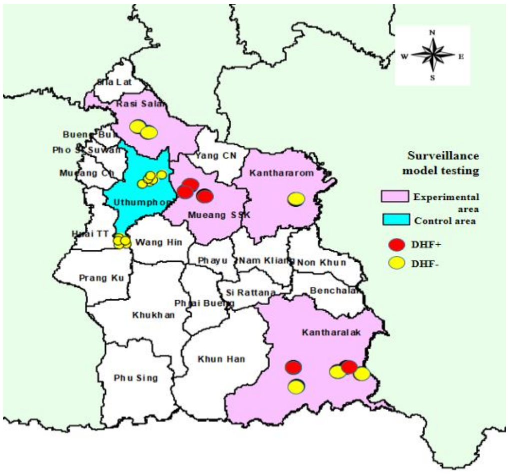

Figure 9: Experimental and control area in the model

Table 5: Comparisons of the vector-borne and the risk level of village

Variable	No Risk n=145	Risk Level1 n=15	Risk Level2 n=14	Risk Level3 n=40	Risk Level4 n=6	Risk Level5 n=22	Test Statistics	*p*-value
The *Aedes* larval indices	$\bar{x}$(SD)	$\bar{x}$(SD)	$\bar{x}$(SD)	$\bar{x}$(SD)	$\bar{x}$(SD)	$\bar{x}$(SD)		
HI (House Index)	7.51 (7.96)	12.01 (12.22)	21.48 (17.70)	15.15 (10.28)	28.11 (17.10)	14.08 (16.12)	H=35.95	0.000***
BI (Breteau Index)	11.98 (10.10)	16.46 (17.25)	38.22 (48.91)	27.58 (16.63)	51.46 (4.53)	14.91 (13.75)	H=42.05	0.000***
CI (Container Index)	8.23 (7.99)	9.15 (10.88)	16.86 (15.30)	20.10 (15.83)	37.31 (38.91)	12.94 (21.63)	H=24.21	0.000***

*** $p < 0.001$

Table 6: The logistic regression equation of the variables

Variable	**B**	**S.E.**	**Wald**	**df**	**Exp(B)**	**p**
Breteau Index (BI)	0.044	0.018	5.778	1	1.045	0.016*
Villages with trash(VWT)	0.738	0.357	4.272	1	2.092	0.039*
Villages have been flooded(VHF)	0.729	0.345	4.455	1	2.072	0.035*
Ethnic Kuoy(EK)	-2.156	0.832	6.705	1	0.116	0.010*
Number patient (NP)	0.356	0.150	5.662	1	1.428	0.017*
Distance from reservoirs(DFS)	-0.001	0.001	6.179	1	0.999	0.013*
Constant	-0.883	0.679	1.692	1	0.413	

The greatest of the distance from reservoirs already shown 2,450 meters (high) in Phu Sing district. It is followed by Khukhan, Phrai Bueng and Si Rattana district showed the distance from reservoirs were 2,345.83, 2,325.45 and 2,085.63 meters respectively as shown in Figure 6. The drainage in the village was also divided into three categories (50-64% low, 64-78% middle and 78-93.3% high). The highest of the drainage in the village (93.30%) is in Rasi Salai and Khukhan district. It is followed by Si Rattana, Yang Chum Noi and Muang district with 88.32%, 86.90% and 82.20%, respectively and shown in Figure 7. The trash in the village was divided into four categories (50-62.00 % low, 62-75.00 % middle, 75-88.00% meters rather high and 88-100.00 % high). The highest of the trash in the village already shown 100.00% in Wang Hin district. Followed by Phrai Bueng, Pho Si Suwan and Kantharalak district shown the trash in the village were 80.40%, 80.00% and 68.20% shows that Figure 8. That showed the equation of:

$$P(risk\ area) = {}^{1}/_{1 + e^{-z}},$$

Equation 4

$$z = -0.883 + 0.044(BI) + 0.738(VWT) + 0.729(VHF) - 2.156(EK) + 0.356(NP) - 0.001(DFS)$$

Equation 5

As shown in Table 6. This study used the logistic regression equation for developing the dengue surveillance system. The results of this study offer summarized and established DHF Surveillance model. The process of strengthening the village and DHF surveillance system by community participation (grassroots) are as follows; (1) short-term (immediate action on Day 1) by focusing on passive surveillance that established Center for DHF Prevention and Control by the village which created health policy and the Community of War Room

(CWR); (2) Mid-term assessment of the implementation of the short-term solution. Development of a model dengue surveillance system that was reliable. As well as the empowerment and DHF prevention and control and disasters. This term focused on active surveillance with selected volunteers making DHF surveillance and screening by a simple tourniquet test. The long-term operation was to assess this mid-term. At present to assess the relevant policies and guidelines, improving DHF surveillance in the community as proper in the area context. The results showed that only one of the dengue patients in all 11 experimental villages was infected outside the area. Additionally, the indexes of the prevalence of mosquito larvae reduced in the model. It was found that the experimental area showed HI CI and BI value which decreased in safety criterion for DHF. Yet, the control area found that the HI, CI and BI value still at risk of DHF. However, our results show that in the control area of 11 villages, there are five patients in five villages, while in all six villages were still at risk for DHF shown in Figure 9.

4. Conclusion and Discussion

This study showed that the environment in the villages is the major cause of the risk of DHF. The villages were HI≥5 (OR_{adj}=5.02), BI>50 (OR_{adj}=4.84) and flooded village (OR_{adj}=2.47). Patients with dengue 2013 (OR_{adj}=2.31), patients with dengue 2014 (OR_{adj}=1.81) and housing area >100 Rai (OR_{adj}=1.73) in comparison with the environment and the risk level of the village. We found out those drainage channels in the villages can make a lot of difference (p<0.05). The trash in the villages is also can make much difference (p<0.05). By comparison with the vector-borne cause into six groups, HI BI and CI have shown a much different (p<0.001). Results of the logistic regression equation of GIS and the environmental factors were able to estimate the risk of DHF. Which showed as $P(risk\ area) = {}^{1}/_{1+e^{-z}}$, $z = -0.883 + 0.044(BI) + 0.738(VWT) + 0.729(VHF) - 2.156(EK) + 0.356(NP) - 0.001(DFS)$.

The results of the experimental villages showed that no of Dengue patients in 11 experiment areas. Also, found that in the control area of 11 villages, there were five Dengue patients in five villages. While in six control villages were still at risk for DHF. However, we found that the experimental area showed HI CI and BI value decreased in the safety criterion for DHF. Yet, the control area found that the HI, CI and BI value were still at risk of DHF. The results obtained in this study revealed that the risk factors of dengue needed more awareness. Also in 2011-2012, the number of patients decreased to 95 patients, and the number of patients increased in 2013 to 4,574 patients, while in 2014-2015 the number of patients decreased to 288 patients, Therefore, DHF had an outbreak in study areas in 2016. According to the effect of the Dengue surveillance system, the research results can provide useful in other areas. The dengue surveillance system should be promoted to apply in other areas with similar context.

The ongoing vector control programs for DHF in study areas in Thailand should focus on provisions for health instruction to increase public awareness, national campaigns for larval control, and environmental standards for habitat reduction, adult mosquito control and personal protection. The vector control is the solitary direction and the best intervention to prevent the virus. The primary lesson learned from the experience of Singapore confirmed that vector control programs should be efficient, it must be found on carefully gathered, and analysis of epidemiological and surveillance data. Of course, as pointed out by Ooi et al., (2006) and Beatty et al., (2010). GIS technologies applied to investigate surveillance data through correlation of spatial analysis of geographical and environmental practices, which are prominent in disease-prone areas. This is consistent with other studies. It suggested ways to develop risk maps analysis model and can be used to elaborate the relationship between outbreaks of Dengue with 10 factors, spatial the result has valuable information and techniques that can be used for prediction and prevention of DF and DHF in Malaysia. Of course, as pointed out by Shafie, (2011) and Kikuti et al., (2015), the phenomena of informative outcome from this study would sign and carry out in another area. They integrate with another clinical sign and feature will be further studied to prove a crucial predictive incidence model. We plan to distribute to other area and encourage the policymaker for initiating for DHF prevention and control.

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