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THE APPLICATION OF GEOGRAPHIC INFORMATION SYSTEM IN DENGUE HAEMORRHAGIC FEVER RISK ASSESSMENT IN SAMUT SONGKHRAM PROVINCE, THAILAND

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ABSTRACT: Samut Songkhram is one of popular tourist destinations in Thailand; however, it is the very high risk province of the dengue hemorrhagic fever (DHF) outbreak. Therefore, it is essential and urgent to monitor the tourists within the areas from the DHF. This research aimed to study the application of Geographic Information System (GIS) in DHF risk assessment and to study factors influencing of this province. The researcher collected 11 factors data including population density, household number, elevation, temperature, humidity, rainfall, residential areas, drainage areas, agricultural areas and man-made and natural water resources from related organizations to analyze relationship with DHF patients in the province. With the Pearson's Correlations statistic, there were four main factors relating the DHF incidence including population density, household number, residential areas and man-made water resources. According to the created GIS model of DHF risk assessment, it was discovered that 9% of the total areas were the very high risk areas, 23.89% were the high risk areas, 13.14% were the moderate risk areas, and 53.97% were the low risk areas. At a district level including Muang Samut Songkham, Bang Khonthi and Amphawa, it was found that Muang Samut Songkham was the only very high risk area covering 79.78km^2. At a subdistrict level, Mae Khlong and Lat Yai were the very high risk areas. The factors influencing showed residential areas. After applying the GIS in DHF risk assessment, it was demonstrated that the GIS was one of an effective tools for DHF surveillance.

Keywords: Dengue Haemorrhagic Fever (DHF), Geographic Information System (GIS)

1. INTRODUCTION

Dengue Haemorrhagic Fever (DHF) is a mosquito-borne disease that has become a major public health problem worldwide [1], including Thailand because the wide spread of the disease and the steadily increasing number of patients, especially for countries in tropical and temperate zones [2]. According to the reports in the past three years from Bureau of Vector Borne Diseases, Department of Disease Control, Ministry of Public Health of Thailand, there were 64,374 patients and morbidity rate of 100.78 per 100,000 populations in 2011. There were 74,250 cases of DHF or morbidity rate of 116.24 per 100,000 populations in 2012. In 2013, there were 150,934 patients or morbidity rate of 234.86 per 100,000 populations. As the numbers of patients continue to increase every year, DHF remains a major public health in Thailand and is needed to be controlled and prevented urgently.

Samut Songkhram is a small province in the middle of Thailand with the total area of 413.39 square kilometers. According to the Bureau of Epidemiology, Samut Songkhram is one of the provinces that have the highest number of DHF cases. In 2012, there were 1,328 patients and morbidity rate of 263.52 per 100,000 populations; there were 1,009 patients and morbidity rate of 202.16 per 100,000 populations in 2013. In 2014, there were 507 cases of DHF or morbidity rate of 101.58 per 100,000 populations. During the past three years, even though the number of patients tended to decrease, DHF cases in the province remained high.

As Samut Songkhram is one of popular tourist destinations with a lot of famous tourist attractions around the province, a number of visitors are drawn in each year. The travelers also have a high risk of developing DHF within the province and other areas. The geography and the environment of the province are key factors of DHF which is a disease caused by a virus transmitted by *Aedes* mosquitoes, especially *Ae. aegypti.* Accordingly, *Aedes* mosquito population and sources are closely related to the disease [3] [4]. It is vitally important to study risk and factors influencing of DHF in Samut Songkhram in order that we can make a strategy for effectively controlling the disease in the province and tourists surveillance from the disease in the risk areas.

Geographic Information System or GIS is a system of collecting spatial data with attribute data or non-spatial data integrated [5]. The data is stored in database and can be modified and analyzed by overlay Analysis. Overlay analysis of GIS is the technique to combine two data layers into one data layer which contained information. The collected data, moreover, discloses area-based information which is used for resource and surveillance planning for public health [6]. GIS, in addition, is an effective tool for presentation of disease incidence, analysis of disease factors, and designation of risk areas for disease control and prevention [7], [8].

As this result, The number of travelers in the province continues to increase every year because of a number of tourist attractions. Therefore, it is essential and urgent to monitor the tourists within the areas from the DHF. In an attempt to enhance efficiency in the disease surveillance in Samut Songkhram, this research aimed to study the application of Geographic Information System (GIS) in DHF risk assessment and to study factors influencing of this province. The GIS, in addition, was also expected to help the government's disease control departments to formulate a policy, a strategy, and a plan of DHF surveillance and it can contribute to efficient outbreak control in an area.

2. MATERIALS AND METHODS

The objectives of this research are to study factors that cause Dengue Haemorrhagic Fever (DHF) and build Geographic Information System to assess risks and to study factors influencing of the disease of Samut Songkhram province. GIS, in addition, was used in this research. The methods of this research were as follows.

2.1 Data Used in the Research

This research used secondary data collected from related organizations. The secondary data included the number of Dengue Haemorrhagic Fever (DHF) patients in the past two years, 2014 and 2015, and other data for analysis as follows:

1. The data of the DHF patient number in each subdistrict of Samut Songkhram from 2014 to 2015, derived from Epidemiology Department, Samut Songkhram Provincial Public Health Office.
2. The data of population density in each subdistrict of Samut Songkhram from Samut Songkhram Provincial Statistical Office.
3. The data of the household number in each subdistrict of Samut Songkhram from Samut Songkhram Provincial Statistical Office.
4. The spatial data on administration at the village and subdistrict levels in Samut Songkhram from Department of Provincial Administration.
5. The spatial data on roads and rivers in Samut Songkhram from Department of Provincial Administration.
6. The spatial data on land utilization in Samut Songkhram from Department of Provincial Administration. The data included:
    - Residential areas
    - Drainage areas
    - Agricultural areas
    - Man-made water resources
    - Natural water resources
7. The data on the elevation of Samut Songkhram from Department of Provincial Administration.
8. The data on the average rainfall of Samut Songkhram from 2013 to 2014 from Thai Meteorological Department.
9. The data on the average temperature of Samut Songkhram from 2013 to 2014 from Thai Meteorological Department.

2.2 Data Collection and Management

Samut Songkhram was selected for this research. It is a central province of Thailand and has an area of 413.39 square kilometers. The province is administratively divided into 3 districts, 36 subdistricts, and 284 villages.

The researcher collected data and received secondary data with the kind support of related organizations. This research adopted the QGIS program, which is free, downloadable, and effective. Organizations can apply the program to their study. All the collected data were organized into a data file and analyzed with the QGIS program for Geographic Information System from the website: https://www.qgis.org/en/site/forusers/download.html.

2.3 Research Methods

2.3.1 Determining related factors in the DHF causation

1. Reviewing research, concepts, and theories relevant to factors in Dengue Haemorrhagic Fever (DHF) causation in order to employ concepts, theories, and analysis types which are the most suitable for this research and consulting specialists about the related factors in the disease causation.
2. Determining factors for the DHF risk assessment in the areas of Samut Songkhram. The factors are as follows:

lndependent variables;

1) The data of population density
2) The data of the household number
3) The data on the elevation

4) The data on the average temperature
5) The data on the average Humidity
6) The data on the average Rainfall
7) The data on total number of residential areas
8) The data on total number of drainage areas
9) The data on total number of agricultural areas
10) The data on total number of man-made water resources
11) The data on total number of natural water resources

Dependent variables;

The data number of the DHF patient

According to Marianni's research, it also demonstrated these factors were relevant to the increase in the DHF outbreak in each area [10].

2.3.2 The created GIS model of DHF and Disease Risk Assessment in Samut Songkhram

The researcher contacted related organizations and asked them for the support of the data to be used in the research and to be analyzed with Geographic Information System (GIS).

1. Analyzing all of the factors as mentioned earlier of the province's areas. This research adopted Pearson's Correlations statistic to measure the relation between 11 independent variables and dependent variables which was the number of DHF patients in Samut Songkhram with SPSS program version 20.

Afterwards, assessing risks of the disease with the analyzed factors at the statistical significance less than 5% (p-value < 0.05).

2. Building the Geographic Information System Models of the DHF and disease risk assessment after analyzing the related factors in the DHF causation with the QGIS system. Each factor was scored by five specialists on a scale ranging from 1-3.

Using the Overlay Analysis of GIS to analyze the obtained scores and assess risks of the DHF in each subdistrict of Samut Songkhram. Dividing risk degrees into four colors including, dark red, red, pink, and light pink and setting the score level of the very high risk at 39-45, the level of the high risk at 32-38, the level of the moderate risk at 25-31, and the level of the low risk at 18-24 respectively. To create a frequency distribution, the interval width equaled to range divided by the number of intervals. Afterwards, analyzing the DHF risks at four administrative levels: province, district, subdistrict, and village.

2.3.3 The study factors influencing of Samut Songkhram

Stepwise multiple regression was selected as the method for studying the DHF factors influencing of the DHF. first of all, determined whether there was multicollinearity among the 11 gathered factors of lndependent variables. After that, we employed the stepwise multiple regression to analyze the independent factors at p-value= 0.05.

3. RESULTS

3.1 Related Factors in the DHF Causation for the Created GIS Model

The researcher analyzed the total 11 factors related to the disease causation with the statistical analysis and employed Pearson's Correlations Coefficient to measure the relation between independent and dependent variables. The result discovered that four of them were the factors relating the DHF outbreak in Samut Songkhram with the statistical significance of p-value < 0.05 including population density, household number, residential areas and man-made water resources as shown in Table 1.

Table 1 Related factors in the DHF causation and statistics for measuring DHF patient number relation

Factors	Pearson's Correlations	*p*-value
Population density	.834	< .001**
Household number	.843	< .001**
Elevation	.279	.100
Temperature	.000	1.00
Humidity	.109	.527
Rainfall	-.165	.337
Residential areas	.884	< .001**
Drainage areas	-.011	.948
Agricultural areas	.608	.695
Man-made water resources	.603	< .001**
Natural water resources	.210	.219

**p-value < 0.05

The number of DHF patients was the most important factor causing the spread of the disease. The researcher, therefore, analyzed the DHF patient number together with the other four factors for the created GIS model

Afterwards, five factors were scored by five specialists on a scale ranging from 1-3 for Overlay analysis of GIS as shown in Table 2.

Table 2 Determining related factors for DHF risk assessment in Samut Songkhram

Variables	Types	Weighted score	Score	Total score
DHF patient number	>10/population 1000 people	5	3	15
	5-10/ population 1000 people	5	2	10
	< 5/ population 1000 people	5	1	5
Household number	>2,000	4	3	12
	1,000-2,000	4	2	8
	< 1,000	4	1	4
Population density	>600/square kilometer	3	3	9
	200-600/square kilometer	3	2	6
	< 200/square kilometer	3	1	3
Residential areas	>3 square kilometers	2	3	6
	1-2 square kilometers	2	2	4
	< 1 square kilometer	2	1	2
Man-made water resources	> 50,000 square meters	1	3	3
	20,000-50,000 square meters	1	2	2
	< 20,000 square meters	1	1	1

3.2 GIS Model of DHF and Disease Risk Assessment in Samut Songkhram

3.2.1 DHF risk assessment at a provincial level

According to the GIS model of DHF, created with the application of the GIS and Overlay Analysis based on related factors including the DHF patient number, populations, the household number in subdistricts, residential areas, and man-made water resources as shown in Fig. 1, risk assessment in Samut Songkhram with the total area of 413.39 square kilometers was divided into four degrees: very high risk areas, high risk areas, moderate risk areas, and low risk areas.

It was found that the very high risk areas covered 37.17 square kilometers, equivalent to 9% of the total areas; the high risk areas covered 98.76 square kilometers or 23.89% of the total areas. The moderate risk areas covered 54.34 square kilometers or 13.14% of the total areas and the low risk areas covered 223.12 square kilometers or 53.97% of the total areas.

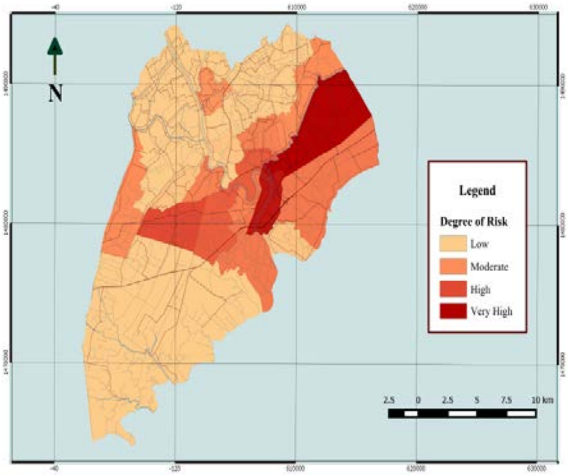

Fig. 1 GIS model of DHF in Samut Songkhram

3.2.2 DHF risk assessment at a district level

According to the GIS model created for DHF risk assessment in four degrees in Samut Songkhram's three districts including Muang Samut Songkhram, Bang Khonthi, and Amphawa (Fig.2), it was discovered that in Muang Samut Songkhram District, which has the total area of 175.57 square kilometers, the very high risk areas covered 37.19 square kilometers of the total areas, equivalent to 21.18%. The high risks areas covered 79.78 square kilometers, equivalent to 45.44% of the total areas; the moderate risk areas covered 22.01 square kilometers or 12.53% of the total areas. The low risk areas covered 36.59 square kilometers or 20.85% of the total areas (Fig. 2(C)).

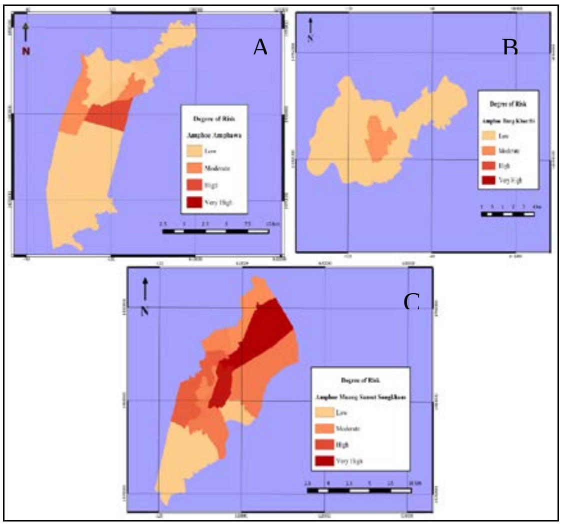

Fig. 2 GIS model of DHF in Samut Songkhram at a district level; Muang Samut Songkhram District (A), Bang Khonthi District (B) and Amphawa District (C)

In Bang Khonthi District with the total area of 66.58 square kilometers, the moderate risk area covered 6.13 square kilometers or 9.21% of the total areas and the low risk areas covered 60.45 square kilometers or 90.79% of the total areas (Fig. 2(B)).

In Amphawa District with the total areas of 171.24 square kilometers, the high risk areas covered 18.97 square kilometers or 11.08% of the total areas and the moderate risk areas covered 26.18 square kilometers or 15.29% of the total areas while the low risk areas covered 126.09 square kilometers or 73.63% of the total areas (Fig. 2(A)).

3.2.3 DHF risk assessment at a subdistrict level

According to the results of DHF risk assessment at four degrees in 36 subdistricts as shown in the Table 3, it was found that Mae Khlong and Lat Yai subdistricts, Muang Samut Songkhram District were the very high risk areas.

The high risk areas included eight subdistricts namely Bang Khan Taek, Ban Prok, Bang Kaeo, Thai Hat, Laem Yai, Khlong Khoen, Suan Luanga and Plai Phong Phang in Muang Samut Songkhram and Amphawa districts.

The moderate risk areas were six subdistricts including Nang Takhian, Bang Cha Kreng, Kra Dang Nga, Wat Pradu, Bang Chang and Bang Khae in the three districts of the province.

The low risk areas included 20 subdistricts: Khlong Khon, Bang Sakae, Bang Yi Rong, Rong Hip, Bang Khon Thi, Don Manora, Bang Phrom, Bang Kung, Chom Pluak, Bang Nok Khwaek, Yai Phaeng, Bang Kra Bue, Ban Pra Mot, Amphawa, Tha Kha, Mueang Mai, Khwae Aom, Phraek Nam Daeng, Yi San and Bang Nang Li in the three districts.

Table 3 DHF degree of risk at a subdistrict level

District Name	Sub District Name	Point	Degree of Risk
Muang Samut Songkhram	Mae Khlong	43	Very High
	Bang Khan Taek	36	High
	Lat Yai	45	Very High
	Ban Prok	36	High
	Bang Kaeo	33	High
	Thai Hat	32	High
	Laem Yai	33	High
	Khlong Khoen	32	High
	Khlong Khon	21	Low
	Nang Takhian	31	Moderate
	Bang Cha Kreng	25	Moderate
Bang Khonthi	Kra Dang Nga	30	Moderate
	Bang Sakae	18	Low
	Bang Yi Rong	18	Low
	Rong Hip	18	Low
	Bang Khon Thi	18	Low
	Don Manora	24	Low
	Bang Phrom	21	Low
	Bang Kung	18	Low
	Chom Pluak	22	Low
	Bang Nok Khwaek	21	Low
	Yai Phaeng	18	Low
	Bang Kra Bue	18	Low
	Ban Pra Mot	18	Low
Amphawa	Amphawa	24	Low
	Suan Luang	32	High
	Tha Kha	24	Low
	Wat Pradu	31	Moderate
	Mueang Mai	22	Low
	Bang Chang	25	Moderate
	Khwae Aom	21	Low
	Plai Phong Phang	38	High
	Bang Khae	25	Moderate
	Phraek Nam Daeng	21	Low
	Yi San	19	Low
	Bang Nang Li	23	Low

3.2.4 DHF risk assessment at a village level

The results of DHF risk assessment at four degrees in 284 villages of Samut Songkhram showed that 13 villages were at very high risk, 81 villages at high risk, 49 villages at moderate risk, and 141 villages at low risk, as shown in Fig. 3.

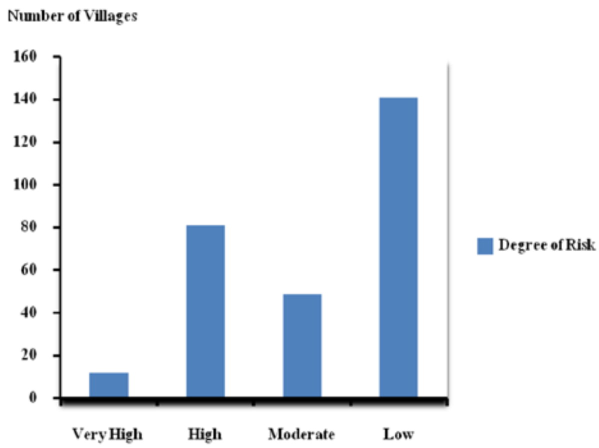

Fig. 3 Degrees of DHF risk in villages

3.3 Factors influencing of Samut Songkhram

According to an interpreted result of 11 independent variables from the multiple regression analysis, the major factor influencing in the DHF patient number was residential areas as shown in the table 4.

Table 4 DHF factor influencing

		Factor influencing	
		Constant	**Residential areas)X1(**
coefficient	B	0.217	13.14
	Beta		0.88
Adjusted R^2			0.775
t test			11.03
F test			121.57
p-value			< .001

According to the multiple regression analysis, the variation between residential areas and DHF patient number was 77.50 (R^2 = 0.775) and coefficient) B) was 13.14. It demonstrated that when other factors were controlled, an increase in residential areas of every one km^2 caused the increase in DHF patient numbers by 13.14.

When taking coefficient) B) changed to Beta into account, residential areas influenced the increase in the number of DHF patients) Beta = 0.88). In addition, according to the t test, residential areas were related to DHF patient number, showing the statistical significance of $p < 0.001$. Residential areas, therefore, could explain the variation of DHF patient number.

According to the F test, residential areas were related to DHF patient number, showing the statistical significance of $p < 0.001$. Residential areas, therefore, could explain the variation of DHF patient number.

4. DISCUSSION

For the DHF risk assessment in the areas of Samut Songkhram, the researcher employed the GIS and the Pearson's Correlations Coefficient method for measuring the statistical relation of the disease after analyzing all the related factors examined by the specialists. The researcher found that there were totally four related factors for the DHF incidence. They included population density, the household number, residential areas, and man-made water resources. The population and household number and residential areas were the important factors the increase in *Aedes Aegypti* breeding places and number. According to this result of factor influencing, the major factor of DHF showed residential areas. This finding was in accordance with of Marianni *et al.*'s research studying Density of *Aedes aegypti and Ae. albopictus* and its association with number of residents and meteorological variables in the home environment of dengue endemic area [10]. Meanwhile, the meteorological factors [11] including area height, temperature, and rainfall were found in studies to be relevant to the DHF incidence [12], [13]. However, the DHF incidence in Samut Songkhram were not related to the meteorological factors because the province is small and drainage areas and natural water resources in Samut Songkhram were the *Ae. Albopictus* habitats more primary than *Ae. Aegypti* [4]. Another important factor for creating the GIS model was the average DHF patient number per year, which relation measure was unnecessary.

As for the degrees of DHF risk in Samut Songkhram, it was discovered that the very high risk area covered 9% of the total areas and the high risk area covered 23.89% of the total areas. The areas in the two risk degrees were mainly urban and high density residential areas since *Ae. Aegypti* primarily live around human habitations [14], [15]. Therefore, the number of *Ae. Aegypti* in residential areas with high density was much higher in residential areas with low density [16]. The finding was in accordance with Marianni's research, the DHF risk assessment result demonstrating that low risk areas were mostly suburb and less-dense residential areas [10].

At district and subdistrict levels of DHF risk assessment, Muang Samut Songkhram district was at very risk and higher risk than the other two districts. Mae Khlong and Lat Yai subdistricts of Muang Samut Songkham District were at very high risk as well. Muang Samut Songkhram District, in fact, has a number of tourist attractions such as Maeklong Railway Market drawing a lot of Thai and foreign travelers. This possibly caused a risk of DHF infection development to the tourists, in accordance with the Thavara U who studied Dengue vector mosquitos at a tourist attraction [17]. Therefore, government agencies in Samut Songkhram accordingly should give a main focus to this area in order to monitor the DHF outbreak among tourists from the area to other areas.

For the DHF risk assessment at a village level, it was found that there were only 13 villages at very high risk and 141 villages at low risk. Even though most of the villages were at low risk, DHF control and prevention are still essential. Because Samut Songkhram is a small province, this can facilitate population dispersal [18]. All residents of the villages should cooperate in controlling and preventing the DHF incidence and outbreak. After results of applying the GIS in DHF risk assessment in this research, it was demonstrated that GIS was one of an effective tools to help the government agencies to formulate a policy, a strategy, and a plan of DHF surveillance in Samut Songkhram provice.

5. CONCLUSION

The GIS nowadays is applied in discovering risk areas of epidemic diseases including the DHF globally [19], [20]. According to the research findings, the GIS is one of highly effective tools for DHF surveillance in an area. The GIS, moreover, has no complexity, making the local residents and tourists to easily understand the information about DHF infection risk in the areas, derived from the system. Tourists, therefore, are able to monitor themselves from the disease [21].

Our recommendation for research improvement is to consider two more important factors in the risk assessment including a period of time and mosquito index such as House Index, Container Index, and Breteau Index since these two factors can also contribute to the risk of DHF outbreak.

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