Malaria Risk Areas in Thailand Border

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Background: *Malaria is a serious public health problem of the world especially in Africa and Asia where the areas are located in the tropical and subtropical regions. Malaria is a mosquito-borne infectious disease of humans caused by parasitic protozoans of the genus Plasmodium.*
Objective: *The present study aims to analyze the risk areas by using Potential Surface Analysis (PSA) with Geographic Information Systems (GIS) in Thai-Cambodia border including Buriram and Surin provinces.*
Material and Method: *The study divided the factors into six factors including population density, land used (agriculture, houses, water reservoirs, forest), anopheles adult density in villages with reported cases, average annual rainfall, average annual temperature, average annual relative humidity and analyzing risk areas by analysis of PSA.*
Results: *846 malaria cases were reported between 2008 and 2012, 80.50% and 19.50% from to the Surin and Buriram provinces, respectively. The most cases were found in females, in the 31-40-year age group and agricultural people. The predominant cases were Plasmodium vivax with 45.36%. The high-risk areas of malaria cases was on the 3,014.79 kilometer Thai-Cambodian border consisting of four districts: Nangrong and Nondaeng districts of Buriram province and Sangka and Buached districts of Surin province. The relationship between malaria morbidity with environmental factors found that malaria morbidity rates were associated with land use (forest areas), population density, anopheles adult density of statistical significance and influenced morbidity rates by 12.3% (Adjusted $R^2 = 0.261$), 17.0 (Adjusted $R^2 = 0.170$), and 11.1 (Adjusted $R^2 = 0.111$). The climate factor associated to malaria morbidity with average annual relative humidity by percentage of 5.7 (Adjusted $R^2 = 0.057$).*
Conclusion: *This study showed that malaria is still a problem in Thailand-Cambodia border and the analysis of PSA with GIS can be used to assess the risk of malarial morbidity, and lead to planning, control, and prevention of the morbidity.*

Keywords: *Malaria, Risk area, Thailand, Border*

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Malaria is a serious public health problem of the world especially in Africa and Asia where the areas are located in the tropical and subtropical regions because rainfall, warm temperatures, and stagnant waters provide an environment ideal for mosquito larvae. Malaria is a mosquito-borne infectious disease of humans and other animals caused by parasitic protozoans of the genus *Plasmodium*, commonly, five species of *Plasmodium* can infect and be transmitted by humans. The vast majority of cases or deaths are caused by *P. falciparum*, *P. vivax*, *P. ovale*, *P. malariae* and *P. knowlesi*. Annual report by World Health Organization, in year 2013, found 207,000,000 cases and 627,000 deaths[1].

In Thailand, malaria is still a serious problem in Thai border areas. Annual reports of cases and death rates in the years 2009, 2010, 2011, 2012, 2013 were 36.61, 40.25, 33.01, 25.20, and 23.01 per 100,000 populations, and 0.03, 0.05, 0.017, 0.027, and 0.01 per 100,000 populations[2-6]. The cases and deaths are found frequently on Thai-Myanmar, Malaysia, Laos PDR, and Cambodia borders. The problem of malaria in border areas persists primarily due to uncontrolled migration from neighboring countries, particularly from Myanmar and Cambodia with its political difficulties. The border

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areas are densely covered by forests, which are breeding gounds for the predominant malaria vectors, *Anopheles dirus* and *An. minimus*. Malaria control measures are hampered by the remoteness of these areas[1]. This problem requires the means to eradicate and improve the situation. Therefore, the identification of malaria risk areas is the one best choice when planning I being developed.

Objective

The present study aims to analyze the potential risk areas by using Potential Surface Analysis (PSA) with Geographic Information Systems (GIS) to create maps to display the areas at risk for malaria epidemics on Thai-Cambodian border, which includes Buriram and Surin provinces, and to study the relationship between malarial morbidity with environmental factors and climate factors by multiple regression analysis.

Material and Method

In the present study, the focus was on Buriram and Surin provinces, located in the northeastern part of Thailand. They are situated along the Thai-Cambodian border and cover 18,446.9 km^2 (7,122.7 sq mi). This study area has divided into 2 provinces: 23 districts of Buriram province (10,322.9 km^2 or 3,985.7 sq mi), and 17 districts of Surin province (8,124 km^2 or 3,137 sq mi).

Study protocol

Descriptive and analytical studies were performed in this study. Data were collected for the period 2008 and 2012. Geographic data were collected from the administrative organizations of Buriram and Surin provinces, satellite data collected from Geo-Informatics and Space Technology Development Agency (Public Organization) and malaria cases collected from the bureau of the Epidemiology, Department of Disease Control, Ministry of Public Health.

Statistical analysis

This study used six factors including population density, land used (agriculture areas, number of houses, water reservoirs, forest areas), anopheles adult density in villages with reported cases, average annual rainfall, average annual temperature, and average annual relative humidity. After that, the researcher analyzed the factors by rating values from the relevant research which was divided into four levels from 1 (low risk) to 3 (high risk). Part of weighting values, considers the level of importance from 0 (no importance) to 10 (extreme importance) by the experts from Communicable Diseases Control Department and Public Health Office in Buriram and Surin provinces.

The Relationship between malaria morbidity rates with Environmental factors in Buriram and Surin Province was analyzed by Multiple Regressions. The relationship of dependent, variable data of the morbidity rates of malaria (Y) and independent variables including anopheles adult density (X_1), forest areas (X_2), water reservoirs (X_3), average annual rainfall (X_4), average annual temperature (X_5), average annual relative humidity (X_6), agriculture areas (X_7), population density (X_7), number of houses (X_8). These were then analyzed by using multiple linear regression analysis to provide reliability in a percentage of 95 ($p<0.05$).

The relationship between malarial morbidity rates with climate factors was established. The data used in the analysis were dependent variables, the morbidity rate of malaria (Y) and independent variables such as annual rainfall (X_1), number of rainy days (X_2), annual relative humidity (X_3), maximum temperatures (X_4), minimum temperatures (X_5), and average annual temperatures (X_6). All data are from between 2008 to 2012 time frame. The data analyzed used multiple linear regression analysis and gave the reliability with a percentage of 95 ($p<0.05$).

Results

Risk area level of malaria epidemic in Buriram and Surin province

Of the 846 malaria cases reported from 2008 through 2012, 80.50% and 19.50% belonged to the Surin and Buriram province, respectively. The majority of cases were found in females, between 31-40 years old, in the agriculture population (Table 1). The majority of malaria cases was *Plasmodium vivax* with 45.36% (Table 2).

According to weighing and rating of malaria epidemic factors by using overlay technique found, the high-risk areas covered 3,014.79 km^2 (16.34**%**) in 4 districts of Nangrong and Nondaeng districts of Buriram province (1,640.95 km^2), and Sangka and Buached districts of Surin provinces (1,373.84 km^2). Moderate risk areas covered 8,672.55 km^2 (75.6**%**) included Buriram province with 6,641.93 km^2 (64.34%), and Surin provinces with 2,031 km^2 (25%). Low-risk areas covered 2,819.65 km^2 (15.29%) including Buriram province with 2,030 km^2 (19.67%), and Surin provinces with 789.65 km^2 (9.72%) (Fig. 1).

Table 1. Baseline characteristics

Characteristics	Number of cases	% of infection
Sex		
Male	769	90.90
Female	77	9.10
Age		
1-10	16	1.84
11-20	83	9.83
21-30	184	21.80
31-40	225	26.61
41-50	207	24.46
51-60	88	10.44
>60	42	5.02
Occupation		
Agriculture	501	59.26
Soldier	90	10.64
Student	55	6.45
Employee	55	6.45
Gorvernmental officer	43	5.12
Others	35	4.09
Unknown	30	3.58
Monk	15	1.74
Housewife	14	1.64
Self-employed	9	1.02
Province		
Surin	681	80.50
Buriram	165	19.50
Total	846	100.00

Table 2. Types of malaria cases in Thailand-Cambodia borderline included Buriram and Surin province, by species

Type of Malaria species	Number of cases	% of infection
Plasmodium vivax	384	45.36
Plasmodium falciparum	344	40.66
Mixed infection	73	8.66
Not identified	45	5.32
Total	846	100.00

The relationship between the risks area of malaria epidemic with environmental factors

The relationship between malaria morbidity and environmental factors was analyzed and determined that the land use (forest areas), population density, anopheles adult density were of statistical significance and influence regarding morbidity rates of 12.3 (Adjusted $R^2 = 0.261$), 17.0 (Adjusted $R^2 = 0.170$), and 11.1 (Adjusted $R^2 = 0.111$). The relationship between water reservoirs, agriculture areas, numbers of houses was not associated with morbidity rates (Table 3).

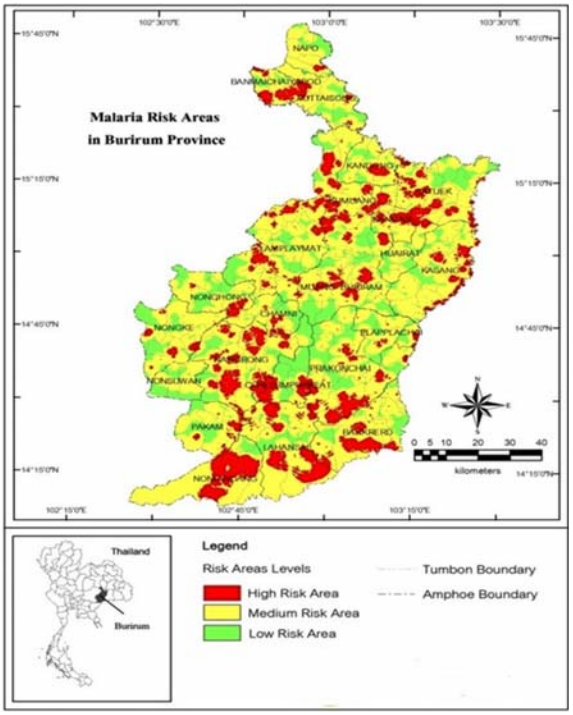

Fig. 1 Risk area mapping of malaria epidemic in Buriram province.

Table 3. The relationship between the risks area of malaria epidemic with environmental and climate factors

Factor	R^2	Sig.
Land used	1.001	0.06
Agriculture area	0.651	0.03*
Forest areas	0.261	0.06
Water reservoirs	1.000	0.09
Houses	0.111	0.03*
Anopheles adult density	0.170	0.03*
Population density	0.110	0.06
Average annual rain fall	0.231	0.06
Average annual humidity	0.057	0.03*

* Statistical significant

The relationship between malaria morbidity with climate factors

The results of relationship analysis between the factors (X) with the morbidity rates (Y) are shown

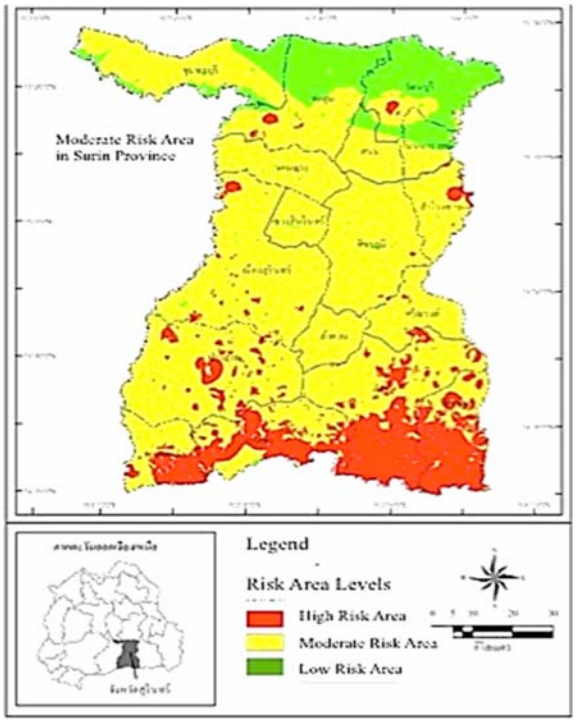

Fig. 2 Risk area mapping of malaria epidemic in Surin Province.

in Table 1. The climate factor associated with malaria morbidity with an average annual relative humidity of 5.7 (Adjusted $R^2 = 0.057$) (Table 3).

Discussion

Malaria is still a serious problem on Thai border where the cases and deaths are found frequently. Our study first reported 846 malaria cases in 2008 through 2012, 80.50% and 19.50% in the provinces of Surin and Buriram, respectively. The majority of cases were found in females, aged 31-40 years old, and of the agricultural population. The majority of malaria cases was *Plasmodium vivax*. This figure showed a serious problem for local and Thailand public health because both provinces are frequently visited areas, especially Buriram which has a sport complex for international car circuits and popular football clubs[1-6].

The high-risk areas of malaria cases in Thailand border were along the 3,014.79 kilometer, encompassing the Buriram (1,640.95 km^2), and Surin provinces (1,373.84 km^2). The distribution of malaria cases in both provinces was different. Buriram province cases were found widely dispersed covering all areas, while in Surin's were clusters along Thai-Cambodian border. This study shown that malaria is still a problem on Thailand-Cambodia border. The analyses of PSA with GIS can be used to assess the risks of malaria morbidity and lead to planning, control and prevent the morbidity of malaria. The high risk area in both provinces may be able to select a different campaign for prevention and control in both provinces[8,9].

The relationship between malaria morbidity and environmental and climate factors found that malaria morbidity rates were associated with forest areas, population density, anopheles adult density, and the average annual relative humidity associated with morbidity rates, due to the fact that the world is experiencing climate change which will exacerbate infectious diseases through insect vectors thus becoming again a serious problem and spread the disease more easily[9].

Conclusion

In conclusion, the application of PSA with GIS can assess the risk of an outbreak of malaria, which is beneficial to the prevention and control of disease epidemic. The present study indicated that malaria is still a problem on Thailand-Cambodia border. Therefore, this study may be useful for the prevention and control to related organizations.

What is already known on this topic?

The application of PSA with GIS can assess the risk of an outbreak of malaria, which is beneficial to the prevention and control of disease epidemic.

What this study adds?

The present study indicated that malaria is still a problem on Thailand-Cambodia border; therefore, this study may useful for prevention and control to related organizations.

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Potential conflicts of interest

None.

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พื้นที่เสี่ยงของโรคมาเลเรียตามแนวชายแดนไทย

ณัฏฐวุฒิ แก้วพิทูลย์, ไรอัน เอ ลอยด์, สรญา แก้วพิทูลย์, รัตนา รุจิรกุล

ภูมิหลัง: *มาลาเรียเป็นปัญหาภาวะสุขภาพของประชาชนทั่วโลก โดยเฉพาะอย่างยิ่งในแถบแอฟริกาและเอเชียที่พื้นที่ตั้งอยู่ในภูมิภาคเขตร้อนและกึ่งเขตร้อน โดยยุงก้นปล่องเป็นพาหะของโปรโตซัวจีนัสพลาสโมเดียม*

วัตถุประสงค์: *เพื่อวิเคราะห์พื้นที่เสี่ยงโดยการวิเคราะห์ศักยภาพพื้นที่เสี่ยงด้วยระบบสารสนเทศภูมิศาสตร์ ในพื้นที่จังหวัดบุรีรัมย์และสุรินทร์*

วัสดุและวิธีการ: *การศึกษาแบ่งปัจจัยหลักเป็น 6 ปัจจัย ประกอบด้วย ความหนาแน่นของประชากร การใช้ประโยชน์ที่ดิน (การเกษตรกรรม บ้าน แหล่งน้ำ ป่าไม้) ความหนาแน่นยุงในหมู่บ้านที่มีการรายงานผู้ป่วยมาลาเรีย ปริมาณฝนเฉลี่ย ปริมาณอุณหภูมิเฉลี่ย ความชื้นสัมพัทธ์เฉลี่ย นำข้อมูลวิเคราะห์พื้นที่เสี่ยงด้วยการวิเคราะห์ศักยภาพพื้นที่เสี่ยง*

ผลการศึกษา: *พบว่ามีผู้ป่วยมาลาเรียจำนวน 846 ราย ระหว่างปี 2550-2555 เป็นผู้ป่วยจากสุรินทร์ 80.50% และบุรีรัมย์ 19.50% ตามลำดับ ผู้ป่วยส่วนมากเป็นเพศหญิง กลุ่มอายุ 31-40 ปี มีอาชีพเกษตรกรรม ผู้ป่วยส่วนใหญ่ติดเชื้อมาลาเรียชนิด Plasmodium vivax 45.36% พื้นเสี่ยงตามแนวชายแดนไทยรวม 3,014.79 ตารางกิโลมตร ประกอบด้วย 4 อำเภอ คือ นางรอง โนนแดง ของจังหวัดบุรีรัมย์ และอำเภอสังขะและบัวเชด ของจังหวัดสุรินทร์ อัตราป่วยด้วยมาลาเรียมีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติกับปัจจัยสิ่งแวดล้อมด้านการใช้ประโยชน์ที่ดิน (ป่าไม้) ความหนาแน่นของประชากร ความหนาแน่นของยุง และมีอิทธิพลต่อการป่วยด้วยร้อยละ 12.3 (Adjusted R^2 = 0.261), 17.0 (Adjusted R^2 = 0.170), และ 11.1 (Adjusted R^2 = 0.111) อัตราป่วยด้วยมาลาเรียมีความสัมพันธ์อย่างมีนัยสำคัญทางสถิติกับปัจจัยด้านภูมิอากาศ คือ ความชื้นสัมพัทธ์เฉลี่ย และมีอิทธิพลต่อการป่วยด้วยร้อยละ 5.7 (Adjusted R^2 = 0.057)*

สรุป: *การศึกษาแสดงให้เห็นว่ามาลาเรียยังคงเป็นปัญหาที่สำคัญตามแนวชายแดนไทย-กัมพูชา การวิเคราะห์หาพื้นที่เสี่ยงและการจัดทำแผนที่เสี่ยงสามารถวิเคราะห์พื้นที่เสี่ยงมาลาเรียและสามารถไปเป็นข้อมูลประกอบการใช้วางแผนควบคุมและป้องกันโรคมาลเรียได้*