Journal of Communicable Diseases
Volume 51, Issue 2 - 2019, Pg. No. 45-53
Peer Reviewed & Open Access Journal

Research Article

The Spatio-Temporal Distribution of Malaria in Thailand from 2006-2015

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DOI: https://doi.org/10.24321/0019.5138.201916

I N F O

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How to cite this article:
Kingsawad K, Krongthamchat K, Puttanapong N et al. The Spatio-Temporal Distribution of Malaria in Thailand from 2006-2015. *J Commun Dis* 2019; 51(2): 45-53.

Date of Submission: 2019-05-20
Date of Acceptance: 2019-06-20

A B S T R A C T

Background and Objective: Malaria is a vector-borne disease in the tropical zone which the one of major health problem in Thailand. This study is aimed to determine the spatial and patterns of malaria and to identify clustering in Thailand during 2006-2015.

Methods: Data were obtained from inpatient reported by Ministry of Public Health, was obtained during 2006 to 2015. The spatio-temporal technique including, local indicators of spatial autocorrelation technique and cluster analysis at the country level, were conducted for the spatio-temporal distribution of malaria incidence.

Results: Outbreaks occurred in three waves over the past 10 years with the lowest incidence rate occurring at the beginning of each wave. The incidence of malaria in Thailand shifted from the western to the southern and the north-eastern regions. A spatial clustering analysis identified multiple clusters of high incidences in provinces in southern, Thailand from 2006-2015 and differed cluster in north-eastern region (Si Sa Ket).

Conclusion: A malaria clustered map will be best technique for identified the risk areas, which the one step of surveillance. It has been considered effectiveness prevention plan and allocated a healthcare resources of vector-borne diseases.

Keywords: Malaria, Spatial Analysis, Thailand

Introduction

Malaria is the one of vector-borne disease in the tropical zone that anopheles which is a carrier among human.[1,2] Although the disease has been eliminated in the equatorial area and some areas in West Europe and North America[3] Malaria infection is caused by Plasmodium (*Vivax, Malariae, Ovale, Knowlesi and Falciparum*) that can't be controlled under a certain temperature but is responded by temperature and humidity.[1]

Malaria diseases is a significant public health problem in highly endemic countries and distributed in 91 countries since 2000.[1,2] In 2015, we found that malaria patients in Africa were around 129, 585, 751 cases and South-East Asia were 1,513,705 cases, especially, Cambodia, Laos, Myanmar and Thai.

Malaria transmission can be partly controlled by environmental conditions, which variability may mainly. The climate change effects to malaria such as the rainfall are very important to predict the disease sensitivity resulting from climate change.[4,5]

Geographic Information System (GIS) used for analyzing, shows the creation of data in another dimension and spatial.[6] The spatial limitation of its distribution and seasonal conditions are sensitive to climate change, so we would like to reduce limitation of spatial and seasonal changes caused by rainfall that effect the trend of the malaria incidence. If we use spatial analyzation that is one of best choices for better controlling disease.[7-9]

The malaria pandemic in Thailand occurred 5 years ago (2011-2015), which found decrease of malaria cases from 2011 (49,521, 48,109, 52,808, 37690 and 24364 by sequence). However, 5.9% of malaria cases had increased from the year 2012 especially in rubber growing areas in North-East region of Thailand.10 So, we should be using a lot of measures to analyzing pandemic disease.

Source: http://www.thailandmaps.net/

One of measurement tool using to analyze the risk areas and climate change is Geographic Information System (GIS). The environmental and seasonal affect to the transmission of malaria patterns. Rainfall is the major climate risk factors that affects the specially breeding cycle of anopheles.[11] The spatial and seasonal changes must be taken into analysis to obtain an absolutely pattern of the incidence. So spatio-temporal analysis among health issues are an important measurement in epidemiological, environmental and public health study.[12]

This study conducted a spatial analysis that involved spatio-temporal to geographical transmission pattern of malaria cases in Thailand. Spatial statistic was used to identify the high risk in both areas and the population in the country. A propose to determine malaria incidence to visualize the spatial and patterns of malaria risk and identify clustering during 2006-2015.

Methods

Study Area

Thailand is a country in Southeast Asia, situated between 15° 00′ north latitude and 100° 00′ east longitude and exist of 514,000 square kilometers. Myanmar, Cambodia, Laos and Malaysia shared borders with Thailand**.** Thailand is consisting of 76 provinces, the area was subdivided using its political-administrative division.

Data Collection

The malaria incidence rate in Thailand for the year from 2006 – 2015, were obtained from Ministry of Public Health of Thailand were compiled for spatial analysis.[13] Use of these datasets were approved by the ethical committee in Khon Kaen University IRB.

Implementation of GIS and Spatial Analysis

In this study, the spatial temporal of malaria incidence rate and malaria cases in Thailand were obtained in the boundaries of shapefile for malaria incidence rate from DIVA-GIS.[14] The Quantum GIS version 2.8.5 and custom encoding were used as tool to generated a polygon shapefile from a paper map of province boundaries was generated. The described temporal transmission of malaria incidence rate in each province were used as characterize outbreak pattern of vector-borne diseases or malaria from historical data during 2006-2015.[15]

Spatial Autocorrelation Analysis

Global spatial autocorrelation analysis was performed in GeoDa software. This study tested for spatial temporal in Thailand's malaria incidence rate and applied the indicator of spatial autocorrelation called Moran's I.[16] Moran's I index to measure the spatial autocorrelation and focused on the distance between the outcomes.[17] It tested to find the attribution of values or features clusters, not given under their locations to another one. Moran's I and spatial autocorrelation statistic was calculated and demonstrated the result with the Moran Scatter Plot. Its scale was during -1 to 1. Scale "1" was a positive spatial autocorrelation, while "-1" was a negative spatial autocorrelation and "0" meant a spatial random cluster.[18] Local Moran's I index can be expressed by:

$$I_i = \frac{z_i - \bar{z}}{\sigma^2} \sum_{j=1, j\neq i}^{n} \left[W_{ij}\left(z_j - \bar{z}\right)\right]$$

Where; $\bar{z}$ is mean value of z with the variable of n

z_i is the value of the variable at areas i; z_j is the value at another areas (where $j \neq i$)

σ^2 is the variance of z

W_{ij} is a weighted distance between z_i and z_j, which can be defined as the inverse of the distance.[19]

The weight W_{ij} can also be determined using a distance: samples within a distance are given the same weight, while those outside the distance band are given the weight of 0.

The spatial distance weight for each threshold 1.2 kilometers distance was created in this study. Spatial autocorrelation statistics for malaria cases were calculated based on the assumption of constant variance. This assumption was usually infringed when incidence at county level or province level diverse greatly in different populations. The measurement (i.e. a function in GeoDa) was performed to adjust for infringe of the assumption. We created Moran's scatter plot with spatial lag of cases on the vertical form, which used a quartiles was categorized by outlier in any observation. A significant test of the malaria incidence rate was randomly distributed was operated through the permutation test under the assumption. The repeated of number was time to 999 and the significant level was 0.001.[20]

Spatial Cluster Analysis

The spatial statistic was used to investigate the statistically significant spatial clusters of malaria. It was also performed to detect spatial clusters or risk areas for malaria during 2006-2015 using Geoda software.[21] The spatial analyses including the time dimension of the cases were performed to detect the malaria clusters under area study. Therefore, at different locations, the window included different sets of neighboring provinces. The clusters were identified by a comparison of the expected and observed number of cases within and outside a scanning frame that has a varying radius and center.[22,23] The spatial autocorrelation was quantify clustering areas by Local Indicators of Spatial Autocorrelation (LISA) which focused in small areas or study area for identified risk areas.[24] LISA can be expressed by:

$$l_i = Z_i \sum_{i=1}^{N} W_{ij} Z_j$$

$$Z_i = \frac{(y_i - \bar{y})}{S}$$

Where; W_{ij} is the spatial weight between i and j province.

Z_i, Z_j, is the value of z-score in i and j province.

y_i is the number of malaria incidence rate of i province.

S is the aggregate of spatial weight.

Result

The total number of 113, 856 malaria cases in Thailand were reported during 2006 to 2015. 53% of malaria cases were infected *P. Vivax* and 37% were infected *P. Falciparum*. Wave I malaria incidence rate per 1,000 populations appeared between the year 2006 and 2009 and peaked in 2006. The malaria incidence rate was approximately the same level and had become slightly complicated since 2006. Malaria incidence rate in Thailand showed an overall decline over the past decade in all regions except in the north-eastern region showed a slightly change in this period. Wave II started in 2009, the turning point is to increase upon the year 2010 in western and southern region, and turned it to complicate and to decrease until year 2011. Wave III began during year 2011 to 2015. The Western, eastern, northern, and middle regions were slightly decrease but in south region turned point to increase in 2013 and turned it to slightly decrease until year 2015, in north-east slightly increased until 2015. The malaria incidence rate was beginning from the lowest of each wave and highest at its peak (Figure 1).

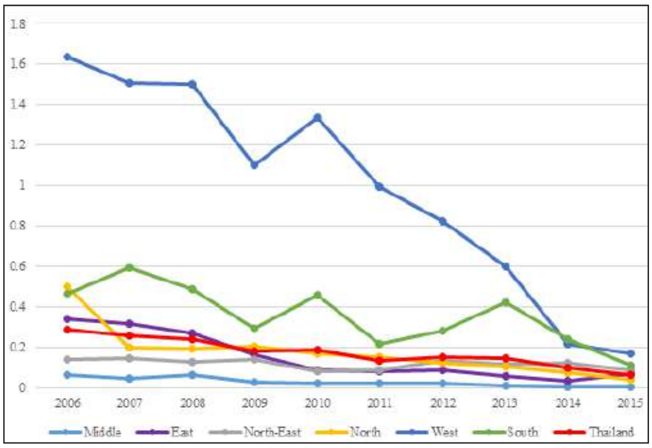


Figure 1.Malaria incidence rate in Thailand during year 2006-2015

Spatial Distribution of Malaria in Thailand

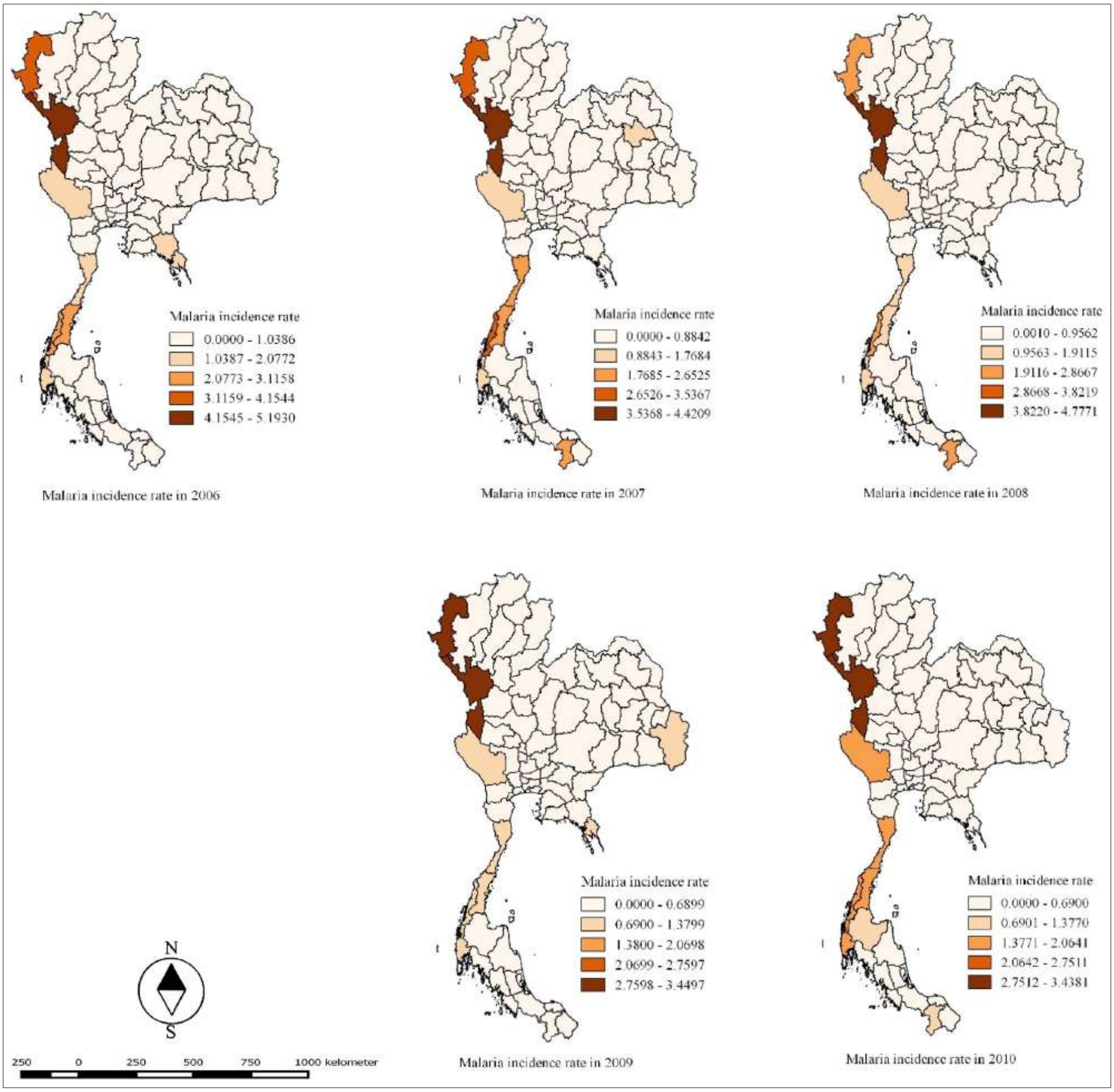
To access the spatial distribution of malaria cases in Thailand reported by Ministry of Public Health demonstrated substantial spatial heterogeneity from year to year, the classes were divided by standard deviation. Wave I (2006

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.201916

to 2009): malaria incidence rate was the highest at western region (Tak province and Mae Hong Son province) and began to changed transmission to southern region and north-eastern region in the end of wave I (2008) (Figure 2). Wave II (2009 to 2011): malaria incidence rate was increased in southern region (Chumphon province and Ranong province). Wave III (2011 to 2015): malaria incidence rate was still decreased in southern region especially in Yala province and Ranong province. Malaria incidence rate slightly increased in the north-eastern region since wave II in Surin, Si Sa Ket province and Ubon Ratchathani province. In the end of wave III between 2014 and 2015, malaria incidence rate was the highest in some provinces of north-eastern (Ubon Ratchathani province) and southern region (Yala province).

Spatial Clustering of Malaria in Thailand during 2006 to 2015

Statistically significant spatial clusters of provinces with malaria incidence rate were identified in Thailand during 2006 to 2015. the change of concentrated to other regions showed in Table 1. This study also identified clusters in the upper-southern region during 2006 to 2013 in Chumphon province and neighboring areas. In 2014, clusters in Chumphon province shifted to lower-southern region in Yala province. The new clustered began in north-eastern region nearly the border of Laos and Cambodia in Si Sa Ket province (Figure 3). When malaria incidence rate clustered was focused, the north-eastern region was observed some changes and this region was not found to be clustered in the past.



ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.201916

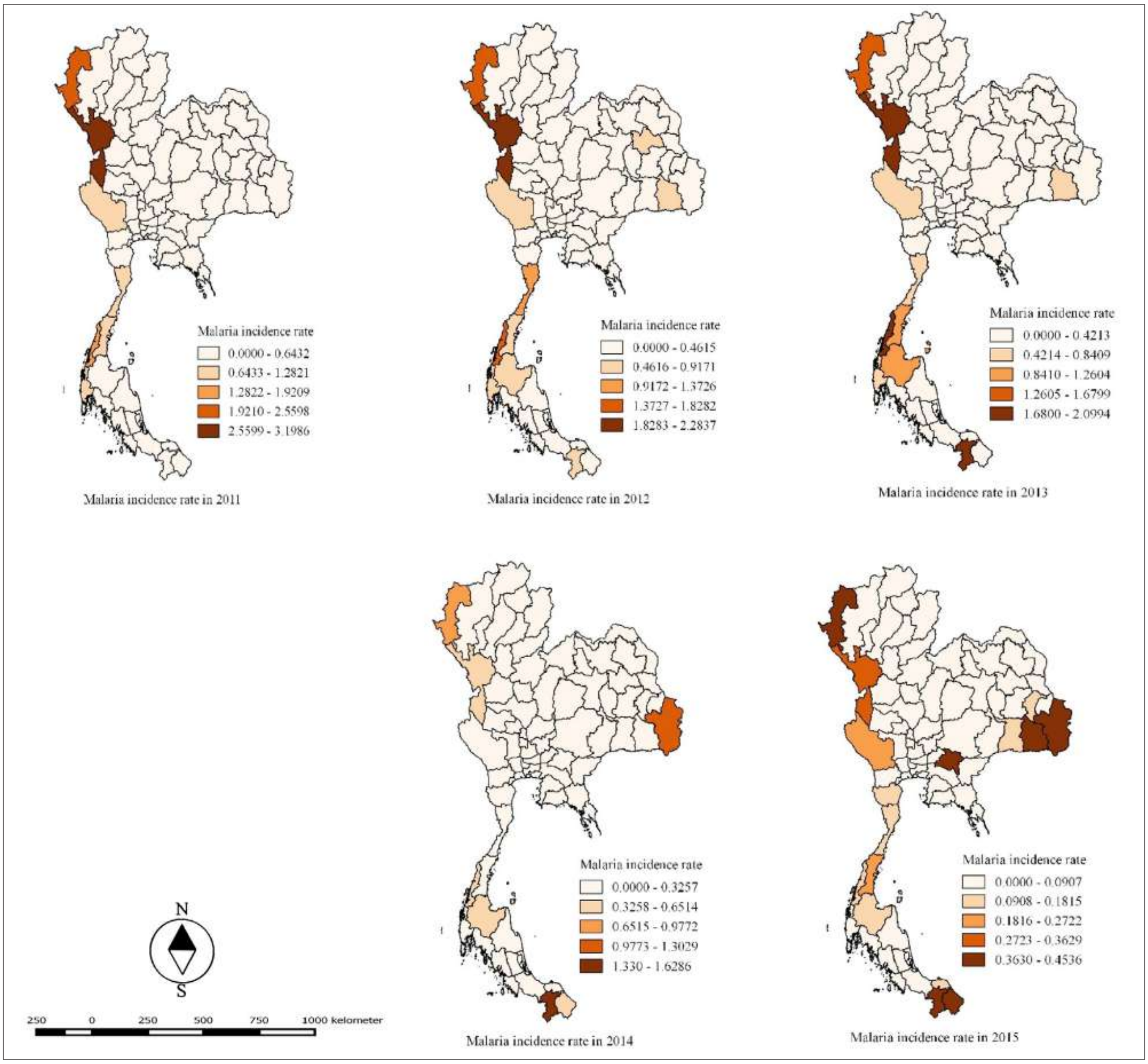


Figure 2.The spatial distribution of malaria incidence rate in Thailand during 2006 to 2015

Table 1.Spatial autocorrelation analyses for annualized incidence of malaria cases in Thailand during 2012 to 2016

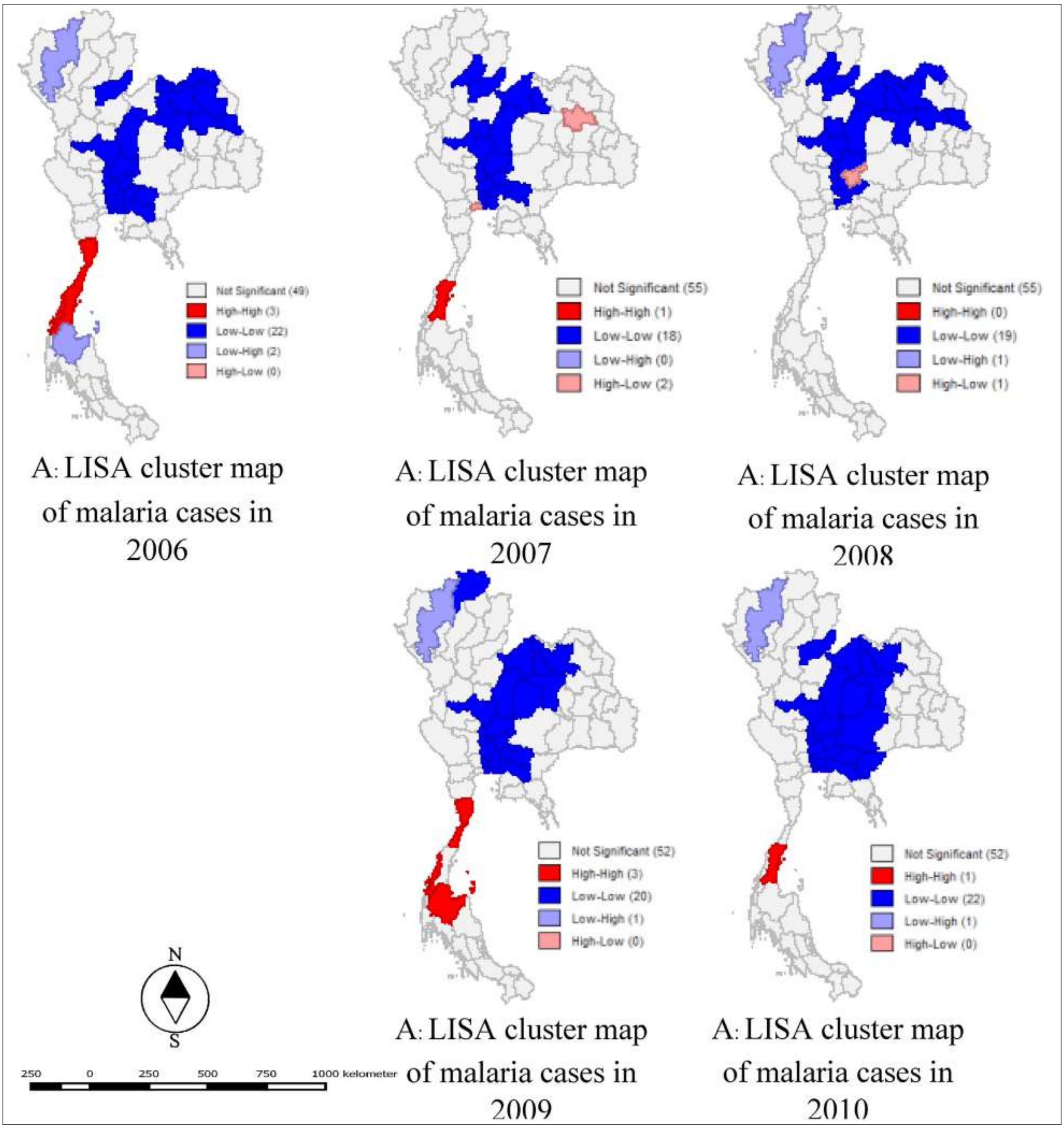
Year	Malaria cases	Malaria Incidence Rate (Per 1,000 populations)	Moran's I	p-value
2006	19,646	0.29	0.251698	0.000
2007	16,489	0.26	0.229959	0.000
2008	15,454	0.24	0.139282	0.000
2009	11,775	0.19	0.110096	0.000
2010	11,931	0.19	0.231102	0.000
2011	8,798	0.14	0.0894513	0.000
2012	9,650	0.15	0.196046	0.000
2013	9,577	0.15	0.252166	0.000
2014	6,366	0.10	0.136315	0.000
2015	4,170	0.07	0.182492	0.000

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.201916

Discussion

This study used spatial analysis method in GIS to map and analyze a surveillance dataset of 10 years. This method could offer an opportunity to formulate the burden of health from malaria incidence rate within risk areas.[20, 25-27] The malaria were clustered on the northern forest region in 2002, 2003, 2004, 2005 and 2012.[28, 29] The spatial pattern was confirmed by our spatial clustering analysis of the data and the changing of trend and transmission trend of malaria in Thailand from 2006 – 2015.

The malaria incidence rate was decreased but the transmission of malaria was changed from the northern region to the north-eastern region (Ubon Ratchathani province) and the southern region (Yala Province). Ubon Ratchathani province had a border closed to Champasak in Laos which was the highest malaria incidence rate.[30] The number of immigrant worker in Thailand has increased in the commercial border area which affected to disease control. The malaria incidence rate in Yala province was clustered close to the Thailand – Malaysia border, due to the separatist insurgency in the lower-southern region. The violence situation affected on disease control and the climate change. The malaria incidence rate in Perak, Malaysia were increased from 2007 to 2011, and occurred in a clustered.[31]



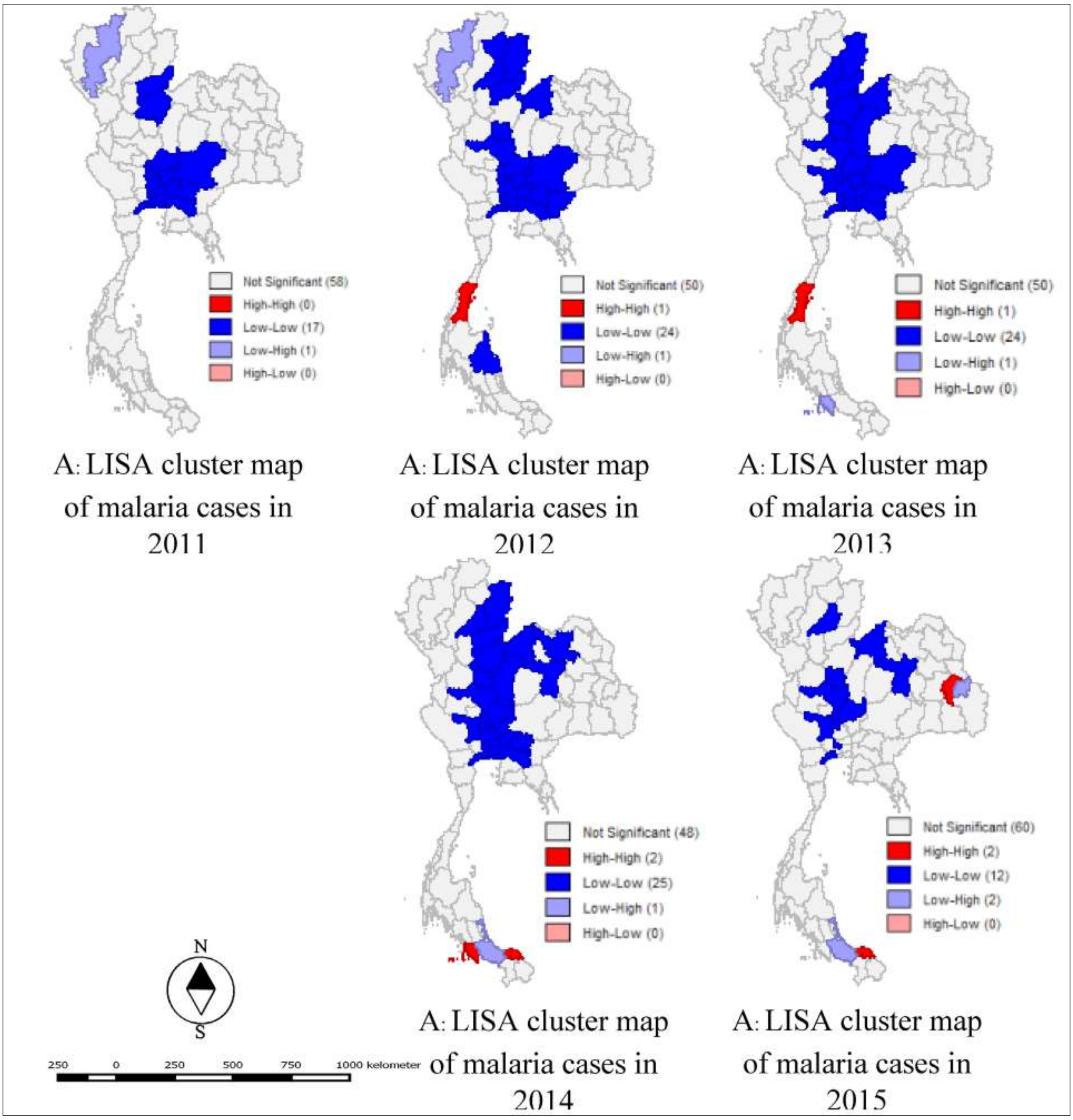


Figure 3.The spatial cluster map of malaria case in Thailand during 2006 to 2015

At the community level, the breeding site of vectors in endemic regions was 2-3 kilometers from patient's houses. The clustered malaria incidences increased the risk of malaria infection.[31] The outbreak dynamics showed a clear non-random pattern of transmission from the first province to other provinces each year. The clustering of disease focused on local malaria followed different patterns, which indicated differences in the environment possibly vacillating their transmission.[25,27] Malaria needed to be mapped on many different layers, from country level down to village level for a quality control measure.[30]

The risk factors of malaria in Thailand that the use of suitable statistical models were regions (Eastern, Southern and North-Eastern), borders (Myanmar, Malaysia and Cambodia) and monthly (May-Jul and Nov-Jan).[33] This border region is long distance (2000 km) and has various of geographical features including mountains, thick forests, growing urban areas and wet-rice fields. It is also a biologically diverse region. There are at least three anopheles vector species complexes with widely varying behavioral characteristics and over ten different ethnolinguistic groups. They exist in the area and affect to malaria control.[34,35] Although the malaria incidence rate shifted to different border, from Thai - Myanmar border to Thai - Laos border and Thai - Malaysia border, then Thai government should be used the clustered map to consider a policy to controlled the malaria transmission along border areas in Laos and

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.201916

Malaysia, which the risk area, especially Ubon Ratchathani province, Si Sa Ket province and Yala Province.

Conclusion

Malaria prevalence in Thailand from 2006-2015 were decrease in every year. The spatio-temporal analysis was showing a significant spatial relationship of malaria. Then a malaria clustered map will be one of best technique for identified the risk areas, which the one step of surveillance. It has been considered effectiveness prevention plan and allocated a healthcare resources of vector-borne diseases.

Acknowledgment

The authors would like to thank Ministry of Public Health for the malaria reported data.

Conflict of Interest: None

References

1. World Health Organization. Eliminating malaria. WHO, Geneva, Switzerland. 2016.
2. World Health Organization. 2016 World malaria report. WHO, Switzerland. 2016.
3. Kovats S, Ebi LK, Menne B. Health and global environmental change. World Health Organization, Copenhagen, Denmark. 2003.
4. Arne B, Jean BD, Elfatih ABE. A mechanistic approach for accurate simulation of village scale malaria transmission. *Malaria J* 2009; 8(223): 1-12.
5. Arne B, Elfatih ABE. Assessment of the impact of climate shifts on malaria transmission in the Sahel. *EcoHealth* 2009: 426-437.
6. Phothong D, Thongbu T, Srisang W. *Spatial analysis of malaria risk in Phitsanulok province using geographic information system*. Independent study Master of Science in Natural Resources and Environmental Management, Naresuan University, 2008.
7. Cyril C, Sari K, Joacim R et al. Impact of climate change on global malaria distribution. *PNAS* 2014; 111: 3286-3291.
8. Sonsa A. *Spatial modeling for liver fluke distribution in Khon Kaen province*. Master of Science thesis in Remote Sensing and Geographic Information System, Graduate school, Khon Kaen University, Thailand.
9. Van Dervort DR, Dina LL, Carlos MO et al. Spatial distribution of unspecified chronic kidney disease in El Salvador by crop area cultivated and ambient temperature. *MEDICC Review* 2014; 16(2): 31-38.
10. Bureau of Vector-Borne Disease. Malaria annual report 2015. Bureau of Vector-Borne Disease. Bureau of Vector-Borne Disease, Department of Disease Control, Ministry of Public Health, Bangkok. 2016.
11. Abellana R, Ascaso C, Aponte J, et al. Spatio-seasonal modeling of the incidence rate of malaria in Mozambique. *Malaria J* 2008; 7: 1-11.
12. Yoep N, Hasim H, Yusoff NU et al. Spatio-temporal distribution of malaria in Perak, Malaysia. *Advance in Infectious Disease* 2015; 5: 154-161.
13. Strategy and Planning Division, Ministry of Public Health. *Reported 505 inpatient and diagnosis by ICD10 each province from 2006-2015*. 2017 Cited Feb 13, 2017.
14. Hijmans R, Rojas E, Cruz M et al. *Spatial data, DIVA-GIS*. 2015. Cited Jul 12, 15. Available from: http://www.diva-gis.org/datadown.
15. Wen TH, Lin NH, Chao DY et.al., Spatial-Temporal patterns of Malaria in Areas at Risk of Malaria Hemorrhagic Fever in Kaohsiung, Taiwan, 2002. *Int J of Infectious Diseases* 2010; 14: e334-43.
16. Moran PAP. Notes on continuous stochastic phenomena. *Biometrika* 1950; 37: 17-23.
17. Cliff AD, Ord JK. Spatial Process: Models and applications. Pion, London. 1981.
18. Tu J, Xia ZG. Examining spatially varying relationships between land use and water quality using geographically weighted regression I: Model design and evaluation. *Sci Total Environ* 2008; 407: 358-378.
19. Levine N. *Crime Stat III: a spatial statistics program for the analysis of crime incident locations*. Ned Levine and Associates, Houston, Texas, and the National Institute of Justice, Washington, DC. 2004.
20. Fang L, Yan L, Liang S et al. Spatial analysis of hemorrhagic fever with renal syndrome in China. *BMC Infectious Diseases* 2006; 6(77): 1-10
21. Kulldorff M, Rand K, Gherman G et al. *Software for the spatial and space-time scan statistics*. SaTScan, Version 2.1. National Cancer Institute, Bethesda, Madison. 1998.
22. Agay-Shay K, Amitai Y, Peretz C, et al. Exploratory Spatial Data Analysis of Congenital Malformations (CM) in Israel, 2000-2006. *Int J Geo-Information* 2013; 2(1): 237.
23. Kulldorff M. SaTScanTM User Guide for version8.0.2009.2008.44. Available from: https://www.satscan.org/cgi-bin/satscan/register.pl/SaTScan_Users_Guide.pdf?todo=process_userguide_download.
24. Getis A, Ord JK. The analysis of spatial association by use of distance statistics. *Geographical Analysis* 1992; 24(3): 189-206.
25. Wilson J, Fotheringham AS. *The Handbook of Geographic Information Science*. Blackwell Publishing, Victoria, Australia. 2008.
26. Hundessa HS, William G, Lo S, et al. Spatial and space-time distribution of *Plasmodium vivax* and *Plasmodium falciparum* malaria in China, 2005-2014. *Malaria Journal* 2016; 115: 1-11.
27. Jeefoo P, Tripathi KN, Souris M. Spatio-temporal diffusion pattern and hotspot detection of dengue in Chachoengsao province, Thailand. *Int J of Environmental*

J Environmental Research and Public Health 2011; 8: 51-74.

28. Ngwa MC, Liang S, Kracalik IT et al. Cholera in Cameroon, 2000 – 2012: Spatial and temporal analysis at the operational (Health district) and sub climate levels. *PLOS Neglected Tropical Diseases* 2016; 10(11): e0005105.
29. Lekdee K, Sammatat S, Boonsit N. Spatio-temporal analysis and mapping of malaria in Thailand. *Int J of Medical, Health, Biomedical, Bioengineering and Pharmaceutical Engineering* 2014; 8(7): 393-397.
30. Chaikaew N, Tripathi NK, Hara S. Exploring spatial and apatio-temporal clusters of malaria in Chiang Mai, Thailand. *Int Symposium on Geoinformatics for Spatial Infrastructure Development in Earth and Allied Sciences* 2008; 1-6.
31. Souris M, Marcombe S, Laforet J, et al. Modeling spatial variation in risk of presence and insecticide resistance for malaria vectors in Laos. *PLOS One* 2017 12(5): e0177274.
32. Yoep N, Hasim H, Yusoff UN, et al. Spatio-temporal distribution of malaria in Perak, Malaria. *Scientific Research Publishing* 2015; 5: 154-161.
33. Sangsayan J. *Spatial analysis on the malaria distribution patterns and its relation to environmental factors at community level in endemic regions*. Master of Science in Environmental Planning for Community and Rural Development, Mahidol University, 2008.
34. Lekdee K, Ingsrisawang L. Risk factors for malaria in Thailand using Generalized Estimating Equation (GEE) and Generalized Linear Mixed Model (GLMM). *J health Science* 2010; 19(3): 364-373.
35. Parker DM, Carrara VI, Pukittayakamee S, et al. Malaria ecology along the Thailand-Myanmar border. *Malaria J* 2015; 14(388): 1-12.

ISSN: 0019-5138
DOI: https://doi.org/10.24321/0019.5138.201916