EXPLORING SPATIAL AND SPATIO-TEMPORAL CLURSTERS OF MALARIA IN CHIANG MAI, THAILAND

Nakarin Chaikaew[1], Nitin Kumar Tripathi[1], and Shoichiro Hara[2]

[1]Remote Sensing and GIS FoS, School of Engineering and Technologies,
Asian Institute of Technology, Klongluang, Pathumthani, Thailand, 12120
Email: nakarin.chaikaew@ait.ac.th, Email: nitinkt@ait.ac.th
[2]Division of Area Informatics Center for Integrated Area Studies (CIAS) Kyoto University, Japan
Email: shara@cias.kyoto-u.ac.jp

ABSTRACT

The objective of this study was to identify the spatial and spatio-temporal clusters of malaria in Chiang Mai province, Thailand. The data of village locations, patients with malaria, and population during 2001-2006 were collected to support the objective. The spatial and space-time scan statistics were then used to identify clusters of villages with elevated proportions of malaria cases.

In the purely spatial analyses, the most likely clusters were in the forest area of the north (2002, 2003, 2004 and 2005) and the south (2001 and 2006) of study area. In the space-time analysis, the most likely cluster was the group of villages which locates in the Wiang Haeng district, Chiang Dao district, Chai Prakan district, Mae Ai district and Fang district (in 2004). The north part of Chiang Mai was the most likely to have a cluster with a significantly high occurrence of malaria.

1. INTRODUCTION

Basic elements of outbreak examinations and epidemiology are person, place and time. The epidemiology research has been emphasized in person and time over a hundred years. The element of place has not been much focused, only the disease mapping is considered in some areas. The development of geographic information systems (GIS) over last 30 years has been provided a more powerful and rapid ability to investigate spatial patterns and processed. This is referred to and more useful in epidemiologic investigations and also disease surveillance including policy relevant issues such as health services and planning (Matthews, 1990).

Spatial, temporal, and space-time scan statistics are now commonly used to detect and evaluate statistically-significant, spatial clusters (e.g. disease, crime, etc). These methods can be analyzed by using the space-time scan statistic (SatScan) software (Kulldorff, 2006) which is used widely in an increasing number of applications including epidemiology and other research fields. SatScan is useful for determining which cluster alarms merit further investigation and which clusters are likely to be occurring by chance.

The occurrences of malaria incidence are random in space and time. The space-time scan statistic was used to identify where and when the prevalence of malaria in high in the study area during 2001-2006. It can be used to detect malaria outbreaks which is important for local and national health departments to minimize morbidity and mortality through timely implementation of malaria prevention and control measures.

2. STUDY AREA

Chiang Mai is the second-biggest province of Thailand, located in the north of the country. It covers the area of 22,061.17 square kilometers, most of which is forested mountains (Chiang Mai Province Office, 2006).

3. METHODS

3.1 Data sources

The study of spatio-temporal patterns of malaria covers the period 2001-2006 and the 2,054 villages of Chiang Mai province at that time. Data on patients with malaria and the number of population in village level were obtained from the records of Chiang Mai Provincial Public Health Office (CMPHO), Thailand. These records included the malaria cases referred from other hospitals and the number of population from Ministry of Interior, Thailand. The spatial data in this study were the village location points in Shape file format which were collected from Geo-Informatics and Space Technology Centre (Northern Region), Thailand.

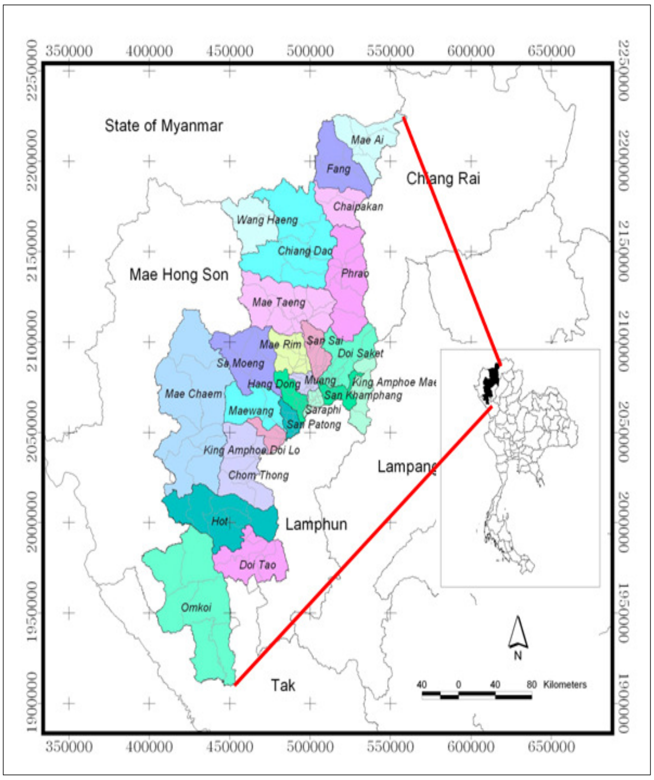

Figure 1. The study area: Chiang Mai.

3.2 Data analysis

In this study, Spatial scan statistic (Kulldorff, 1997) was used to identify clusters of malaria in Chiang Mai province. SaTScan identifies a cluster at any location of any size up to a maximum size, and minimizes the problem of multiple statistical tests. Scanning was also set to search only for villages with high proportions of malaria. No geographic overlap was used as a default setting, so secondary clusters would not overlap the most significant cluster. In order to scan for small to large clusters, the maximum cluster size was set to 50% of the total population at risk. To ensure sufficient statistical power, the number of Monte Carlo replications was set to 999, and clusters with statistical significance of $p < 0.001$ were reported.

4. RESULTS

4.1 Data exploration

Chiang Mai province is an endemic area for malaria in the upper northern of Thailand. This province is subdivided according to the Ministry of Interior, Thailand to 2,054 villages in 2006. Its population according to the 2006 census is 1,512,716.

A total of 3,414 malaria cases were reported in Chiang Mai from 2001 to 2006 with an average raw incidence rate of 35.5 annual cases / 100,000 populations. The distribution of malaria disease in 6 years (2001 – 2006) was shown in the figure 2. It shows that malaria infected cases were highest in rainy season (May-September) in every year. The temporal evolution of malaria was depicted at the figure 3 and in figure 5; moreover from figure 5 one may observe a tendency of high incidence rates to occur at the northern part of the study area as time evolves. There was an obvious outbreak of the disease in 2004. The Kulldorff's scan statistic reports a significant temporal cluster of high rates occurring in 2004 (observed cases are 1.581 times the expected with a log-likelihood ratio of 94.309

and a p-value less than 0.001). Moreover, it was indicated by the graph at the figure 4, there was a strong association between malaria cases per village in 2004 and total malaria cases during the six-year study-period.

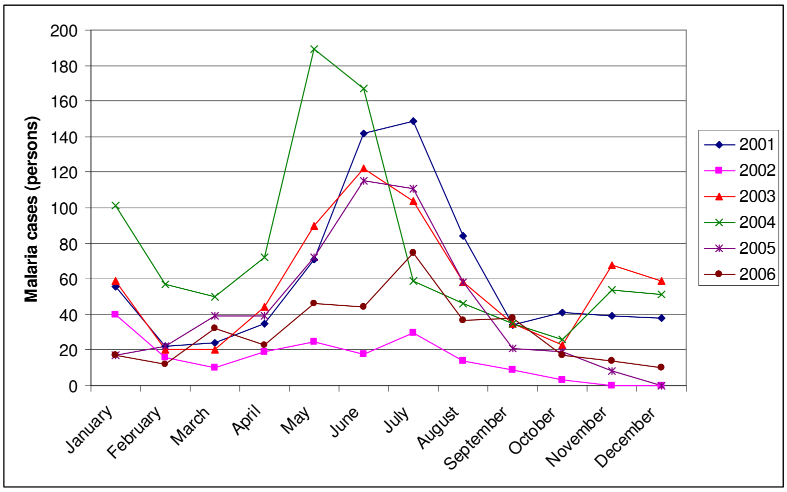

Figure 2. Monthly malaria cases during 2001-2006.

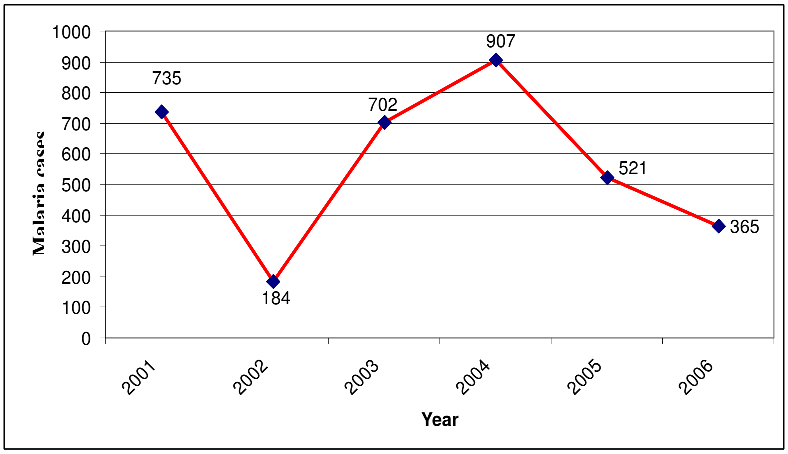

Figure 3. Malaria cases in Chiang Mai from 2001-2006.

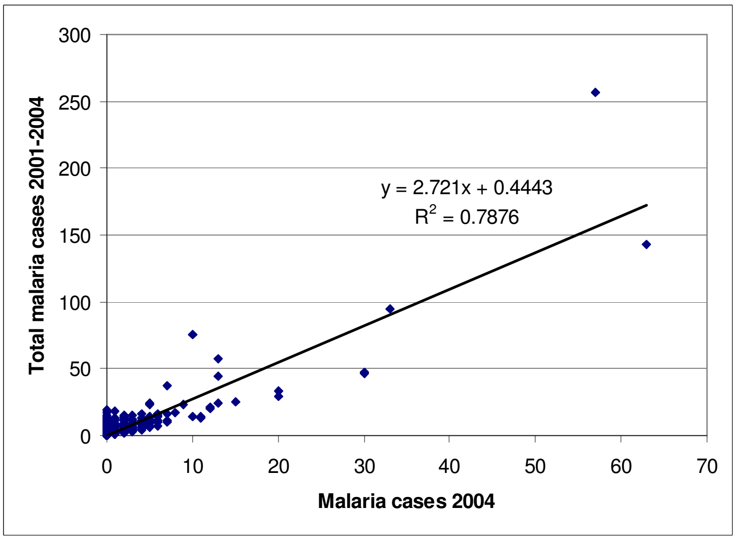

Figure 4. Linear association between cases observed in 2004 and total cases from 2001 to 2006 for the 2,054 villages.

4.2 Identification of spatial and spatio-temporal clusters

The results of the purely spatial analysis of malaria data from 2001 to 2006 were shown in tables 1 and 2, and in figures 6 and 7. The most likely significant clusters for a high occurrence of malaria were listed in table 2, and represented on the map in figure 6. For the purely spatial analyses, the most likely cluster was detected for each year. The most likely cluster had 178 observed cases in 2001, when 33.52 were expected theoretically (RR = 6.736, p = 0.001); 67 vs. 5.26 cases (RR = 20.369, p = 0.001) in 2002; 264 vs. 20.57 cases (RR = 20.378, p = 0.001) in 2003; 691 vs. 188.05 cases (RR = 16.333, p = 0.001) in 2004; 306 vs. 94.54 cases (RR = 7.488, p = 0.001) in 2005; and 46 vs. 1.39 cases (RR = 38.579, p = 0.001) in 2006. The most likely clusters were in the forest area of the north and the south of study area. Especially, in the North which was the border of Thailand and Myanmar found the spatial clusters of malaria were in Wiang Haeng, Chiang Dao, Chai Prakan, Mae Ai and Fang, (in 2002, 2003, 2004, 2005). The clusters of malaria in the South were in Doi Tao and Om Koi (in 2001 and 2006). We also detected several secondary clusters, which were not significant.

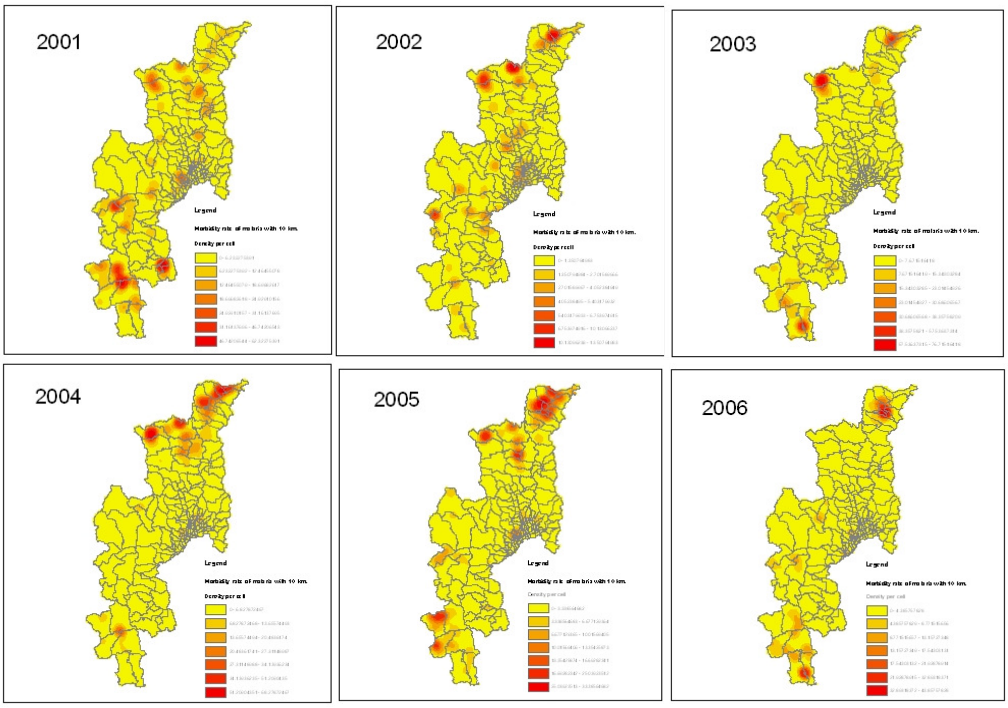

Figure 5. Choropleth maps of malaria incidence rates (per 100,000 populations) in Chiang Mai from 2001 to 2006

Table 1. The most likely clusters of malaria detected using the purely spatial analysis.

Data Years	Cluster Villages(n)	Observed Cases	Expected Cases	Relative Risk	p-value
2001	121	178	33.52	6.736	0.001
2002	33	67	5.26	20.369	0.001
2003	32	264	20.57	20.378	0.001
2004	362	691	188.05	16.333	0.001
2005	306	306	94.54	7.488	0.001
2006	85	46	1.39	38.579	0.001

Next, we tested the space-time analysis of the malaria data from 2001 to 2006. The most likely significant clusters for a high occurrence of malaria were listed in table 2, and represented on the map in figure 7. In the 2001–2006 data, the most likely cluster had 691 cases, when 118.94 were theoretically expected (RR = 7.139, p = 0.001) in 2004. In the 2002–2006 data, the most likely cluster had 691 cases, when 110.80 were theoretically expected (RR = 8.266, p = 0.001) in 2004. In the 2003–2006 data, the most likely cluster had 691 cases, when 128.78 were theoretically expected (RR = 7.236, p = 0.001) in 2004. In the 2004–2006 data, the most likely cluster had 691 cases, when 120.78 were theoretically expected (RR = 9.210, p = 0.001) in 2004. We also detected several secondary clusters, which were not significant.

Table 2. The most likely clusters of malaria cases detected using the space-time analysis.

Data Years	Cluster Villages(n)	Cluster Years	Observed Cases	Expected Cases	Relative Risk	p-value
2001-2006	362	2004	691	118.94	7.139	0.001
2002-2006	362	2004	691	110.80	8.266	0.001
2003-2006	362	2004	691	128.78	7.236	0.001
2004-2006	362	2004	691	120.78	9.210	0.001
2005-2006	306	2005	306	79.77	5.633	0.001

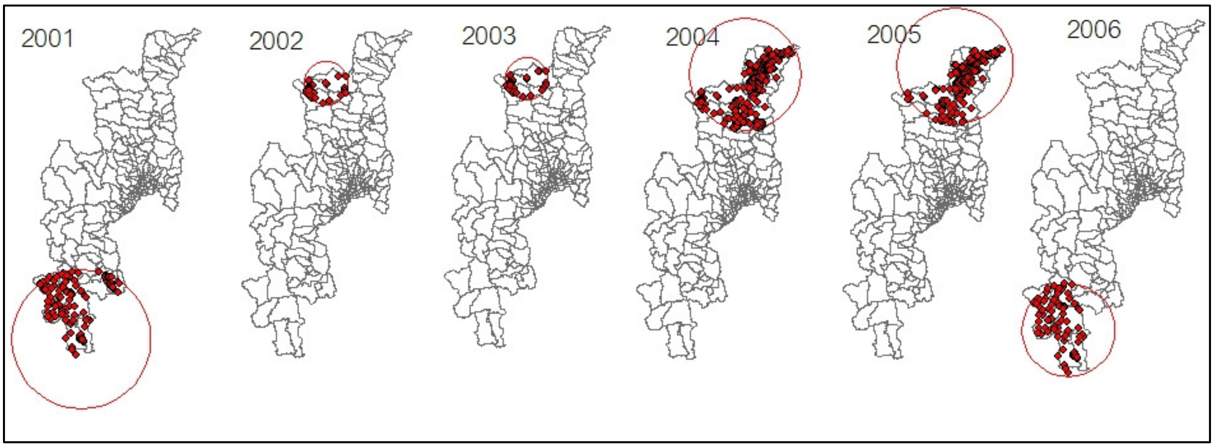

Figure 6. Detected clusters of malaria cases (2001 to 2006) based on a purely spatial analysis.

5. CONCLUSION

In the present, the attempt to plan for monitoring and controlling the malaria epidemics in Thailand has become the critical issue. The space-time scan statistic (SatScan) was applied to examine clusters of malaria disease in Chiang Mai from 2001 to 2006. The result of this study can be identified the most likely significant cluster for a high occurrence of malaria in the north of Chiang Mai. The space-time scan statistic can contribute to health program evolution. Moreover, it can be supported public health officers to plan for controlling and preventing the risky area of malaria disease in the future.

Although the method used here could help prioritize the assignment and investigation of diseases, the applicability of our methodology might be limited due to considering only limited factors. We need to include more factors and develop more sophisticated methodology in future studies.

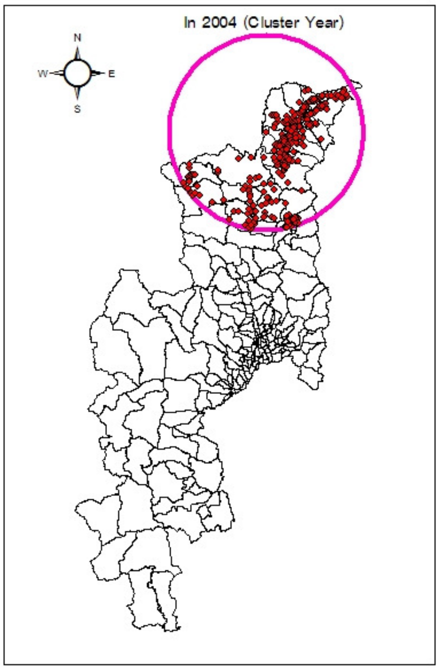

Figure 7. Locations of the detected clusters of malaria cases, using historical data from 2001 to 2006, based on the space-time analysis.

6. ACKNOWLEDGMENTS

Special thanks to the Chiang Mai Provincial Public Health Office and Geo-Informatics and Space Technology Centre (Northern Region) for providing data.

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