Epidemiological Surveillance of Pneumonia using GIS in Ayutthaya Province, Thailand

Southanome Keola, Mitsuharu Tokunaga* and Vivarad Phonekeo
STAR Program, School of Advanced Technologies
Asian Institute of Technology, Pathumthani 12120, Thailand
E-mail: keola@ait.ac.th; vivarad@yahoo.com
* Environmental System Engineering, Kanazawa Institute of Technology
7-1, Ogigaoka, Nonoichi, Ishikawa 921-8501, Japan
Tel: 81-76-248-4716 Fax: 81-76-294-6713 E-mail: mtoku@neptune.kanazawa-it.ac.jp

Abstract

Pneumonia is highest tendency ranking epidemiological disease in the Ayutthaya province. This disease increased since Ayutthaya became the Heritage City in 1991. Public health researchers have conducted several epidemiological studies in this area. However there is no study using geo-informatics technologies. The application of these technologies, particularly GIS to epidemiological research would produce a better understanding of the pneumonia pattern. In this study incidence ranking of pneumonia across the districts was found using statistical and spatial analysis of the public health data. The triangular model of human ecology was used to identify main factors, associated with the high incidence diseases. There are two main factors affected to pneumonia rising, which are climate and social living change. The core disease area covers three urban density districts with location quotient greater than 1. Based on these finding, associated risk factor maps were generated on a GIS platform. Finally, the provincial risk maps for highest tendency ranking of pneumonia was generated.

1. Introduction

The environment and society has changed in the last ten years, many researchers had studied different disease pattern in Thailand such as: the pattern of AIDS diffusion in Chiang Mai, which is the most urbanized province. As its origin followed by a spread to lesser urbanized areas, and it diffused along the main highways (Wisesjindawat, 2000). The Japanese Encephalitis increased due to the environment changed, particular climate in Chiangrai province, north of Thailand (Adsavakulchai, 2001). The diarrhea has been increasing in children age between 0-1 years old due to less breast-feeding in Bang Pa In district of Ayutthaya. The main reason was the economic collapse. For surviving of women and their families, many women became factory workers. Due to this, they have less time to breast feed children, and that lead to diminished children immunities. Moreover, they leave their children staying with elder people who lacks of appropriate nutrition knowledge (Vilay, 1999).

Pneumonia is the most dreaded respiratory illness among children. It causes high morbidity and mortality especially in young children in developing countries, including Thailand. Pneumonia is the leading cause of infant mortality rate and accounts for 25% of all causes of death in children under five years old in Thailand (Chantarojanasiri, 1993). The pneumonia incidence per 100,000 in 1998 was 243.27 and the number of deaths was 1.60-2.29, moreover it causes highest death among epidemiological surveillance disease in Thailand. The sickness ratio of 225.35-252.03 per 100,000 is trend to be stable since 1993-1998 (Annual Epidemiological Surveillance Report, 1998). This disease also gradually increases in Ayutthaya province and become the highest epidemiological surveillance disease. After Ayutthaya was registered in 1991 as World Heritage City, urban facility and infrastructure were built for tourism promotion. Therefore, the cultural and living conditions have been changed which led to possible pneumonia pattern changes. This disease gradually increasing by time, thus a study on time trend is needed. One important issue for this study is to identify pneumonia rising incidence, as to provide understanding of the causes, and associated factors of this disease.

2. The Study Area

2.1 Geographic Information

Ayutthaya is the 11th largest province, out of 24 central region provinces, with an area of 2,547.62 sq. km, it is 76 km north of Bangkok, at the latitude 14° 6' 33" N and longitude 100° 14' 53" E at the sea elevation of 3.50 m. (Figure 1(a)). Ayutthaya is bordering with Angthong, Lopburi and Saraburi provinces on the north, Saraburi on

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the east, Nonthaburi and Pathumthani on the south and Suphanburi on the west (Ayutthaya Provincial Annual Report, 1999).

Ayutthaya is located on a flood plain with several rivers and canals; no forest and mountainous land exist in this province. Ayutthaya province is administratively divided into 16 districts (Amphoe) (Figure 1(b)), 209 sub-districts and 1467 villages (Phra Nakhon and Sena districts)

2.2 The Health Care Network

Ayutthaya is the first place in Thailand to establish a Community Health Service Center (CHCSC) in 1990. This center aims to reduce patient density in the central hospital. The main task is to provide primary health care services. With a growing population, it responds for 200.000 patients per year. There are four CHCSC in Pra Nakhon Sri Ayutthaya district, and will be expand in

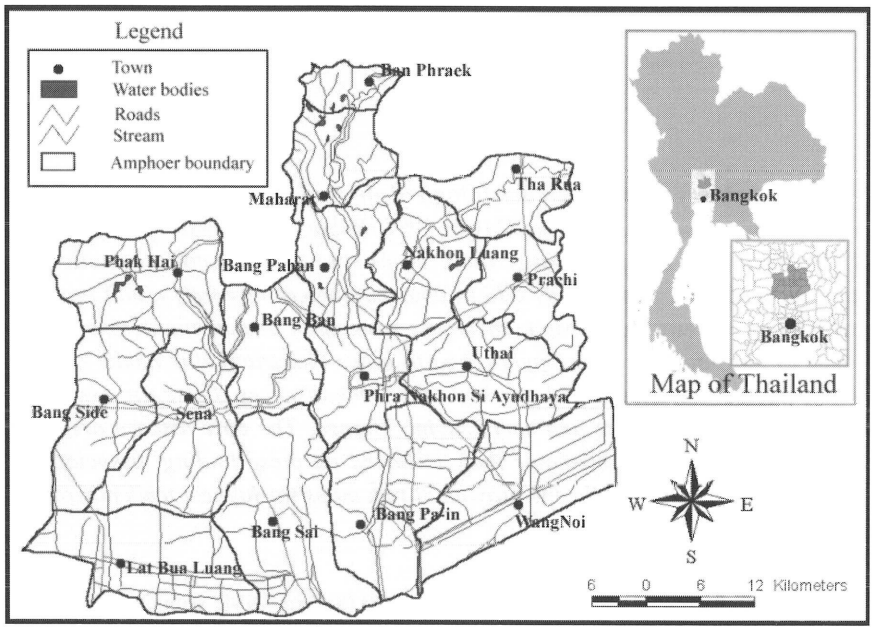

Figure 1 (a): Map of the study area, Ayutthaya province
(Source: Land Development Department and Environmental Systems Research Institute (ESRI), 1996, scale: 1:250,000)

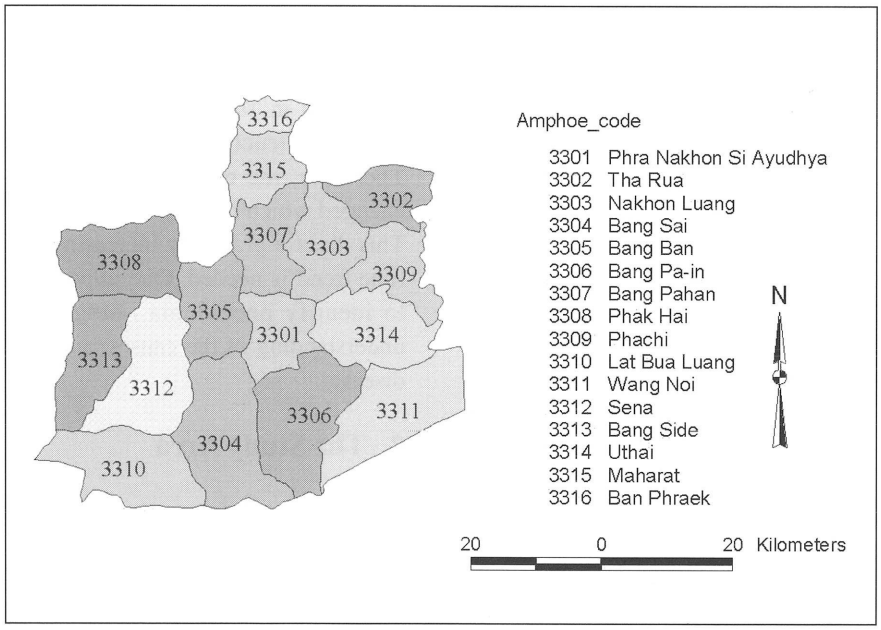

Figure 1 (b): The internal boundaries (administrative unit areas and codes)
(Source: Land Development Department and Environmental Systems Research Institute (ESRI), 1996, scale:1:250,000)

future (The Report of Seeking Behavior to Community Health Care Service Center, 1996). Other health facilities are: 16 hospitals, 205 local clinics, some private and traditional health clinics (Ayutthaya Provincial Annual Report, 1999).

Based on such geographical conditions and health care network specified above Ayutthaya province was selected to be the study area.

3. Methodology

The methodology of this research can be described as below.

3.1 Disease Selection by the Number of Cases per 100,000 Population and Its Tendency in Last 10 Years

The secondary data of epidemiological surveillance diseases were colleted from Statistical Health Care Department of Ayutthaya Province. In particularly epidemiological diseases were collected by the "Patient Record Form 506". Occurred 31 surveillance diseases were found in the Ayutthaya province. (Annual Provincial Report, 1999).

The disease selection category was based on the condition that diseases used to occurred and widely spread in the past. Epidemiological diseases, were grouped using the unit of "cases per 100,000 persons" for ten years, processed and classified into two groups:

1. The epidemiological surveillance diseases used to spread and the cases per 100,000 persons is over than 100/100,000
2. The epidemiological surveillance diseases used to spread and cases per 100,000 persons is less than 100/100, 000 and have a trend to increase

As result, two groups were classified as "high-ranking diseases". In the first group 6 diseases were found and in the second group 2 diseases were found (Table 1)

3.2 The Correlation Coefficient Related to Time and the Case Incidence in the Pperiod of 10 Years

Correlation analysis is a statistical tool that can be used to describe the degree to which one variable is linearly related to another. Frequently, correlation analysis is used in conjunction with regression analysis to measure how well the least squares line fits the data. It can also be used by itself to measure the degree of association between two variables (Page and Patton, 1991).

In this section two measurements for describing the correlation between two variables are presented: the coefficient of determination and the coefficient of correlation. Out of 31 diseases, only 10 diseases were classified for the widely spreading disease category. The highest tendency ranking diseases found by calculating the correlation coefficient between time and cases of incidence per 100,000 in ten years. The result shows that pneumonia is the highest surveillance epidemiological disease in Ayutthaya province (Table 1).

3.3 Analytical Framework

Exploring the disease distribution requires a conceptual framework that addresses to the complexities of biological, socioeconomic, cultural, behavioral and environmental factors over time and space. Triangular ecology is proposed to be one model would enable us to investigate the possible factors (see the end block in the bottom of the research methodology flowchart shown in Figure 2).

The triangular ecology concept is to understand why human disease and health vary over the surface of the earth. Health is defined in terms of adaptability and is related to complex systems of interaction among *habitat* (environment), *population* and *cultural behavior. These three components* compose a triangular model of human ecology and underlie disease etiology, consequences and prevention. Each component is considered in turn (Melinda et al., 1988).

Table 1: Diseases group and their correlation

Diseases		Coefficient of correlation (R^2)
Group 1 (More than 100 cases per 100,000 population)		
1	Pneumonia	0.94
2	Food poisoning	0.79
3	Acute diarrhea	0.78
4	Conjunctivitis	0.28
5	Hemorrhagic fever	0.20
6	All dysentery	-0.79
7	Measles	0.01
8	Unknown fever	-0.63
Group 2 (More than 100 cases per 100,000 population)		
9	Lung tuberculosis	0.88
10	Leptospirosis	0.76

Habitat, population and behavior form the vertices of a triangle that encloses the state of human health. *Habitat* is that part of the environment within which people live, that which directly affects them. *Population* is concerned with humans as organisms, as the potential hosts of disease. *Behavior* is the observable aspect of culture. It springs from cultural precepts, economic constraints, social norms and individual psychology. It includes mobility, roles, cultural practices and technological interventions. The summarized flowchart of the methodology of the study is illustrated as shown in Figure 2.

4. The Core Area Distribution of Pneumonia Found by Applying Location Quotient

The quotient is to calculate ratio between the local observed data (district) and the observed data of some reference unit (province) (Equation 1). This ratio is calculated for all districts to determine whether or not the local observed data has a greater share of that reference unit.

The location quotient (LQ) is an index for comparing an area's share of a particular activity with the area's share of some basic or aggregate phenomenon (Page and Patton, 1991).

$$LQ = \frac{\frac{N_{District}}{P_{District}}}{\frac{N_{Province}}{P_{Province}}} \qquad \text{Equation 1}$$

Here, N represent the Number of incident cases and P represent the Population of the district and province, respectively. The result of location quotient can be considered into two cases:

$LQ < 1$ indicates the activity is less concentrated in the region

$LQ > 1$ indicates the activity is more concentrated in the region

The result of LQ calculation is shown in Table 2, Figure 3(a) and (b). Using LQ, core area can be identified, which is varied by seasons and in the rainy season pneumonia cases covered 51.48% of the province. In our case, LQ is greater than 1.0 that main activity is more concentrated in the main core areas, covering three districts 8.54% (Phra Nakhon Sri Ayutthaya, Bang Pa In and Bang Pa Han). These districts are well served in terms of medical personnel, hospitals and clinics). The highest case incidence is

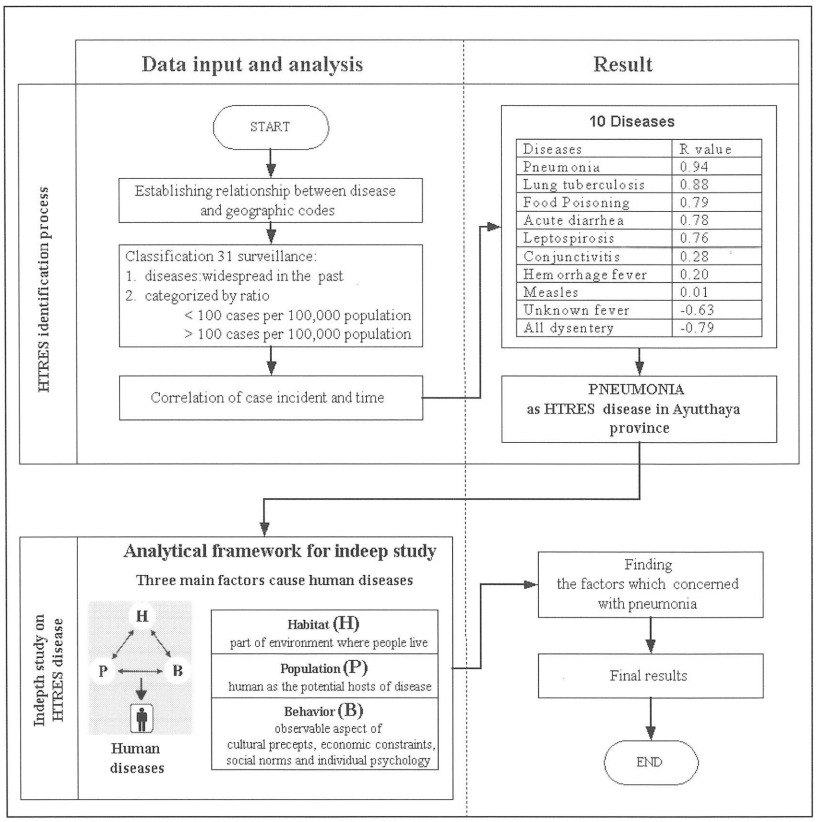

Figure 2: Research methodology flowchart

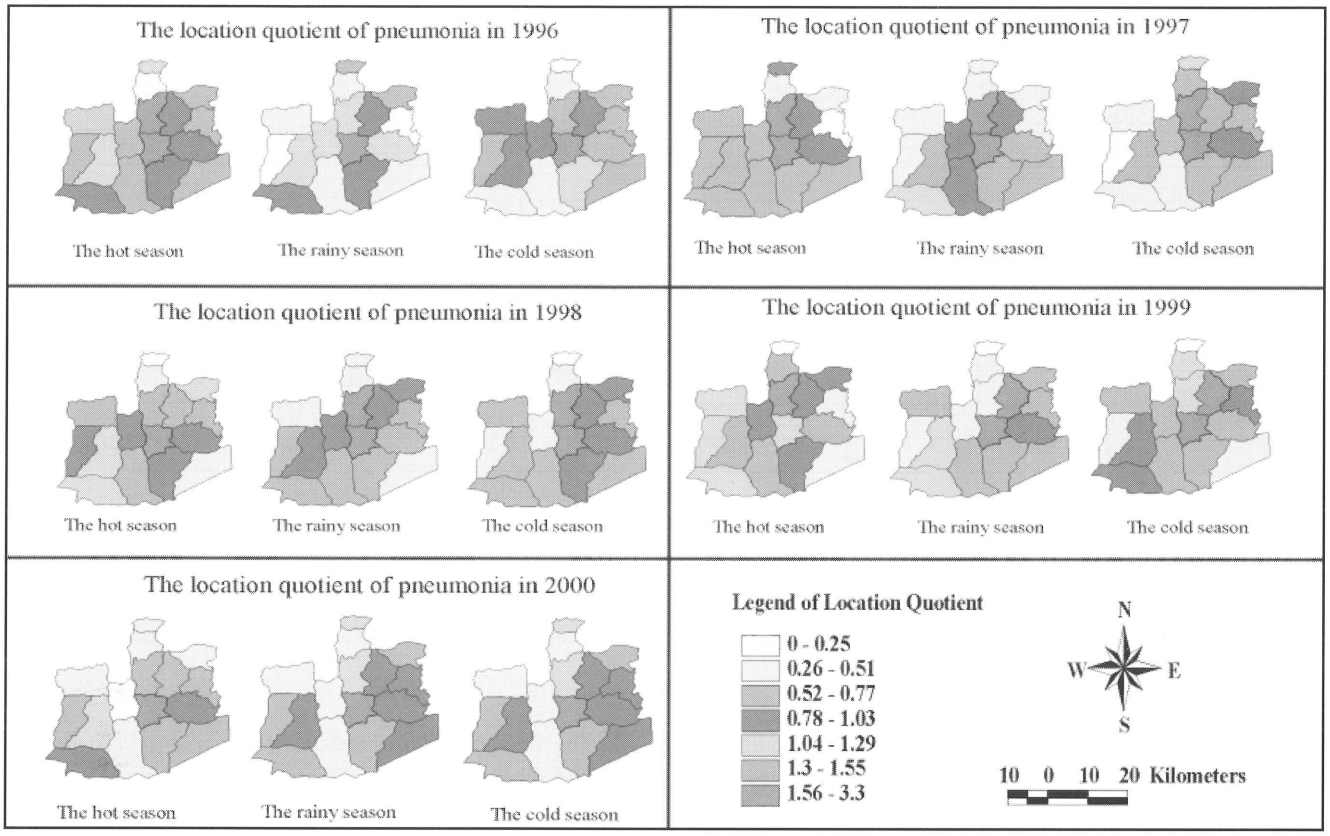

Figure 3 (a): The location quotient in five years (1991-2000)
(Source: Statistical Health Care Department, 2001)

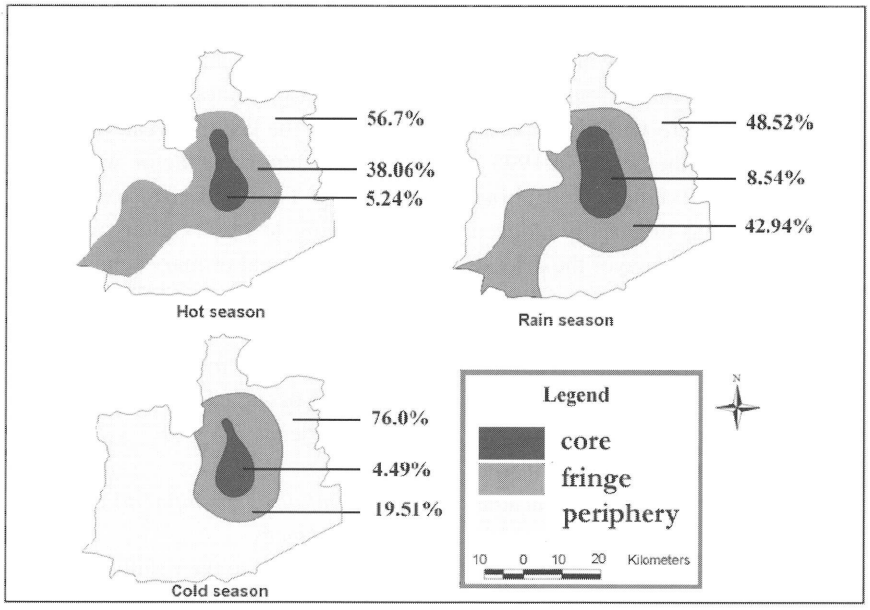

Figure 3 (b): The core pneumonia area in three seasons
(Source: Statistical Health Care Department, 2001)

Table 2: Location quotient (LQ) in each district

Districts/year	LQ1996	LQ1997	LQ1998	LQ1999	LQ2000
3301	1.94	1.86	1.70	1.78	2.39
3302	0.60	0.58	0.87	0.71	0.51
3303	0.94	1.13	0.79	1.51	0.67
3304	0.56	0.64	0.66	0.57	0.44
3305	0.94	0.71	0.80	0.61	0.12
3306	0.92	0.63	0.82	0.75	0.88
3307	1.40	1.97	2.55	1.16	1.26
3308	0.57	0.48	0.50	0.87	0.31
3309	0.44	0.38	0.61	0.64	0.60
3310	0.79	0.74	0.85	1.10	0.89
3311	0.60	0.61	0.52	0.46	0.76
3312	1.07	1.40	0.92	1.23	0.91
3313	0.40	0.38	0.54	0.64	0.61
3314	1.00	0.79	0.83	0.74	0.85
3315	0.34	0.48	0.43	0.69	0.33
3316	0.90	0.75	0.34	0.14	0.38

increased mainly during the rainy season period. In addition to this, other social and environmental factors may also be the possible factors of high pneumonia incidence in the area.

5. Environmental and Social Factors as Causes of Increasing Pneumonia

5.1 Application of Remote Sensing to Urban Area Change Detection

Application of remote sensing is useful to identify landuse classification, in particularly, the urban area change in Ayutthaya province. In this study, the remote sensing data of year 2000 were used to compare with the landuse data of 1993. The result shows that in the period of 1993 – 2000, the urban area has drastically increased about 61.52%, while the agriculture area has drastically reduced (Table 3). This change can lead to the change of the disease pattern. The main pneumonia core area contains more concrete build up area (Figure 4) and high population density (Figure 5), particular in Pra Nakhorn Si Ayutthaya district. In the rainy season pneumonia cases occurrence covered 51.48% of the provincial area. During the rainy and hot season fringe cover not only urban area, but also agriculture as well, and cold season cover only in urban area. Therefore, in the urban area pneumonia case occurred in whole years, however in the agriculture area occurred pneumonia only in the rainy and hot season. This is the reasonable understanding of the pneumonia cases and province morphology.

5.2 The Seasonal Characteristic of Pneumonia in Ayutthaya

The climate pattern in Thailand falls into three seasons, which are cold season (October-February), hot season (February-May), and rainy season (May-October). Observation to the epidemiological characteristics of diseases will follow in these three seasons. Due to unavailability of the raw epidemiological surveillance data between 1991-1995, this research had used data between 1996-2000, which was provided by the provincial health care department in Ayutthaya.

The pneumonia distribution pattern in whole Thailand occurred and became highest incidence during rainy season (Annual Epidemiological Surveillance Report, 1998) as well as in the last five years 1996-2000 (Figure 6).

One important factor was found using in dept interview by Thai pediatric expert Dr. Kitiya Pasanvong[1]. According to observations made from academic term of playground and primary school children, it was shown that pneumonia cases increased during the starting period of new academic term, then decreased during the term break (Figure 6). The most of pneumonia patients, aged 1 to 5 years old occupied 71.9% of the total average in five years case incidence.

5.3 Rainfall as an Influential Factor to Cause Pneumonia Incidences

According to the results above, the cause of pneumonia perhaps is also related to rainfall. Table 4 demonstrates that during the rainy season, rainfall and humidity are high as well as number of pneumonia cases. The peak of cases

[1] Dr. Kitiya Pasanvong is a pediatric in Ayutthaya hospital; she works in the pediatric department for more than 10 years.

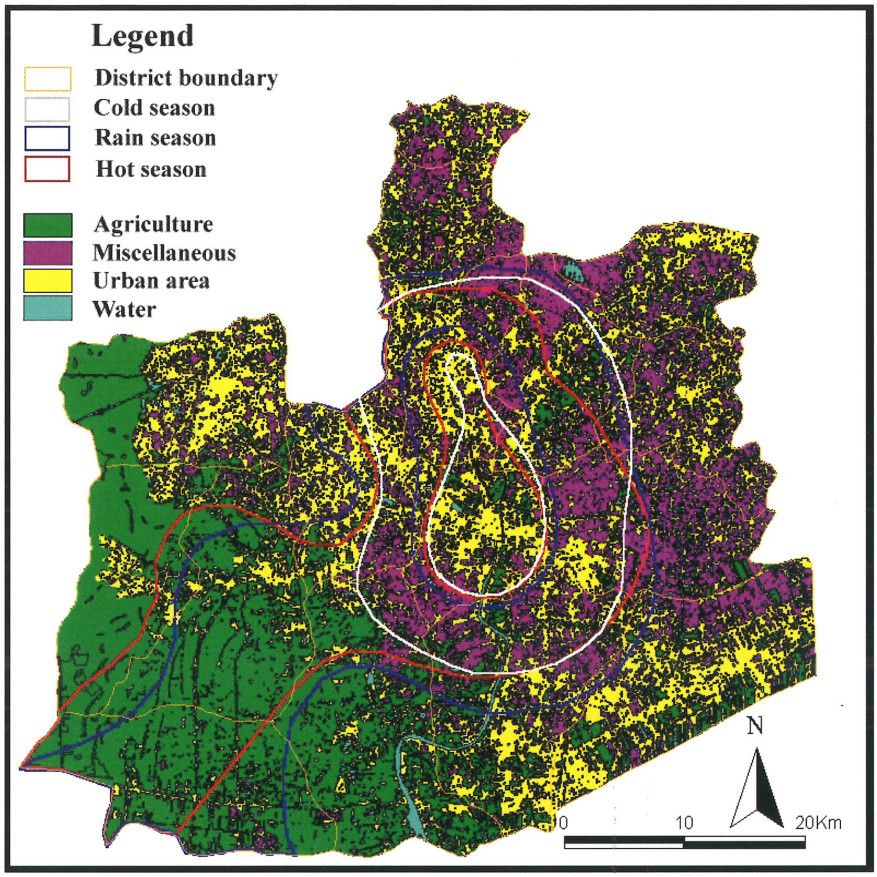

Figure 4: Land use map of Ayutthaya province in year 2000
(Source: Geo-Informatics and Space Technology Development Agency (GISTDA) Landsat TM5, year 2000)

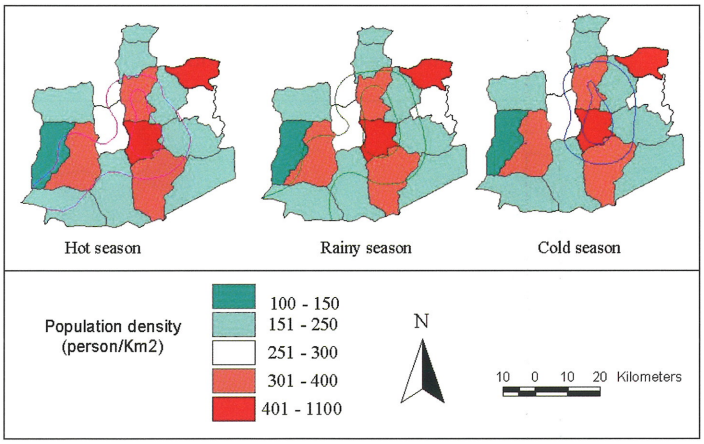

Figure 5: The distribution of population density
(Source: Ayutthaya Annual Provincial Report, 2001)

Table 3: Comparison of land use in 1993 and 2000

Area/year	Year 1993 (m^2)	Year 2000 (m^2)	Difference (m^2)	Change (%)	
Agriculture	2,237,043,673	962,099,822.3	-1,274,943,850	-132.51	Decreased
Urban	231,097,391	600,604,027.8	369,506,637	61.52	Increased
Water body	67,962,222	56,078,065.6	-11,884,157	-21.19	Decreased
Misc.	10,250,714	927,572,084.3	917,321,370	98.89	Increased

occurred in September. The Pearson correlation and two tail tests were implemented to prove the relationship of each variable. The obtained result is correlation of pneumonia to rainfall and humidity was significant at the 0.01 level (2-tailed) or 99.9% significant. Moreover the rainfall and humidity is also significant at the 0.01 level (2-tailed). In terms of spatial distribution of pneumonia and rainfall density, Figure 7 shows the high density of rainfall area pneumonia incidence which is located in agriculture area.

5.4 The Pneumonia Distribution by Age

The patients of pneumonia were classified into three groups of different age, which are: 1-5 years old group, 0-1 year old group, and over 60 years old group. The last group is the group of high pneumonia concentration (Figure 8). The result from comparing highest pneumonia infection shows that, the group of 0-5 years old is still the highest pneumonia infected group. Based on the Report Acute Respiratory Infection in Children, between 1990-1996 the

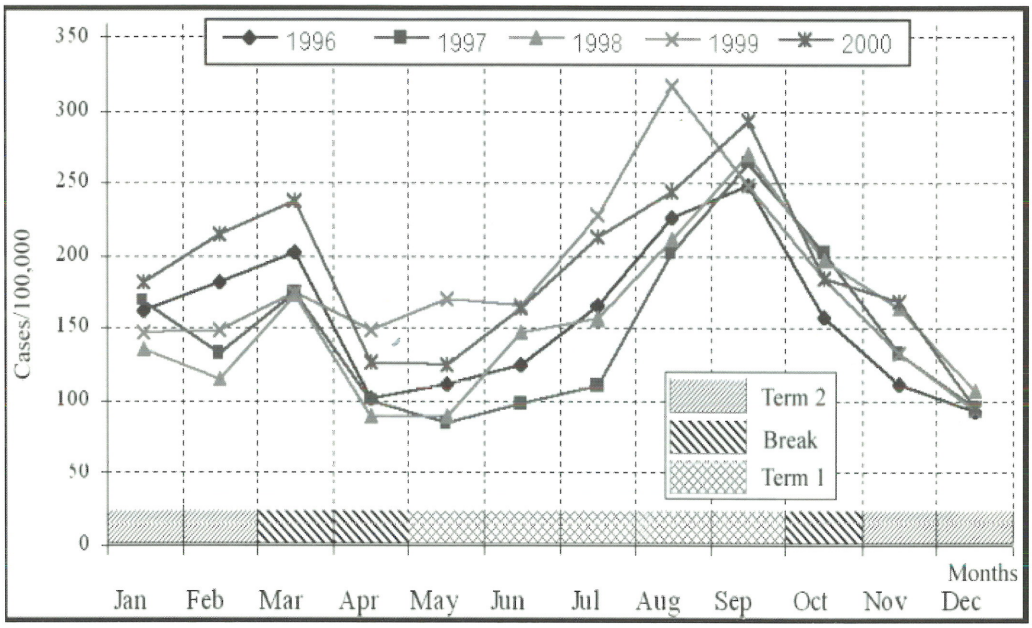

Figure 6: The distribution of pneumonia in the period of 1996 – 2000
(Source: Statistical Health Care Department, 2001)

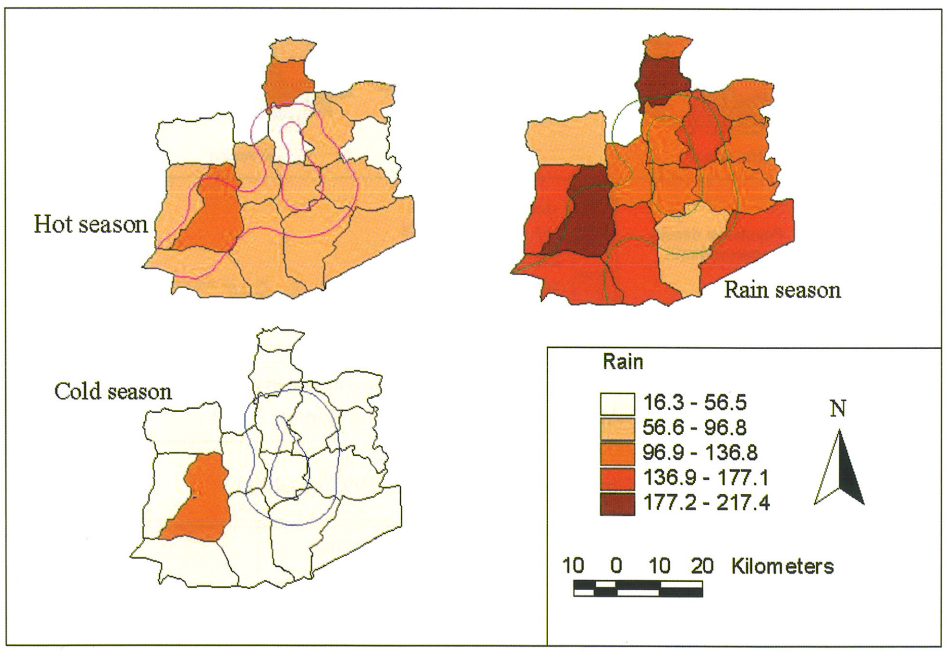

Figure 7: The distribution of rainfall density in core pneumonia area
(Source: Meteorological Department, 2001)

pneumonia incidence in the group of 0-5 years had increased 70% of the total pneumonia patients (Bounsom, 1998). From the findings result, since 1996-2000 the patient group of 0-5 year old still not reduced for 72%. Although health facilities and physicians has increased in the period of ten years (1990-2000), but these affected age group was not able to avoid from pneumonia disease. The increasing of birth rate was not influenced, therefore the disease incidence R in this case is 0.012.

5.5 Living Pattern and Malnutrition as an Socio Economical Influence to Pneumonia Incidence

Several local physicians have mentioned three main reasons that cause pneumonia. One is the uncontrolled antibiotic use in influenza; it possibly builds some antibiotic resistance. The second one is the social pattern has changed Most of the people prefer to bring their kids to playgrounds or schools at early age. The children could not manage themselves properly in term of sanitation. Finally the last reason that was mentioned is parents have to work outside; mothers lost their opportunities to breast-feed their children. They had to rely on artificial milk. The feeding pattern would diminish the immunity of young children 0-1 years old and possibly contribute to the incident cases of pneumonia. Malnutrition found nearly 50% among children 0-5 years old; which is shown in Table 5. The correlation value (R) between pneumonia and malnutrition is 0.93, which means malnutrition is a factor of pneumonia in 0-5 years old group.

Table 4: Summary of monthly average of humidity, temperature and rainfall in five years
(Source: Report from the Meteorological Department of Thailand in five years (1996-2000))

Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	26.7	28.0	30.1	30.3	30.0	29.3	29.0	28.8	28.2	28.3	27.1	25.9
Humidity (%)	61.2	61.1	63.3	68.6	70.3	71.4	72.5	72.4	75.9	74	69.2	62.3
Rainfall (mm)	29.9	33.0	61.0	449.5	815.3	669.5	675.9	850.8	959.4	676.4	107.8	0.0
Pneumonia (cases)	159.4	158.6	192.4	113.4	116.2	140.2	174.6	240.6	265	185.6	141.8	96.8

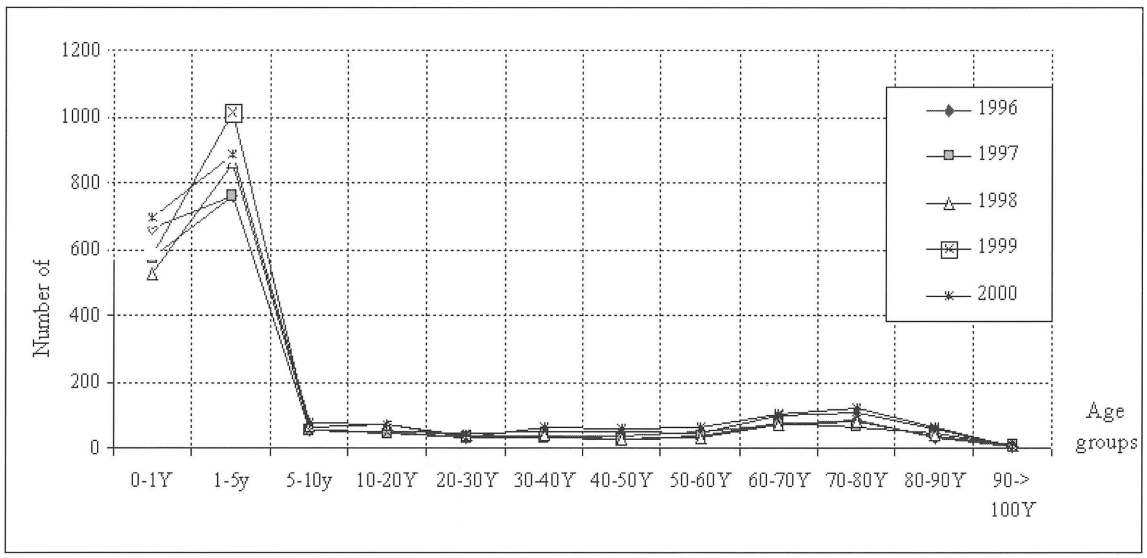

Figure 8: The distribution of pneumonia by age
(Source: Statistical Health Care Department, 1999)

Table 5: Relationship between pneumonia and malnutrition among children (0-5 years old)

Years	Age (0-5 years old)		
	Total children (%)	Total malnutrition (%)	Pneumonia (%)
1996	6.90	3.22	2.50
1997	10.9	2.84	1.73
1998	6.90	3.02	2.67
1999	6.74	3.50	3.20
2000	7.55	4.19	3.37

6. The Increasing Prediction for the Next Five Years

The pneumonia prediction had applied Projection techniques. These are quantitative methods for estimating the future. Techniques to project the future are essential for making plans and for most policy decisions. In this process we predict the LQ in each district, where linear projection suitable for prediction, because of the R = 0.94, means it nearly became linear. The prediction of pneumonia and population in the next five years were calculated using the Gibbs Method (Equation 2). This method is described in population projection, written in Annual Rural-Regional Planning Workshop (Rural-regional development planning students, 2000).

$$D_t = D_1 + D_1 \left(\frac{R}{100t} \right) \qquad \text{Equation 2}$$

Where:

Dt : pneumonia projection
D_1 : number of pneumonia cases latter data in 2000
R : disease ratio in last five years
t : time interval (e.g. in 2005, $t = 2005 - 2000 = 5$, $t = 5$)

With the result of pneumonia incidence and population trend in next five years 2001 – 2005, the case per 100,000 rate was calculated and shown in Table 6. This table shows that this rate will gradually increase.

Gibbs method was applied for the prediction of pneumonia cases and population in each district. Location Quotient was used to find the density of spatial distribution in the next five years. Pneumonia arises within the district that has high population density (Figure 9), such as Bang Pa In, Uthai, Wang Noi, Na Khon Luang and others.

7. Conclusion

Statistical analysis, remote sensing and GIS techniques were applied to this study. Using these techniques, pneumonia diffusion pattern in specific spread areas was clarified. The pneumonia movement changes according to urbanization and rainfall change.

The highest pneumonia spread rate in the whole province is 51.48% for rainy season, 43.3% during hot season and 24% during cold season, respectively. The increasing tendency of pneumonia goes with urbanization. Since 1993 until 2000 urban area has increased 61.52% and pneumonia incidence per 100,000 rate has also increased from 205.8 to 305.5, which can be observed from core area change. Moreover pneumonia incidence trends to arise in high-density urban area.

According to the pneumonia seasonal characteristic, it was found that during the rainy season, pneumonia is widely spread; it covers 51.49% of the province, in particularly in the agriculture area, which covers high rainfall density. The pneumonia incidence gradually reduced by rainfall pattern, but still exists in three districts, which are located in the core area. Pneumonia core area does not change by season, and it is located in the urban areas of high population density. Therefore finding another associated factor which is socio-economical factor is necessary. From the finding by this factor, it shows that children of 0-5 years old is the main group that effected by pneumonia.

Since the cases of pneumonia increased during the starting period of new academic term, then it decreased during the term break. The academic terms are still long as well as pneumonia incidence is increasing by the long period of time, thus possible to cause of pneumonia incidence in children 3-5 years old. Moreover the living pattern changed, parent sent their kids to schools at in early age less than 2.5 years old. It is obvious that some of them could not take care themselves properly in terms of sanitation, thus pneumonia may happen and spread easily at schools.

According to the difficult economical condition, artificial milk started to be widely used instead of breastfeeding. Mothers have to go to work outside home and spend less time with their children, more over some mothers leave their kids with elder persons, who can not take care properly both children and housework (Vilay, 1999). Thus, this

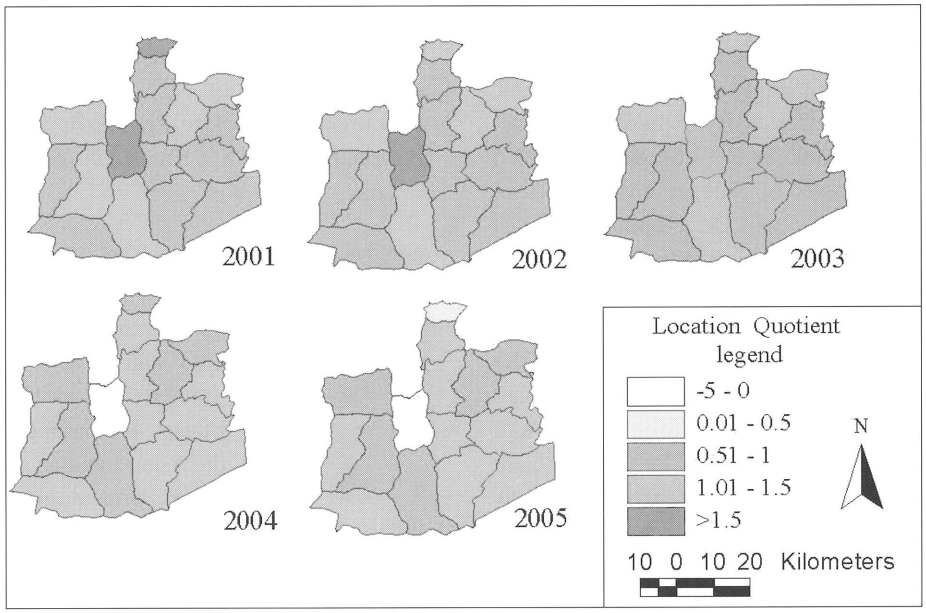

Figure 9: The prediction of spatial pneumonia incidence in the next five years

Table 6: Pneumonia in the next five years 2001-2005

Years	2001	2002	2003	2004	2005
Total Number of Population	740241	747570	754899	762228	769558
Pneumonia case per 100,000	315	323	330	337	345

condition diminished children's immunity and then, let them prone to the infection. This is the main factor for pneumonia incidence in children 0-2 years old

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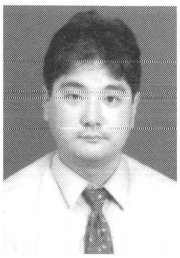
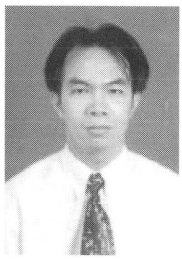
Soutthanome Keola received her Bachelor Medical Doctor (B. MD.), from the Faculty of Medical Sciences, National University of Laos, Vientiane, Laos in 1996. In 1999, She has completed her Master of Science (M. Sc.) from the Gender and Development Studies program, Asian Institute of Technology, Bangkok, Thailand. In 2001, she was awarded for the ASEAN Foundation Research Fellowship Award for comprehensive human resources development in the Greater Mekong Sub-Region. Her research interests are Public Health and Geoinformatics, Public Health and Environmental Change, Women and Children Health Care and Local Community Development. Currently, she is doing her research at the MAMAS project, Aquaculture and Aquatic Resources Management, Asian Institute of Technology, Bangkok, Thailand.



Mitsuharu Tokunaga received the Doctor of Engineering from the University of Tokyo in Civil Engineering in 1997. He was a researcher in Remote Sensing in Mapping Applications at Institute of Industrial Science (IIS), the University of Tokyo, from 1988 to 1990. He worked at Central Computer Services Co. Ltd, Japan as project manager for system development for Satellite Data Processing. Since 1999, seconded by the Japanese Government, he worked as Assistant Professor at Asian Institute of Technology (AIT). Currently, he is working as Associate Professor at the Environmental System Engineering, Kanazawa Institute of Technology, Japan.



Vivarad Phonekeo obtained Bachelor of Educational Sciences in Physics and Mathematics Department from Volgograd State Pedagogical Institute, Volgograd, Russia in 1990. He pursued his Master degree in Computer Sciences at the Asian Institute of Technology (AIT), which was completed in 1994. He obtained Ph.D. from the Space Technology Application and Research (STAR) Program, Asian Institute of Technology (AIT), Bangkok, Thailand in 1999. In 2000, he was awarded the Award of Surveying Technology 2000 for the outstanding paper by The Japanese Association of Surveyors (JSA), Tokyo, Japan. His research interests are 3D Modeling and Visualization of Spatial Data, Computer Graphics, Computer Vision and Animation, Virtual Reality and Remote Sensing and GIS for Environmental and Social Sciences.