GIS Modeling for Avian Influenza Risk Areas

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Abstract
Given the first outbreak of highly pathogenic avian influenza (HPAI) in Thailand in 2004, the zoning of HPAI disease is needed for effective prevention and control and also to reduce the socio-economic impact of the outbreak. The purpose of this study is therefore to establish a model for predicting the areas at risk of the avian flu using the integrated variables or themes involved. The risk areas can be used for surveillance of avian flu outbreaks and eradication. The methodology included an analysis of affected theme layers, the overlay processing of the themes and the assessment of the result. The theme layers are: a distance from the former outbreak communities (C), density of poultry population (D), a distance from the poultry farms (F), land use type (L), and a distance from the market or the slaughterhouse or the cockpit (P). Khon Kaen province was selected as the study area, which covers an area of about 10,886 sq.km and is located in the Northeastern part of Thailand. Each of the above theme layers mentioned with its associated attribute data were digitally performed in GIS database to eventually create five thematic layers. Simultaneous overlay operation on these layers with the defined model produces a resultant polygonal layer, each of which is a mapping unit with the risk area class. The process involved the formulation and tested the model followed by the iteration of the model to the geo-referenced information. We used the model (Risk Area = CDFLP) with 5-factor ratings and selected the best choice of the ratings for each variable and overall value. These are classified into 4 classes of high, moderate, low and very low risk areas. The study indicates that the high, moderate, low and very low risk areas cover an area of about 1.60, 26.31, 71.88 and 0.21 % of the entire province area, respectively. The reliability of the result was also tested to validate the defined model. The established information has been stored in GIS and can be rapidly used for future analysis.

1. Introduction

Bird flu or Avian influenza is an infection caused by virus called "Orthomyxoviridae". The highly pathogenic avian influenza (HPAI) is a form that causes severe symptoms and spreads rapidly through flocks of poultry. Influenza virus type A is responsible for causing bird flu, which was first found in Italy in 1878. The subtype H5N1 virus of type A is the main cause of the bird flu. Bird flu can be transmitted from person to person and from country to country. In 2004 the Thai national reference laboratory confirmed the presence of H5N1 virus in a layer chicken farm in Suphanburi province (Tiensin et al., 2005). The transmission route by which the virus took place could not be identified. In January-February 2004, the first H5N1 surfaced in Khon Kaen province, corresponding to the cool season. On July 2004, the recurrence of H5N1 was confirmed in Khon Kaen. The first outbreak in Khon Kaen led to the destruction of about 848,294 chickens from of 18 farms (Department of Livestock Development [DLD], 2004). The national levels outbreak of bird flu has a profound effect socio-economic at local, regional and the whole country as well. The outbreak has diminished the poultry trade, poultry product consumption, poultry raising, demand and supply of feeding ingredients. The outbreak effects extended widely over the vast areas of communities. As a result, the spread of the epidemic and its impacts were covered extensively for numerous provinces, and geographic information on the infection of bird flu was then developed in Thailand during the outbreak period. The information can be used to understand the transmission route for surveillance and control strategies. When the information was stored in the form of a spreadsheet, it required effort to visualize geographic distribution as related to severity of the epidemic and environmental factors involved. The conversion of that information into a GIS database was then performed. The information obtained could then be digitally analyzed to study the area at risks. In Thailand, three different zones are defined: the infected farm, a restricted area from 0-5 km., a surveillance zone from 5-10 km. and movement control 10-50 km. Gilbert et al., 2006 conducted the study on the risk factors for the HPAI in Thailand and provided information about the spatial distribution of HPAI outbreak in relation to numerous variables. This study demonstrated a strong association between H5N1 virus in Thailand and abundance of free-grazing ducks and, to a lesser extent, native chickens, cocks, wetland and humans. Wetland used for double-crop rice production where free-grazing ducks feed year round in rice paddies, appears to be a critical factor in HPAI persistence and spread. Ehlers

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et al., 2003 reported the application of VetGis to perform analysis of numerous indices for effective management of avian influenza in Italy. In order to define control, buffer zone or surveillance areas, risk assessment studies are necessary. GIS capability in integrating various spatial risk parameters could be a valuable tool to carry out risk assessment and assist defining sound control strategies (FAO, 2004a). Surveillance and eradication of avian flu require knowing the extent of areas at risk. This study was conducted with the objective of establishing a model for predicting avian flu risk areas with respect to an integration of spatial risk variables.

2. Description of the Study Area

The study area, Khon Kaen province (Figure 1) is located in the central portion of Northeast Thailand and covers an area of about 10,886 sq.km with elevation between 100 m. and 900 m. mean sea level. Physiographically, the province includes strong topography in the North West portions and flat to gently undulating landscapes in other portions of the area. The province is drained to the south-east by the Phong and Chi rivers and eventally by the Mun River. Ubol Ratana Dam, with storage capacity of 2,264 million m^3, is the main water resource supply for agriculture and domestic uses. The total population of Khon Kaen province in 2004 was about 1.77 million persons, 75% of whom are engaged in rain fed agriculture and livestock feeding. The average temperature of Khon Kaen is approximately 27°C with 33 °C mean max. and 22.5 °C mean min. The duration of the cool season covers the period October-February, followed by dry season February-May. The rainfall pattern starts in May and ends in October with mean annual rainfall of about 1,200 mm. and its peak during August-September. The land use in Khon Kaen is dominated by paddy rice, field crops, forest and others which account for 42.26%, 30.69%, 11.14% and 15.91% respectively.

3. Methodology

3.1 Variable Analysis

This study uses a synergistic approach, combining the outbreak data of Khon Kaen province during the year 2004, the previous study made by a number of agencies, and spatial analysis of the outbreak variables. The actual data for outbreaks of bird flu collected by DLD were used for this study. In January-February 2004 and July-December 2004, the H5N1 virus spread in Khon Kaen province, covering mainly the eastern portion of the province. The data collected by DLD included the locations and their associated attributes of the outbreaks, number of poultry farms and chicken, poultry markets, slaughterhouses and cockpits. Those records of data in form of a spread sheet were partially synthesized as in Table 1. The data types for poultry farm, slaughterhouse, cockpit and market were recorded in the MS Excel format containing the owner name and address, poultry type, number of poultry and coordinates of farm locations. The outbreak location included the records of address, date, poultry type and number of destroyed. In the process of the analysis we also considered the transmission route carried by migratory birds.

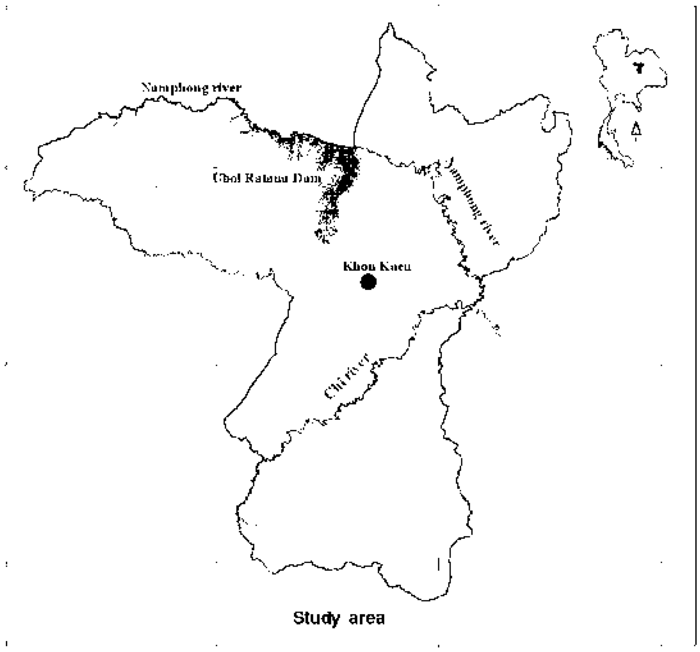

Figure 1: Study area

Table 1: Data types collected by department of livestock development in Khon Kaen Province

[redacted]		
Poultry farm	267	Total number = 941,117 chickens
Slaughterhouse	58	Rate of chicken killed = 10,584 per day
Cockpit	45	Operating once a week
Market	42	Live chicken and products
The 1st outbreak (Jan-Feb 2004)	18 (location)	Total destruction 848,294 chickens
The 2ed outbreak (July-Dec 2004)	7 (location)	Total destruction 2,183 chickens

Table 2: Thematic layers and factor ratings

[redacted]				
The 1st outbreak region	Distance to the 1st outbreak (C)	km.	[redacted]	DLD)2004,(CDC (2004), FAO (2004b)
Poultry density	Poultry density (D)	number / km^2		FAO(2004b), FAO(2005), Ehlers et al., (2003)
Poultry farm	Distance to the poultry farm (F)	km.		FAO (2004d)
Land cover	Land cover type (L)	-		FAO(2004c), FIC(2005), Tiensin et al., (2005)
Distance to commercial poultry production	Distance to market, to slaughterhouse/ to cockpit (P)	km.		FAO (2004c)

Remark: W = Wetland, rice paddies, swamp and communities, X = Evergreen forest and field crop, Y = Plantation and range land, Z = Others

They require a certain habitat during their short period in Khon Kaen. The food and covers suitable for the migratory birds in the area are considered as an important variable which enhances the risk area. The food and covers can be inferred from the pattern of land cover which can be carried out using satellite data. Spatial exploration was then performed to visualize and to define the abundance and presence of the infected chickens as related to the spatial risk variables. As a result we are able to initially define areas at risk in relation to each spatial variable for further analysis.

3.2 Model for Bird Flu Risk Area

A model for bird flu infection was based on an integration of spatial risk variables concerned. The risk area for bird flu infection in Khon Kaen province was formulated by coupling a GIS to additional model relating the variables. Susceptible poultry become infected when they come in contact with the contaminated surfaces within a certain distance of the outbreak. In Thailand DLD defined a protection zone having a radius of 5 km., a surveillance zone with radius 10 km. and a movement control with radius 50 km. (FAO, 2004b) The risk factor of a potential infection source for a herd of interest decreases with decreasing animal density (Ehlers et al., 2003). The outbreaks in January were concentrated in the central and southern part of the Northern and Eastern regions of Thailand which are wetlands, water reservoirs and dense poultry areas (Tiensin et al., 2005).The areas at risk of infection include those of shorter distance to poultry farms, to wetlands and to rice paddies. The consistent dissemination of infection was confined to backyard chicken and duck raising on the wetlands. In addition the vicinity to commercial productions of poultry is high risk of HPAI infection. The commercial productions encompass market, slaughterhouse and cockpit which facilitate and enhance the virus transmission. Based on a number of criteria, as discussed, the spatial risk variables to be applied in this study thus included the distance to the outbreak location, poultry density, distance to poultry farm, land cover and distance to commercial poultry production. (Centers for Disease Control and Prevention (CDC), (2004), FAO (2004b), FAO (2005), FAO (2004c))

3.3 The Organization and GIS Database Establishment

The development of the spatial database of geo-referenced data and its associated attributes for the study area was established. The spatial database consisted of the five thematic layers: the outbreak region, poultry density, poultry farm, land cover and area of commercial poultry production. Each layer encompasses a diagnostic factor and associated attributes on which a factor rating of risk is assigned. (Table 2). The factor rating assigned was based on the outbreak area in relation to the variables at risk. The individual layer was assigned the factor rating as 1.0 (S1), 0.6 (S2), 0.4 (S3) and 0.2 (N) for high, moderate, low and very low, respectively. The outbreak region was generated using the location data collected by DLD with the GIS capability, and the buffer zone of 0-5, 5-10, 10-50 and >50 km. was produced and encoded in the GIS database. The poultry density was digitally performed on the basis of chicken number within a given area with the Kernel Density function available from ArcView 3.2a. The poultry farm locations available provided information to digitally perform the buffer zone of 0-5, 5-10, 10-50 and >50 km. to the farms. Landsat TM data on December 2002 was processed to generate land cover layer which provided information about the susceptible area for the bird flu infection. The distances to commercial poultry production of 0-5, 5-10, 10-50 and >50 km. were produced, based on the locations of markets, slaughterhouses and cockpits collected. The five thematic layers were digitally encoded in the GIS database and were used for further analysis. Figure 2 represents the spatial risk variables generated using the GIS database established.

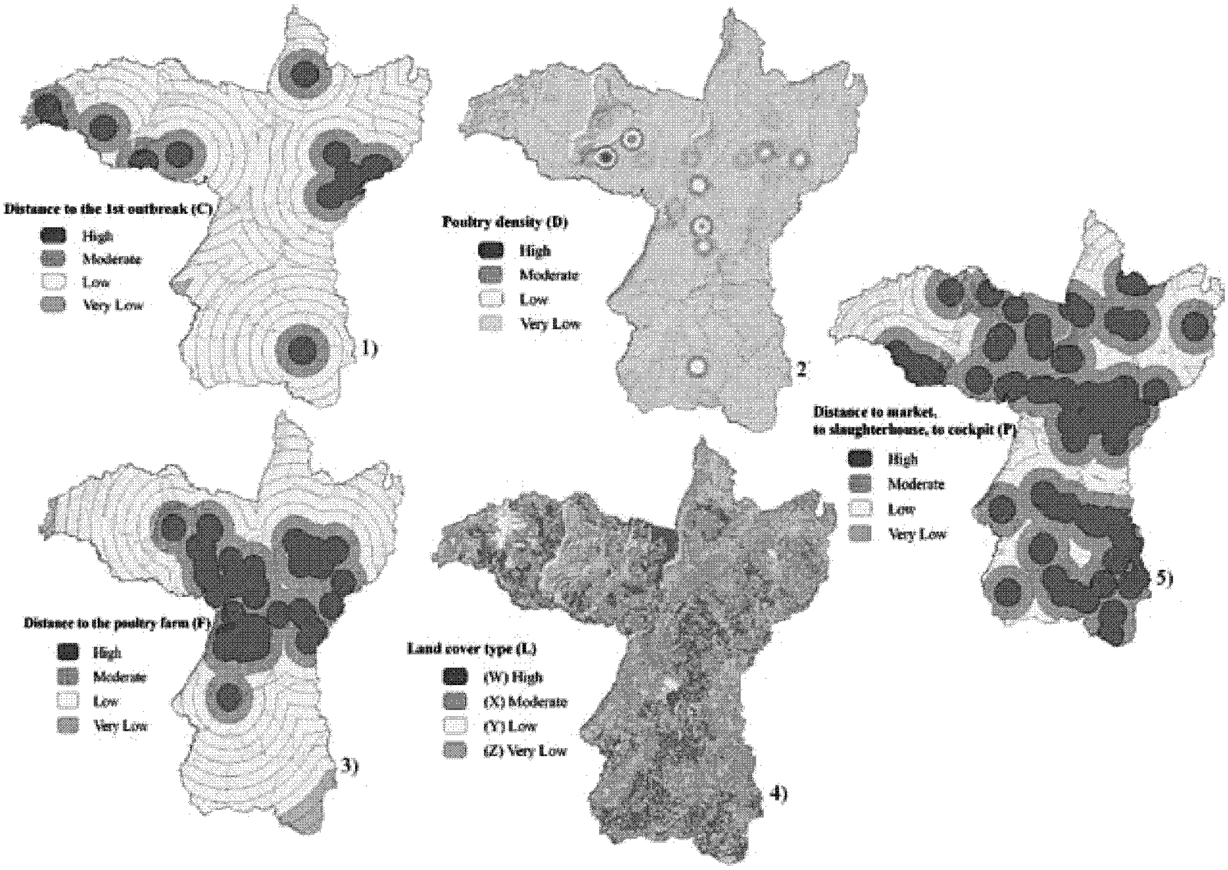

Figure 2: Diagnostic factor for the analysis 1) Distance to the 1st outbreak (C), 2) Poultry density (D), 3) Distance to the poultry farm (F), 4) Land cover type (L) and 5) Distance to market, to slaughterhouse, to cockpit (P)

Table 3: Class of risk and overall evaluation

High (S1)	1.0000 - 0.0779
Moderate (S2)	0.0778 - 0.0103
Low (S3)	0.0102 - 0.0003
Very low (N)	< 0.0003

3.4 The Development and Iteration of the Model

This phase involved the formulation and testing of the model followed by the integration of the model to the geo-referenced area information to create the map output. As a result of testing the combination of variables for class of the risk area was given using the value of the factor ratings as follows:

Risk area = C x D x F x L x P

These layers were integrated by spatially overlaying each with the risk model of the defined five layers which yielded 4 classes according to the results shown in Table 3. The overall factor rating was based on the multiplication (C x D x F x L x P) on which each layer was assigned a value of 1 for S1, 0.6 for S2, 0.4 for S3 and 0.2 for N. These values were then multiplied and used for identifying the risk area. The upper limits of overall values for S1, S2, S3 and N were $(1)^5$, $(0.6)^5$, $(0.4)^5$ and $(0.2)^5$ for 5 layers used respectively (Table 3). The validation of the model for the area at risk was assessed, based on the areas of bird flu infection by which the information was collected by DLD during the outbreak period. Adjustment of the limit and range of values could be iterated until the reliable result was obtained.

4. Results and Discussions

4.1 Spatial Distribution and Acreage of Risk Area

The risk area for bird flu infection resulting from the spatial overlay of the variables is shown in Figure 3. The acreage of the risk for the bird flu in Khon Kaen province in addition to spatial distribution is shown in Table 4. The study provides the overall insight into each variable for bird flu infection and the area at risk resulting from the integrations of the variables spatially and quantitatively. It is evident from the study that the risk area for bird flu infection covers 1.60% and 26.31% for highly and moderately at risk areas, respectively. It is evident that the risk area resulting from this study is the region with short distance to the outbreak area, dense poultry population, short distance to the farm, surrounding area of commercial poultry production with wetland and rice paddies land types. Results demonstrate a strong relationship between H5N1 virus in Khon Kaen province and wetland ecosystem, to a lesser extent, for the dry areas.

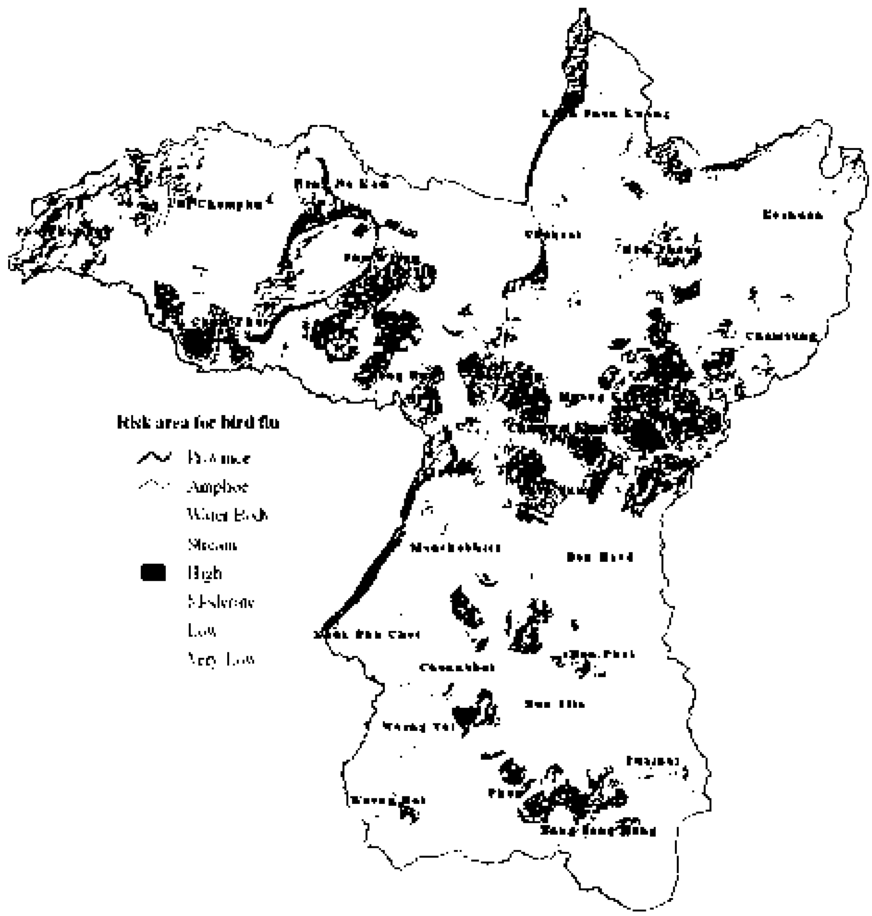

Figure 3: Risk area for bird flu infection

Table 4: The risk area for bird flu infection in Khon Kaen province

High risk (S1)	174.44	1.60
Moderate risk (S2)	2,864.32	26.31
Low risk (S3)	7,824.42	71.88
Very Low risk (N)	22.78	0.21

4.2 Validation of the Model

The validation of the model was carried out by comparison of the map production and the area of the infection with reference to the same location with the Extension Hawth's tools available in the ArcGIS. The selection of 25 locations of the virus infection was randomly checked and compares of the 25 locations we used 8 locations, mismatch of 2 locations or about 25%. However it would suggest caution in the application of this model. Numerous factors likely contribute to the apparent inaccuracies of the output prediction. The validation method was less than perfect because the infection of bird flu in some areas poorly fitted to the condition defined. Rationales behind this are the human actors involved in the raising of chicken, the movement of poultry, the migration of birds and etc. In conclusion this study implements an integrated approach combining static variables. Difficulties in using dynamic variables for the analysis process may cause inaccuracies of the result. The effective control measures made by veterinary authorities, sanitary raising of chicken and climatic variation may cause the contrary result of this study. However, the geo-informatics technologies offer the tool to visualize the spread of an epidemic, to establish an information database in relation to location and to effectively model the variables. In addition, the computer-based GIS provides information rapidly available for up-dated model in case further knowledge is developed.

References

CDC. 2004. Highly Pathogenic Avian Influenza H5N1. Bangkok, Th. DOI=ttp://www.cdc.gov/ncidod/EID/vol11no11/05-0608.htm+OIE+stamping+out+5+km Thailand+&hl=th

DLD .2004. Avian Influenza Control and EradicationMeasure. Bangkok, Th. DOI=http://www.dld.go.th/me/bird_flu/chick3.html

Ehlers, M., Moller, M., Marangon, S., and Ferre, N. "The use of Geographic Information System (GIS) in the frame of the contingency plan implementedduring the 1999–2001 Avian Influenza (AI) epidemic in Italy", Avian Disease, 2003, 47, 1010-1014.

FAO, 2004a., Control strategies currently in implementation. DOI=http://www.fao.org/ag/a-gainfo/subjects/en/health/diseases-dcards/Table108.html

FAO, 2004b, FAO Recommendations on the Prevention, Control and Eradication of Highly Pathogenic Avian Influenza (HPAI) in Asia. DOI=http://www.fao.org/ ag/againfo/subjects/en/health/diseases-cards/27septrecomm.pdf

FAO, 2004c. FAO Expert Meeting on Surveillance and Diagnosis of Avian Influenza "Guiding Principles forHighly Pathogenic Avian Influenza Surveillance and Diagnostic Networksin Asia". Bangkok, Th. DOI=http://www.fao.org/docs/eims/upload//210749/GuiprinciplesHPAI_july04_en.pdf

FAO. 2004d. Control measures undertaken in Asia during thecrisis.DOI=http://www.fao.org/docre/007/y5537e/y5537e07.htm

FIC,2005. China: Concrete measures to tackle avianinfluenza. Zhejiang, Cn.DOI=http://www.flu.org.cn/en/news-7524.html

Gilbert, M., Chaitaweesub, P., Parakamawongsa, T., Premashthira, S., Tiensin, T., Kalpravidh, W., Wagner, H., and Slingenbergh, J., "Free–grazing Ducks and Highly Pathogenic Avian Influenza, Thailand", Emerging Infectious Diseases, 2006, 12, 227-234.

Tiensin, T., Chaitaweesub, P., Songserm, T., Chaisingh, A., Hoonsuwan, W., Buranathai, C., arakamawongsa, T., Premashthira, S., Amonsin, A., Gilbert, M., Nielen, M., and Stegeman, A., "Highly Pathogenic Avian Influenza H5N1, Thailand, 2004", Emerging Infectious Diseases, 2005, 11, 1664-1672.