

Spatial decision support systems for risk analysis of the Exporting Farms in China

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Credits

This document has been produced in the framework of the OIE Cooperation Project “Capacity development for implementing a Geographic Information System (GIS) applied to surveillance, control and zoning of avian influenza and other emerging avian diseases in China”.

Related documents

This document derives from the elaboration of the following documents:

- GIS applications to support entry-exit inspection and quarantine activities
Authors: Nicola Ferrè, Qiu Songyin, Matteo Mazzucato, Andrea Ponzoni, Paolo Mulatti, Matteo Morini, Ji Fan, Liu Xiaofei, Dou Shulong, Lin Xiangmei and Stefano Marangon
- Framework for the evaluation of the spatial factors that influence the quarantine station and exporting farm performances in China.
Authors: Nicola Ferrè and Qiu Songyin

Terminology

Quarantine station

An establishment under the control of the Veterinary Authority where animals are maintained in isolation with no direct or indirect contact with other animals, to ensure that there is no transmission of specified pathogen(s) outside the establishment, while the animals are undergoing observation for a specified length of time and, if appropriate, testing and treatment [ref. OIE - Terrestrial Animal Health Code].

Exporting farm

Farm organised to export its livestock production.

Candidate quarantine station

Farm that has submitted the request to become a quarantine station.

Candidate exporting farm

Farm that has submitted the request to become an exporting farm.

POI (Point Of Interest)

Facility that exposes or is exposed to a risk of infection or contamination due to the presence of an exporting farm or a quarantine station located nearby.

Impact

The effect that the presence of a POI in the study area produces in the evaluation process of the facility performance.

Total impact

The cumulative effect of the whole POI impacts in the study area.

WebGIS

A technology used to display and analyse spatial data on the Internet. It combines the advantages of both the Internet and GIS. It offers the public a new means to access spatial information with no need of expensive GIS software.

Reference

Decree of the General Administration of Quality Supervision, Inspection and Quarantine of People's Republic of China No. 122 "Administrative Measures for the Supervision on the Use of the Quarantine Station of Entry animals" dated October 22nd, 2009.

Source: Framework for the evaluation of the spatial factors that influence the candidate quarantine station performances in China.

Introduction

Geographic information systems (GIS) can provide tools and analytical solutions to support activities related to the inspection of entry-exit animals and animal products. For example, with a GIS it is possible to depict the spatial distribution of the quarantine station with respect to the entry point (ie.g.: port, airport etc.), or to evaluate the land use composition surrounding a quarantine station or exporting farm, and so on.

The AQSIQ has introduced the systematic application of the spatial evaluation to assess the requests from candidate quarantine stations and candidate-exporting farms (candidate facility). The spatial evaluation essentially consists of a visual analysis of the POIs surrounding the candidate facility (within a radius of 3Km).

To improve the reliability of the spatial analysis outcomes, a spatial decision support system based on the adoption of a webGIS to collect data, a process for field data collection made by the local CIQs and an explorative spatial analysis have been proposed. The explorative spatial analysis is based on a Multi Criteria Method. The proposed method requires some detailed theoretical and technical descriptions in order to allow an easy implementation by the CAIQ personnel.

Purpose of Document

The aim of this document is to describe the relevant elements required to perform the explorative spatial analysis to support the risk analysis associated to the evaluation of a candidate facility.

In particular, the document describes:

- spatial evaluation process;
- AHP method;
- re-classification method;
- threshold calculation method.

Spatial evaluation process

The spatial evaluation process is based on the following three elements:

1. Pre-requisites

The pre-requisites consist of a series of conditions that need to be already in place before starting the spatial evaluation process. These pre-requisites are:

- a webGIS able to collect the information about the POI from the local CIQ;
- a set of weights associated to the type of POIs;
- a diagram to re-classify the observed POI's characteristics;
- a set of values used as threshold during the output analysis.

2. Analysis development

The analysis consists of the calculation of a so-called "total impact".

The total impact can be considered as a numerical value that represents the riskiness at which the candidate facility is exposed due to the presence of the surrounding POIs.

To calculate the "total impact" the Simple Additive Weighted (SAW) method is used. The SAW method consists essentially in adding-up the contribution of every single POI surrounding the candidate facility. POI's contribution consists of a value calculated as the product by the weight

assigned to that specific type of POI, times the dimension of the observed POI. For example if the surrounding POI are 2 farms and 1 abattoir the SAW calculus is:

$$\begin{array}{|c|} \hline \text{Farm 1 dimension} \\ \hline \text{X} \\ \hline \text{Farm weight} \\ \hline \end{array} + \begin{array}{|c|} \hline \text{Farm 2 dimension} \\ \hline \text{X} \\ \hline \text{Farm weight} \\ \hline \end{array} + \begin{array}{|c|} \hline \text{Abattoir 1 dimension} \\ \hline \text{X} \\ \hline \text{Abattoir weight} \\ \hline \end{array} = \text{Total Impact}$$

To obtain POI's weight the Analytical Hierarchy Process (AHP) is used.

To obtain POI's dimension the data collected by the local CIQ will be re-classified according to a well-defined diagram.

3. Outcome evaluation

The outcome evaluation consists of the comparison of the obtained total impact value with the threshold values, the production of a map that presents the location of the candidate facility with the 3Km buffer and the surrounding POIs and finally a map that represents the location of the candidate facility with the 10Km buffer and, eventually, the protected site areas that are included or nearby the buffer.

Spatial analysis

The spatial analysis protocol consists of a sequence of steps presented in figure 2. As already mentioned, the protocol is based on the SAW method. The SAW method is based on the concept of a weighted average in which continuous criteria are standardized to a common numeric range and then combined by means of a weighted average in order to obtain a score. In our context:

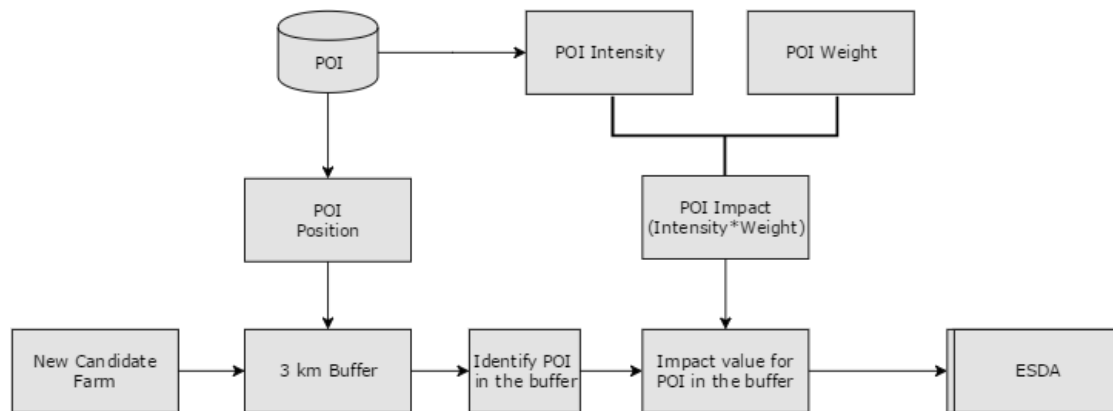


Figure 1. SAW process

- the criteria are represented by a set of features called Point of Interest (POI). The POIs are premises that directly or indirectly can be exposed to a disease problem derived from the presence of animals in the quarantine station. The list of POIs includes: (i) flocks or herds, (ii) animal hospitals, (iii) animal markets, (iv) slaughterhouses, (v) veterinary research institutes, (vi) rendering plants, (vii) fur and leather plants, (viii) artificial insemination stations, (ix) embryo transfer stations, (x) bio-safety disposal stations, (xi) human hospitals, (xii) border posts, and (xiii) animal storage depots;
- the score, called “Total Impact”, is obtained by multiplying the importance weight assigned to each POI class with the classified value of the observed POI and then summing the products over the POIs that fall inside the study area (area of 3Km radius surrounding the candidate facility).

$$\text{Total Impact} = \sum w_i x_i s_i \times \prod c_j$$

Where:

Total Impact = is the impact associated to the POI distribution in the area that surrounds the candidate facility.

w = is the weight for the i type of POI.

x = is the intensity of the observed i POI. The intensity is a quantifiable measure and represents the dimension of the POI. For example, the intensity for the “farm” class of POI is its size (number of animals), for a hospital the number of beds, etc. The values are re-classified according to a re-classification diagram.

s = is a value that is placed equal to 1 if the POI houses a species that can be exposed, at least, to one disease that can infect the introduced animals, and 0 if the POI houses a species that cannot be exposed, at least, to one disease that can infect the introduced animals.

c = Boolean constraint. Take into account the “critical POIs”. The critical POIs are the class of POIs that shall not be near a quarantine station. The presence of a critical POI in the area surrounding the candidate quarantine station leads directly to reject the request to become a quarantine station.

Outcome evaluation

The Total Impact is compared with a defined threshold value. If the impact is above the threshold, the request to become a new quarantine station will be rejected. The threshold value is defined by means of a scenario analysis.

The spatial evaluation process is completed by the following outputs:

1. map of the candidate facility with the surrounding land use and a buffer of 10 Km;
2. map of the candidate facility with a buffer of 3 Km and all the POIs evaluated;
3. a short report with the SAW outcome and a brief evaluation of the total impact calculated included the comparison with the threshold value.

Pre-requisites

Data collection

The spatial evaluation process is based on data collected through the webGIS by the local CIQ.

The webGIS manual provides instruction to:

1. Add a POI farm
 - a. Visually identify a farm facility;
 - b. Add the farm location with a point;
 - c. Select the value “farm” as the type of POI;
 - d. Select the dimension of the farm according to a well defined classification.
2. Add POIs that are not farms:
 - a. Input the geographical coordinates collected with a GPS;
 - b. Select the correspondent type of POI;
 - c. Select the dimension value based on a well-defined classification.

Re-classification

The information about POI's dimension is collected by the local CIQ and stored in the webGIS database. The information “dimension” describes how big is the observed POI. Since the evaluation process combines

different types of POIs, we need to express the dimension information as a dimensionless value. In lay terms, if among the observed POIs there is a farm that is breeding 300 chickens and an animal hospital that is able to take care of 300 animals each day, the two observed values are the same (300) but clearly a farm of 300 chickens can be considered a small farm, while an hospital that nursing 300 animals each day is quite a large facility. Therefore, if we consider only the number 300 we can overestimate or underestimate the “effect” of POI’s dimension in the evaluation process.

A possible solution to avoid the problem of misusing the dimension value, it is transforming the observed values according to a re-classification diagram. With a re-classification a value is transformed into a new range of values; the new value becomes dimensionless and it can be compared with other types of information.

A typical re-classification of values is based on the small, medium and large significance (where small has value 1, medium 2, and large 3).

The re-classification diagram assigns the re-classified value for each observed value. For instance, for a chicken farm a possible re-classification diagram can be: “if the number of animal is from 1 to 1000, the farm can be considered small, from 1001 to 10000 medium and above 10001 large.” Following the example, the observed farm of 300 chickens can be re-classified as “small” and the animal hospital “large”. The two pieces of information now are comparable.

To define a re-classification diagram for the type of POIs an expert opinion exercise should be performed. The expert opinion exercise could be a Delphi method where the moderator has the goal to reach a consensus over the range of value to classify the various type of POIs.

The AHP method

AHP is the acronym of “Analytical Hierarchy Process”. The AHP belongs to the expert elicitation class of analysis. The AHP is used to derive the relative importance (weight) of a set of well-defined criteria. In this context, the AHP method is used to derive the type of POI’s weight. The outcome of the AHP exercise is a value between 0 and 1 for each type of POI. The sum of values is equal to 1.

To perform an AHP exercise the software Expert Choice is used.

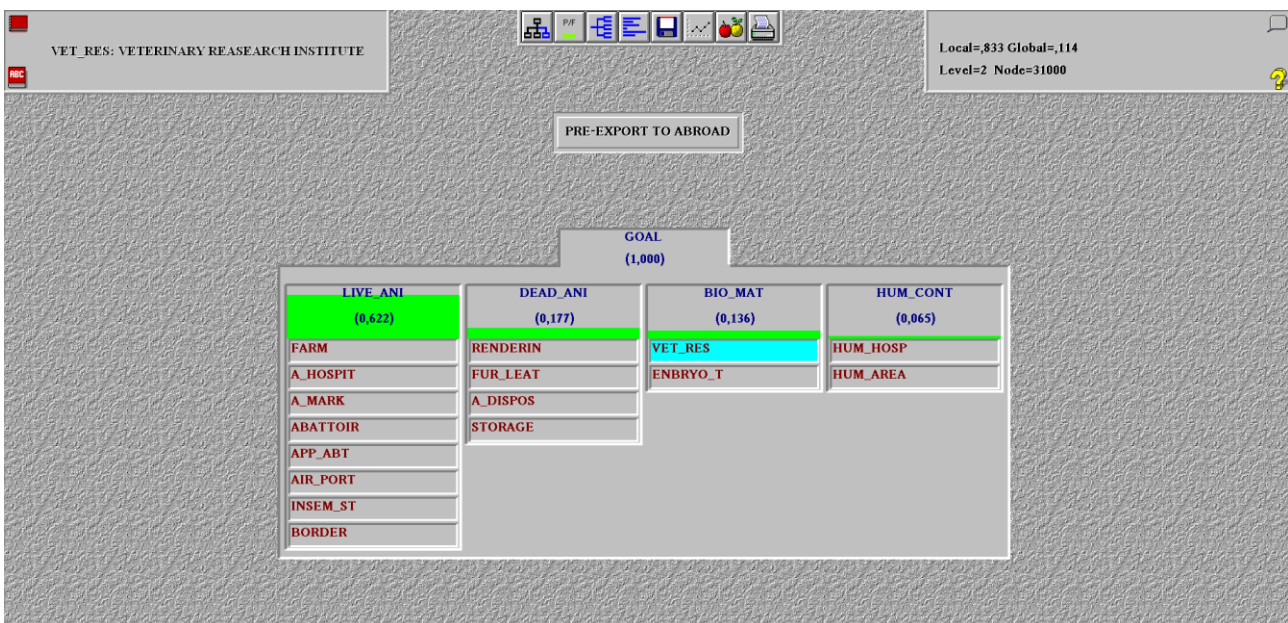
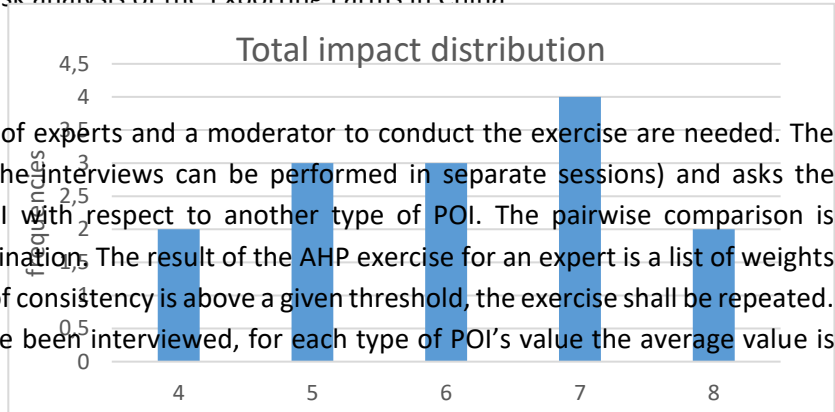


Figure 2. Expert choice print screen

To perform an AHP exercise, a panel of experts and a moderator to conduct the exercise are needed. The moderator interviews each expert (the interviews can be performed in separate sessions) and asks the relative importance of a type of POI with respect to another type of POI. The pairwise comparison is performed for all possible POI's combination. The result of the AHP exercise for an expert is a list of weights and a level of consistency, if the level of consistency is above a given threshold, the exercise shall be repeated. Once all the experts of the panel have been interviewed, for each type of POI's value the average value is calculated.



Expert 1 Type of POI1 weight: 0,3 Type of POI2 weight: 0,2 Type of POI3 weight: 0,4 Type of POI4 weight: 0,1 Sum: 1	Expert 2 Type of POI1 weight: 0,4 Type of POI2 weight: 0,2 Type of POI3 weight: 0,3 Type of POI4 weight: 0,1 Sum: 1	Expert 2 Type of POI1 weight: 0,3 Type of POI2 weight: 0,3 Type of POI3 weight: 0,3 Type of POI4 weight: 0,1 Sum: 1	Result Type of POI1 weight: 0,3 Type of POI2 weight: 0,2 Type of POI3 weight: 0,3 Type of POI4 weight: 0,1 Sum: 1	Mean Type of POI1 weight: 0,3 Type of POI2 weight: 0,2 Type of POI3 weight: 0,3 Type of POI4 weight: 0,1 Sum: 1
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The threshold values

The output of the evaluation process is a numeric value. To assign a significance to this value, it is necessary to compare it with a scale of values. In particular, the comparison shall be between the calculated value and a threshold value. The threshold value represents the limit above which the request should be rejected from the spatial point of view.

The threshold value can be obtained by simulation. In lay terms 12/15 spatial visual analysis already performed should be selected. Between 80% and 85% of the analysis should refer to "Approve" outcome and the remaining to "Reject". The proposed spatial evaluation method should be applied for this use case and the total impact values organised in terms of distribution as the example below.

use case	total impact value	outcome
1	6,5	Approved
2	5,3	Approved
3	3,2	Approved
4	9,3	Rejected
5	4,3	Approved
6	6,4	Approved
7	7,5	Rejected
8	4,1	Approved
9	5,1	Approved
10	6,3	Approved
11	4,3	Approved
12	7,1	Rejected
13	6,9	Approved

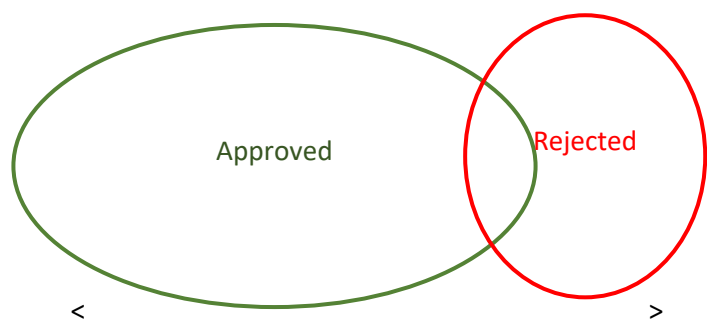


Figure 3 Example of threshold value calculation. Total impact distribution

In the example presented above, the threshold value could be "7". It is clear that the total impact values that are close to 7 need to be carefully evaluated before assigning the "Approved/Reject" evaluation.