SRA_Ch1: Introduction to spatial risk assessment

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1.1 Background

Regulatory authorities need to direct limited resources to the surveillance and control of infectious diseases in areas of greatest risk, particularly when the threat is emerging or re-emerging, or spans national borders. Mapping of the patterns of spatial risk into regions of greater or lesser threat allows the prioritisation of surveillance towards the former to increase the cost-effective use of these limited resources.

The task of prioritising surveillance resources requires several conditions. First, decision-makers in regulatory authorities require a thorough understanding of the causal processes that affect the risk of disease, including the presence of risk groups or behaviours that affect spread of disease. Second, the risk of a particular disease should vary over the area considered, otherwise there would be no point in prioritising activities. Third, relevant data should be available on the patterns of disease and the factors that determine them, together with a process to combine them and determine the risk status for sub-areas.

As a starting point, data for assessing spatial disease risk should include geographically-referenced, quantitative information about disease occurrence, the population at risk and the risk factors that might be

associated with disease occurrence. These data can often be complemented by information on various types of risk factors such as attributes of potentially at-risk individuals or groups, their contact networks, or environmental information.

The task of assessing spatial risk may be achieved broadly by one of two methods.

Data-driven method

- First, the use of exploratory or predictive disease-mapping methods, which combine statistical visualisation and regression modelling with geographical information systems (GIS) methods. These methods require data at a minimum on the occurrence of disease events and the population from which those events occurred. These are known as "data-driven" methods.

Knowledge-driven method

- Second, spatial risk assessment (SRA) modelling, which is a combination of multi-criteria decision aiding (or analysis) (MCDA) techniques and GIS methods. Multi-criteria decision aiding provides a collection of techniques for structuring decision problems and prioritising decision alternatives, based on knowledge about the causal relationships between risk factors

and the disease event of interest. These methods are known as ‘knowledge-driven’ models.

“The method chosen to assess spatial risk of disease, either statistical-GIS or MCDA-GIS, depends crucially on the availability and quality of data to support the analysis. Data-driven models are more suited when disease events and their risk factors are accurately and completely recorded, whilst knowledge-driven methods are suited to situations where there is incomplete or poor quality data. It is additionally important to understand and communicate the assumptions underlying both of these modelling approaches and the possible effect of any selection or information bias that might affect the study results”

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1.2 Data-driven model

Disease mapping methods require high-quality data on the causes of disease and the population at risk from which they arose. Data for these models are usually collected through surveillance systems. They typically use advanced statistical methods in combination with GIS techniques to map and quantify disease risk. The outputs from these models may appear to be precise, but they may suffer from forms of bias as with any modelling technique. Because of their complexity and the time required to teach them, they will not be considered in this course.

Examples of data-driven models that investigated spatial and temporal risk assessment of FMD include Gallego et al. (2007) and Shiilegdamba et al. (2008).

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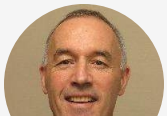
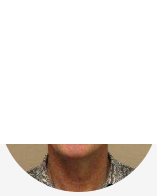
1.3 Knowledge-driven models

Multi-criteria decision aiding provides a range of methods to reach a decision when multiple, and possibly conflicting criteria must be taken into account (Bigaret et al., 2017). In an assessment of spatial risk factors, the term “risk factors” might be used instead of “criteria”. MCDA methods presuppose a preference structure giving preferences on each of the different criteria (Barfod and Leleur, 2014). The purpose of an MCDA is not to search for some kind of hidden truth – but rather to assist the decision-maker in understanding the often complex data involved and advancing towards a solution.

The MCDA process applies methods in a transparent and repeatable way according to the information available and the criteria requirements of the decision-makers (DM). The DMs face several decision alternatives which must be evaluated according to a set of criteria or points of view, which themselves may be conflicting. Ultimately, the DM’s are in charge of and responsible for the decision to be made, and may also express some preferences for the criteria and alternative decisions.



“In the GIS health setting, MCDA modelling of spatial disease risk



uses an “existing or hypothesised understanding of the causal relationships leading to disease occurrence” (Pfeiffer, 2008). A strength of this approach is that it can incorporate information on transmission dynamics and disease spread without requiring quantitative data. The connection between MCDA and GIS is the creation of weighted risk factors from MCDA methods, which are then plotted using GIS methods to visualise spatial variations in risk and inform the allocation of surveillance resources.”

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“An example of the use of knowledge-driven models would be when a country that has not experienced an outbreak of highly pathogenic avian influenza wants to identify areas of the country where an incursion of the disease is more likely to occur. This means that either expert opinion or the application of techniques that gather data at the farmer level can be used to elicit information about disease risk that is not available in any other format. Some disadvantages of MCDA are that the models can become rather theoretical, have a strong subjective element, and are only loosely connected to real data. Validation of the resulting maps is not always possible due to this lack of data and is frequently limited to visual comparisons with existing data sources. An important distinction between MCDA-GIS spatial risk assessment and disease mapping is that the former does not provide an absolute, but rather a relative measure of disease

risk. Maps produced by this method identify regions with relatively greater or lesser risk of disease occurrence without quantifying the absolute risk, but still provide information to target risk management or surveillance activities (Stevens et al., 2009).”

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Examples in the literature

Multi-criteria decision aiding methods have been used in a diverse range of fields, including health, finance, banking, environmental management and urban planning. Additionally, techniques involving MCDA have been applied to several fields in veterinary science, including prioritisation of preventive measures for exotic diseases (Del Rio Vilas et al., 2013; Brookes et al., 2015), spatial prediction of disease status (de Glanville et al., 2014; La Sala et al., 2019) and evaluation of control strategies for contagious diseases (Mourits et al., 2010). Amaral et al. (Amaral et al., 2016) applied a knowledge-driven MCDA spatial risk assessment approach to develop risk maps for the introduction of FMD along the border between Brazil and Paraguay. These methods are particularly suitable where data for regression methods are not available or of poor quality, but instead, either the opinions of experts or a wide range of stakeholders can be elicited. Sometimes an analyst will assist in this process by guiding the DM's through the various steps, and in particular, the statistical methods required. A key aspect of MCDA is that the final decision should be a consensus and acceptable to all stakeholders even though it may not be the best one (Bigaret et al., 2017).

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Exercise 1.1: Create a list of FMD risk factors

"Create a list of risk factors for FMD (or another transboundary disease of interest) occurrence in your country. These can be factors that are either known or suspected to be relevant in your country or factors identified in other countries. Categorise these factors in a two-row, two-column table as incursion- or spread-related, and spatial or non-spatial factors. The table could be set up as shown in Table 1.1.

Spatial risk factors are those for which a map can be obtained to locate the geographic feature that represents a risk factor or is a proxy (substitute) for the risk factor of interest. For example, a border crossing point to a country that is a source of FMD risk animals or products is clearly a spatial risk factor for the incursion, or proximity to a secondary road network might be a proxy spatial risk factor for unobserved illegal movement of animals or their products. Non-spatial risk factors are those factors for which little or no information exists or for which no spatial information is available to locate it on a map, such as compliance rates for importing animal products by the public through a border entry point."

Table 1.1: Minimal example of two-by-two table of risk factors for incursion or spread of FMD cross-classified by whether risk factors are spatial or not

	Spatial	**Non-spatial**
Incursion	Proximity to border crossing point	Compliance with restrictions on import of animal products by public
	Add more below	Add more below
Spread	Proximity to primary road	Compliance with pre-movement testing regulations
	Add more below	Add more below

CONTINUE

"Read one or more of the reference scientific articles provided to you about SRA, and possibly those particularly focused on FMD or the transboundary disease that you are most interested in.

1. **What further ideas about risk factors for FMD or another disease of interest did you gain from reading these references article?**

You may want to add them to your list of risk factors from Exercise 1.1"

CONTINUE

Have you completed and written down notes for potential risk factors for FMD or another transboundary disease that you are most interested in?

- ◯ Yes
- ◯ No

SUBMIT

CONTINUE

"Possible spatial risk factors for incursion or spread of FMD in your country of interest might include some shown in Table 1.2. The actual spatial risk factors you would choose to use in an SRA would depend on the epidemiological situation in your own country and availability of suitable spatial data to represent them."

Table 1.2: Example of two-by-two table of possible risk factors for incursion or spread of FMD cross-classified by whether risk factors are spatial or not

	Spatial	Non-spatial
Incursion	Proximity to border crossing point	Compliance with restrictions on import of animal products by public
	Practices of swill feeding to pigs	Thoroughness of border staff in searching imported items
	Pig population density	Frequency of illegal cross-border movement of animals or products
	Proximity to primary road	
Spread	Communal grazing practices	Compliance with pre-movement testing regulations
	FMD vaccine coverage	Completeness of surveillance of within-border movement of animals or products
	Proximity to local livestock market	Frequency of illegal within-border movement of animals or products
	Cattle population density	

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Congratulations - end of lesson reached

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using Multicriteria Decision Modelling.

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