

Risk Mapping for HPAI H5N1 in Africa  
Improving surveillance for bird flu

## Introduction to Bird Flu Risk Maps for Disease Surveillance



March 2009



**The project:** This publication is part of a series developed to support decision-making for the prevention and control of highly pathogenic avian influenza through the use of risk mapping, and is an output of the Early Detection Response and Surveillance of Avian Influenza in Africa (EDRS-AIA) project, implemented by the International Livestock Research Institute (ILRI) in collaboration with African Union Interafrican Bureau for Animal Resources (AU/IBAR).

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**Acknowledgments:** We thank the following for comments and suggestions: Gary Smith, staff of the United States Agency for International Development (USAID), and members of the ILRI-AU/IBAR Early Detection Response and Surveillance project.

**Support:** This series of bird flu risk-mapping publications is made possible by the generous support of the American people through USAID. The contents are the responsibility of ILRI and/or AU-IBAR and do not necessarily reflect the views of USAID or the United States Government.

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## What is a risk map?



A risk map is a complex, computer-generated image that shows the predicted spatial distribution of disease risk. Figure 1 shows an example of a risk map for the predicted distribution of Theileriosis (East Coast Fever) in Zimbabwe due to infection with *Theileria parva*.

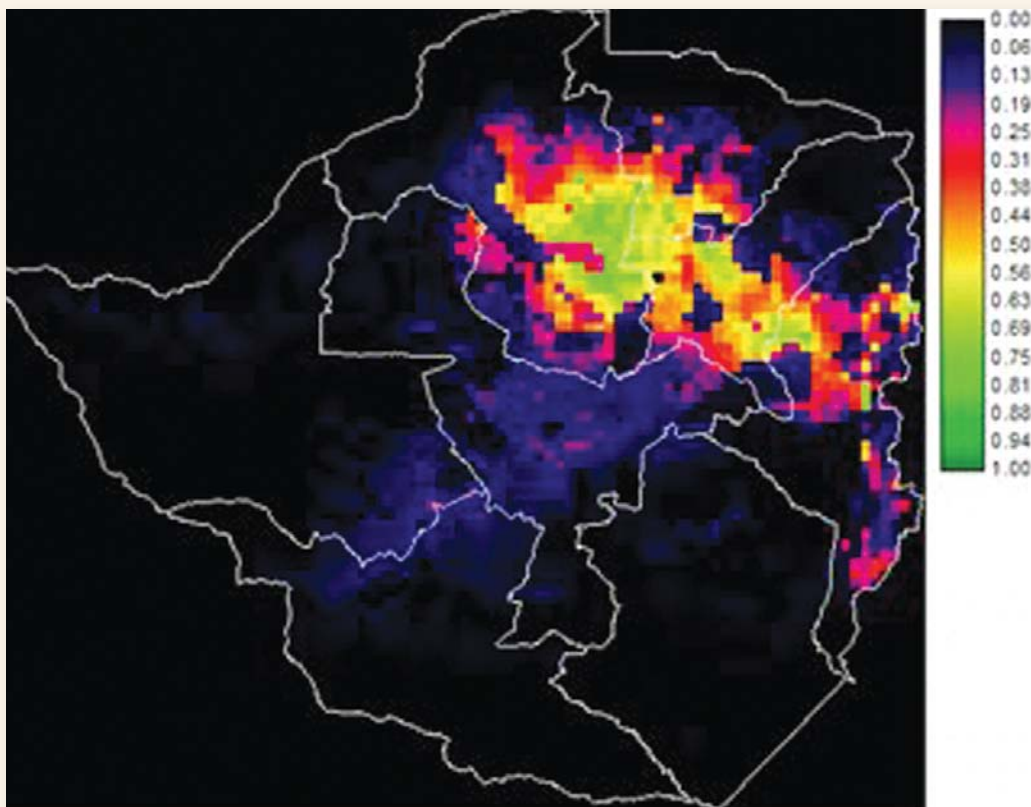


Figure 1:  
Risk map showing the probability of occurrence of theileriosis outbreaks in Zimbabwe due to infection with *Theileria parva*.  
Reproduced with the authors' permission from: Pfeiffer, D.U., Duchateau, L., Kruska, R.L., Ushewokunze-Obatolu, U., Perry, B.D.,  
1997. A spatially predictive logistic regression model for occurrence of theileriosis outbreaks in Zimbabwe. *Epidemiologie et  
santé animale* 12.12.1-3.

## What is “disease risk”?

It is the probability of occurrence of cases of disease.

“Risk of introduction” refers to the probability of disease occurrence in a population or area previously unaffected.

“Risk of spread” refers to the probability of occurrence of new cases following introduction in the population or area.

Disease risk is influenced by risk factors.

## What is a risk factor?

A risk factor is something likely to increase the chances that a particular event will occur.

A risk factor for a disease is something associated with an increased risk of disease.

For example, smoking is a strong risk factor for lung cancer; use of a mobile phone while driving is a risk factor for having a car accident.

Potential risk factors can be suggested during field observations, or by making hypotheses about plausible relationships according to the nature and mechanisms of transmission of the disease of concern.

Risk factors can then be confirmed using statistical methods, for example, by comparing the risk of disease among individuals exposed to the risk factor with the risk of disease among individuals not exposed to the risk factor.

## What are possible ways to describe disease risk?

Two increasingly common ways of describing disease risk based on risk factors are:

- a) Risk assessment. Risk assessment is a standardised process that estimates the probability of occurrence of an unwanted event. If the unwanted event is an outbreak, it describes the full sequence of events leading to a case of the disease, and assigns a probability to each event.
- b) Risk mapping. Risk maps show the spatial distribution of disease risk, i.e. how probabilities of outbreak vary over a given area, based on the location of risk factors as well as their relative importance. Data-driven risk maps show absolute risk estimates whereas knowledge-driven risk maps show relative risk scores (they identify areas at higher or lower risk of disease occurrence).

Both approaches need to be based on available evidence.



## How can risk be represented on a map?

It is possible to produce maps showing the spatial distribution of single risk factors (see Figure 2).

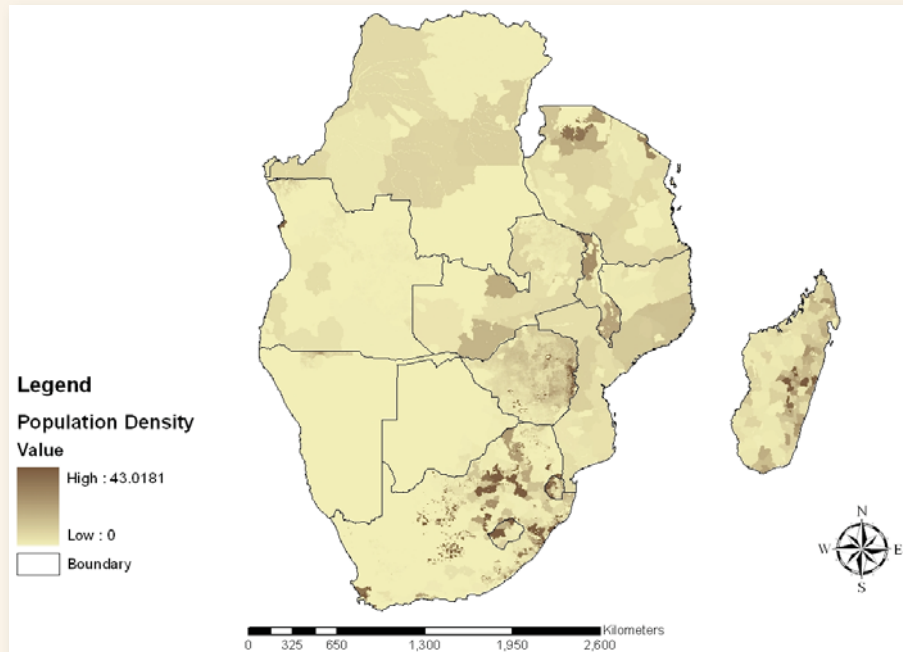


Figure 2:

Map showing the spatial distribution of human density in Southern Africa (Source: ILRI)

The spatial distribution of a risk factor will influence the spatial distribution of disease risk. However, if a number of risk factors exist for a given disease and each has their own degree of association with the disease, then it becomes difficult to estimate the overall likely spatial distribution of the risk of disease.

One option is to overlay and combine the spatial distribution of multiple risk factors, in order to obtain a combined indication of disease risk. This is the approach followed in the creation of knowledge-driven risk maps.

## How are knowledge-driven risk maps prepared?

The procedure for producing knowledge-driven risk maps is to:

- 1) Review the current scientific literature and knowledge to identify risk factors known to be associated with the disease of concern, and to determine their degree of association with the risk of disease
- 2) Map the spatial distribution of the individual risk factors
- 3) Combine these maps, giving them weights (scores) according to their relative importance in contributing to the overall risk of disease (see Figures 3a and 3b on page 6).
- 4) Present, in a risk map, the resulting spatial variation in disease risk.

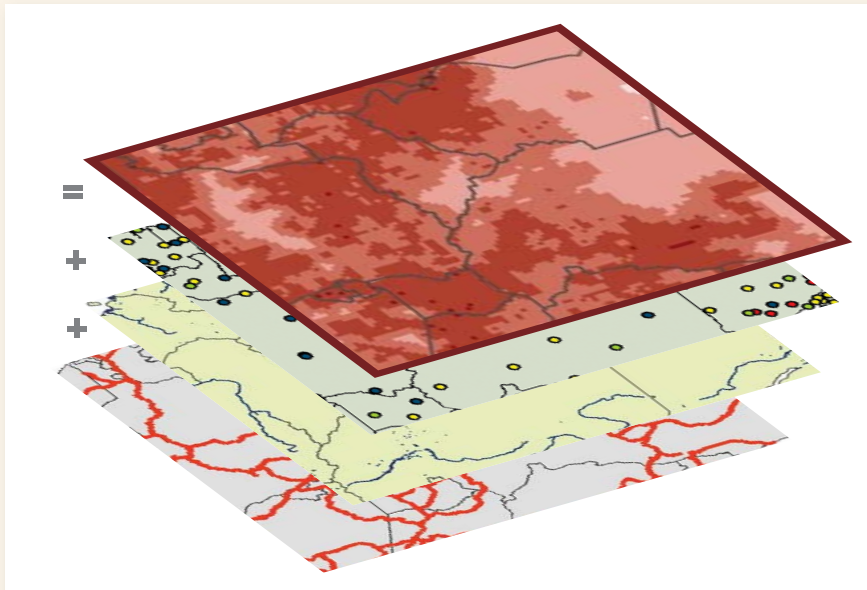


Figure 3a: Building process of a knowledge-driven risk map. The spatial distributions of the different risk factors (bottom three layers) are combined in order to produce the risk map (topmost layer).

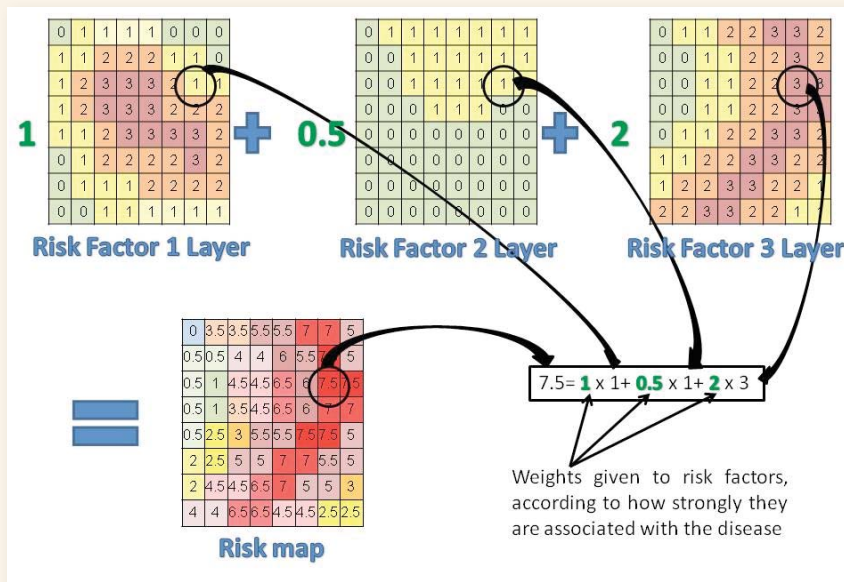


Figure 3b: Building process of a knowledge-driven risk map. For each pixel of the area considered, the risk score of all risk factors are combined according to their relative importance, resulting in an overall risk score for each pixel of the risk map.

## What are the limitations of knowledge-driven risk maps?

The accuracy of a risk map depends on how well we understand the epidemiology of the disease. The spatial variation in disease risk as represented in a risk map depends on the correct risk factors being included in the risk mapping process, and each risk factor being appropriately weighted with respect to the introduction or spread of disease. If the risk factors for a given disease are not all known, or if some are incorrect, then the resulting risk map will be incorrect. Similarly, if the degree of association between each risk factor and the disease is not known or wrong, the risk map produced will be biased.

It is sometimes difficult or impossible to represent some risk factors spatially. Only mappable risk factors can be considered for the preparation of a risk map. There might be important non-spatial risk factors not included in the preparation of the risk map, which nevertheless influence the geographical distribution of disease risk. For that reason, some diseases are inherently more suited to risk mapping than others.

Most suited to risk mapping are diseases that are transmitted by vectors or strongly sensitive to climatic factors, such as Rift Valley Fever, trypanosomosis or malaria. Diseases influenced by individual behaviour and social factors may be less suited to risk mapping (e.g. sexually transmitted disease or oesophageal cancer). In addition, when it is very difficult to get accurate, geo-referenced data on the presence of risk factors and disease, then risk mapping is less useful.

In addition, risk maps depend on the quality of the data used for their preparation. If the maps showing the spatial distribution of individual risk factors are inaccurate or lack precision, so will the resulting risk maps.

Finally, knowledge-driven risk maps cannot predict where disease outbreaks will occur. They show only where outbreaks are more **LIKELY** to happen, according to the spatial distribution and relative importance of the risk factors included in their preparation.

## How can knowledge-driven risk maps be used?

Risk maps can help target disease surveillance and control activities. It makes sense and conserves resources to focus surveillance and control efforts on places where an outbreak is more likely to occur.

Used critically and in conjunction with other tools such as risk assessment and local knowledge, risk maps can help policy makers target areas for strengthened surveillance and /or control activities.

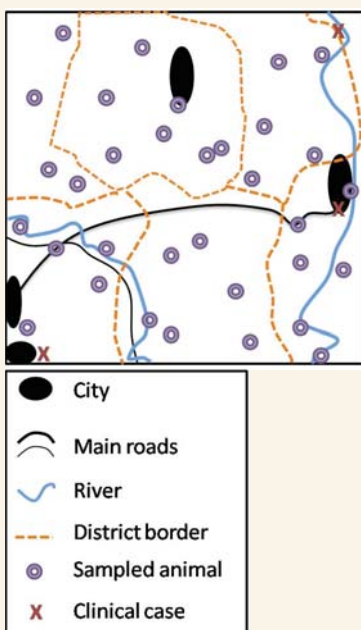




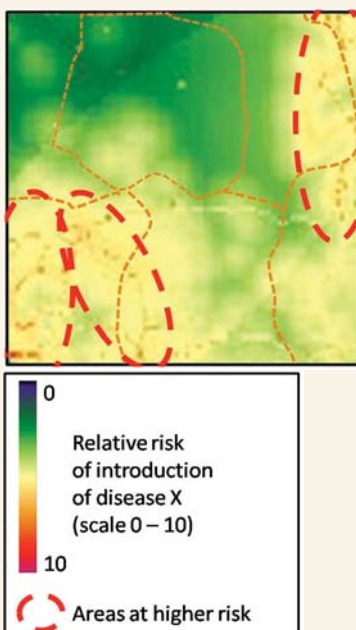
## How can knowledge-driven risk maps help guide surveillance activities, especially Participatory Disease Surveillance?

Since risk maps show where the diseases are more likely to occur, they can be used to guide surveillance activities.

Let's take the example of a Country C where surveillance activities on Disease X are being planned. Disease X is not present in Country C, so surveillance activities aim at detecting clinical cases of Disease X as early as possible in the event of its introduction.



In the 1st situation (see figure to the left), researchers plan to conduct regular surveys, using stratified random sampling of animals. In each district of the country, animals will be randomly selected and observed in order to detect any clinical case of Disease X. However, this sampling strategy might not be the most appropriate for rapid detection of isolated clinical cases if Disease X is suddenly introduced into the country.



In a 2nd situation, the researchers use risk maps to guide the sampling strategy of their survey. Based on the map to the left, they have identified areas of Country C where the disease is more likely to occur (areas circled in red). In these areas at higher risk, they will conduct strengthened surveillance activities. They can use either conventional surveillance using random sampling of the population in the high risk areas, or purposive sampling (e.g. PDS).

As useful as they may be, it is important to keep in mind the limitations of knowledge-driven risk maps and to be critical when interpreting them.

Risk maps are only as good as the data used to generate them:

1) Risk maps depend on the risk factors selected and the weights attributed to each of them in the combination step of the building process. If these are erroneous or incomplete, so is the risk map.

Critical questions to ask when considering a risk map include:

*Who selected the risk factors to consider, and how?*

*Who decided the weight to give each of these risk factors, and on what basis?*

2) Risk factors of disease are not always “mappable.” In addition, accurate spatial data on their distribution may not be available. It is therefore important to check which factors were included in the risk maps, and consider adding additional ones if appropriate when planning disease surveillance activities.

3) Proxies are sometimes used to represent the spatial distribution of risk factors, when spatial data on the risk factor itself are not available. For example, the spatial distribution of cities can be used to represent the spatial distribution of markets. The proxies used may not completely match the spatial distribution of the risk factor, resulting in biased or approximate risk maps. Therefore it is essential to ground-truth the maps.

## How can Participatory Epidemiology help to improve knowledge-driven risk maps?

Using Participatory Epidemiology activities, investigators can collect field data to validate and improve the quality of risk maps.

### *Example 1*

Authorities have decided to conduct surveillance activities in Region R of Country C because a risk map identified Region R as being at higher risk for Disease X. An important risk factor is the presence of live-animal markets. It is therefore decided to conduct investigations in live-animal markets of Region R.

During field activities, investigators collect geographical and other information on these markets (GPS coordinates, animal species in markets, size and relative importance, etc.). They send the data to the mappers, who can check if the spatial information they have used matches what was observed in the field or if the spatial data need to be refined to make more accurate risk maps. If the live-animal-market data are significant for mappers, field staff working in other areas of Country C can also try to update the spatial data on live-animal markets using the same type of investigation.



### Example 2

In the context of surveillance activities on HPAI, surveys are conducted in communities close to a lake known to be a congregation site for many migratory birds. Using participatory tools, investigators collect information on migratory birds observed close to the communities: which species, at what time of the year and for how long, where, and if contacts exist with domestic poultry (backyard or free-ranging). These data can then be used by people preparing the risk maps, either to update the spatial data they have been using, or to validate them.

### Example 3

Formal and informal border crossing points have been identified as risk factors for the introduction of HPAI. However, only spatial data representing formal border crossing points were available. Using participatory mapping, local communities and stakeholders provide information on the location of informal border crossing points, plus additional information including species and volume traded at these points. These data can help risk mappers refine the spatial distribution of border crossing points, and thus improve the quality of the risk map for the introduction of HPAI.

Participatory Epidemiology can be used to critically discuss the use of risk maps.

### Example 4

Participatory tools can be used to collect data on risk factors for a disease and their relative importance, as perceived by communities (e.g. using proportional piling). This information can then be used to critically discuss risk maps prepared for the disease and region of interest. Communities can compare the risk factors and weights selected for the risk maps with the ones they have defined.

It is likely that not all risk factors were included (for example, non-spatial ones are excluded), and weights might also differ. It is therefore essential to crosscheck the information provided by risk maps with other sources of information on disease risk.





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