

# A Surveillance Portfolio for Emerging and Evolving Diseases

- Design, Delivery, Deductions,  
Decisions

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# Global Emergence and Re-Emergence

- This is not a random process, a range of predictor variables can help focus effort
- Most emergence is reported and publicised when it reaches people, but this is typically the last stage of a more complex evolutionary process through animals
- Numerous other diseases are at earlier stages of the evolution from purely animal disease to endemic human disease
- We need to develop approaches which will allow us to detect when diseases are “on the move”

# Identifying Risk Factors for Emergence

- Diseases form a limited number of “epitypes”, diseases in each epitype need same surveillance
- Need to explore the factors involved in disease emergence, and then use these in global and national disease surveillance
- Of 1415 human pathogens, 61% are zoonoses
- 196 emerging disease pathogens, 175 in people, 29 in domestic livestock and 12 in dog/cat
- Ability to infect multiple hosts, especially in other taxonomic orders or wildlife, are risk factors
- Viruses (esp RNA) highly likely to emerge, also protozoa, but helminths and fungi unlikely

# Source species

| Host               | Zoonoses (800) | Emerging z (125) |
|--------------------|----------------|------------------|
| Ungulates          | 315 (39%)      | 72 (58%)         |
| Carnivores         | 344 (43%)      | 64 (51%)         |
| Primates           | 103 (13%)      | 31 (25%)         |
| Rodents            | 180 (23%)      | 43 (34%)         |
| Marine mammals     | 41 (5%)        | 6 (5%)           |
| Bats               | 15 (2%)        | 6 (5%)           |
| Non-mammals        | 109 (14%)      | 30 (24%)         |
| Birds within non-m | 82 (10%)       | 23 (18%)         |

# Relative Risk of Emergence

| Taxonomy          | Human | Livestock | Dog/cat |
|-------------------|-------|-----------|---------|
| Protozoa          | 2.49  | 0.77      | 1.17    |
| Bacteria          | 0.71  | 1.12      | 0.76    |
| Viruses           | 4.34  | 5.66      | 11.07   |
| Multiple spp      | 1.97  | 2.55      | -       |
| >1 taxon order    | 1.97  | 3.82      | 0.37    |
| Human involved    | N.a.  | 2.17      | 1.45    |
| Wildlife involved | 2.44  | 2.64      | 3.50    |
| Domestic ans      | 1.67  | N.a.      | n.a.    |

# Human disease emergence risk factors

| Factor category    | Factor           | Relative Risk |
|--------------------|------------------|---------------|
| Zoonosis           | No               | 0.52          |
|                    | Yes              | 1.93          |
| Taxonomic group    | Viruses + prions | 4.33          |
|                    | Bacteria         | 0.71          |
|                    | Fungi            | 0.33          |
|                    | Protozoa         | 2.49          |
|                    | Helminths        | 0.24          |
| Transmission route | Direct contact   | 1.47          |
|                    | Indirect transmn | 0.80          |
|                    | Vector-borne     | 2.35          |

# Incubator situations

- Most diseases have originated in Europe, Asia or Africa, fewer in Americas
- East Asia and sub-Saharan Africa have contributed more major diseases than might expect
- Emergence may be related to interaction among multiple species, including man
- Some species disproportionately important – eg pig, bats



# **Design** to detect emerging diseases

- Scanning and targeted surveillance, global/focal
- Global scan – “biosurveillance”
- Global targeting – discriminate novel situations from endemic disease issues, especially where more than one country involved
- Focal targeted epidemiology – defining the susceptibility landscape and the risk landscape in a region of interest
- Focal targeted surveillance – designing and conducting surveillance to answer key questions

# Global scanning for emerging issues

- Global early warning of new syndromes – need multiple surveillance methods (including novel approaches), integrated interpretation
- Syndromic surveillance in high risk locations and populations
- Rapid international reporting to recognize transboundary novel syndromes
- Prompt investigation by international epidemiological teams of high risk situations (??)

# Traditional vs Novel Biosurveillance (1)

| Parameters                 | Traditional Disease Surveillance   | Novel Bio-surveillance   |
|----------------------------|--|--|
| Structure                  | Single system, closed  | System of systems, open, multiple channels                         |
| Coverage                   | Single country/several countries<br>Within country, hard to reach remote areas             | Can be global<br>Can reach remote areas                            |
| Timeliness                 | delay in outbreak detection and disease reporting, analysis, feedback<br>Batched reporting | Real-time in data mining, categorization, filtering, and releasing |
| Information Flow           | Vertical   | vertical and horizontal  |
| Availability/accessibility | Authorized access only, closed system  | Open access, greatly improved access                               |

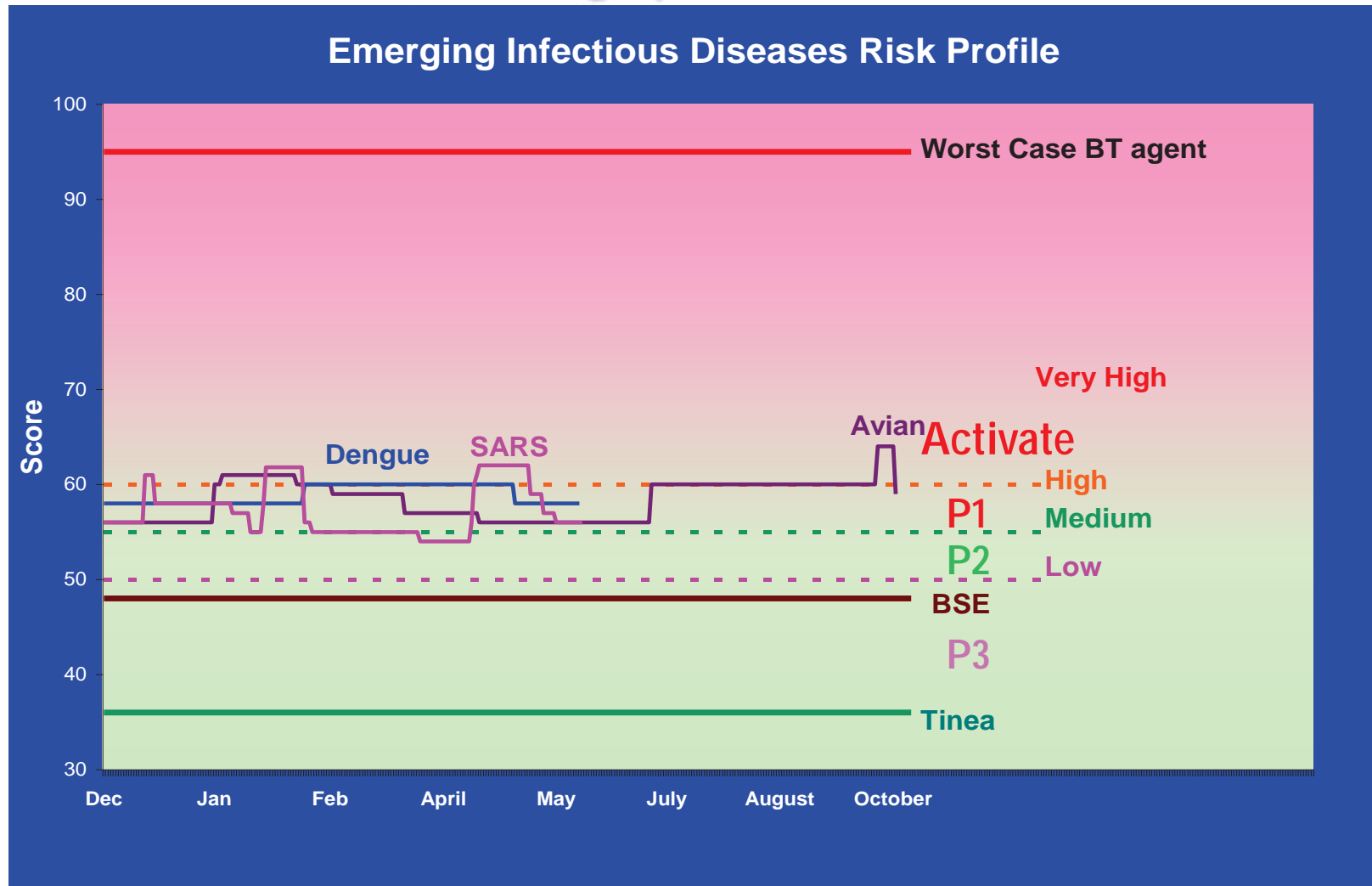
# Traditional vs Novel Biosurveillance (2)

| Parameters             | Traditional Disease Surveillance                     | Novel Bio-surveillance   |
|------------------------|--|--|
| Automation             | Low level of automation or even manual data handling | High level of automation in data mining, filtering, presentation and visualization                                     |
| Sources of Information | health service providers, laboratories               | health service providers, syndromic surveillance suppliers, data volunteers, new aggregators, other opportunistic data |
| Transparency           | Subject to politics                                  | Difficult to manipulate or hide the truth, but rumours may masquerade as evidence                                      |
| Sensitivity            | Reliance on single system, prone to low sensitivity  | Sensitive  |
| Specificity            | Can be highly specific                               | Prone to false alarm   |
| Examples               | Traditional disease reporting system                 | Healthmap, ProMED, GPHIN, MedISys, EpiSPIDER, GDD, etc.  |

# Chronology of Global Disease Surveillance Development

|               | Time | Ownership                                     | Access            |
|---------------|------|---|-------------------|
| Promed/ProPPM | 1993 | International Society for Infectious Diseases | Free              |
| GOARN         | 1997 | WHO   | Authorized        |
| GPHIN         | 1998 | Gov. of Canada                                | Authorized access |
| HealthMap     | 2006 | Consortium of universities and insitutions    | Free              |
| Medlsys       | 2007 | EC  | Free              |

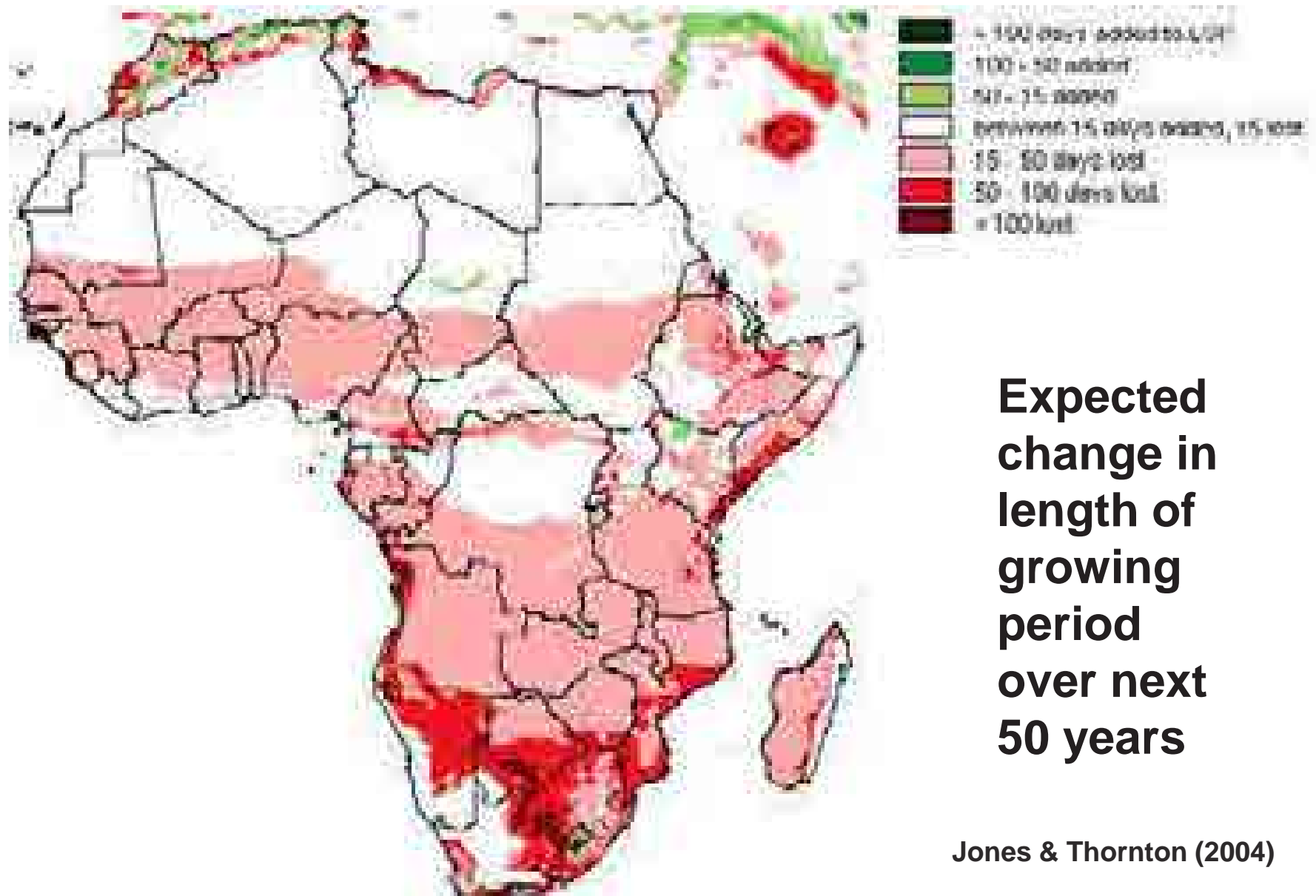
# Risk assessment - Singapore



## Big picture trends

- Evaluate changes over time in multiple factors which may precipitate changes in risk of disease by location, species, environment etc
- Estimate changes in susceptible populations and impact of this on likely epidemiological patterns – susceptibility landscape
- Assess consequent disease risk changes that can be expected – risk landscape

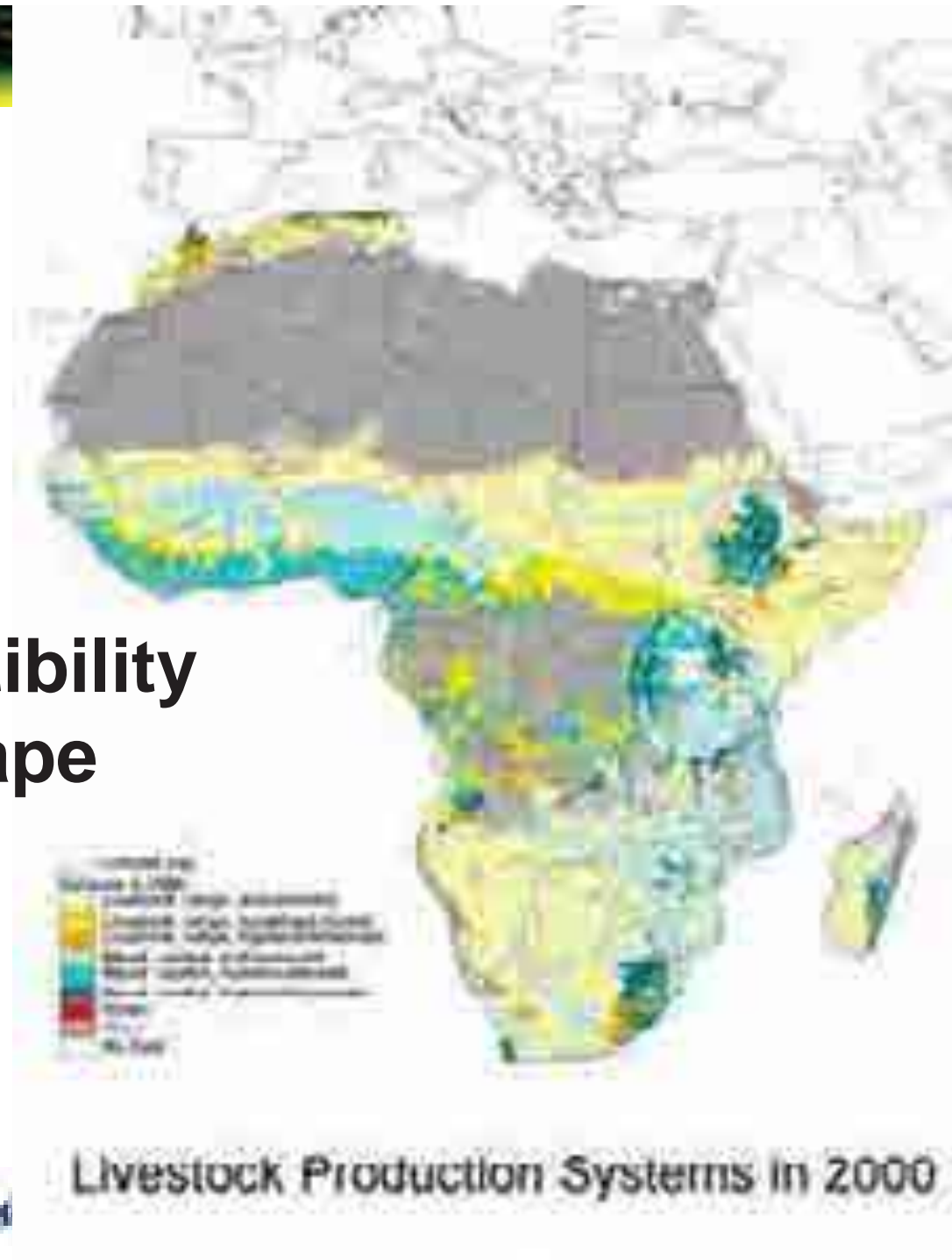
## LGP Difference, 2000 to 2050, SRES A2, Hadley CM3



Jones & Thornton (2004)

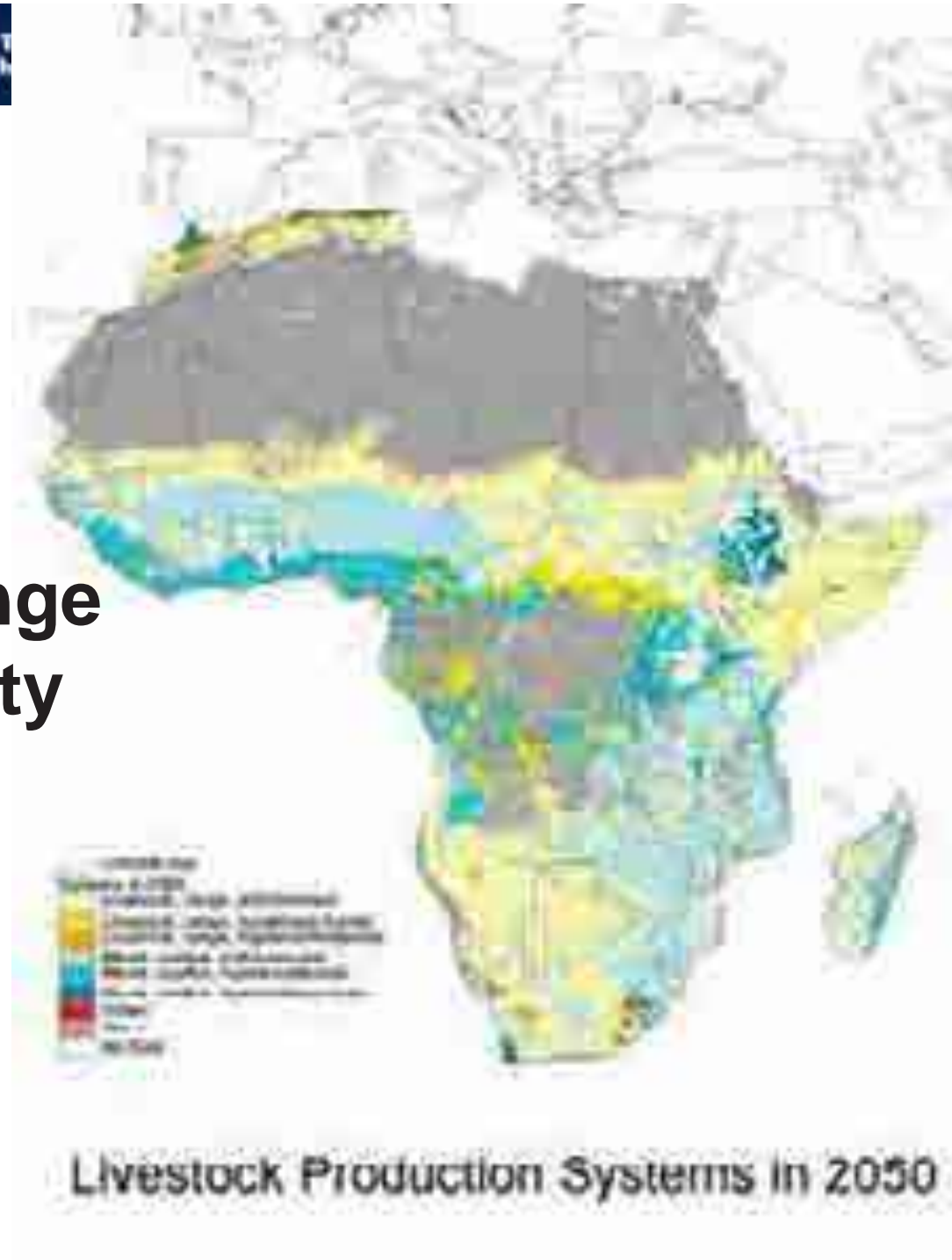


# Susceptibility landscape

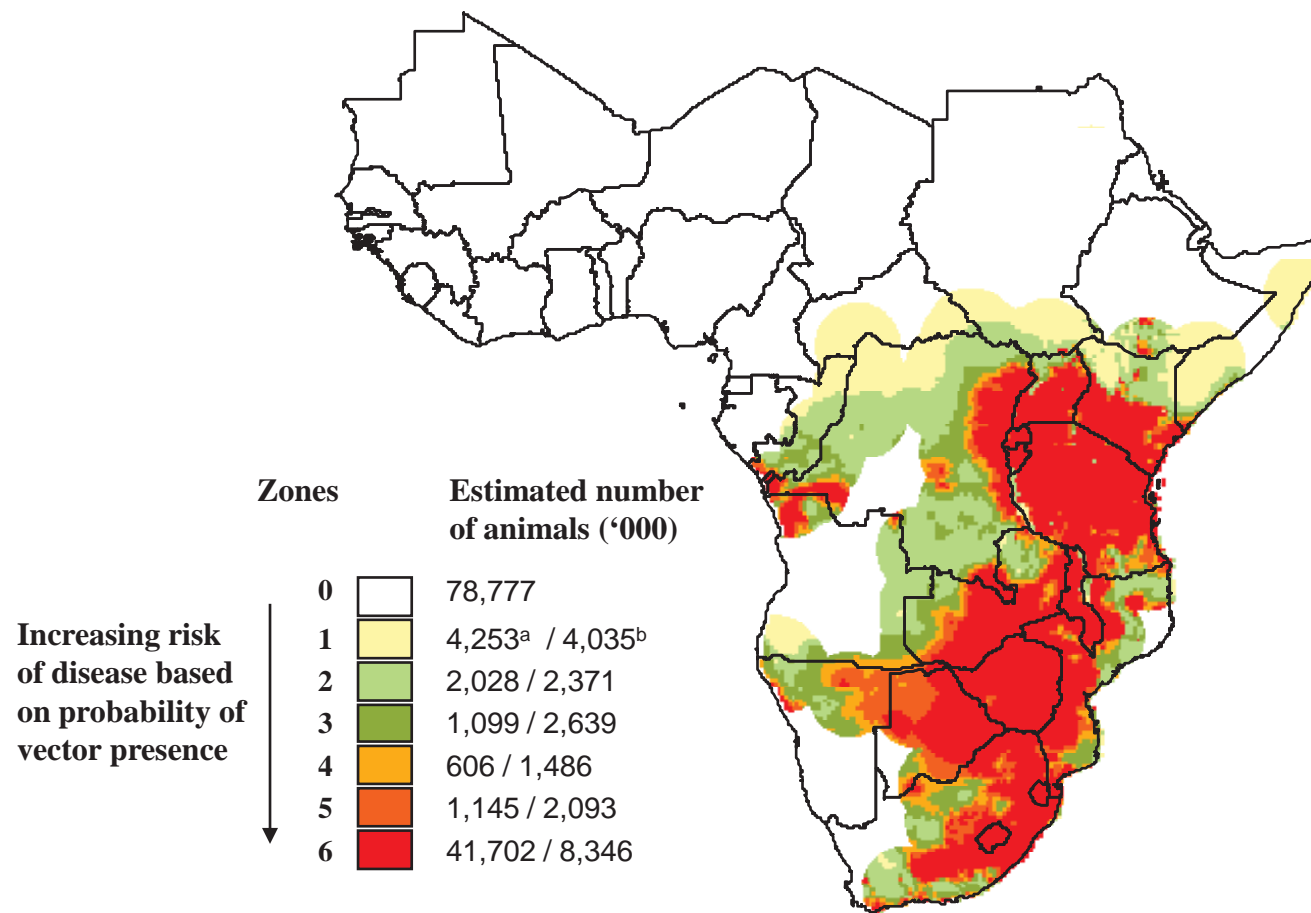




# Predicted change in susceptibility landscape



# *Theileria parva*



<sup>a</sup> Countries in the endemic region

<sup>b</sup> Countries potentially at risk: Vectors suitability but absence of disease

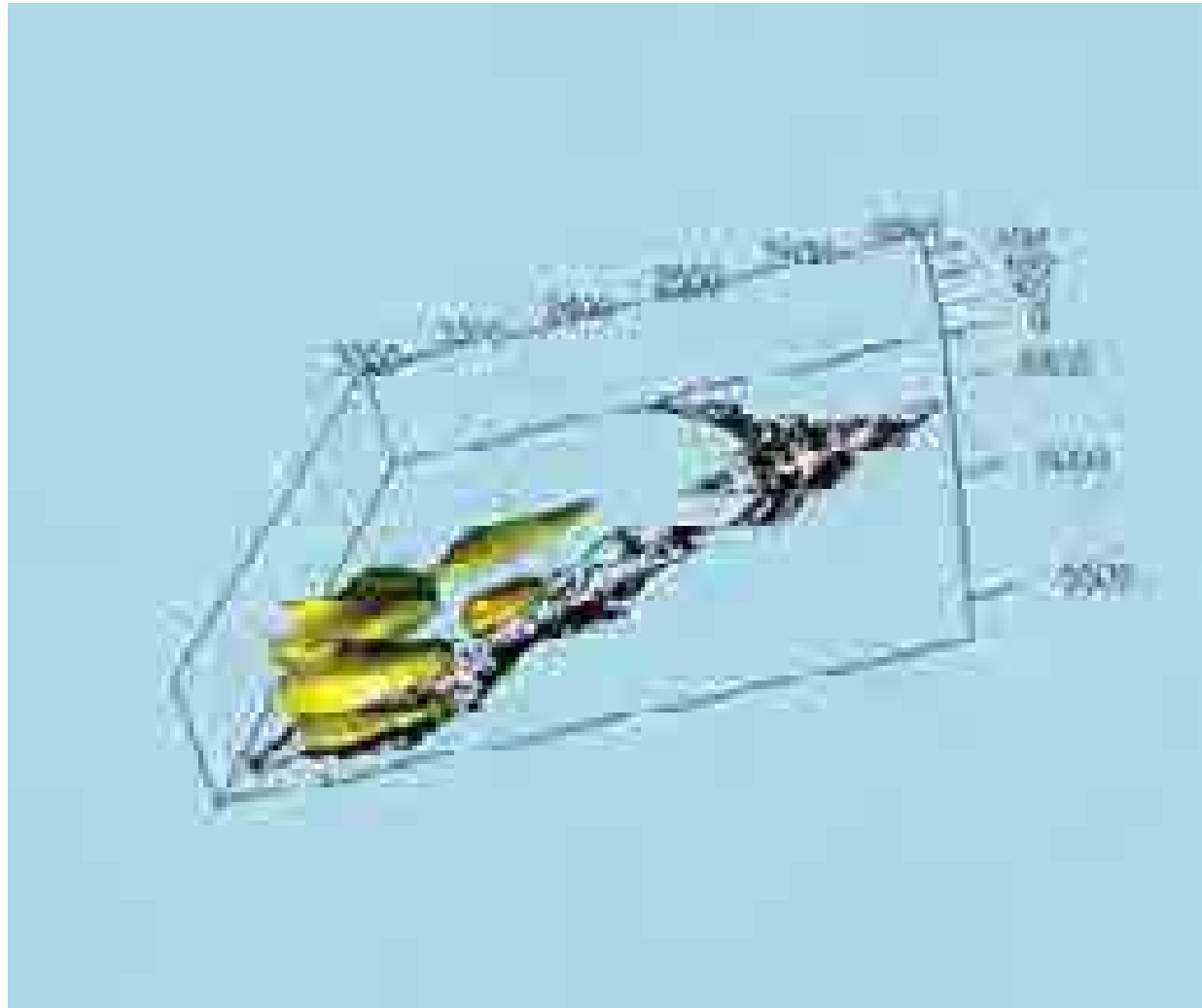
## Local risk trends

- Use available information on population at risk and one or more sources of disease data to examine current disease trends
- Can also use risk factor data to confirm freedom from disease of concern by risk-based sampling of population
- Example of proving that NZ remains free of exotic vector-borne causes of sheep abortion, combining risk factor information, farmer sample submissions and risk-based sampling



Monitoring endemic disease in farmed livestock, January 2007 to December 2008.

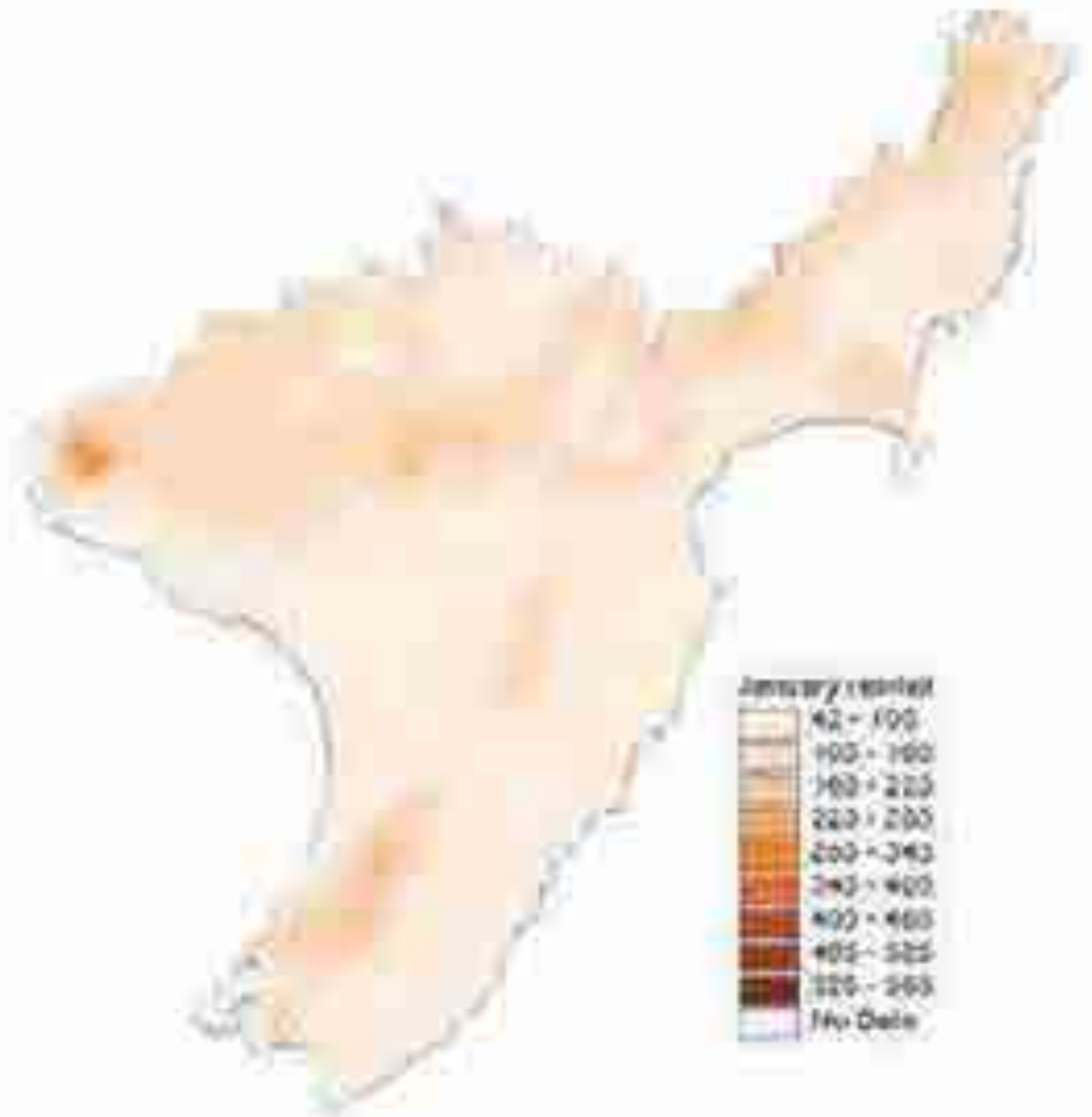
Three-dimensional image plot showing the density of disease-positive farms over time. X and Y axis define location, Z axis defines time (number of days since 1 January 2007).



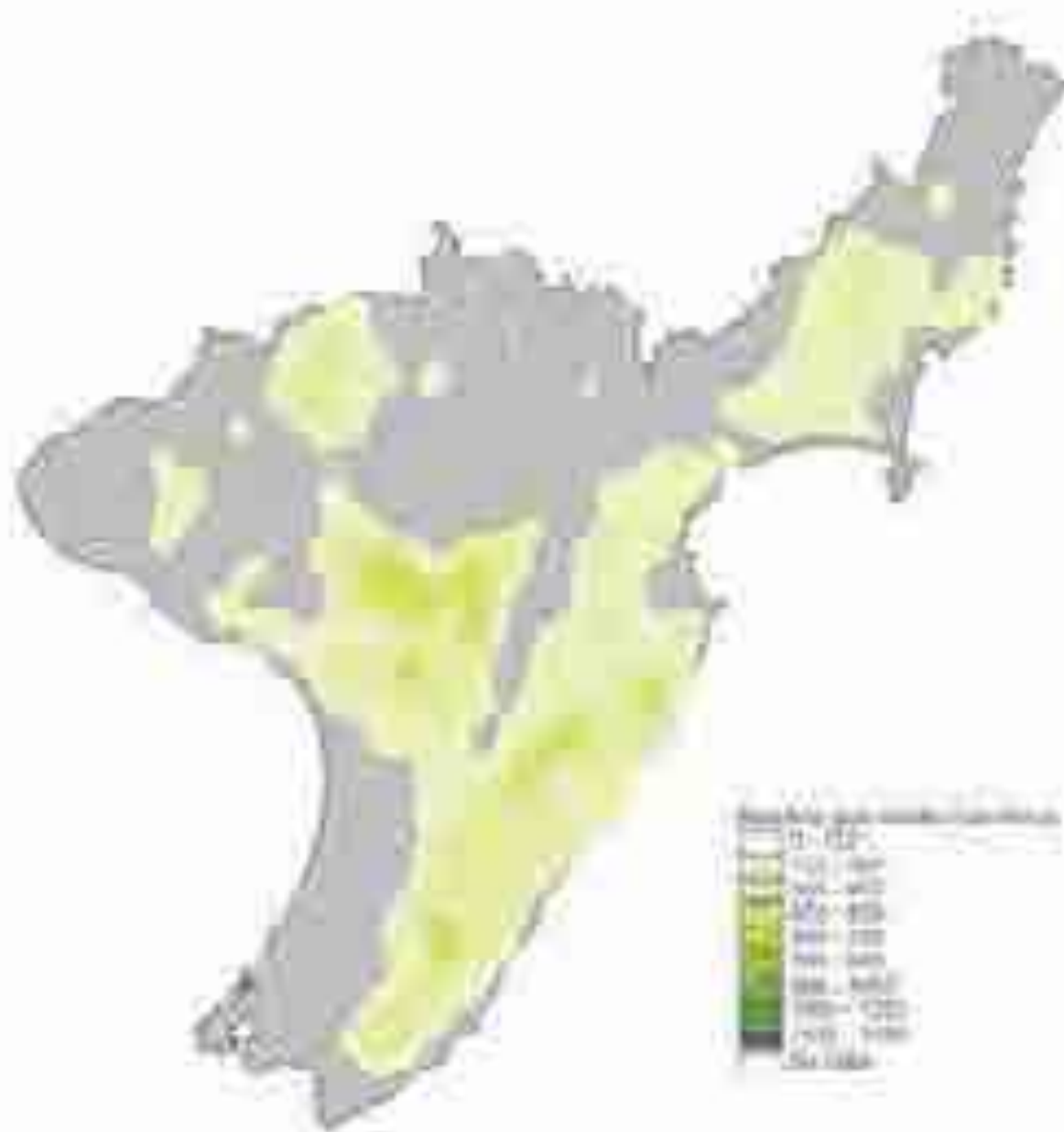
Minimum  
temperature  
for January



Mean  
rainfall for  
January

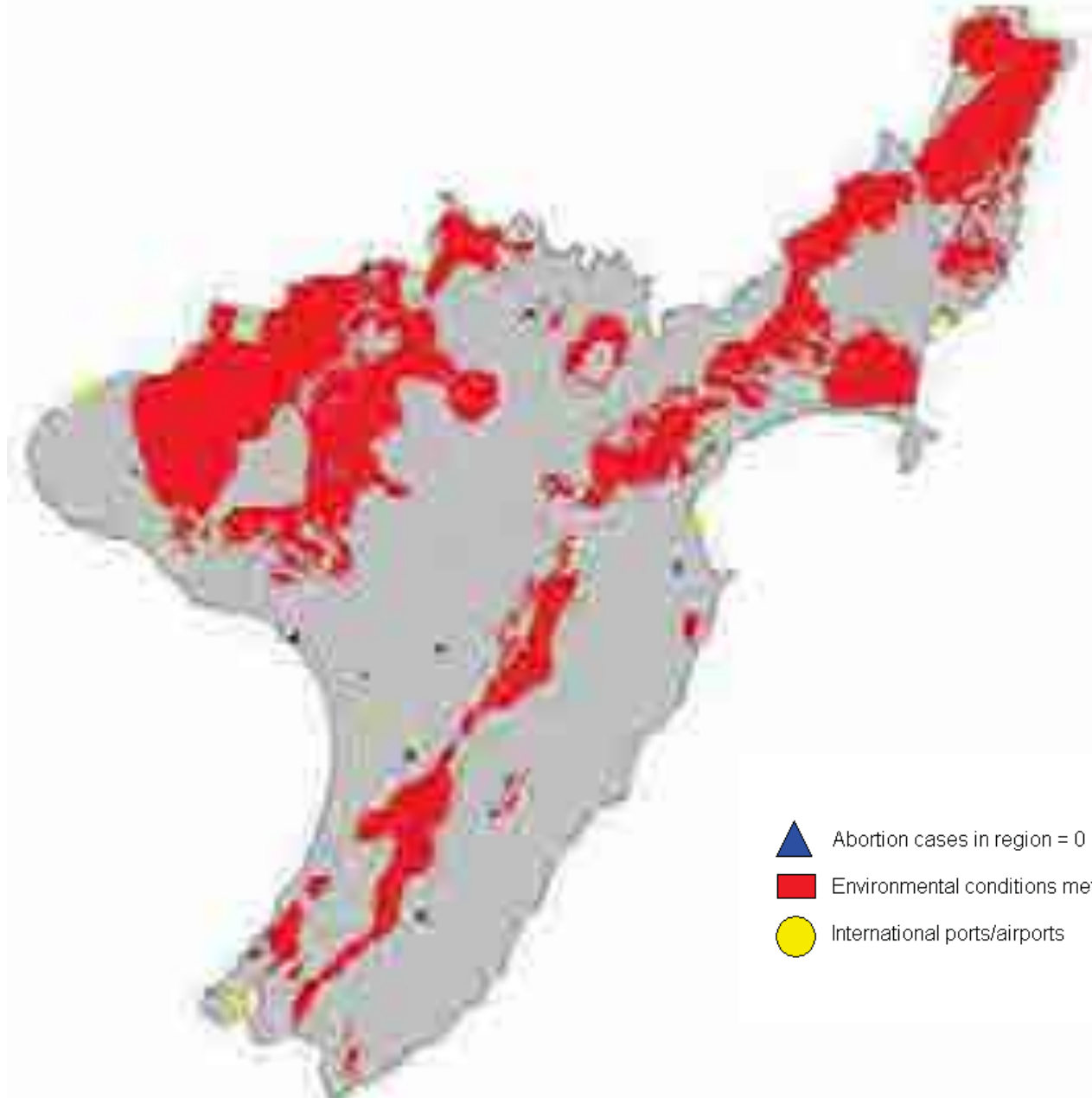


Sheep density  
(breeding ewes  
per sq km)

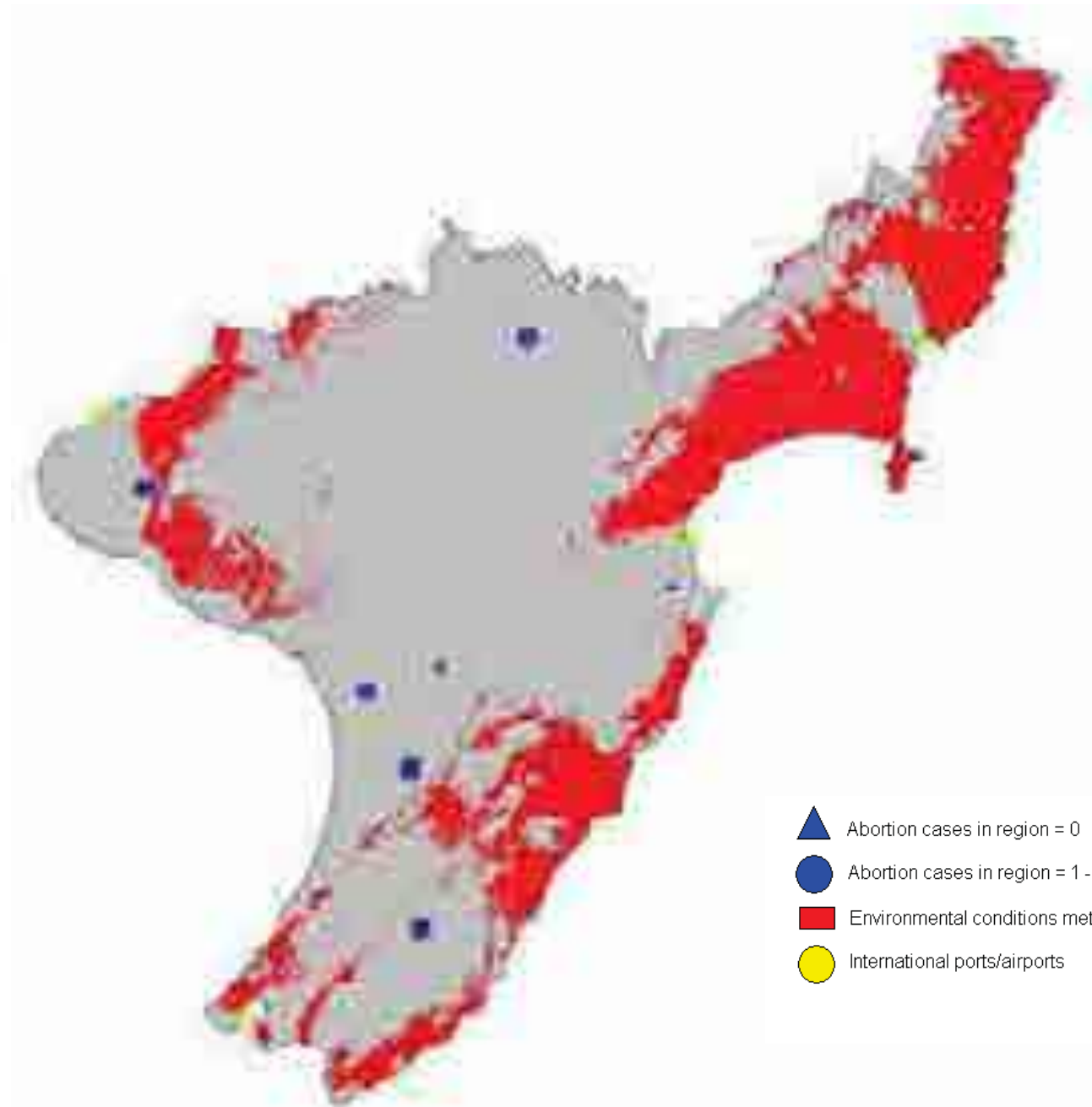


Quarter beginning  
January – risk of  
vector activity  
compared with  
abortion case data

( $T > 8^{\circ}\text{C}$ ,  
rain  $> 100\text{mm}$ ,  
ewes  $> 50/\text{kmsq}$ )

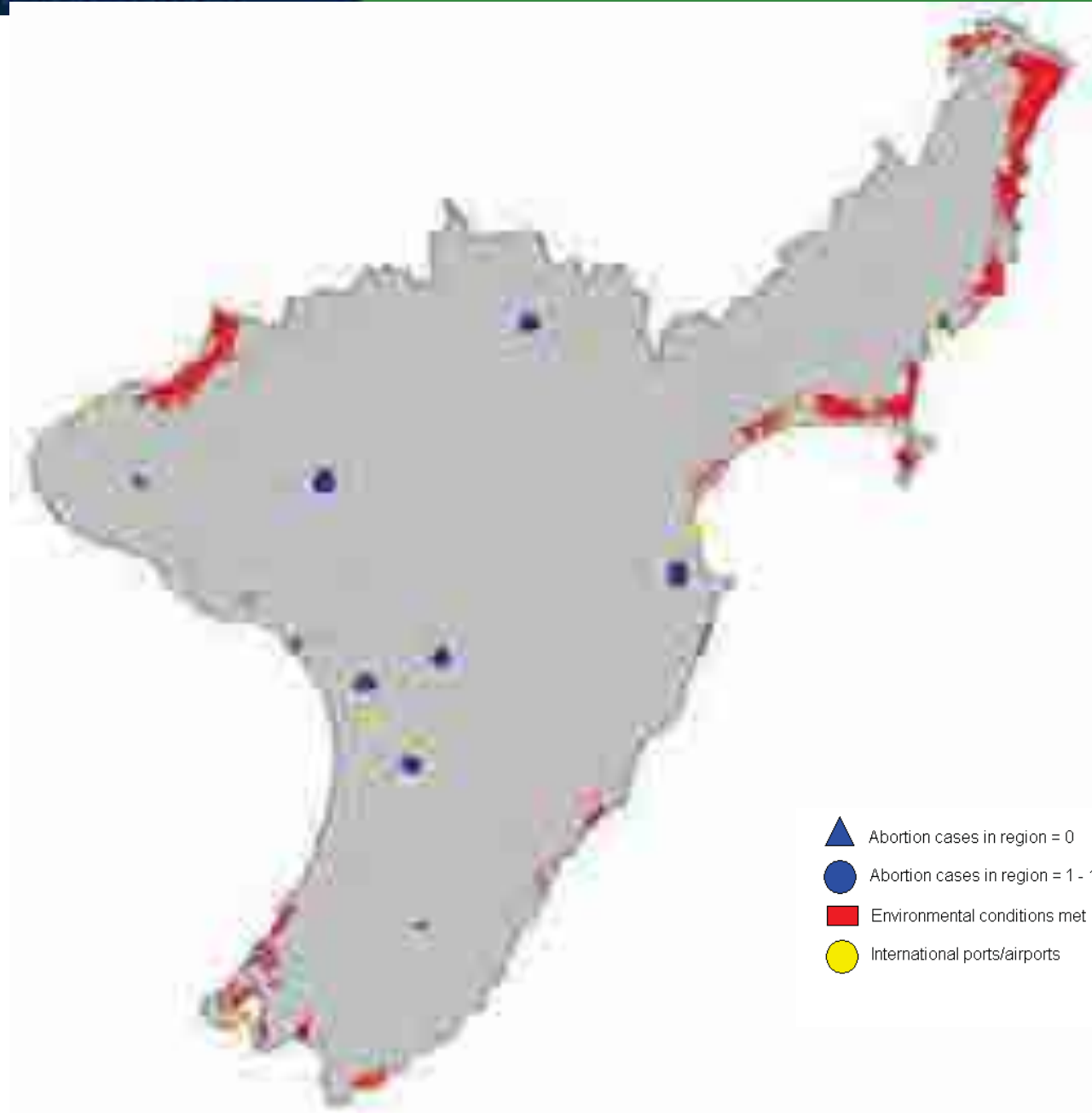


Quarter beginning  
April

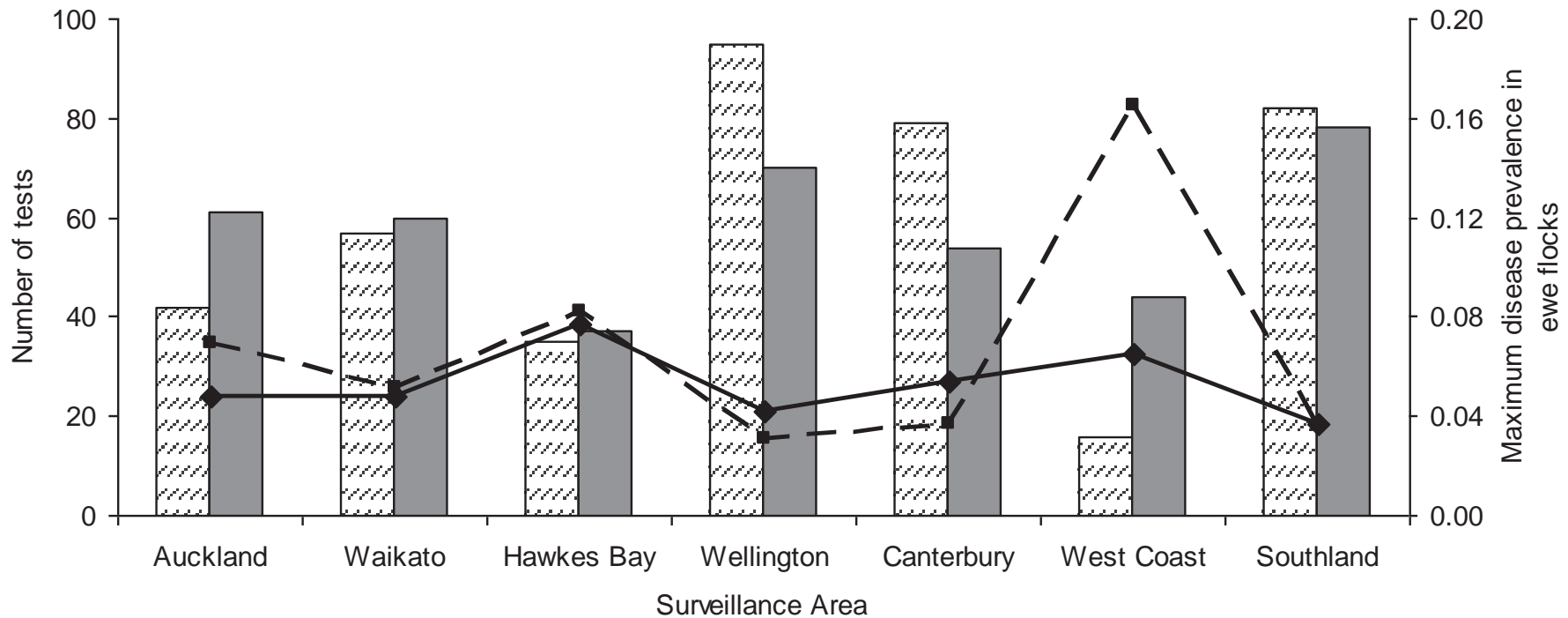




Quarter  
beginning  
October



# Risk-based sampling for exotic disease



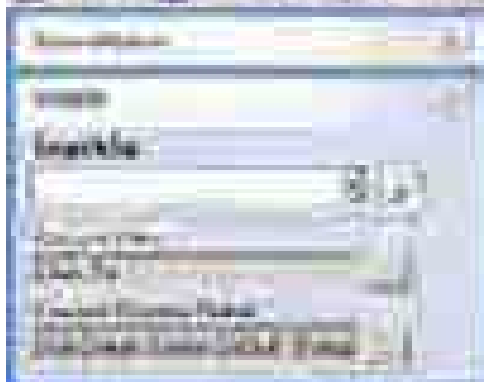
PA: Number of tests     
  PT: Number of tests  
 PT: Maximum diseased flocks     
  PA: Maximum diseased flocks

Comparison of the number of tests allocated per SA and the maximum possible disease prevalence in ewe flocks ( $\alpha = 0.05$ ) when distributing samples using portfolio theory (PT) and proportional allocation (PA)

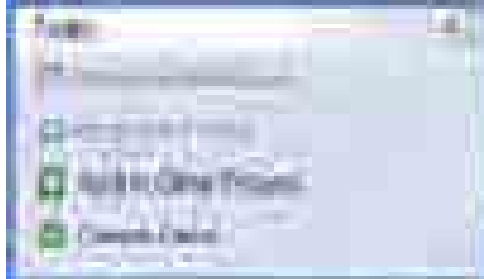
# Delivery

- Need a capable and flexible health information system to handle a range of disease investigation strategies, support sampling procedures, and produce user-friendly reports
- Must have GIS functionality
- Ideally should integrate with any analytical or modelling software
- Must be able to adapt as situation changes
- Developed a system of this kind for Switzerland

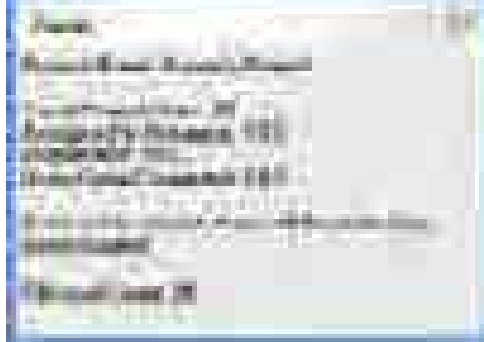
Surveillance plan

A panel containing a list of surveillance activities, including 'Surveillance of the site', 'Surveillance of the environment', and 'Surveillance of the community'. It includes a search bar and a list of items with checkboxes.

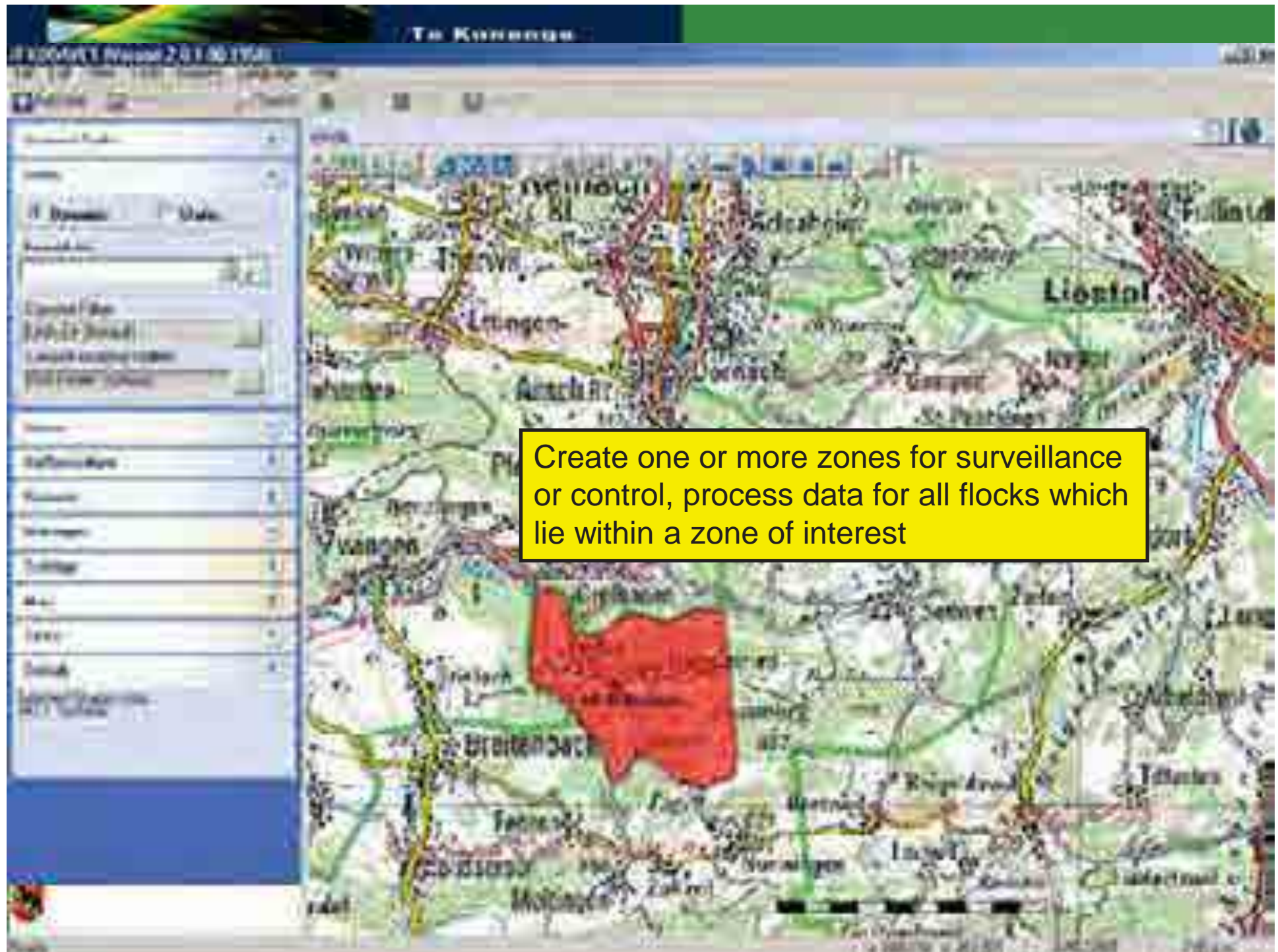
Project management

A panel with a 'Project management' section, featuring a list of tasks and a 'Project management' button. It also includes a 'Project management' section with a list of items and a 'Project management' button.

Data entry to suit

A panel with a 'Data entry to suit' section, featuring a list of tasks and a 'Data entry to suit' button. It also includes a 'Data entry to suit' section with a list of items and a 'Data entry to suit' button.

| Activity                        | Frequency | Priority | Status      | Notes |
|---------------------------------|-----------|----------|-------------|-------|
| Surveillance of the site        | Weekly    | High     | Completed   |       |
| Surveillance of the environment | Monthly   | Medium   | In Progress |       |
| Surveillance of the community   | Quarterly | Low      | Not Started |       |
| Project management              | Weekly    | High     | Completed   |       |
| Data entry to suit              | Weekly    | High     | Completed   |       |



Create one or more zones for surveillance or control, process data for all flocks which lie within a zone of interest

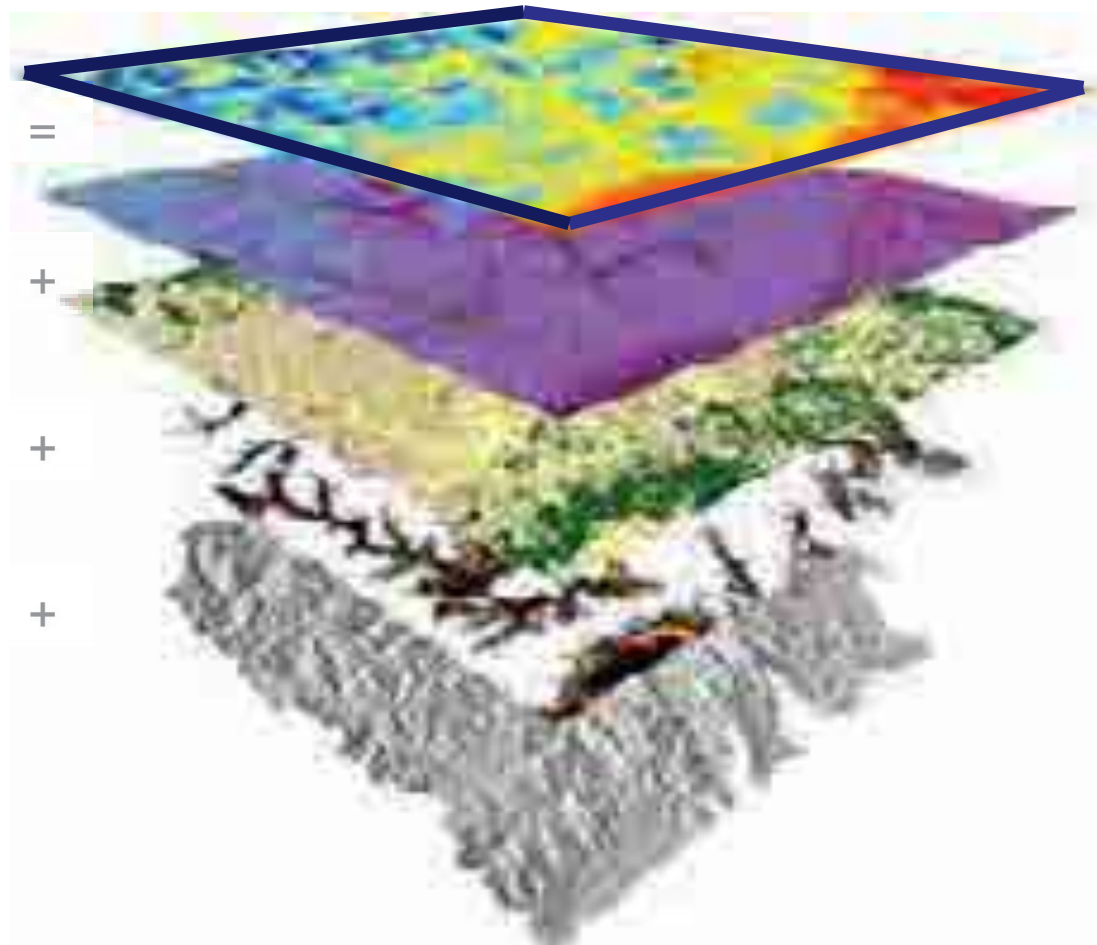
# Deduction

- Use multiple sources of information
- Qualitative, “fuzzy” and low value data can contribute to the overall picture, as long as the information content (value) of each source is taken into account
- Integrate the information sources into a coherent picture using a portfolio approach
- Interpret the evidence to guide decisions on both surveillance and control measures

# Qualitative assessment of AI incursion risk ...

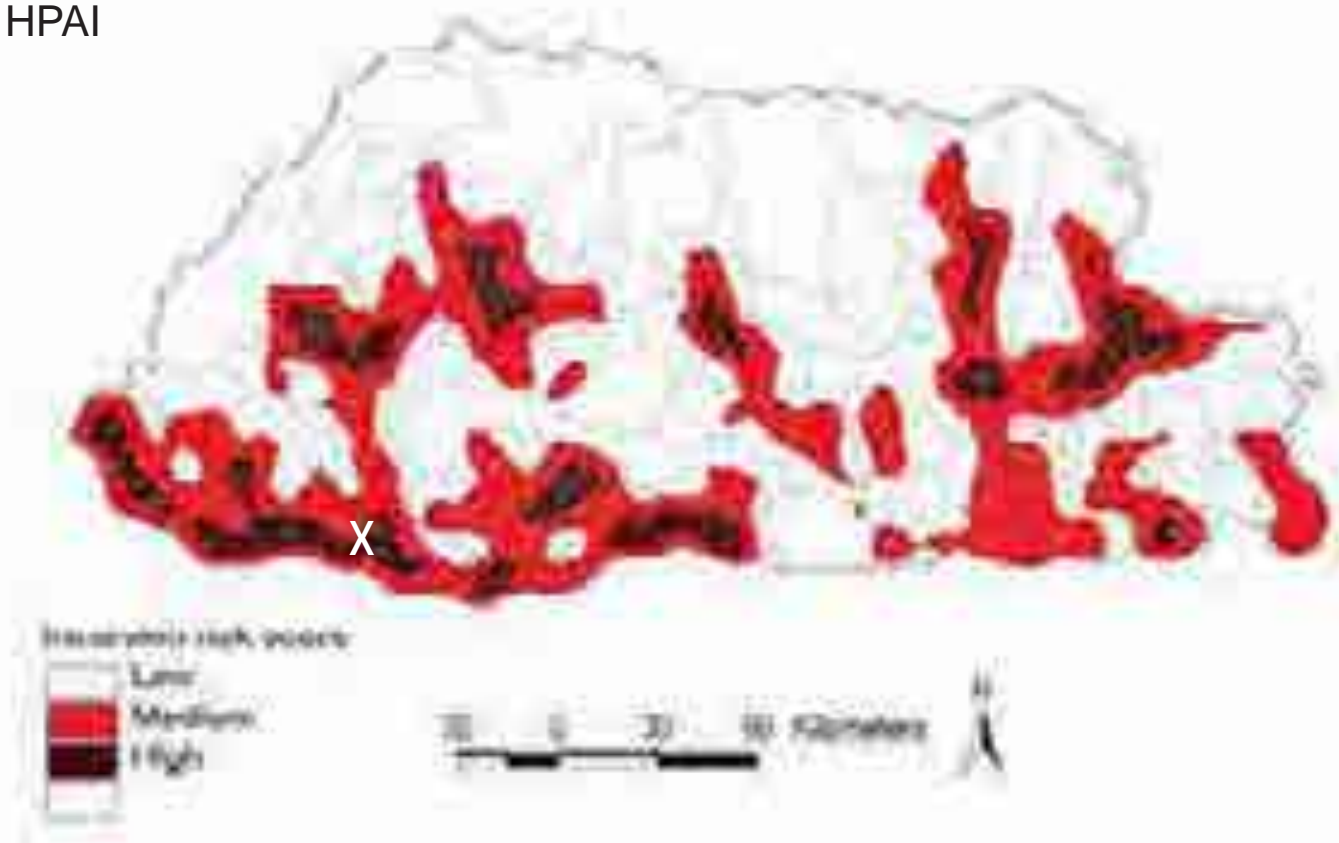


# Building a 'risk landscape' ...



# Bhutan: final (smoothed) AI incursion risk score map

Location of February 2010 H5N1 HPAI outbreak



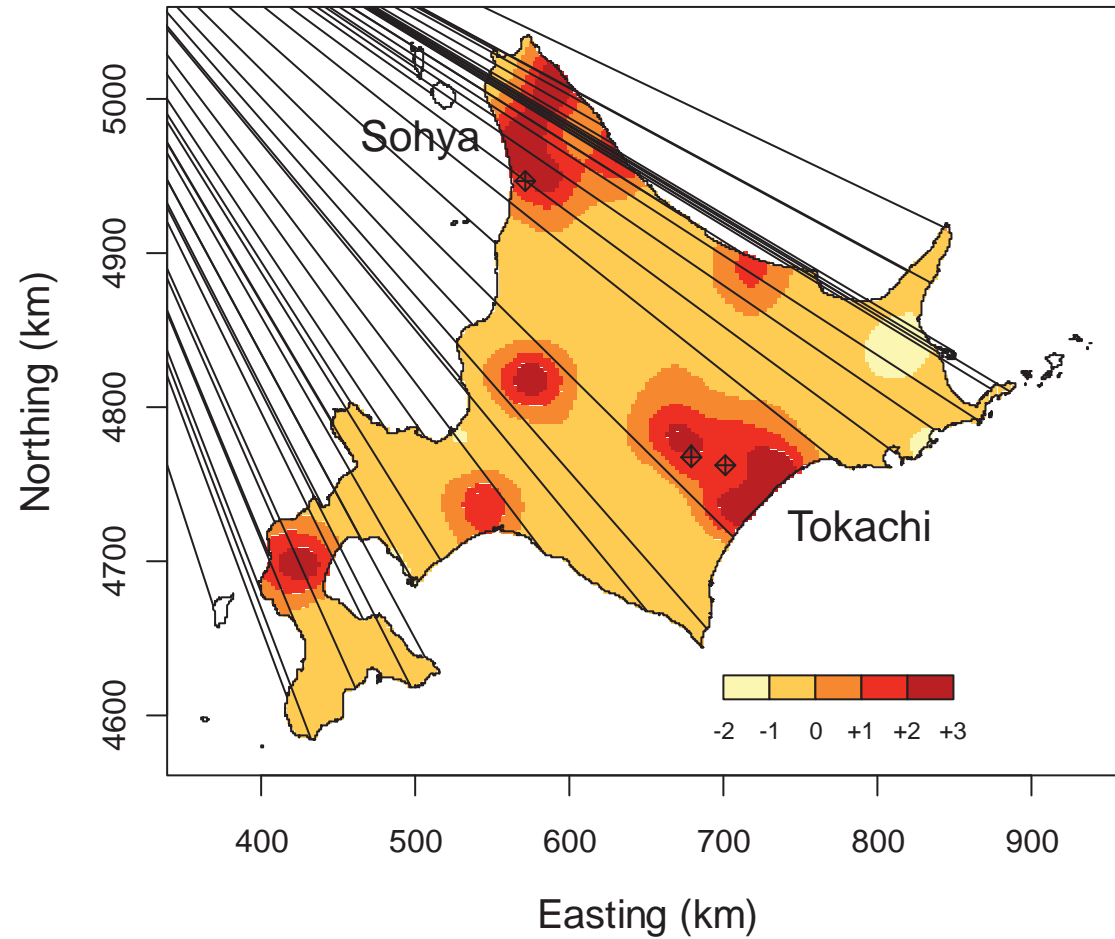


Evidence-based (quantitative) approach

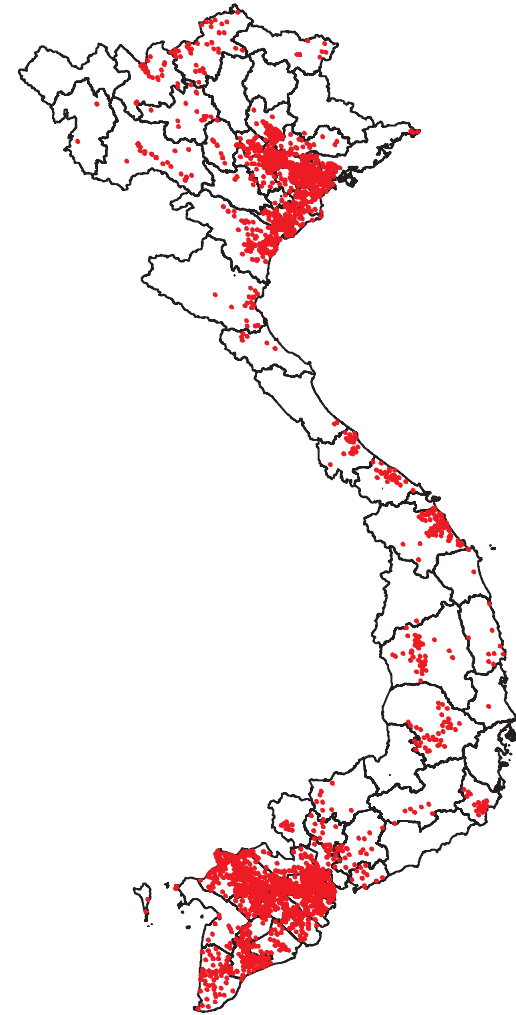
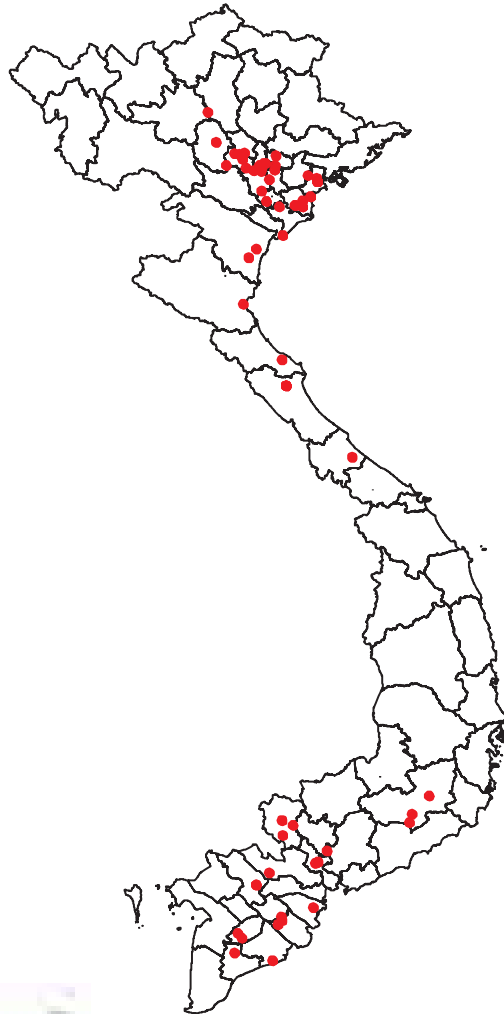


Participatory (qualitative) approach

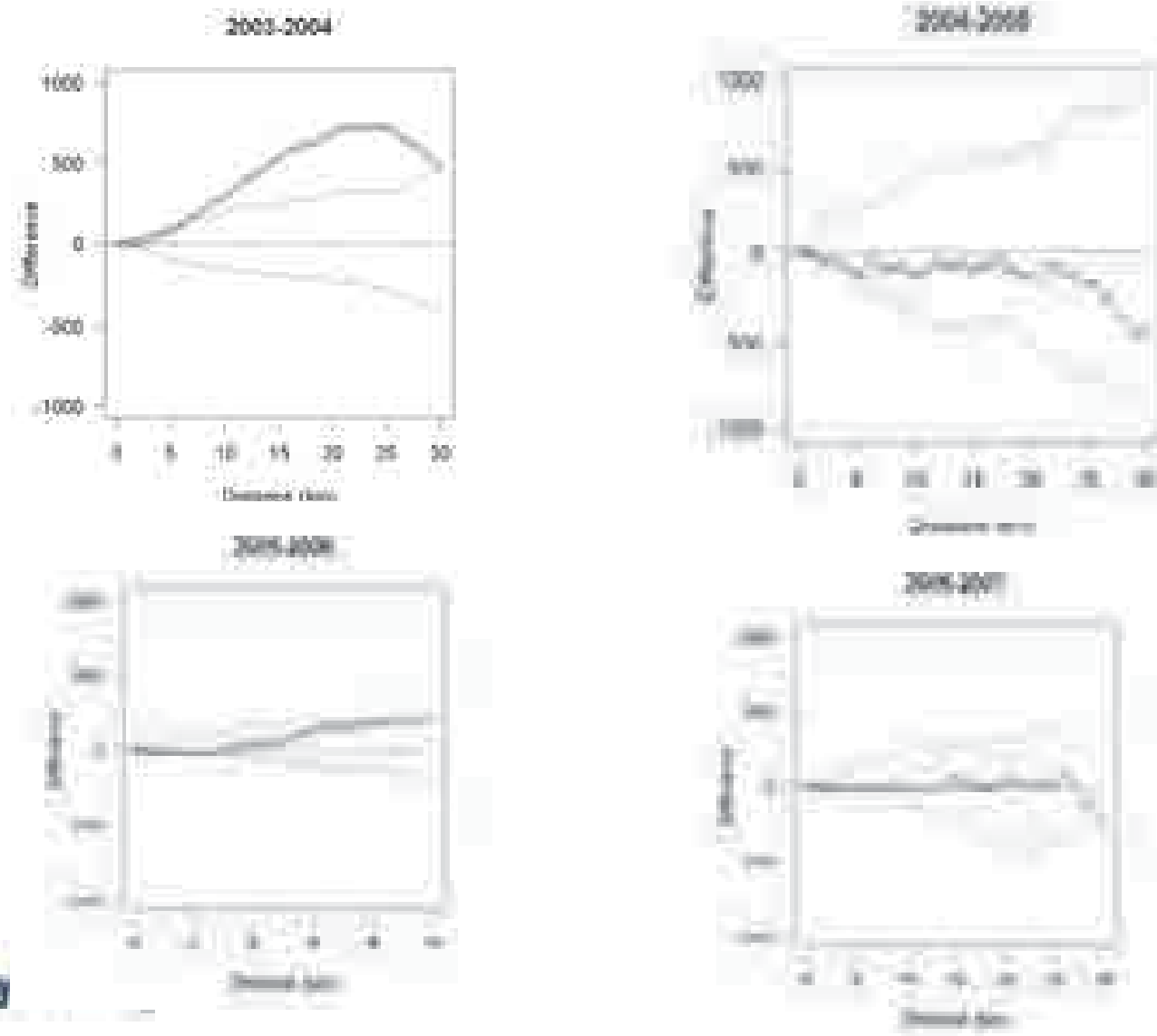
Image plot showing the distribution of positive and negative sign residuals from an ordinal logistic regression model of city level BSE risk. The city of birth of the three BSE cases identified up until March 2008 are shown as points.



# Human<sup>b)</sup> and poultry AI cases in Vietnam



# Spatial autocorrelation to assess AI transmission



# Chains of Affection: The Structure of Adolescent Romantic and Sexual Networks<sup>1</sup>

David A. Aschmann  
University of Wisconsin

James D. Smith  
Ohio State University

Academic Journal  
University of Edinburgh

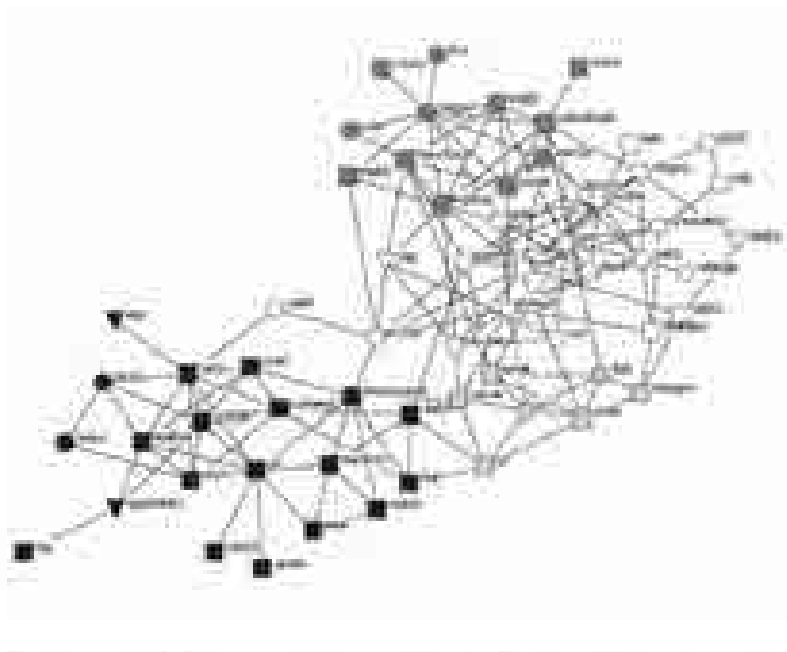
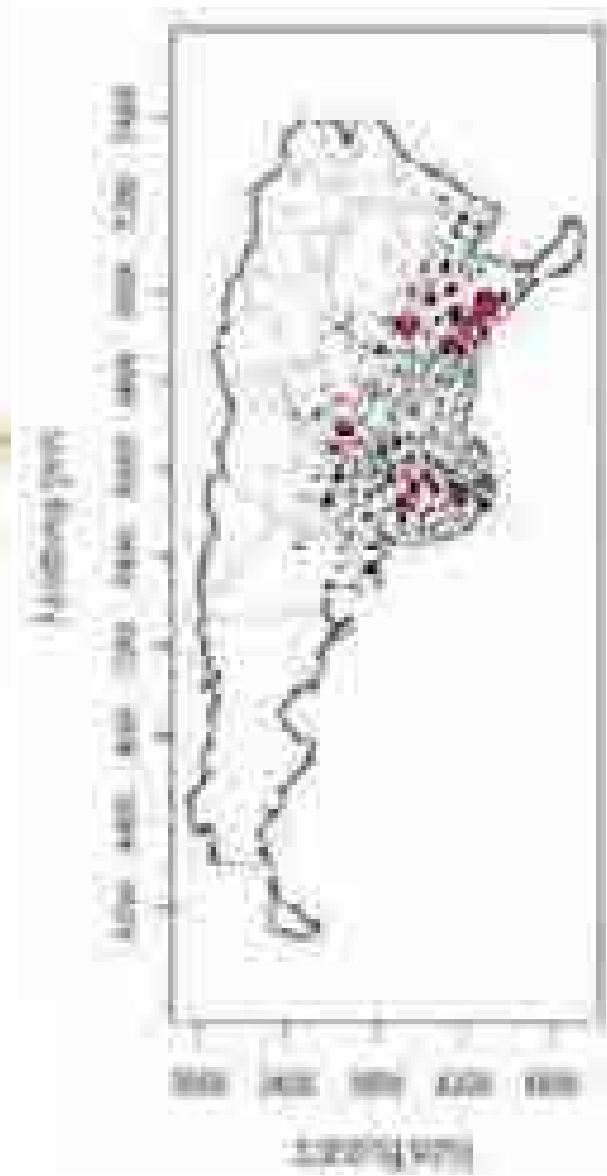


Figure 1 Communities and sub-communities identified in the original social network using the label-oriented algorithm of Girvan and Newman (2002). Vector colour indicates community membership: black and grey/black vertices remained the principal division into two communities. Shades of grey represent sub-communities. Triangles are represented with circles, males with squares and individuals with unknown gender with triangles.



Fig. 2. Visualization of the network.

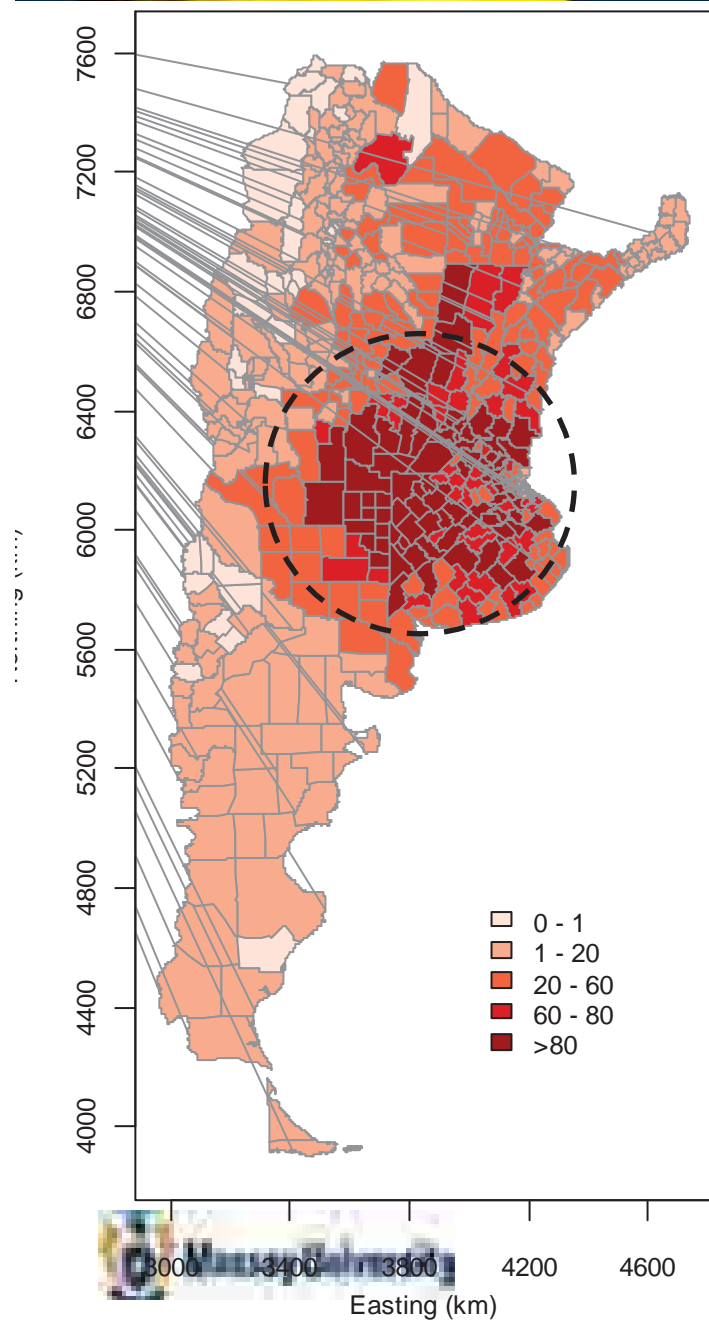


Latitude (N)

100 150 200 250 300

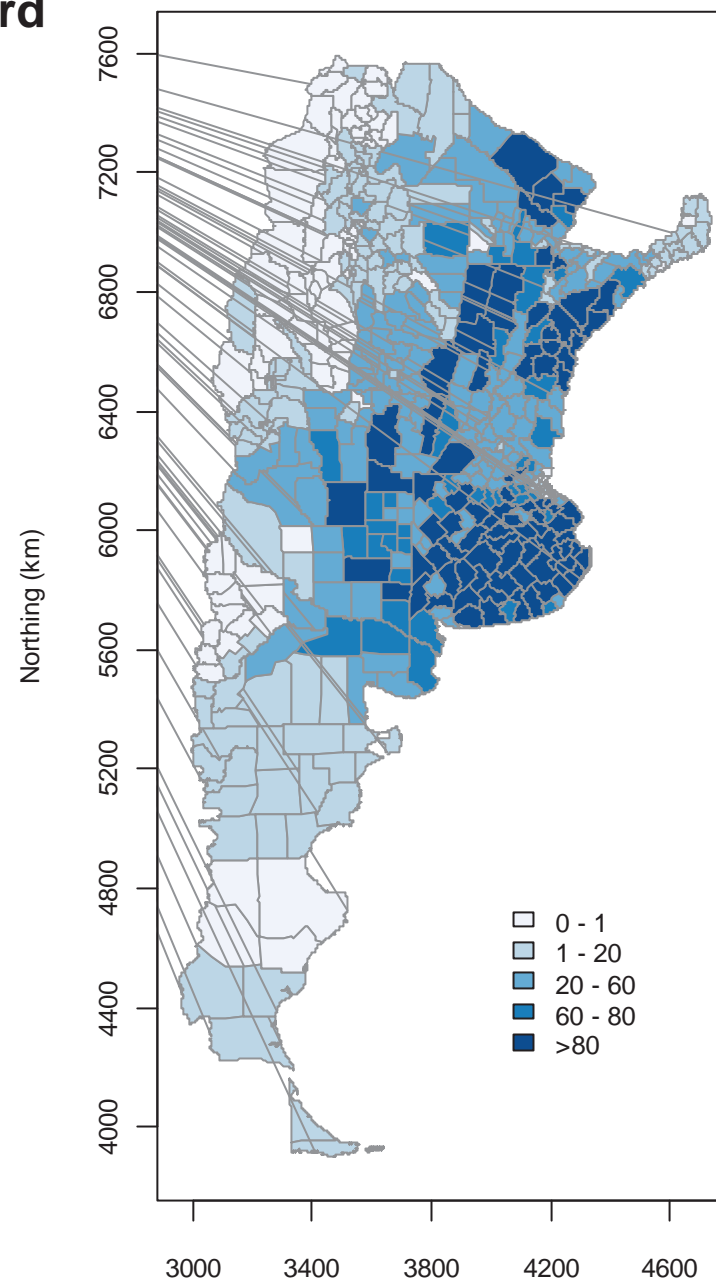
Longitude (W)

Farm-to-farm movements of cattle in Argentina, 2005. Choropleth map showing the spatial distribution of district-level in-degree scores.



## Inward and outward cattle movements In Argentina

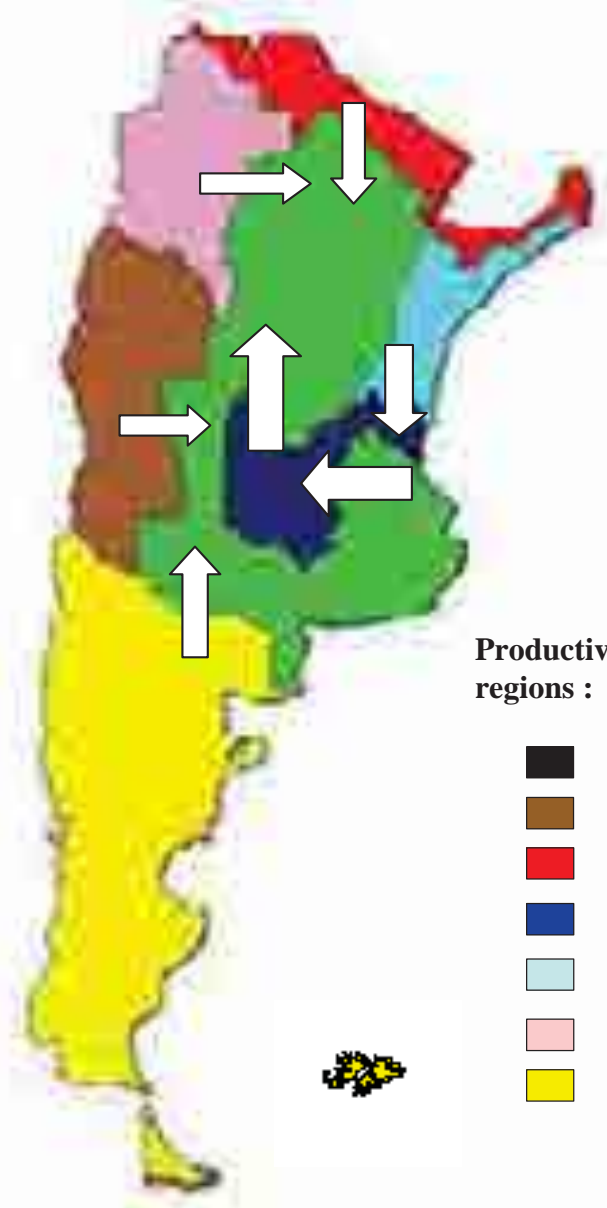
Districts with high in-degree scores in close proximity – a potential risk area for disease incursion



# RESULTS

ND

| Region      |
|-------------|
| Border      |
| Patagonia   |
| Mesopotamia |
| Cuyo        |
| Finishing   |
| North West  |
| Central     |



Productive and epidemiological regions :

- Central
- Cuyo
- Border
- Finishing
- Mesopotamia
- North West
- Patagonia

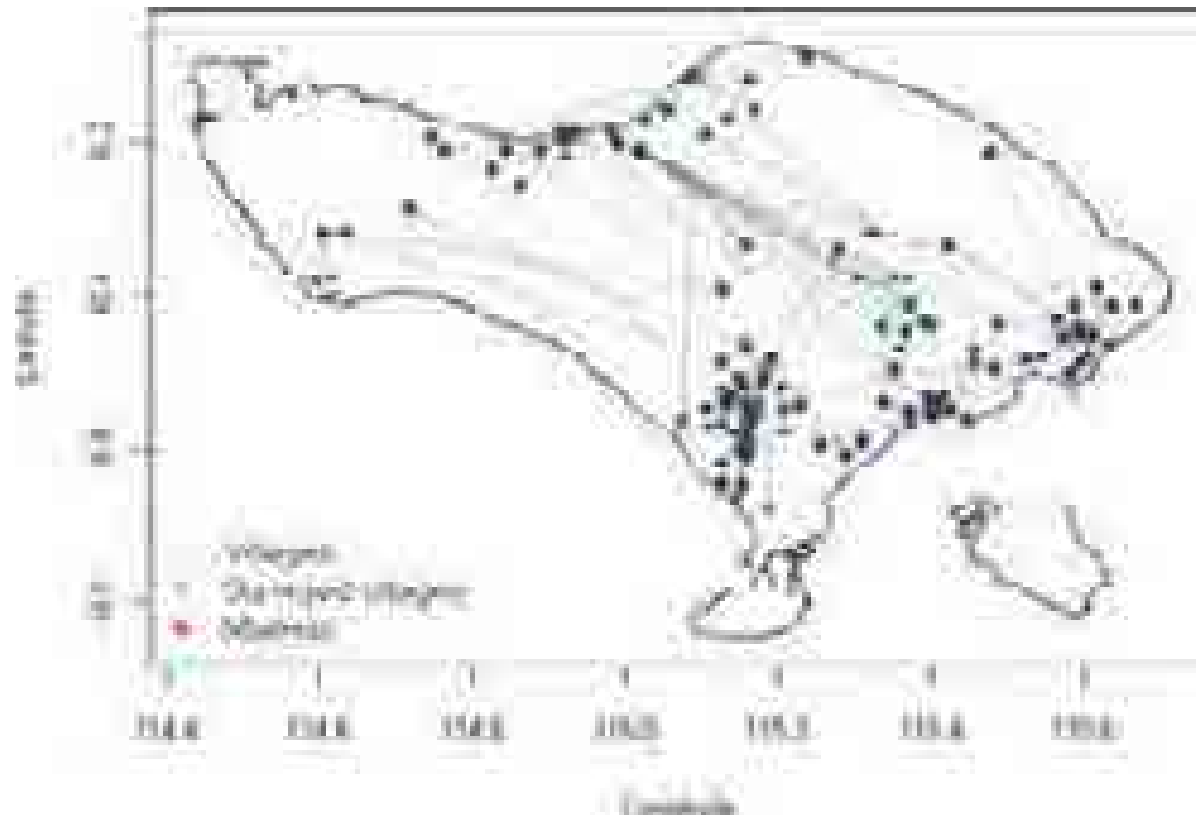
| Events out |       |
|------------|-------|
| n          | %     |
| 9,792      | 39.4% |
| 4,613      | 38.3% |
| 17,748     | 28.3% |
| 1,878      | 26.5% |
| 15,357     | 24.1% |
| 705        | 20.9% |
| 53,395     | 17.3% |



Map of Bali in Google Earth. Overlaid is a kernel smoothed surface showing human population density and point locations of the surveyed markets.



Map of Bali showing the location of villages, surveyed markets, villages referred to in survey responses and contacts between villages and markets.



# Surveillance portfolio

- Method to optimally allocate resources
- Conflicting requirements – need confidence in detecting disease but using as few resources as possible
- Move from sample allocation based purely on population size and structure to sample allocation which weights the sampling strategy by probability and consequences of an incursion incident or other event of concern
- Use also to interpret mixed data to demonstrate freedom or estimate prevalence

## Developing a surveillance portfolio

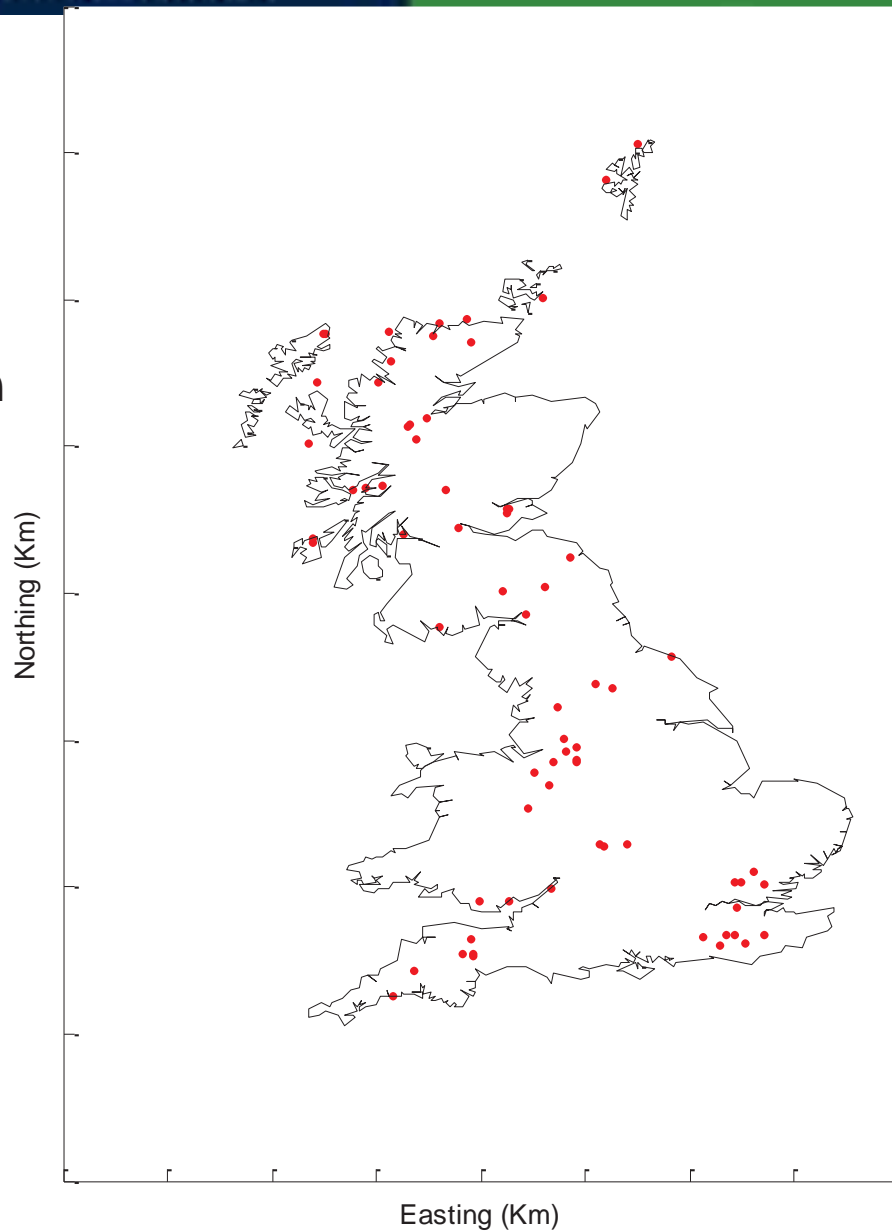
- Invest in multiple surveillance techniques to give balanced picture
- Allocate point value to each category of surveillance data, based on evidence about its epidemiological value
- Use points per sample or investigation, linked to \$ cost of that information source
- Combine the points scores for the different surveillance components, and relate the information to the various populations at risk that have contributed data
- Use “method of moments” by iterative solution to make best interpretation of the combined evidence
- Estimate optimum future mix of surveillance “purchases”
- Already applied to BSE and Trichinella, adapting to other diseases

## Decisions

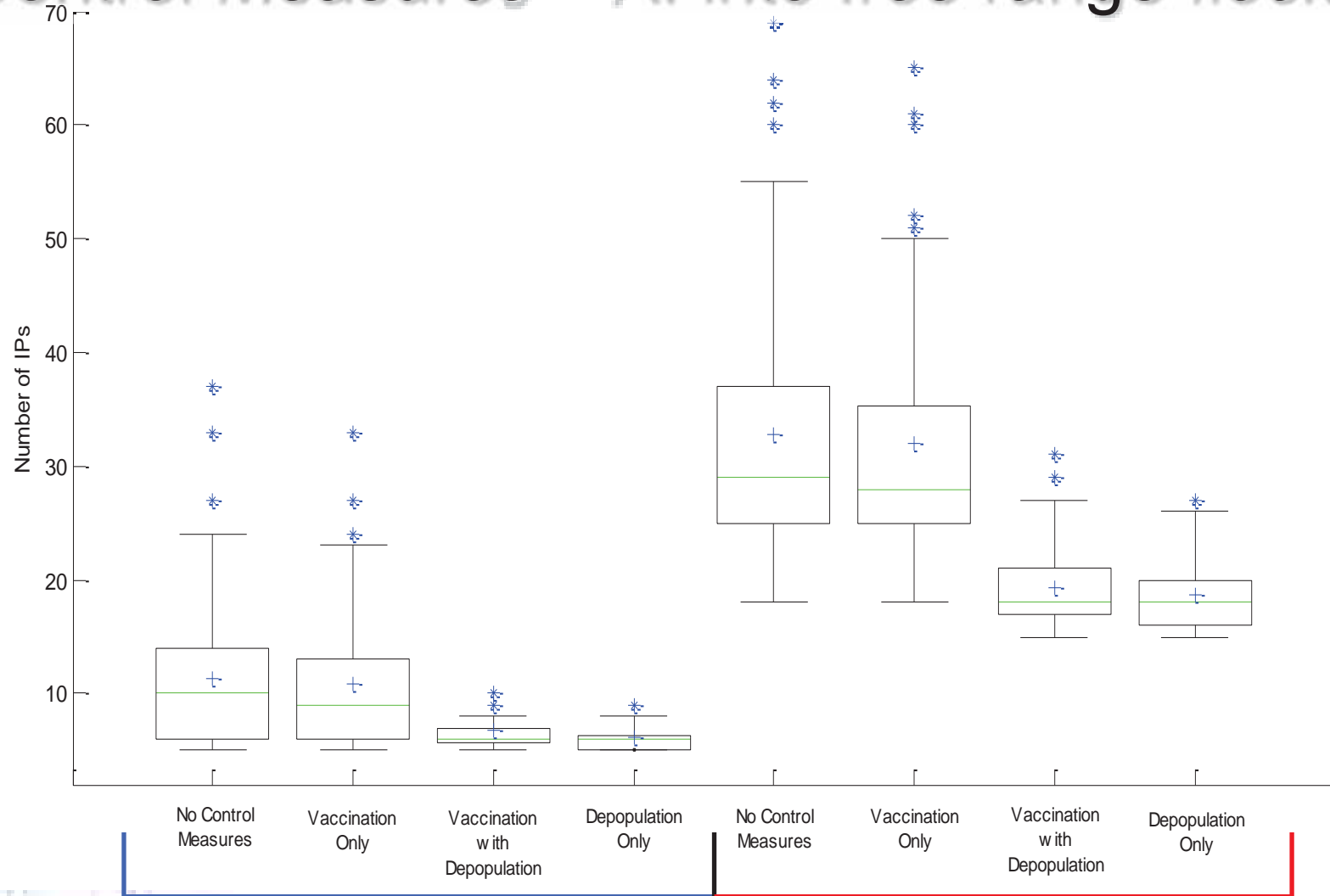
- Using spatial simulation models to test alternative surveillance and control strategies for zoonoses in both animal and human populations, and compare with field evidence where this is available
- Working on developing a risk evaluation tool which could be used in the case of a novel disease such as SARS or H1N1 influenza, to assess the risk of the disease affecting a particular country, and provide guidance on nature and scale of surveillance which would be appropriate

S3 – High

**Avian influenza  
Response to incursion  
Into poultry fancier  
flocks in UK**



# Control Measures – AI into free range flocks



## Conclusion

- We need to be ready to face and solve emerging disease challenges
- Effective surveillance is the key to quick detection and effective control
- Surveillance needs multiple sources of information, and smart tools for interpretation
- Need integrated surveillance and response strategy if we are to control future diseases successfully
- And a toolbox of techniques to quickly determine what is going on