Building a multi-country FMD modelling tool for Europe – the EuFMDiS project

Graeme Garner, Mark Hovari, Richard Bradhurst, Maria de la Puente and Keith Sumption
Overview

• Background

• Briefly review project

• Describe key model functionality

• Model applications

• Demonstration – comparing control strategies (vaccination)
Background

• Disease spread models are increasingly being used to support disease planning and preparedness

• The European Commission for FMD (EuFMD) 41st General Session identified: ‘Continuing support to animal movement and disease spread modelling, with the outputs to inform contingency planning activitie’s as priority

• At 2016 Central European CVO meeting, Austria presented a proposal for a regional cross-border modeling initiative for Transboundary Animal Diseases (CRoBoDiMo)

• A model development project was approved by EuFMD Executive Committee in 2017 and included in EuFMD workplan for 2017-19
EUFMDiS project

• To develop a modelling capability to enable FMD outbreaks to be simulated within and between countries in Europe, in order to provide a robust, flexible tool to support FMD planning, training and response by European countries

• Pilot study with seven central European countries
  – Italy, Austria, Croatia, Hungary, Romania, Bulgaria and Slovenia

• Participatung countries defined
  – Common herd classification (n=9 herd types)
  – Livestock production regions (n=25) that represent different livestock production characteristics and disease risk
  – Country-level disease spread and control parameter values
Approach

• An initial workshop was held, in Vienna, Austria, 5-7 December 2017 to:
  – bring the participating countries together
  – discuss the scope of a multi-country European disease spread model
  – identify the country-specific data required

• A workplan was developed with key milestones

• A dedicated e-learning page to provide a discussion forum and a repository to share resources

• Regular on-line meetings to share progress among the countries discuss relevant issues.

• Second workshop in Budapest, Hungary, 10-12 July 2018 to:
  – Install the software and provide training
  – Discuss on-going support and next steps
Project workplan

1. Country data in agreed formats (Jan- Feb 2018, ongoing)

2. Initial software modifications (March 2018)

3. Data analyzed and processed to fit model schemas and structures (March-April 2018)

4. Interim progress report to 95th Executive Committee meeting (March 2018) with working prototype of European FMD Spread Model

5. Software updates and modifications completed (April 2018)

6. Modelling testing (May 2018)

7. User workshop (June/July 2018) – working model released
EuFMDiS overview

EuFMDiS is based on the conceptual hybrid modelling approach developed for the Australian Animal Disease (AADIS) model*.

- Developed with funding by the Australian Government
- Sophisticated disease modelling platform and decision-support tool for FMD
- Used in EuFMD disease modelling training workshops (in 2014 and 2016)
  - Potential to be used in Europe identified

A formalised collaboration between EuFMD and the Australian Department of Agriculture and Water Resources has provided royalty-free access to the AADIS software and intellectual property

EuFMDiS overview cont’d

• Hybrid model structure:
  – Equation-based modelling (within-herd spread)
  – Agent-based modelling (between-herd spread)
  – Animal movement networks (between regions and countries)

• While AADIS has provided the underlying platform, a new multi-country FMD modelling tool - the European Foot and Mouth Disease Spread (EUFMDiS) model – has been developed
Regions

• Sub-national spatial units - to capture differences in livestock production patterns within a country

• Recognises that risk of disease establishment and spread may vary in different parts of a country

• Participants have defined livestock production regions (n=2-5) that represent different livestock production characteristics of their country

• NUTS* regions or combinations of these regions have proven to be a good starting point

*Eurostat: Nomenclature of territorial units for statistics (NUTS) regions
Herds

• The herd is the epidemiological unit in EuFMDiS. Disease transmission is modelled within and between herds
  – Herd = group of co-mingling animals of the same species
  – Farm may be made up of one or more herds
  – Farms are the units for disease control
  – Depending on production systems and data availability, either farms or herds can be used as the basic epidemiological unit in European model

• For modelling, herds have attributes (e.g. type, size, location) which are important in terms of disease spread and control
  – Location - simple lat./long coordinates
Herd types

- We use a common herd classification that can be applied across countries i.e. a list of herd/farm types that captures
  - species
  - main production characteristics

- We use the buying/selling/management characteristics of herd types to parameterize disease transmission

- We allow the ‘behavior’ of herd types to vary by region and season

- Need to keep the number of different herd types manageable
  - 9 herd types defined for central Europe
## Herd types

<table>
<thead>
<tr>
<th>ID</th>
<th>Species</th>
<th>Herd type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>bov</td>
<td>Large commercial dairy herd</td>
<td>Specialist milk producer. Cattle are kept to primarily produce and sell milk</td>
</tr>
<tr>
<td>2</td>
<td>bov</td>
<td>Large commercial beef herd</td>
<td>Specialist beef production. Cattle are kept to primarily produce and sell meat</td>
</tr>
<tr>
<td>3</td>
<td>bov</td>
<td>Small commercial cattle herd</td>
<td>Cattle are kept, usually in smaller herd sizes, to primarily produce and sell meat and/or milk on a smaller, local scale</td>
</tr>
<tr>
<td>4</td>
<td>buf</td>
<td>Commercial buffalo</td>
<td>Buffalo kept for milk or meat production</td>
</tr>
<tr>
<td>5</td>
<td>ovi/cap</td>
<td>Commercial small ruminants</td>
<td>Small ruminants are kept to primarily produce and sell meat/milk/wool commercially</td>
</tr>
<tr>
<td>6</td>
<td>sui</td>
<td>Large-scale commercial fattening pig herd</td>
<td>Pigs are kept under intensive production system to be grown and sold for slaughter, for pig meat production</td>
</tr>
<tr>
<td>7</td>
<td>sui</td>
<td>Large scale commercial breeding pig herd</td>
<td>Pigs are kept under intensive production system for producing replacement pigs to be sold to other holdings (e.g. fattening farms)</td>
</tr>
<tr>
<td>8</td>
<td>sui</td>
<td>Small-scale commercial pig</td>
<td>Pigs are kept primarily to produce and sell meat on a smaller, local scale. Generally lower biosecurity than intensive systems</td>
</tr>
<tr>
<td>9</td>
<td>mixed</td>
<td>Backyard herd</td>
<td>Small number of animals (cattle, buffalo, sheep, goat, pig) kept primarily for own consumption (non-commercial).</td>
</tr>
</tbody>
</table>
### Total herds by country

<table>
<thead>
<tr>
<th>Country ID</th>
<th>Country</th>
<th>Commercial herds</th>
<th>Backyard herds</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AT</td>
<td>87477</td>
<td>19190</td>
<td>106667</td>
</tr>
<tr>
<td>2</td>
<td>BG</td>
<td>32893</td>
<td>102817</td>
<td>135710</td>
</tr>
<tr>
<td>3</td>
<td>HR</td>
<td>38095</td>
<td>80488</td>
<td>118583</td>
</tr>
<tr>
<td>4</td>
<td>HU</td>
<td>24776</td>
<td>25685</td>
<td>504061</td>
</tr>
<tr>
<td>5</td>
<td>IT</td>
<td>154686</td>
<td>211630</td>
<td>366314</td>
</tr>
<tr>
<td>6</td>
<td>RO</td>
<td>12098</td>
<td>591077</td>
<td>603175</td>
</tr>
<tr>
<td>7</td>
<td>SI</td>
<td>27362</td>
<td>13370</td>
<td>40372</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>377387</td>
<td>1044257</td>
<td>1421644</td>
</tr>
</tbody>
</table>

- For first phase of the project we are focusing on commercial herds
FMD transmission

Within-country spread

- Movements of live animals (*direct contact spread*)
- Movements of products, equipment, etc. (*indirect contact spread*)
- Spread to farms in close proximity to infected farms by unspecified means (*local spread*)
- Longer distance spread by virus in the air (*wind-borne spread*)
- Spread via assembly centres (*assembly centre spread*)
Data needs

• To model spread, countries have provided information on behavior of different herd types e.g.
  – how often they buy and sell animals,
  – when they buy and sell,
  – who they sell to (e.g. destination type, region),
  – No. of indirect contacts (e.g. vets, feed deliveries, milk pick-up, AI technicians, etc) and how often owners they use them
  – By region and season

• Information also needed on:
  – Assembly centres
  – Weather data (European Climate Assessment and Dataset - ECAD- website http://www.ecad.eu/dailydata/predefinedseries.php)
Between-country spread

• Focus is on live animal movements (highest risk pathway)

• The European Trade Control and Expert System (TRACES) data is used to collect and summarise animal movement data

• Done at sub-national ‘regional’ scale (by mapping LVUs to regions).

• Instructions and “R” script provided to participating countries to assist data collection

• EuFMDiS also uses airborne spread and local spread components that apply to infected holdings located ‘close’ to international borders
TRACES data Example: Table 1 (based on 2016 data)

Table 1: Average number of outgoing direct movement consignments per day summarized by country, herd type, region and season.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mar 2016</td>
<td>ES44101</td>
<td>Granada</td>
<td>18800</td>
<td>2500</td>
<td>010410</td>
<td>Ovis aries</td>
<td>1</td>
</tr>
<tr>
<td>Mar 2016</td>
<td>ES44101</td>
<td>Granada</td>
<td>18810</td>
<td>2500</td>
<td>010410</td>
<td>Ovis aries</td>
<td>1</td>
</tr>
<tr>
<td>Mar 2016</td>
<td>ES44401</td>
<td>Huelva</td>
<td>21550</td>
<td>2640</td>
<td>010420</td>
<td>Capra hircus</td>
<td>1</td>
</tr>
<tr>
<td>Mar 2016</td>
<td>ES44401</td>
<td>Huelva</td>
<td>21570</td>
<td>2640</td>
<td>010420</td>
<td>Capra hircus</td>
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</tr>
<tr>
<td>Oct 2016</td>
<td>ES44401</td>
<td>Huelva</td>
<td>21400</td>
<td>8950</td>
<td>0102</td>
<td>Bos taurus</td>
<td>1</td>
</tr>
<tr>
<td>Dec 2016</td>
<td>ES42201</td>
<td>Cádiz</td>
<td>11190</td>
<td>2965</td>
<td>0102</td>
<td>Bos taurus</td>
<td>1</td>
</tr>
</tbody>
</table>
Control measures

• The measures in EuFMDiS are consistent with the approaches described in European FMD Directive (2003)

• Flexible and highly configurable

• Individual measures can be switched on or off

• Success of control measures depend on:
  – Effectiveness of measures
  – Resources for control

• Parameterised with inputs from the individual countries
Control measures

• **First IH detection**
  – Fixed (or passive)

• **Movement restrictions**
  – National livestock standstills
  – Local restrictions (Protection Zone and Surveillance Zone)

• **Surveillance**
  – Surveillance visits, priorities, scheduling, periods

• **Tracing**
  – Trace forwards, trace back, tracing effectiveness

• **Suspect premises reporting**
  – True and false positive reporting
Control measures cont’d

• **Infected Premises operations**
  – Destruction, disposal decontamination

• **Pre-emptive culling**
  – Dangerous contacts, ring culling, suspect premises culling

• **Vaccination**
  – Suppressive, protective, mass vaccination
  – Priorities
  – High risk areas

• **Post-outbreak management**
  – Disease surveillance
  – Managing vaccinated animals
Reporting costs and economic impacts

• Useful to provide economic outputs from the modelling, as understanding the economic impacts and being able to compare costs of different control strategies is very important to decision-makers.

• Keeping it simple. Model tracks and reports:
  – Animal values (for compensation)
  – Cost of managing outbreak including operational activities (surveillance, culling, vaccination, running disease control centres, etc.)
  – Trade losses
  – Post-outbreak management costs (surveillance, vaccinated animals)

• Relative versus absolute costs/impacts

• Adequate for comparing policies
Video – EuFMDiS operation
Applications

• Study size, duration and economic impact of outbreaks

• Assess potential for establishment and spread of FMD under local conditions

• Test surveillance approaches - early detection

• Look at resource needs and resource management issues

• Compare different response strategies (including use of vaccination)

• Support exercises and training activities
Demonstration study

• Look at hypothetical outbreak

• Compare two control options
  – Stamping out
  – Stamping out plus emergency ring vaccination

• Size, duration, control cost, trade impacts
Scenario

- Hypothetical outbreak starting in Austria
- FMD starts on a small commercial pig farm (#43526), n= 332 pigs in south east of the country
- Occurs in September
- First reported in small dairy farm (#4707)
- 18 day delay from first introduction to FMD being confirmed by authorities
Key assumptions

• Control program based on movement controls (3 km PZ, 10 km SZ) surveillance, tracing, stamping out of IPs (+ vaccination)

• Resources for control based on individual country estimates

• Vaccination starts 7 days into control program

• Vaccine applied prospectively, i.e. around new diagnosed infections

• 3 km suppressive ring vaccination

• Vaccination from outside-in


• Potential access to up to 1 million doses in EU stockpile

• Model run until disease eradicated or 365 days
Results

- On Day 1 of the control program, when the authorities are aware of the first case of FMD, in Austria there are already 35 infected farms in three clusters - 2 in AT (with 9 infected farms) – 1 in IT (10 infected farms)
Comparing control strategies

• Number of infected holdings

• Duration of control program

• Total animals culled

• Control program costs

• Trade losses

• Benchmarks
### Infected holdings (all)

<table>
<thead>
<tr>
<th>Size Range</th>
<th>SO</th>
<th>SORV</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;100</td>
<td>58%</td>
<td>64%</td>
</tr>
<tr>
<td>&lt;250</td>
<td>80%</td>
<td>98%</td>
</tr>
<tr>
<td>&lt;500</td>
<td>93%</td>
<td>100%</td>
</tr>
<tr>
<td>&gt;500</td>
<td>7%</td>
<td>-</td>
</tr>
</tbody>
</table>

### Infected holdings (95%)
### Duration

<table>
<thead>
<tr>
<th></th>
<th>SO</th>
<th>SORV</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;90</td>
<td>65%</td>
<td>81%</td>
</tr>
<tr>
<td>&lt;180</td>
<td>76%</td>
<td>100%</td>
</tr>
<tr>
<td>&lt;365</td>
<td>95%</td>
<td>-</td>
</tr>
<tr>
<td>&gt;=365</td>
<td>5%</td>
<td>-</td>
</tr>
</tbody>
</table>
Costs

Control costs
- Does not include costs of managing (removing) vaccinated animals

Trade loss
- Based on minimum time to regain FMD-free status
- Likely to be longer
- AT (40%), IT (60%)
Summary

Under the assumptions of this study, SORV was very effective compared to SO only. On average reduced:

- Number of IHs by 73%
- Duration of the outbreak by 30%
- Number of animals culled by 73%
- Cost of the control program by 70%
- Trade losses by 11%

*Very effective in reducing likelihood of a “large” outbreak*

But with SORV there would be an average 163,000 vaccinated animals that would need to be managed (EU Directive: Suppressive vaccination = removal)

- Additional cost to be considered

EuFMDiS includes post-outbreak management module for evaluating:

- Different approaches to managing vaccinated animals
- Different approaches to surveillance for regaining FMD-free status
Conclusions

• The EuFMDiS model is a sophisticated powerful tool that can be used to
  – study single and multi-country outbreak scenarios in Europe
  – assess implications of various approaches to control, including resource management, vaccination and post-outbreak management
  – support training and simulation exercises

• Modern epidemiological models are specialised tools
  – Training in their use and good understanding of strengths and limitations of particular approaches is essential

• By definition models are simplifications of more complex systems
  – May be realistic, but are not reality
  – What could happen, not what will happen
  – Assist decision-making, not replace it!
Acknowledgements

• Funding from EuFMD FAR program
• Australian Department of Agriculture and Water Resources for royalty-free access to AADIS IP and software
• Participating countries – collaboration and data

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Ian Kopacka</td>
<td>Simon Stockreiter</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>Ivanka Kuzmanova</td>
<td>Samuil Paunov</td>
</tr>
<tr>
<td>Croatia</td>
<td>Vladimir Čačinović</td>
<td>Martina Rubin</td>
</tr>
<tr>
<td>Hungary</td>
<td>Justina Szilágyi</td>
<td>Zsófia Szepesiné Kókány</td>
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<tr>
<td>Italy</td>
<td>Silvia Bellini</td>
<td>Antonino De Angelis</td>
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<tr>
<td>Romania</td>
<td>Laura Sighinas</td>
<td>Mihaela Spiridon</td>
</tr>
<tr>
<td>Slovenia</td>
<td>Marko Potocnik</td>
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Thank you. Questions?