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

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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

**Bradhurst RA, Roche SE, Kwan P and Garner MG (2015) A hybrid modelling approach to simulating foot-and-mouth disease outbreaks in Australian livestock. Front. Environ. Sci., 19 March 2015 | http://dx.doi.org/10.3389/fenvs.2015.00017*

EuFMDiS overview cont'd

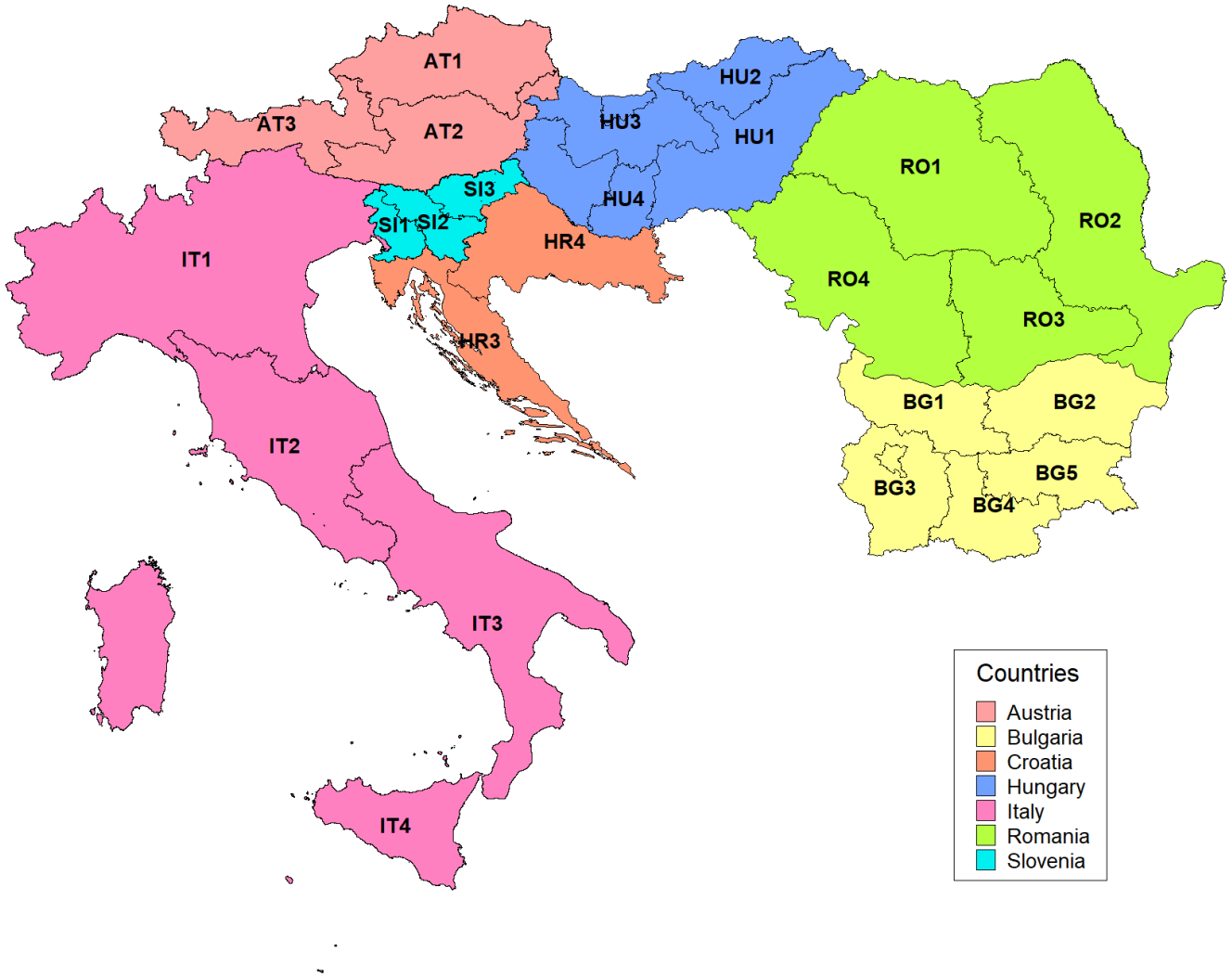
- **Hybrid model structure:**
  - Equation-based modelling (within-herd spread)
  - Agent-based modelling (between-herd spread)
  - Animal movement networks (between regions and countries)
- **While AADIS has provided the underlying platform, a new multi-country FMD modelling tool - the European Foot and Mouth Disease Spread (EUFMDiS) model – has been developed**

EuFMDiS
European Foot and Mouth Disease Spread model

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


AT1
AT2
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HU1
HU2
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SI2
SI3
HR3
HR4
RO1
RO2
RO3
RO4
BG1
BG2
BG3
BG4
BG5
IT1
IT2
IT3
IT4
Countries
Austria
Bulgaria
Croatia
Hungary
Italy
Romania
Slovenia

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

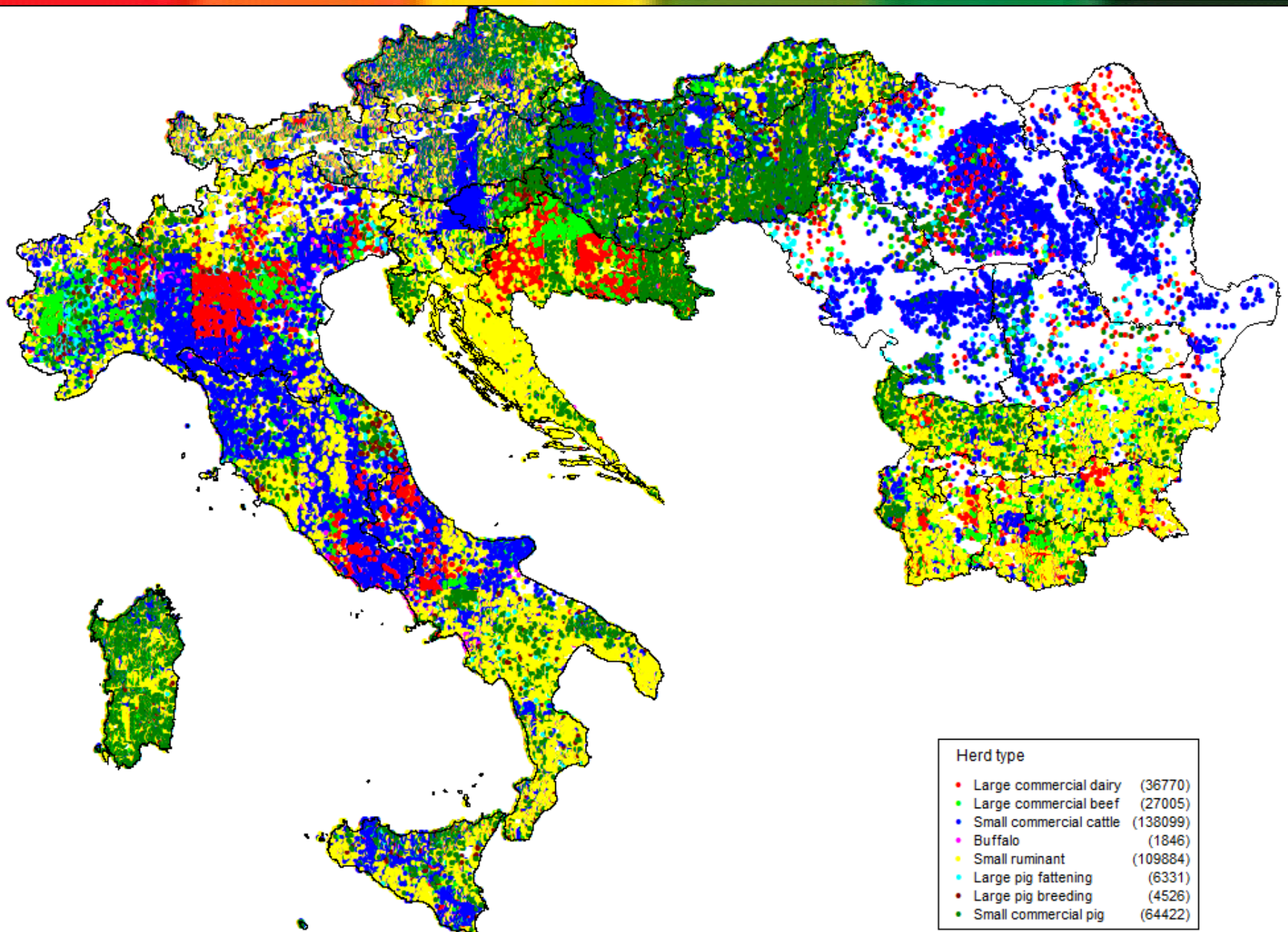
Herd types

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

Total herds by country

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

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


Herd type
Large commercial dairy (36770)
Large commercial beef (27005)
Small commercial cattle (138099)
Buffalo (1846)
Small ruminant (109884)
Large pig fattening (6331)
Large pig breeding (4526)
Small commercial pig (64422)

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

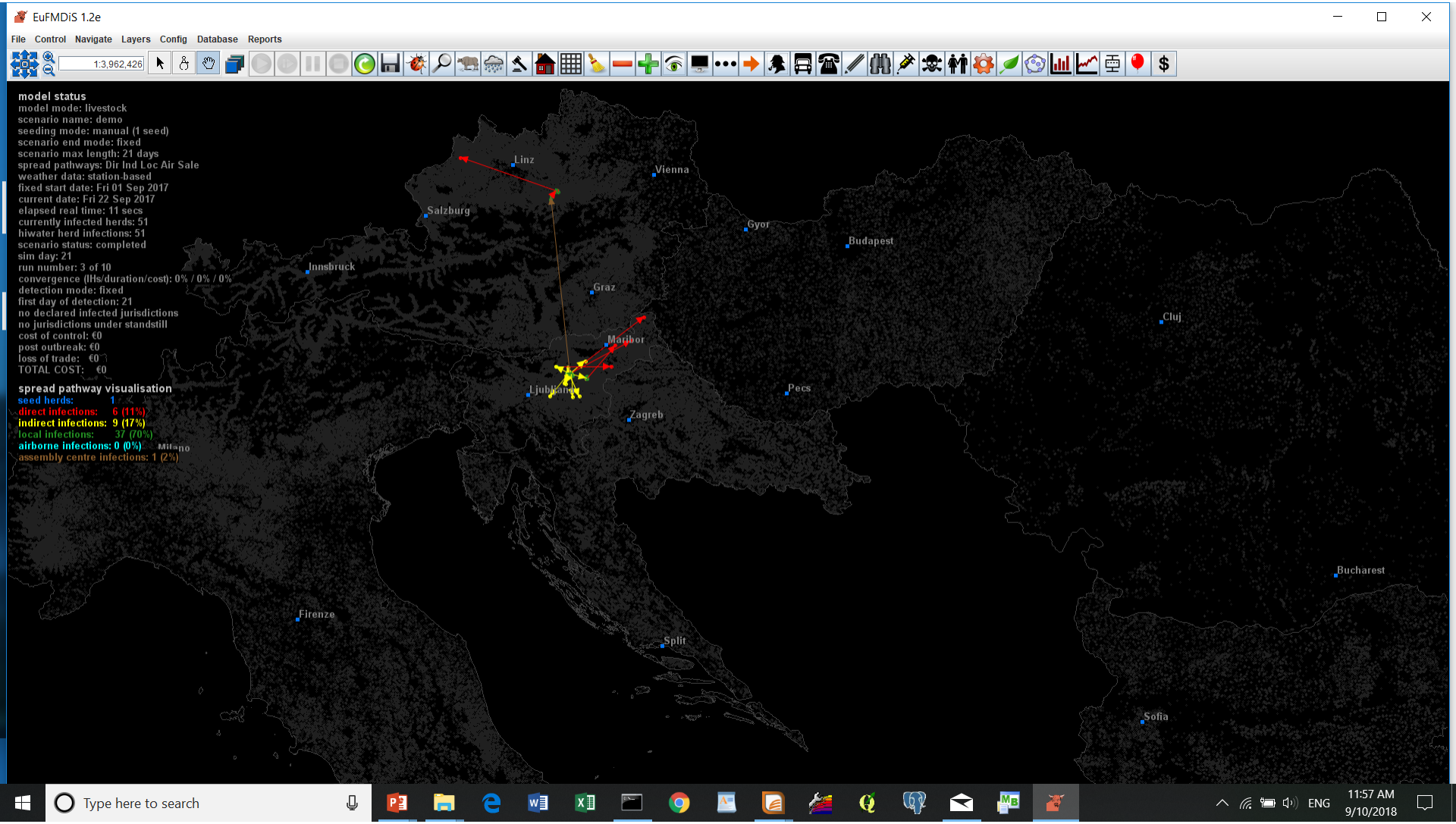
- Focus is on live animal movements (highest risk pathway)
- The European Trade Control and Expert System (TRACES) data is used to collect and summarise animal movement data
- Done at sub-national 'regional' scale (by mapping LVUs to regions).
- Instructions and "R" script provided to participating countries 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.

MyQID - # Of Consignments (7)

II.14. Month of Decision	I.4. Local Competent Authority	I.4. Local Authority Name	I.12. Place of origin Postal Code	I.13. Place of destination Postal Code	I.31. Commodity Code List	I.31. Specie List	# Of Consignments
							7
Mar 2016	ES44101	Granada	18800	2500	010410	Ovis aries	1
Mar 2016	ES44101	Granada	18810	2500	010410	Ovis aries	1
Mar 2016	ES44401	Huelva	21550	2640	010420	Capra hircus	1
Mar 2016	ES44401	Huelva	21570	2640	010420	Capra hircus	2
Oct 2016	ES44401	Huelva	21400	8950	0102	Bos taurus	1
Dec 2016	ES42201	Cádiz	11190	2965	0102	Bos taurus	1


EuFMDiS 1.2e
File Control Navigate Layers Config Database Reports
1:3,962,426
model status
model mode: livestock
scenario name: demo
seeding mode: manual (1 seed)
scenario end mode: fixed
scenario max length: 21 days
spread pathways: Dir Ind Loc Air Sale
weather data: station-based
fixed start date: Fri 01 Sep 2017
current date: Fri 22 Sep 2017
elapsed real time: 11 secs
currently infected herds: 51
hiwater herd infections: 51
scenario status: completed
sim day: 21
run number: 3 of 10
convergence (Ihs/duration/cost): 0% / 0% / 0%
detection mode: fixed
first day of detection: 21
no declared infected jurisdictions
no jurisdictions under standstill
cost of control: €0
post outbreak: €0
loss of trade: €0
TOTAL COST: €0
spread pathway visualisation
seed herds: 1
direct infections: 6 (11%)
indirect infections: 9 (17%)
local infections: 37 (70%)
airborne infections: 0 (0%)
assembly centre infections: 1 (2%)
Linz
Vienna
Salzburg
Gyor
Budapest
Innsbruck
Graz
Cluj
Maribor
Ljubljana
Pecs
Zagreb
Milano
Bucharest
Firenze
Split
Sofia

Control measures

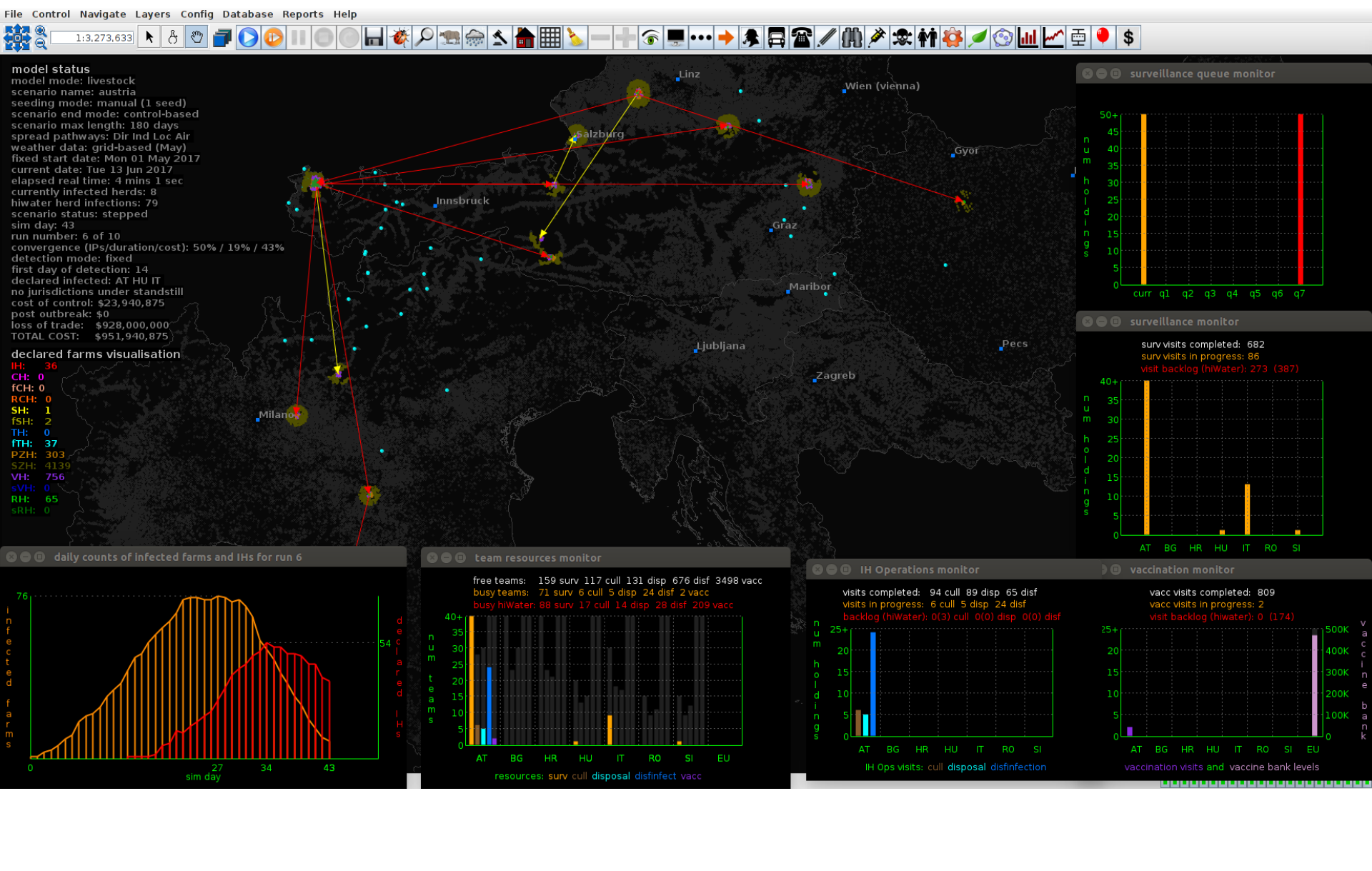
- The measures in EuFMDiS are consistent with the approaches described in European FMD Directive (2003)
- Flexible and highly configurable
- Individual measures can be switched on of off
- Success of control measures depend on:
  - Effectiveness of measures
  - Resources for control
- Parameterised with 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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1:3,273,633
model status
model mode: livestock
scenario name: austria
seeding mode: manual (1 seed)
scenario end mode: control-based
scenario max length: 180 days
spread pathways: Dir Ind Loc Air
weather data: grid-based (May)
fixed start date: Mon 01 May 2017
current date: Tue 13 Jun 2017
elapsed real time: 4 mins 1 sec
currently infected herds: 8
hiwater herd infections: 79
scenario status: stepped
sim day: 43
run number: 6 of 10
convergence (IPs/duration/cost): 50% / 19% / 43%
detection mode: fixed
first day of detection: 14
declared infected: AT HU IT
no jurisdictions under standstill
cost of control: $23,940,875
post outbreak: $0
loss of trade: $928,000,000
TOTAL COST: $951,940,875
declared farms visualisation
IH: 36
CH: 0
fCH: 0
RCH: 0
SH: 1
fSH: 2
TH: 0
fTH: 37
PZH: 303
SZH: 4139
VH: 756
sVH: 0
RH: 65
sRH: 0
Linz
Wien (vienna)
Salzburg
Gyor
Innsbruck
Graz
Maribor
Ljubljana
Pecs
Zagreb
Milano
surveillance queue monitor
num holdings
curr q1 q2 q3 q4 q5 q6 q7
surveillance monitor
surv visits completed: 682
surv visits in progress: 86
visit backlog (hiWater): 273 (387)
AT BG HR HU IT RO SI
daily counts of infected farms and IHs for run 6
infected farms
declared IHs
sim day
team resources monitor
free teams: 159 surv 117 cull 131 disp 676 disf 3498 vacc
busy teams: 71 surv 6 cull 5 disp 24 disf 2 vacc
busy hiWater: 88 surv 17 cull 14 disp 28 disf 209 vacc
num teams
AT BG HR HU IT RO SI EU
resources: surv cull disposal disfinfect vacc
IH Operations monitor
visits completed: 94 cull 89 disp 65 disf
visits in progress: 6 cull 5 disp 24 disf
backlog (hiWater): 0(3) cull 0(0) disp 0(0) disf
num holdings
IH Ops visits: cull disposal disfinfection
vaccination monitor
vacc visits completed: 809
vacc visits in progress: 2
visit backlog (hiwater): 0 (174)
vaccine bank
vaccination visits and vaccine bank levels

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

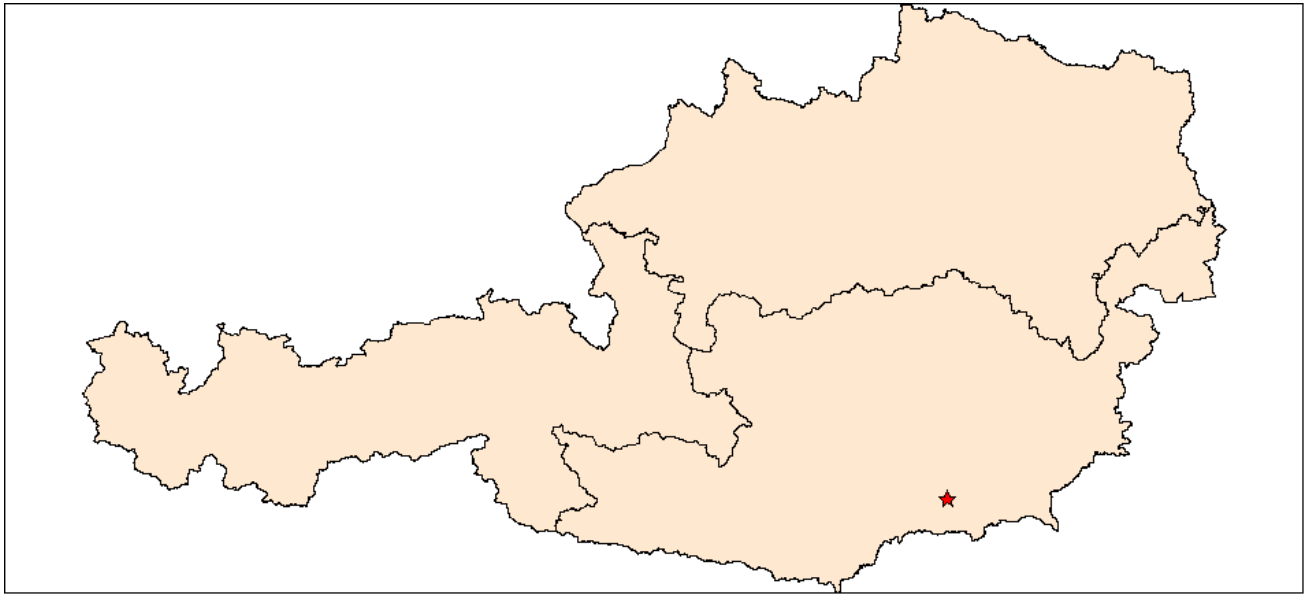
- Study size, duration and economic impact of outbreaks
- Assess potential for establishment and spread of FMD under local conditions
- Test surveillance approaches - early detection
- Look at resource needs and resource management issues
- Compare different response strategies (including use of vaccination)
- 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

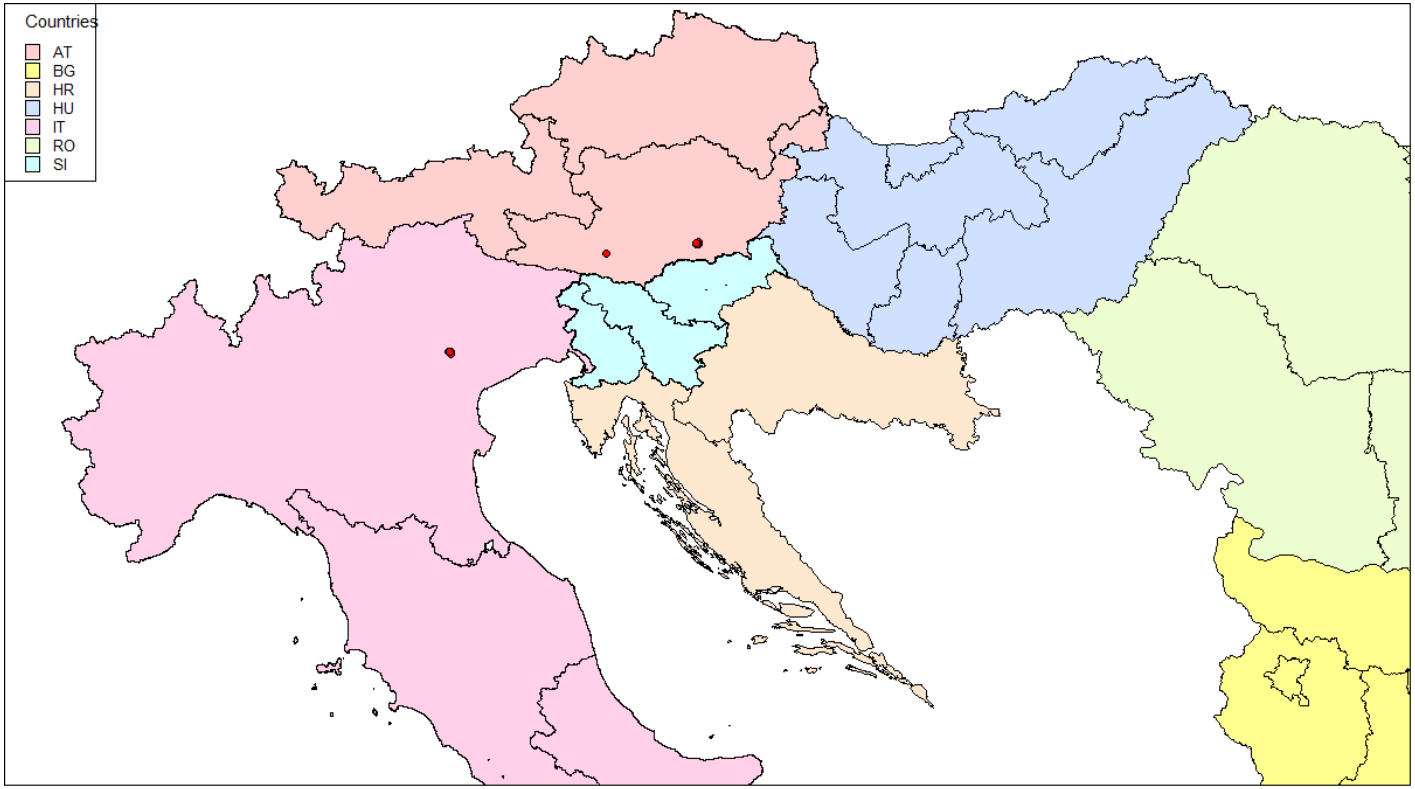


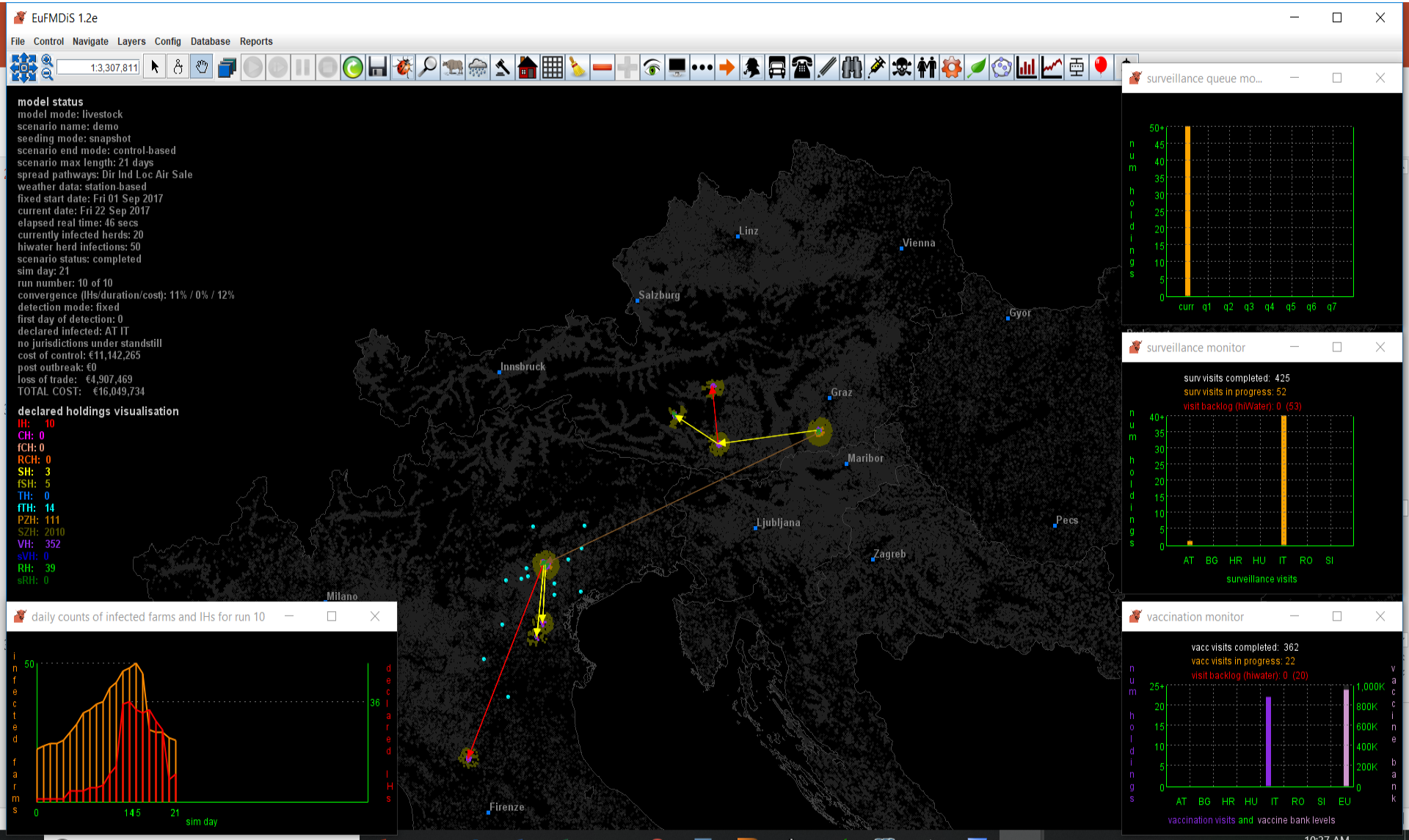
Key assumptions

- 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
- Priority for vaccination: 1. Cattle 2. Pigs 3. Small ruminants.
- Potential access to up to 1 million doses in EU stockpile
- Model run until disease eradicated or 365 days

Results

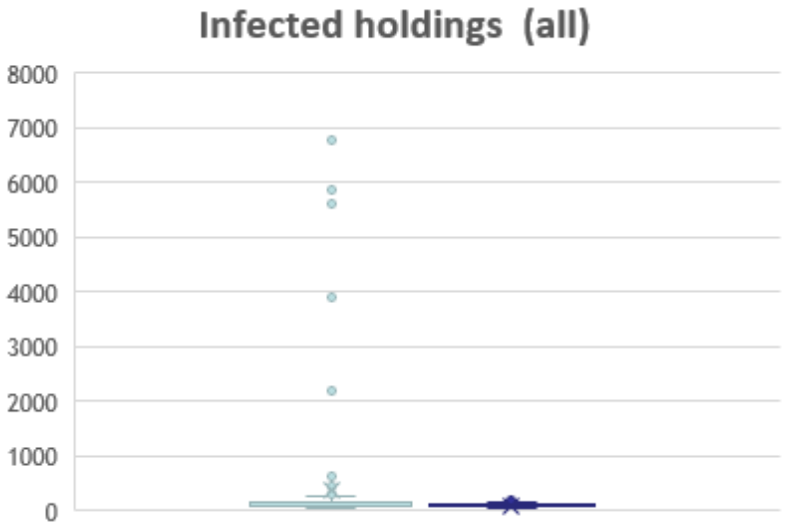
- On Day 1 of the control program, when the authorities are aware of the first case of FMD, in Austria there are already 35 infected farms in three clusters - 2 in AT (with 9 infected farms) – 1 in IT (10 infected farms)

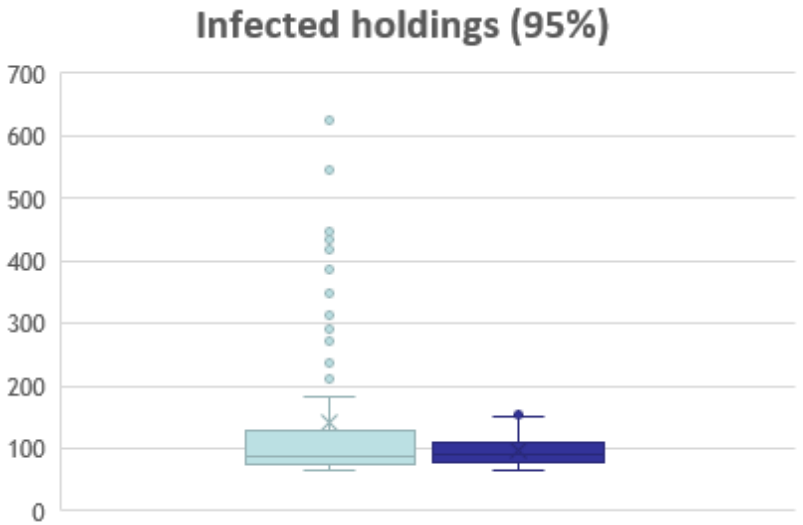



EuFMDiS 1.2e
File Control Navigate Layers Config Database Reports
1:3,307,811
model status
model mode: livestock
scenario name: demo
seeding mode: snapshot
scenario end mode: control-based
scenario max length: 21 days
spread pathways: Dir Ind Loc Air Sale
weather data: station-based
fixed start date: Fri 01 Sep 2017
current date: Fri 22 Sep 2017
elapsed real time: 46 secs
currently infected herds: 20
hiwater herd infections: 50
scenario status: completed
sim day: 21
run number: 10 of 10
convergence (IHs/duration/cost): 11% / 0% / 12%
detection mode: fixed
first day of detection: 0
declared infected: AT IT
no jurisdictions under standstill
cost of control: €11,142,265
post outbreak: €0
loss of trade: €4,907,469
TOTAL COST: €16,049,734
declared holdings visualisation
IH: 10
CH: 0
fCH: 0
RCH: 0
SH: 3
fSH: 5
TH: 0
fTH: 14
PZH: 111
SZH: 2010
VH: 352
sVH: 0
RH: 39
sRH: 0
Linz
Vienna
Salzburg
Gyor
Innsbruck
Graz
Maribor
Ljubljana
Pecs
Zagreb
Milano
Firenze
surveillance queue mo...
num holdings
curr q1 q2 q3 q4 q5 q6 q7
surveillance monitor
surv visits completed: 425
surv visits in progress: 52
visit backlog (hiWater): 0 (53)
AT BG HR HU IT RO SI
surveillance visits
daily counts of infected farms and IHs for run 10
infected farms
declared IHs
sim day
vaccination monitor
vacc visits completed: 362
vacc visits in progress: 22
visit backlog (hiwater): 0 (20)
AT BG HR HU IT RO SI EU
vaccination visits and vaccine bank levels

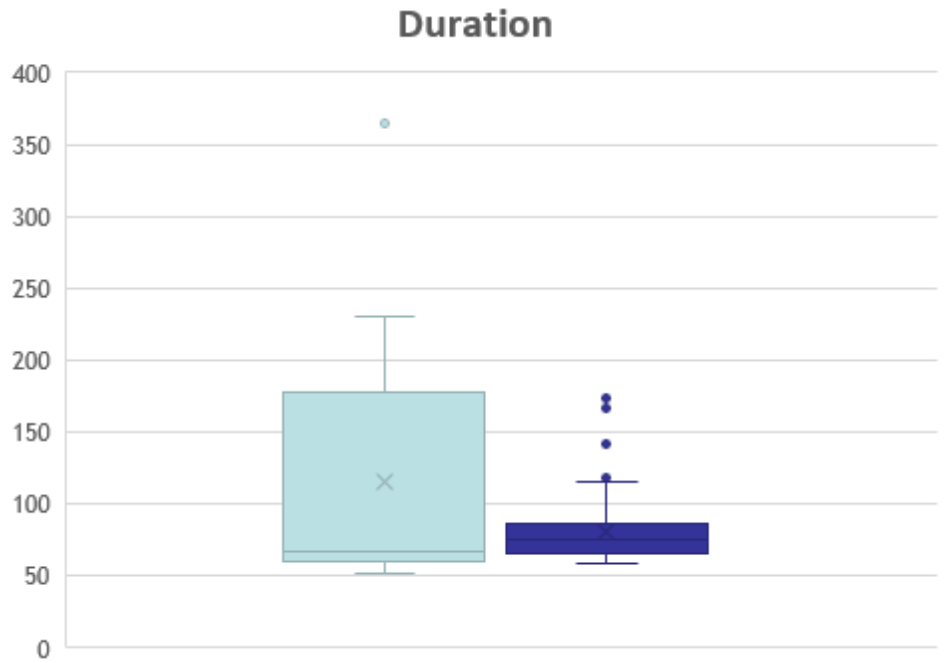
Comparing control strategies

- Number of infected holdings
- Duration of control program
- Total animals culled
- Control program costs
- Trade losses
- Benchmarks



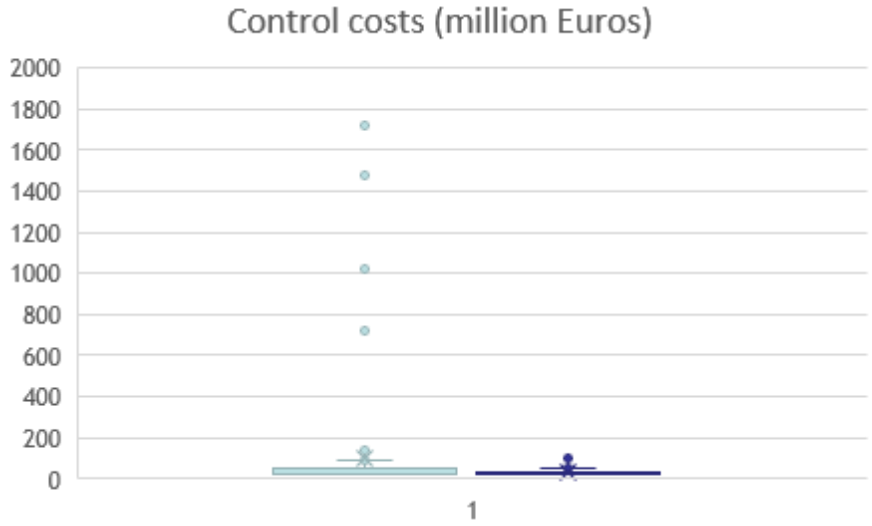


	SO	SORV
<100	58%	64%
<250	80%	98%
<500	93%	100%
>500	7%	-



	SO	SORV
<90	65%	81%
<180	76%	100%
<365	95%	-
>=365	5%	-

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

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Slovenia	Marko Potocnik		

Thank you. Questions?