National Veterinary Institute

Technical University of Denmark

DTU

A comparison of three simulation models using FMD outbreak in Denmark as a model – “the EpiLab Project”

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International EpiLab

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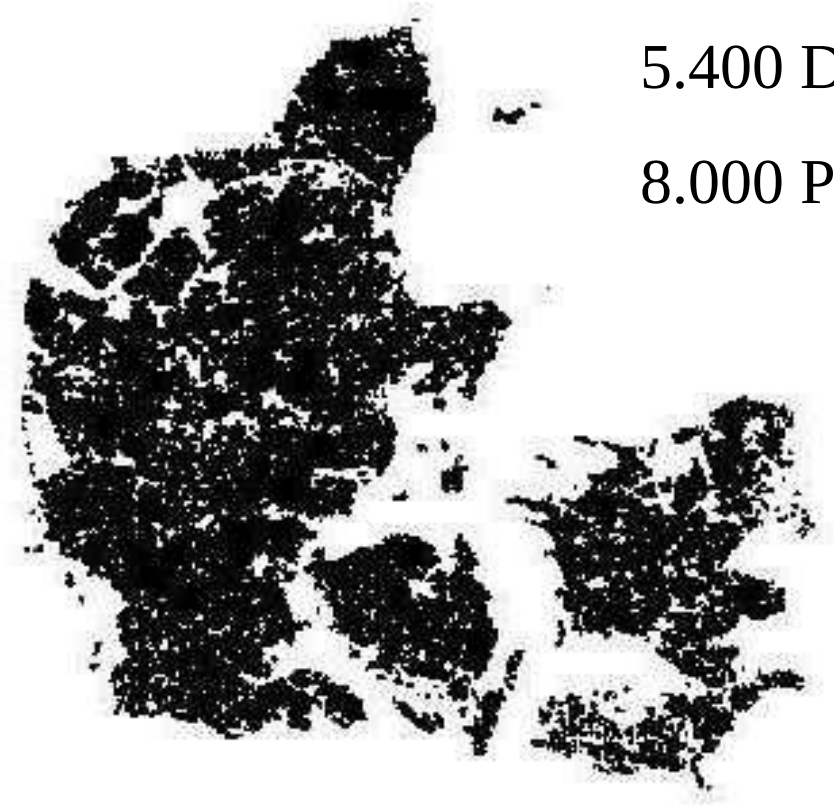
Project partners

- Professor George Milne, The University of Western Australia
- Associated professor Annette Ersbøll, Faculty of Life Science, University of Copenhagen
- University of California, Department of Medicine and Epidemiology, Davies, USA
- University of Warwick, Department of biological sciences, ecology and epidemiology group, Great Britain
- Massey University, New Zealand

Outline

- Background
- Aim and objective of the project
- Materials and methods
- Results
- Conclusion
- Experience gain from the project

Background: Animal production in Denmark 2006



5.400 Dairy herds, 555.000 cows

8.000 Pig herds, 13 mill pigs

Size of Denmark:

43.094 km2, ~50% agriculture

Background: Last outbreak of FMD in Denmark

- 1982-1983
- According to epidemiological studies:
  - Multiple windborne introduction
  - 23 affected herds
  - Mode of transmission from index herd
    - Practising veterinarian (4)
    - Milk truck (4)
    - Collection of slaughter pigs (3)
    - unknown

Aim of this project

- … to provide the decision basis for the choice of control strategies (culling and vaccination) against FMD in Denmark in case of an outbreak

- The assessment should account for livestock demographics and disease control capacity

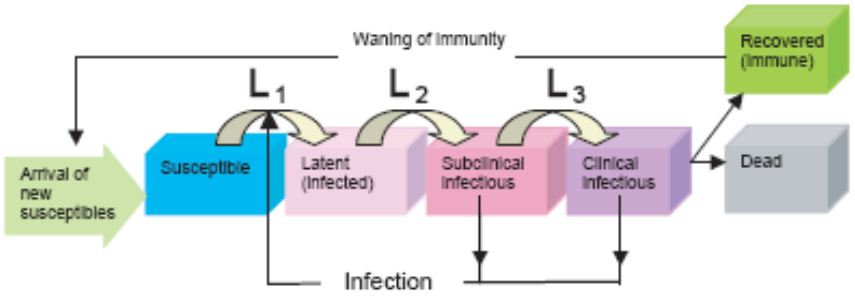
Research hypothesis

- The result from stochastic simulation models for the spread of FMD can partly be explained by method-specific factors, i.e. by the choice of modelling software.

Materials and methods

Conceptual model used in the project

- We used a state-transition concept



- The most important parameter is the rule that defines the transition from susceptible to the infected state

Models used in the project

- Explicit time-space stochastic models:
  - the Warwick model
  - InterSpread Plus
  - the Davies model

Key features of mechanisms of between-herd transmission of FMD

1. Animal movement
2. Indirect movement
3. Windborne spread
4. Local spread

Features of how the models includes mechanism of between-herd transmission of FMD

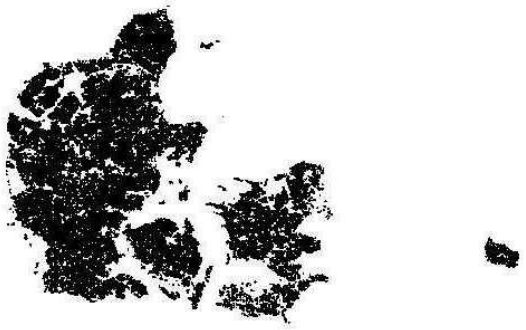
- In the Warwick model, the transmission is model as a function based on a transmission kernel and include all mechanism of transmission.
- InterSpread Plus and the Davies model handle each mechanism separately. Windborne transmission was not considered in these models

Data used in the simulation

- Herd-specific data:
  - Location of holdings
  - Type of holding
  - Species
  - Production type
  - Number of animals in relevant categories (species, age, sex)
  - Number of animal movements in and out of the herd

Restrictions and assumptions in the simulation

- Wildlife, small ruminants and non-registered backyard populations was not considered in the simulations
- Only herds in Jutland were included in the simulation
  - ~27,000 herds with cattle, swine or cattle and swine



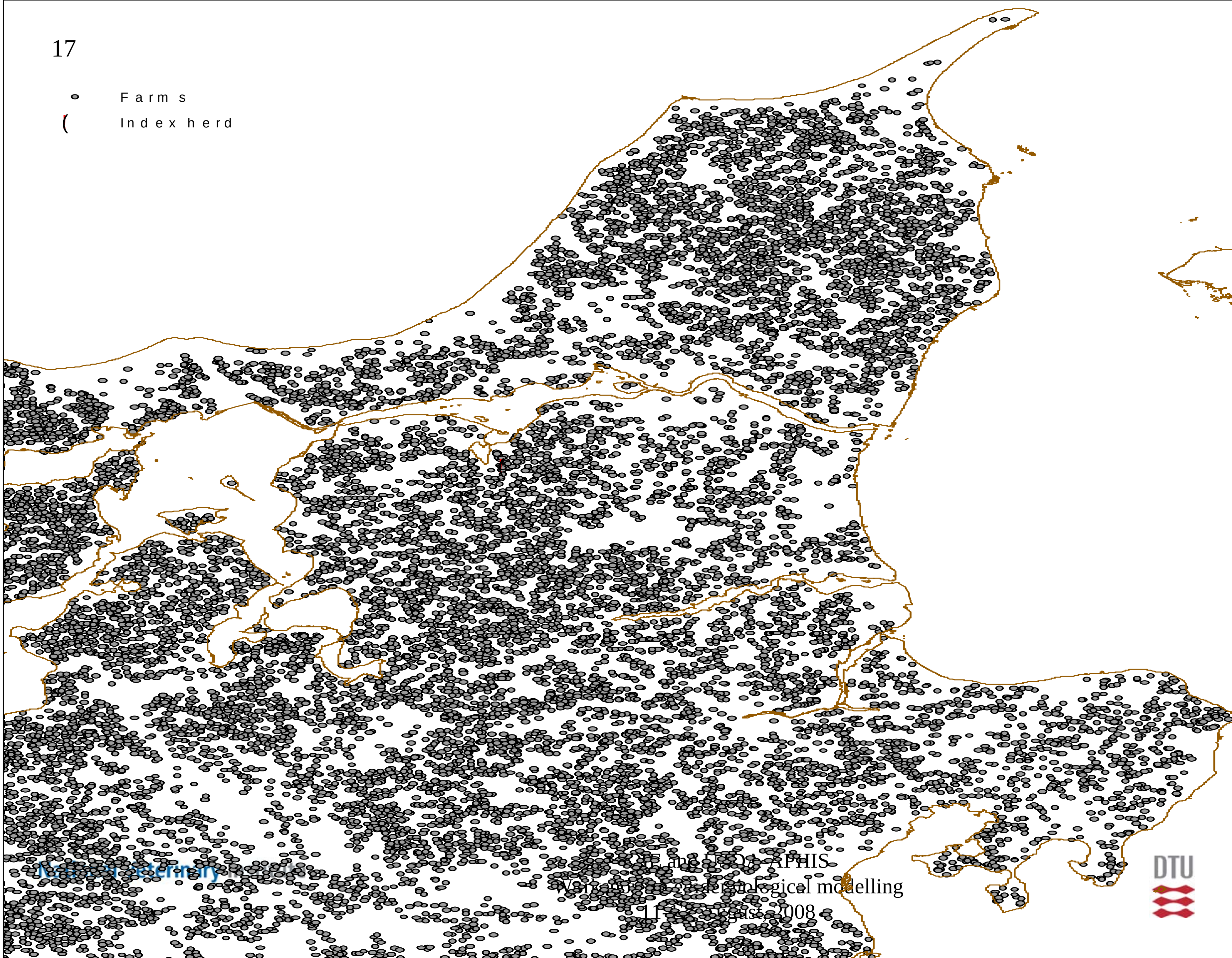
- Susceptibility of swine equal to the susceptibility of cattle

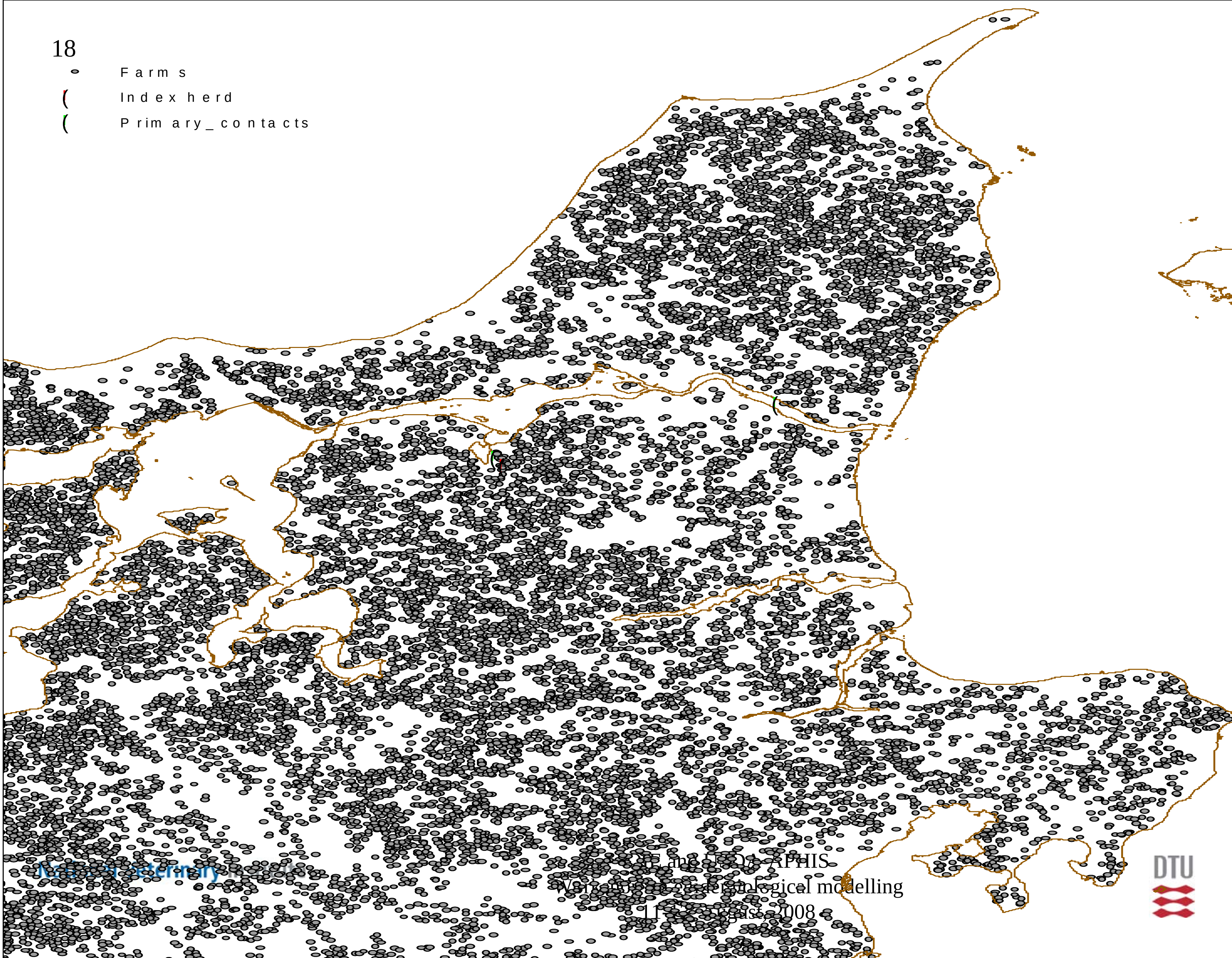
Outbreak scenarios

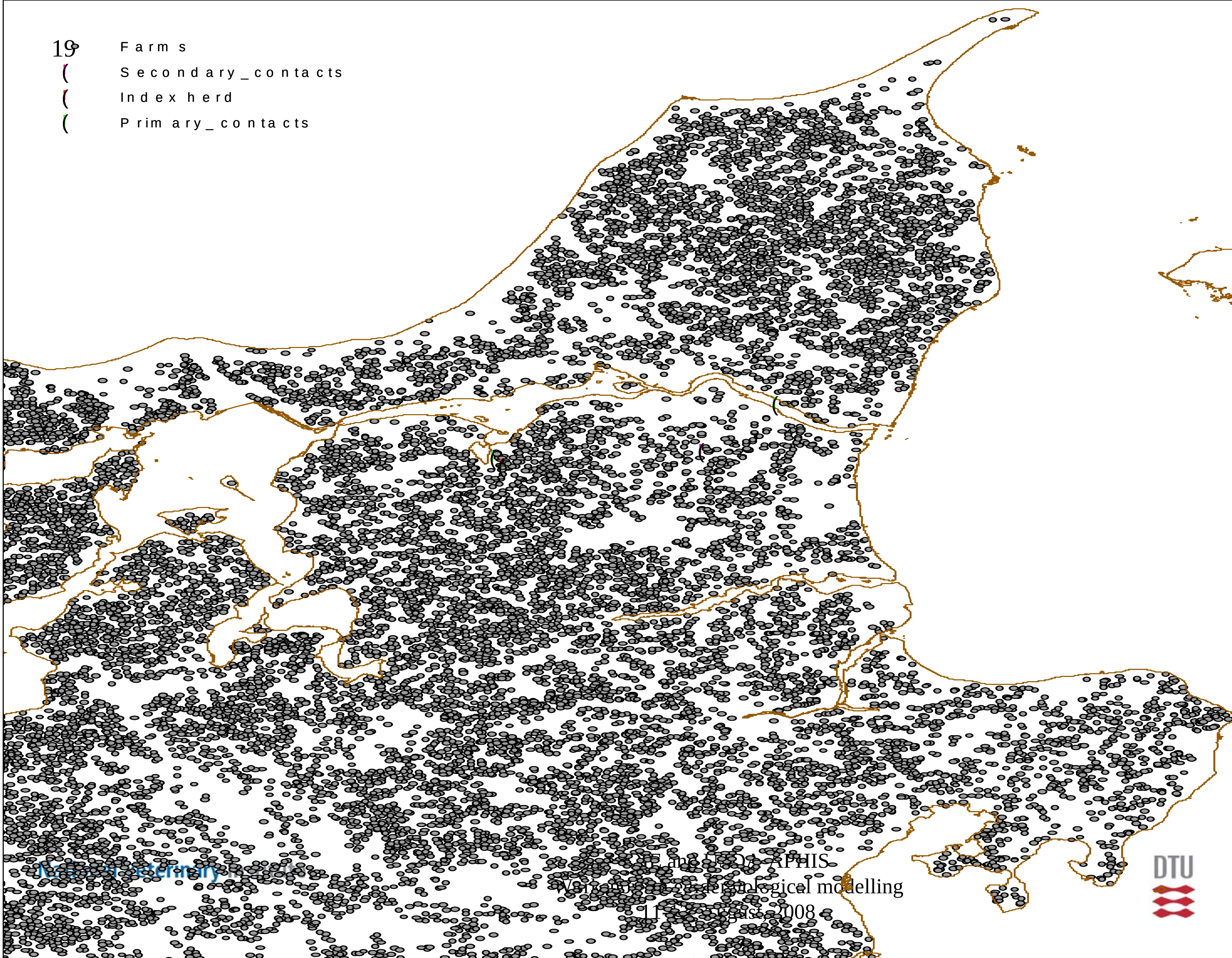
- Two outbreak scenarios were simulated
  - Small outbreak scenario
  - Large outbreak scenario

Small outbreak scenario

- The index herd was a random swine herd with contact to a mixed herd
- During the silent period of 16 days, all direct and indirect contacts to the index herd were traced – in total 6 infected herds before detection
- Standstill at day 17
- All contact is infective
- Local spread in a 3 km. radius

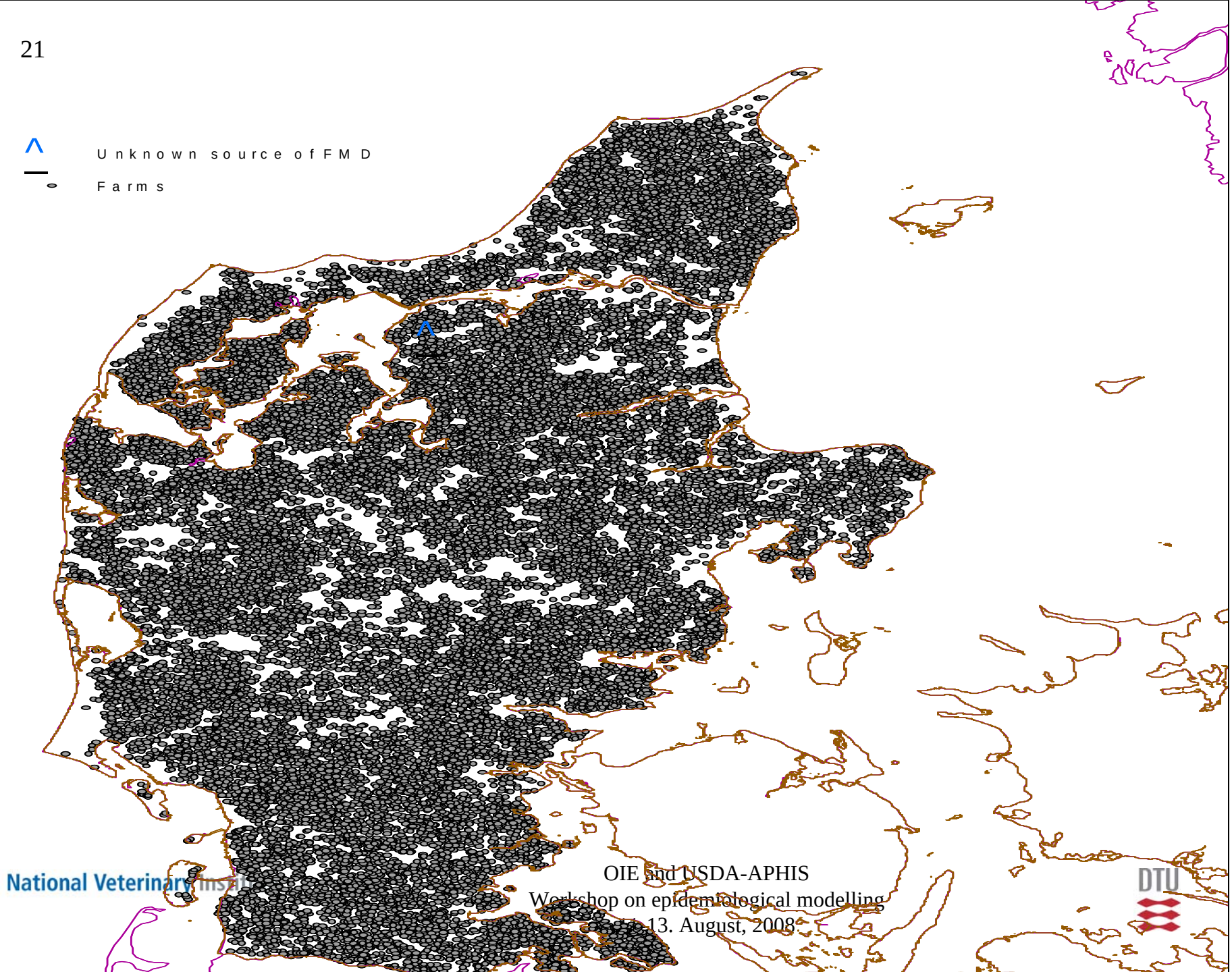

Farms
Index herd

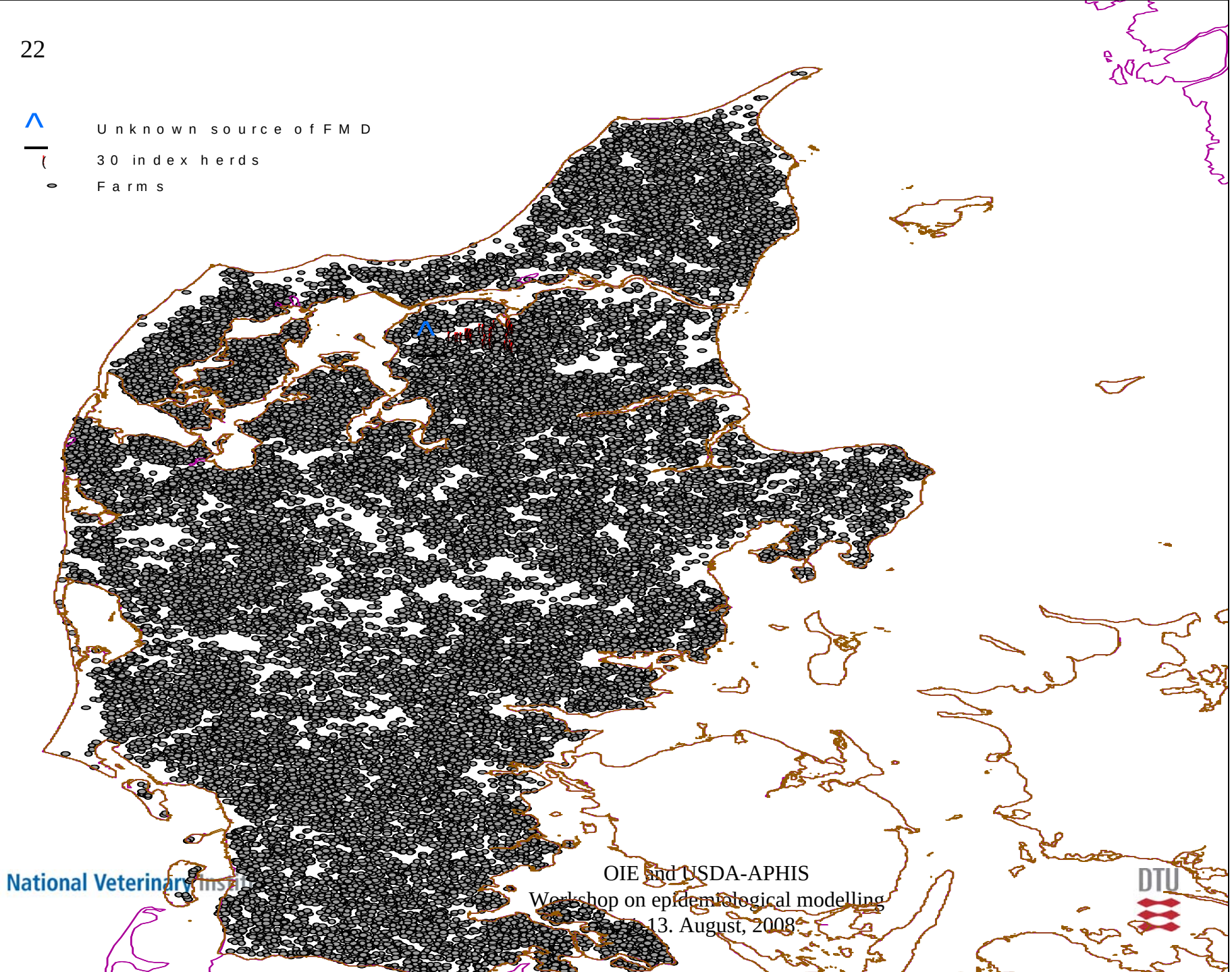

Farms
Index herd
Primary_contacts

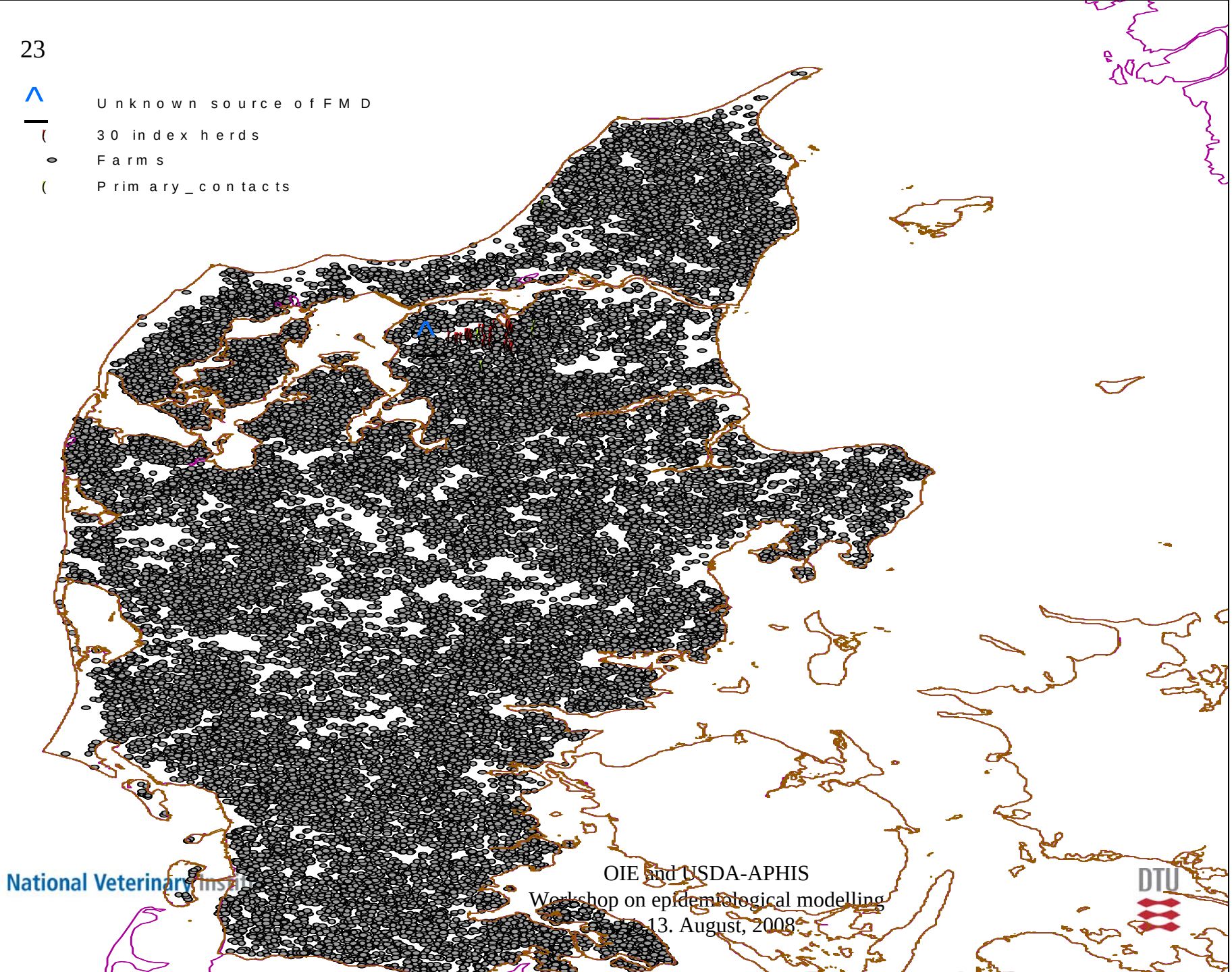

Farms
Secondary_contacts
Index herd
Primary_contacts

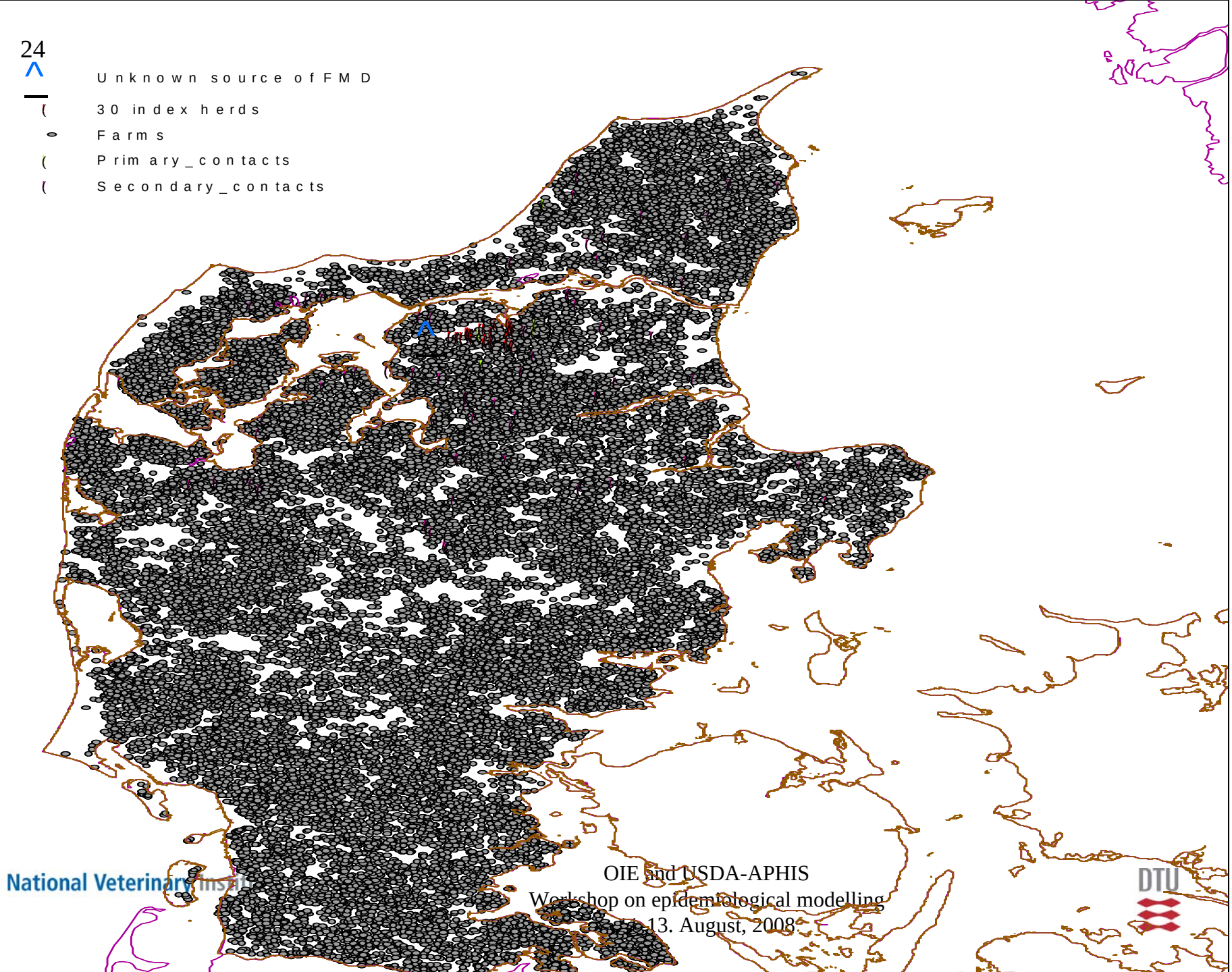
Large outbreak scenario

- Unknown source of FMD at a random coordinate
- Plume spread by western wind at day 1 to 30 dairy herds (index herds)
- During the silent period of 16 days, all direct and indirect contacts to the index herds were traced – in total 106 infected herds before detection
- All contact is infective
- Local spread in a 3 km. radius
- Standstill at day 17


Unknown source of FMD
Farms


Unknown source of FMD
30 index herds
Farms


Unknown source of FMD
30 index herds
Farms
Primary_contacts


Unknown source of FMD
30 index herds
Farms
Primary_contacts
Secondary_contacts

Simulated control options from day 17 and onwards

1. Culling of infected herds and dangerous contacts
2. 1 + culling in 1 km radius of infected premises
3. 1 + vaccination of cattle in 3 km radius of infected herds
4. 1 + vaccination of cattle in 7 km radius of infected herds

Simulation

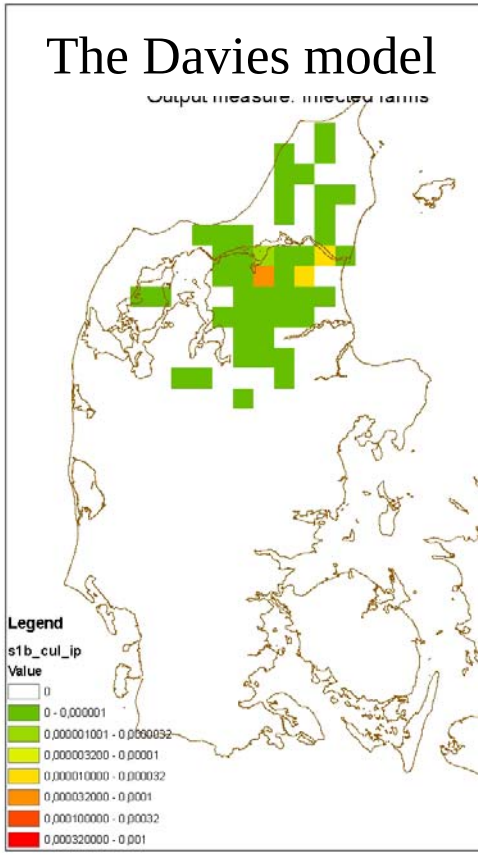
- # simulations
  - 1,000 simulations at each scenario and control strategy
- Input to the models
  - Explicit spatial animal demographics
  - Movement data was included as distributions
- Simulation restricted to Jutland
  - ~27,000 herds with cattle, swine or cattle and swine

Results

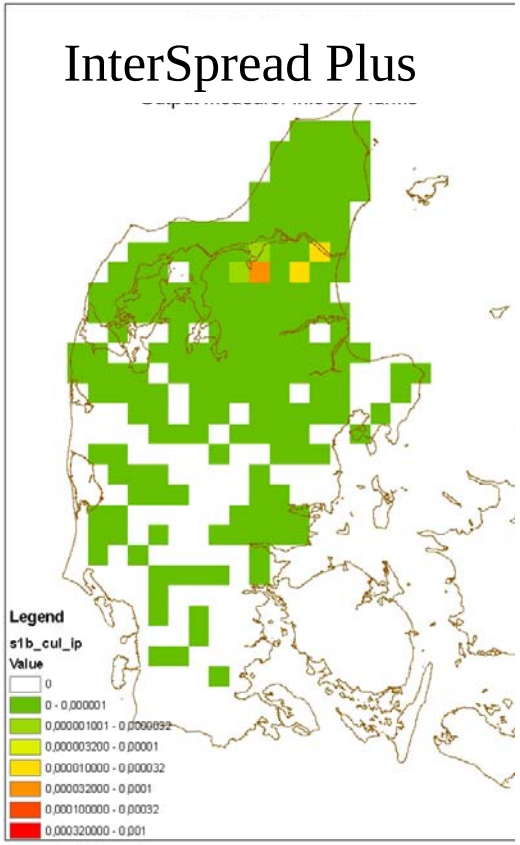
- Heat maps showing the geographical extend and intensity of the outbreak after 120 days
- Cumulative number of infected and culled herds after 120 days

Heat maps of small outbreak scenario and use of culling as control – different models

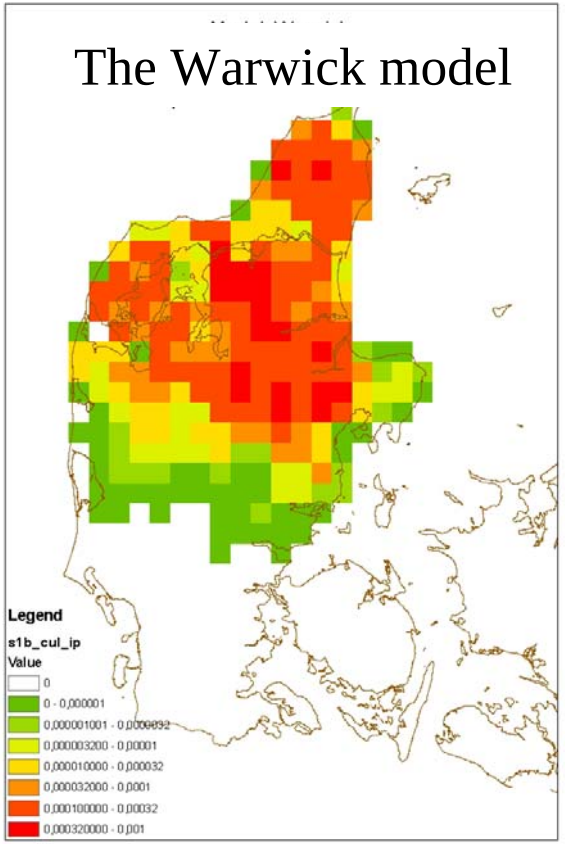
The Davies model



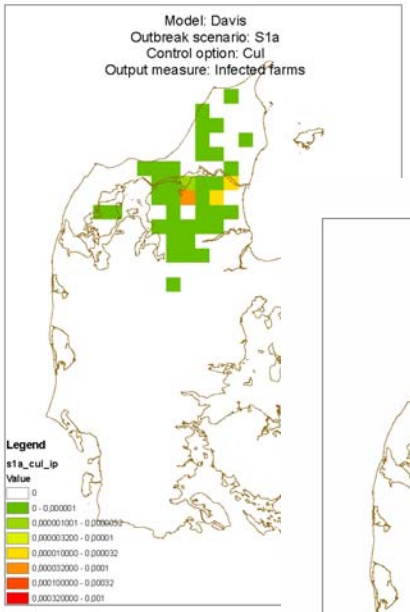
InterSpread Plus



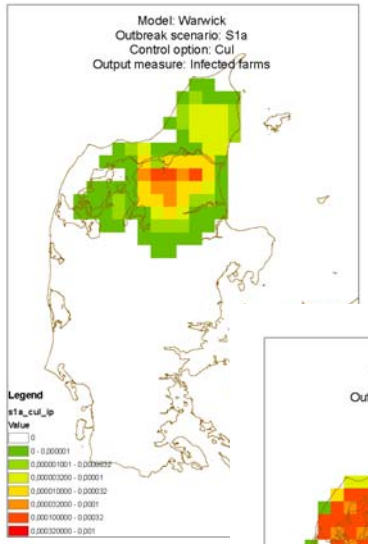
The Warwick model

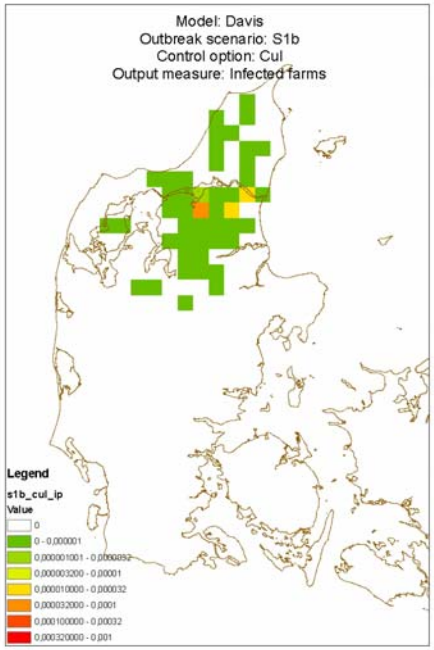


Heat maps of small outbreak scenario varying the susceptibility of swine compared to the susceptibility of cattle and use of the culling control strategy: Davies (left) and Warwick model (right)

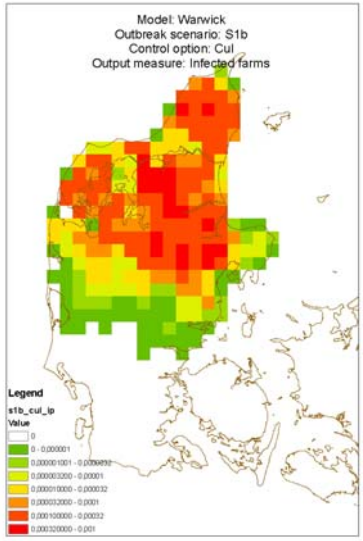


Susceptibility of swine 20 % of the susceptibility of cattle

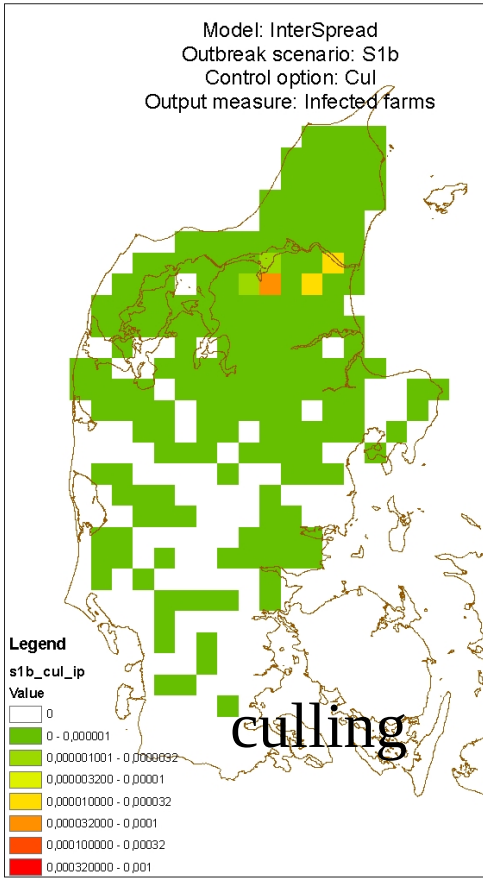


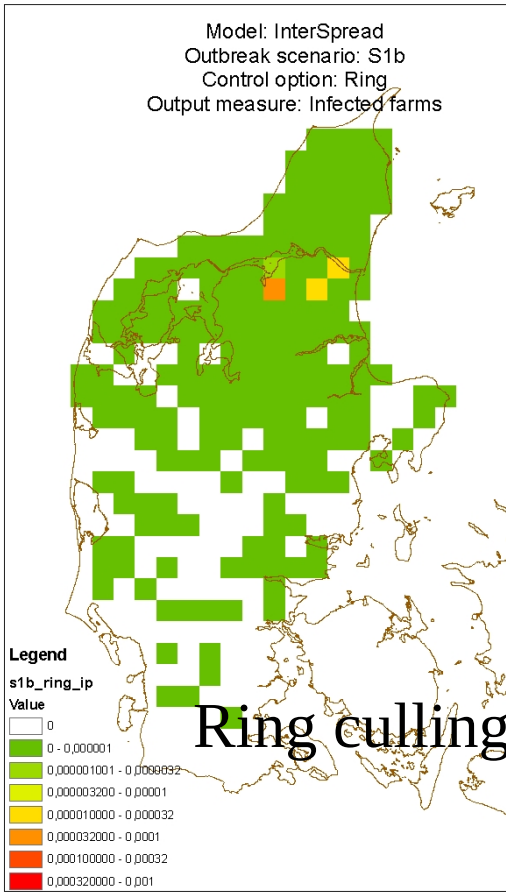


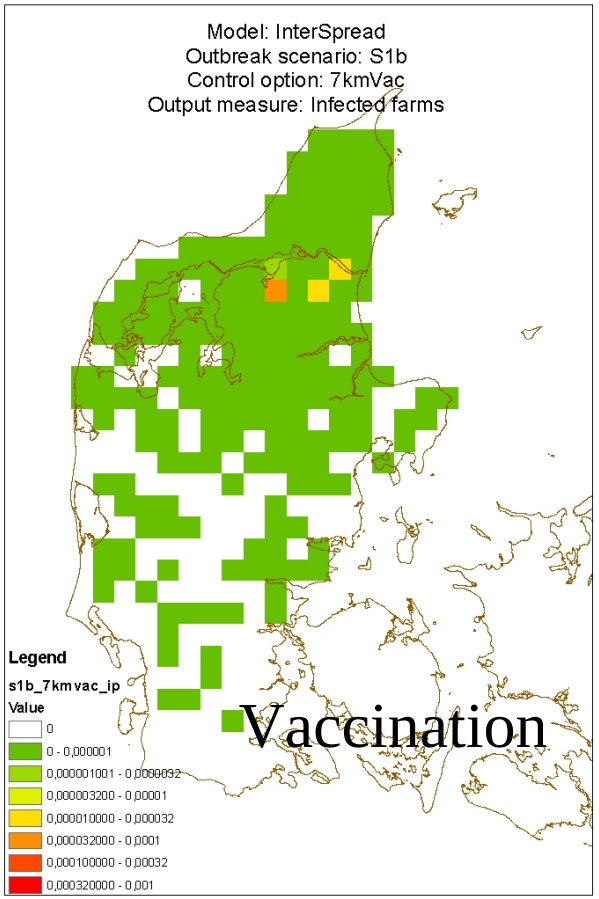
Susceptibility of swine equal to the susceptibility of cattle



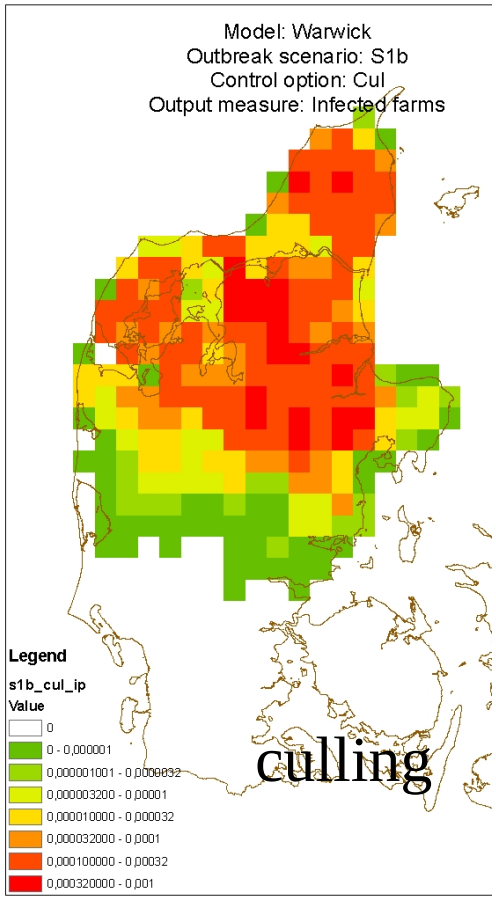
Heat maps of small outbreak scenario and use of different control strategies – simulation done in InterSpread Plus



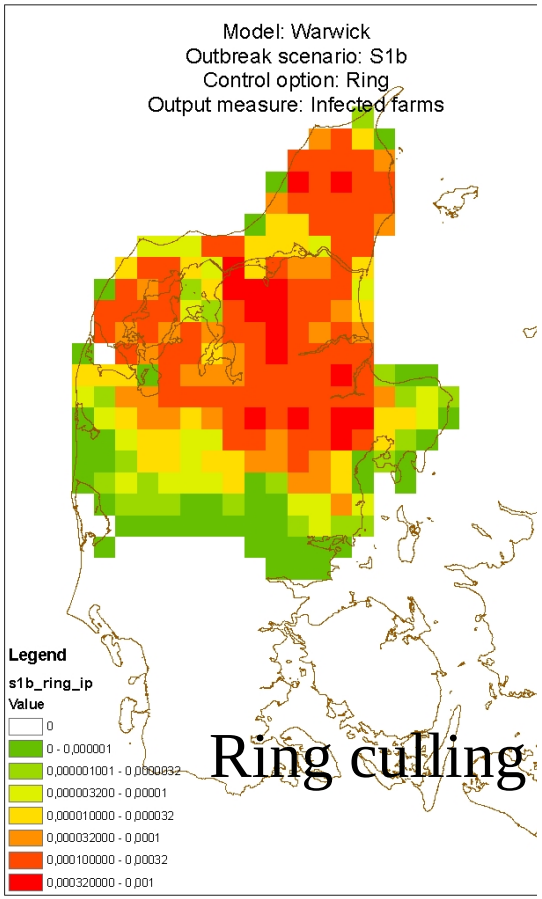




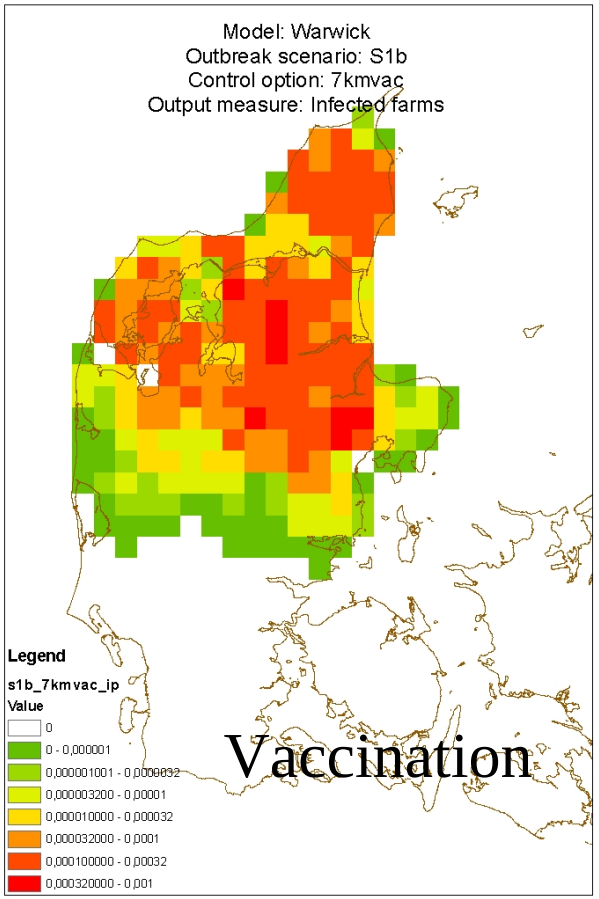
Heat maps of small outbreak scenario and use of different control strategies – simulation done in the Warwick model



culling



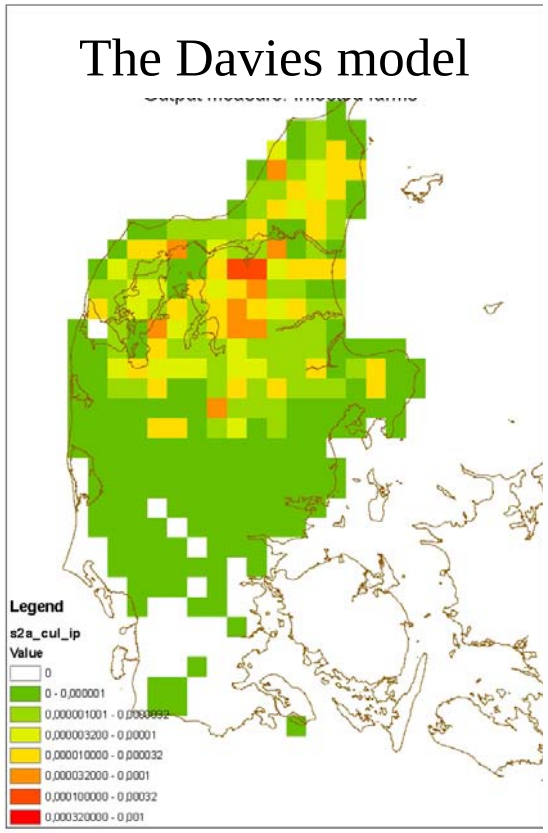
Ring culling



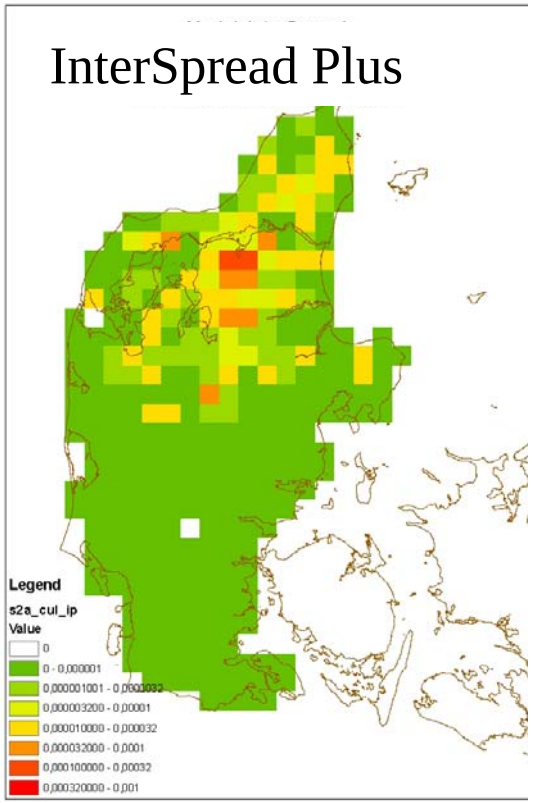
Vaccination

Heat maps of large outbreak scenario and use of culling as control – simulation done in three different models

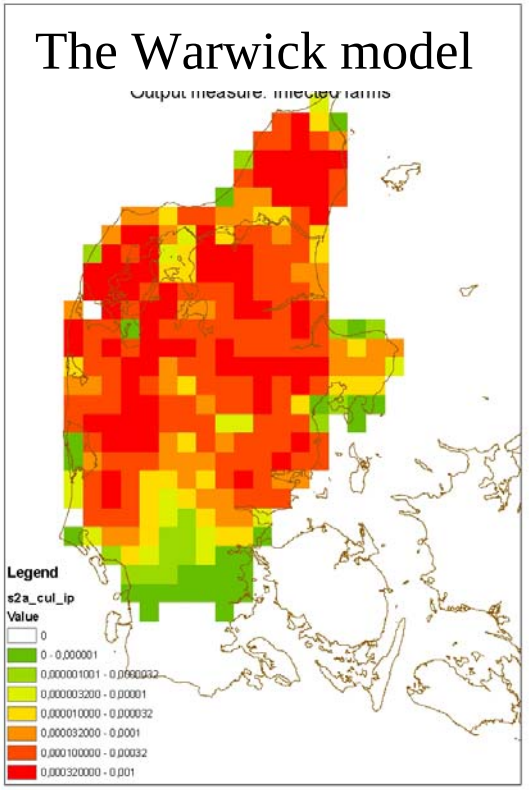
The Davies model



InterSpread Plus

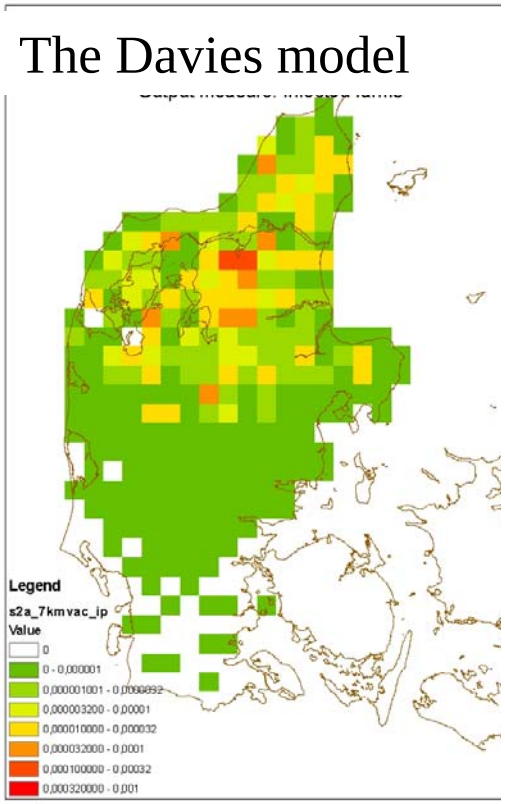


The Warwick model

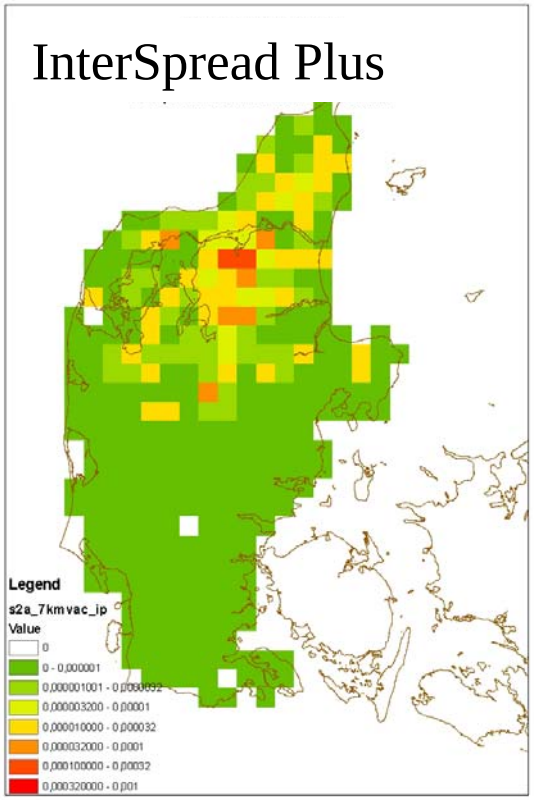


Heat maps of large outbreak scenario and use of vaccination as control – simulation done in three different models

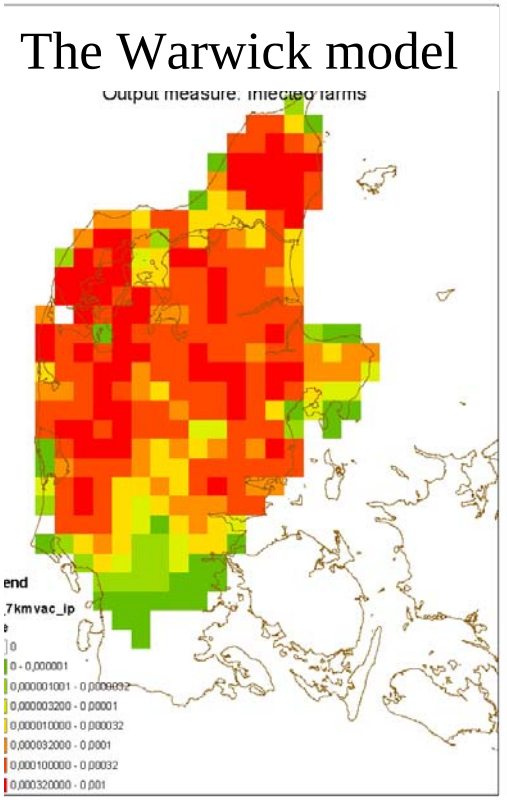
The Davies model



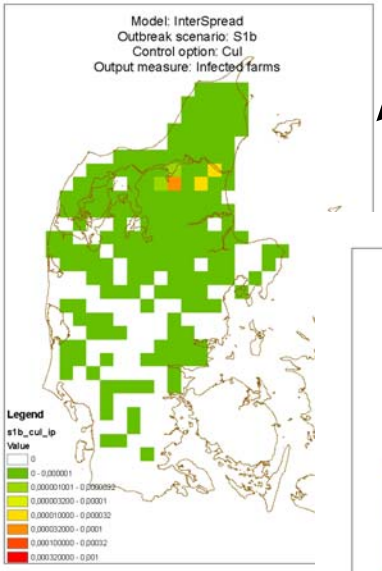
InterSpread Plus



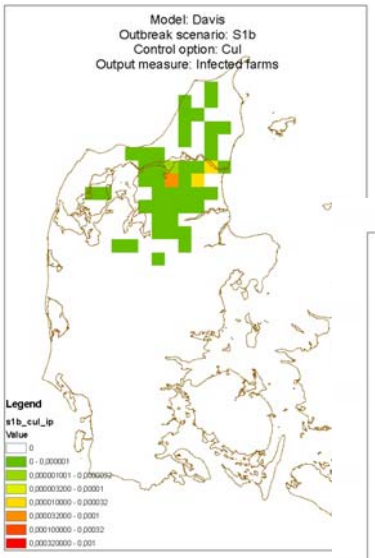
The Warwick model

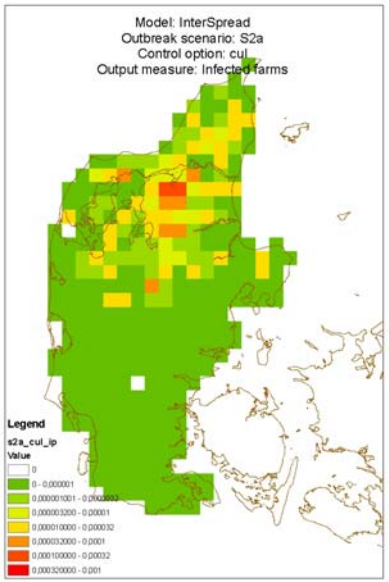


Comparing the effect of initial number of infected herds: InterSpread Plus (left) and the Davies model (right) and use of culling as control strategy

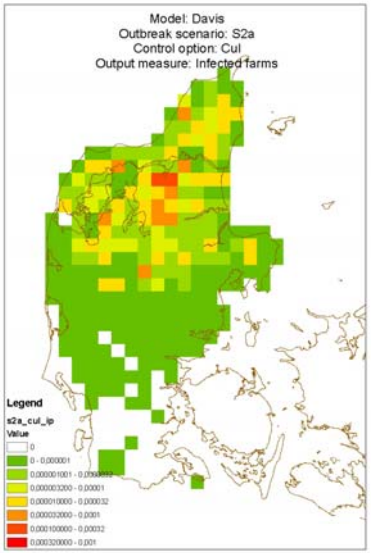


6 infected herds before detection

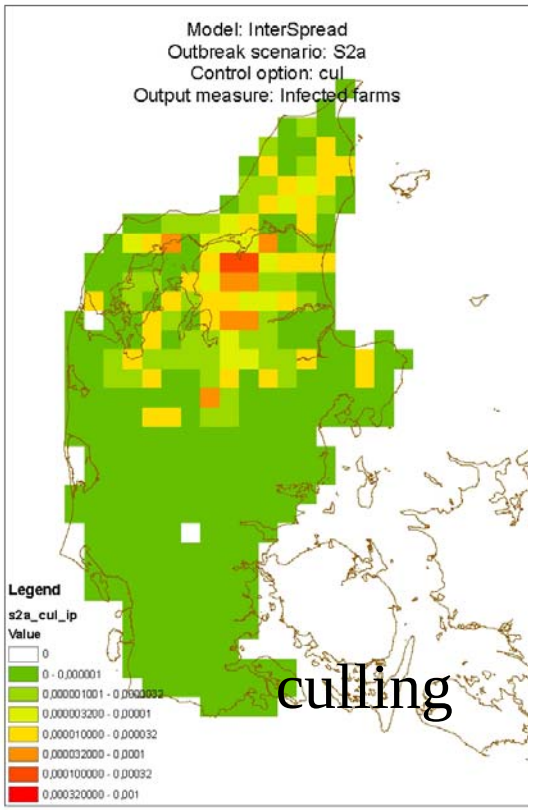




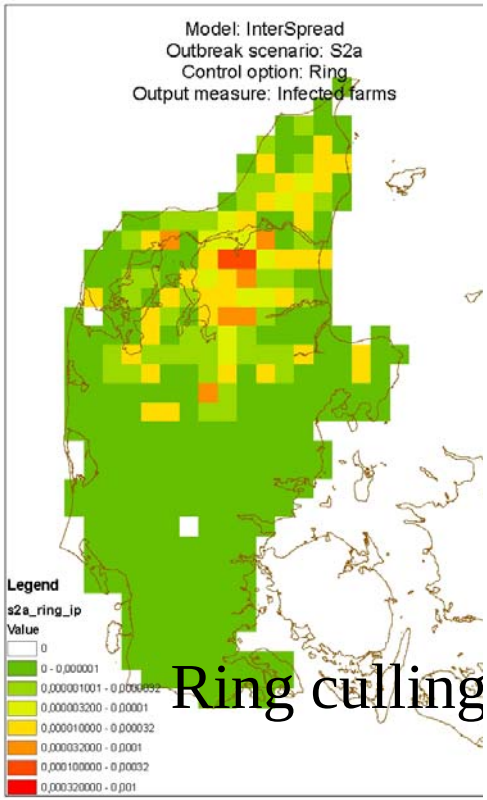
106 infected herds before detection



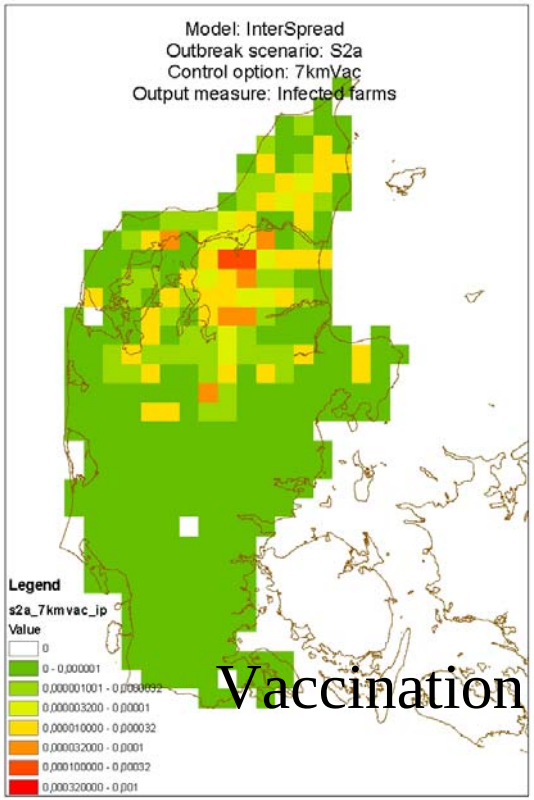
Heat maps of large outbreak scenario and use of different control strategies – simulation done in InterSpread Plus



culling

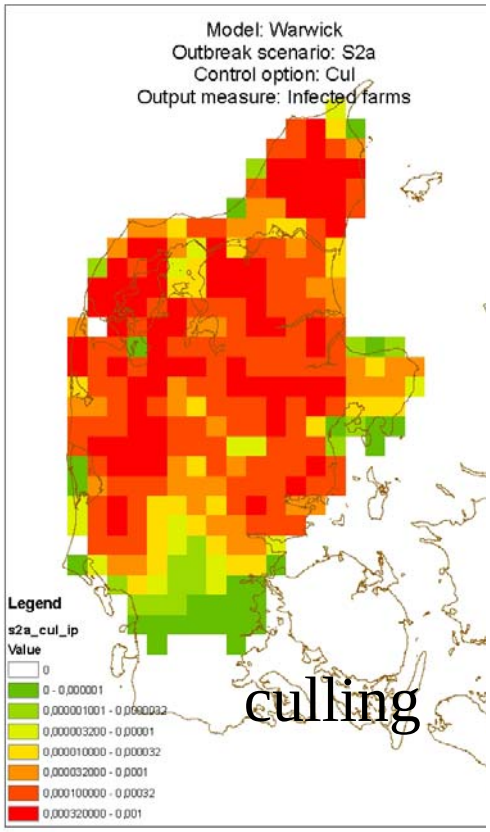


Ring culling

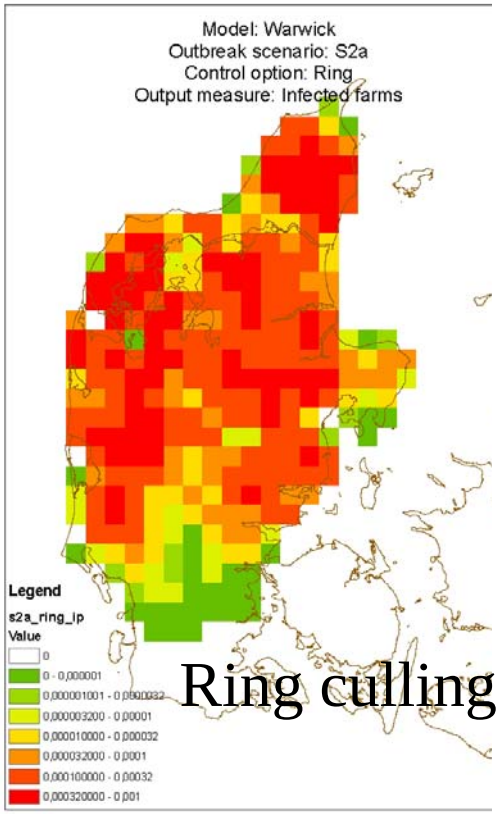


Vaccination

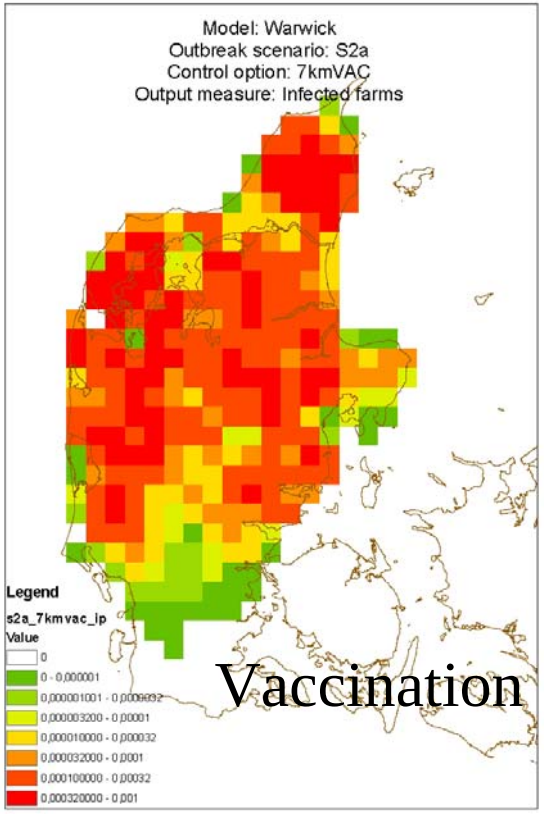
Heat maps of large outbreak scenario and use of different control strategies – simulation done in the Warwick model



culling

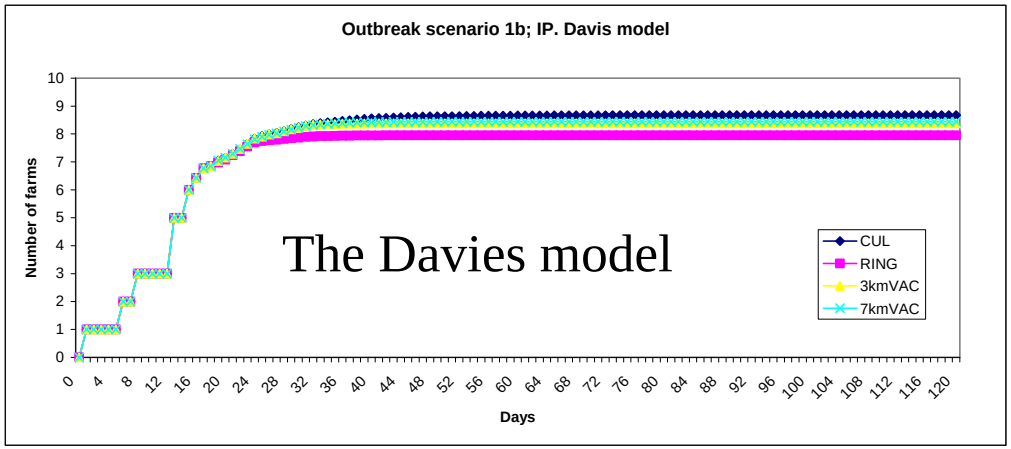


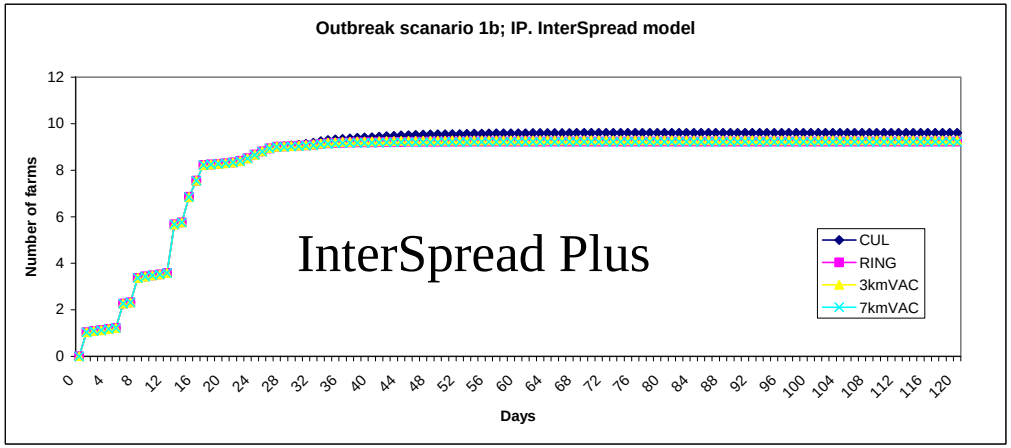
Ring culling

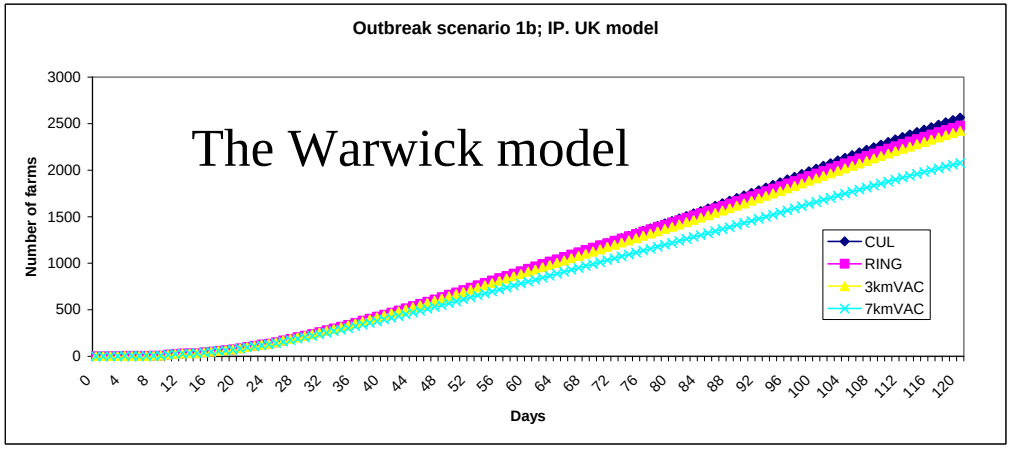


Vaccination

Number of infected herds in the small outbreak scenario after 120 days







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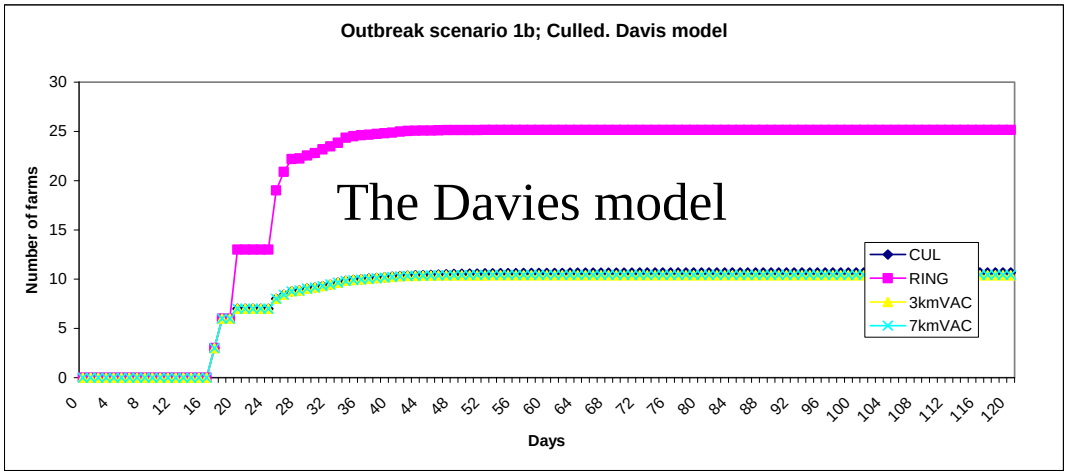
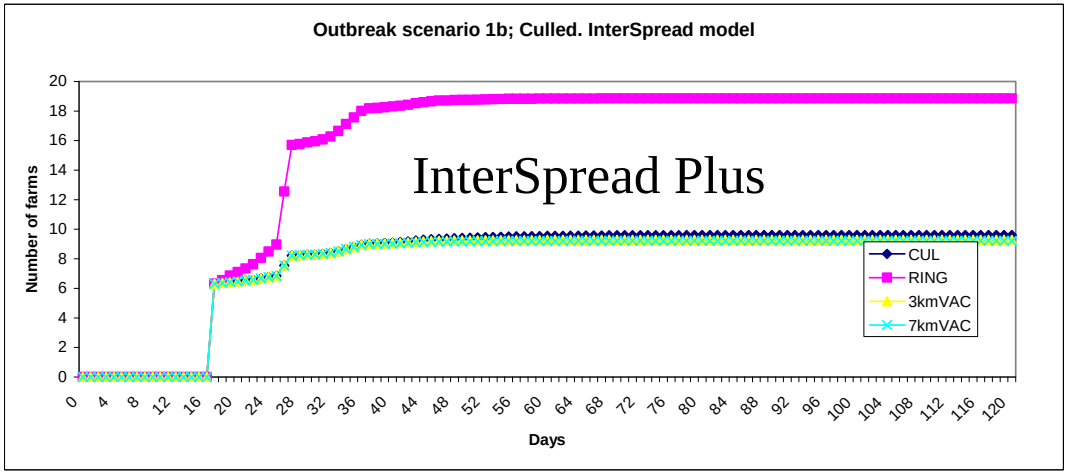
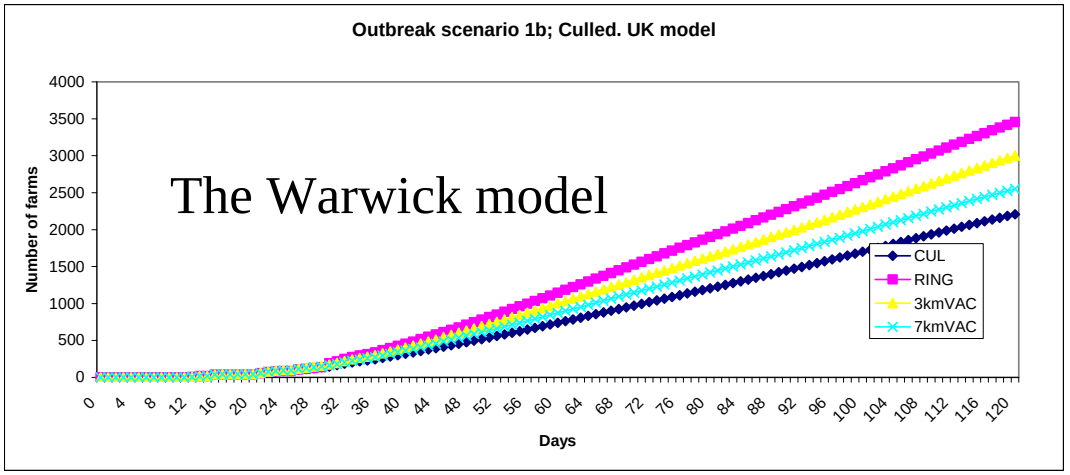
Number of culled herds in the small outbreak scenario after 120 days







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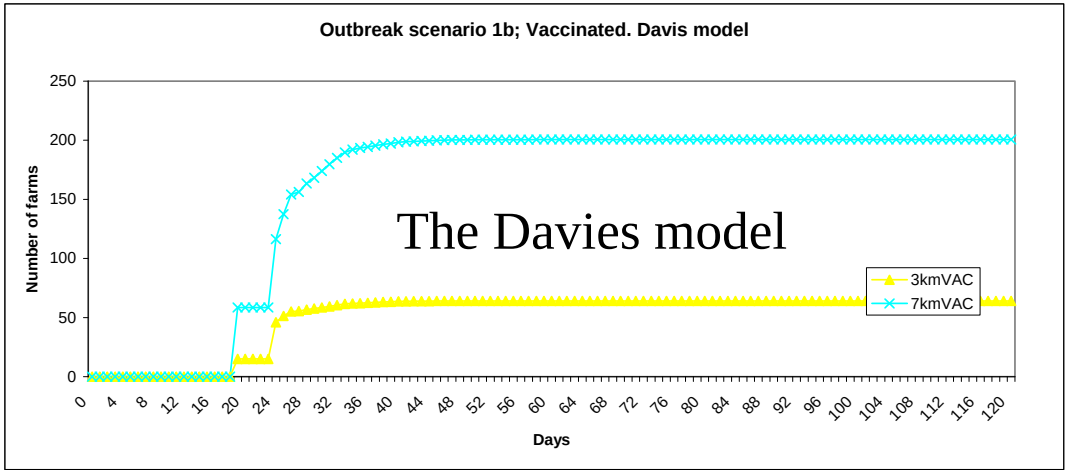
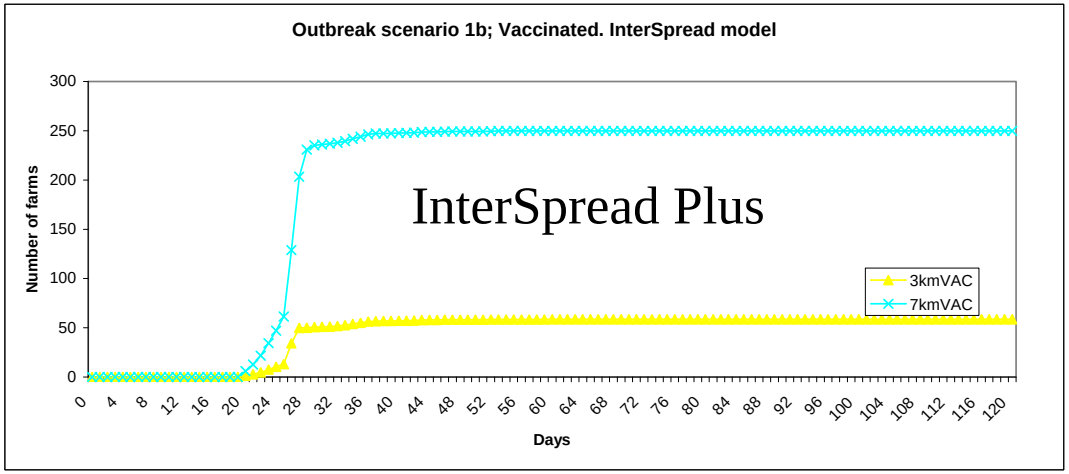
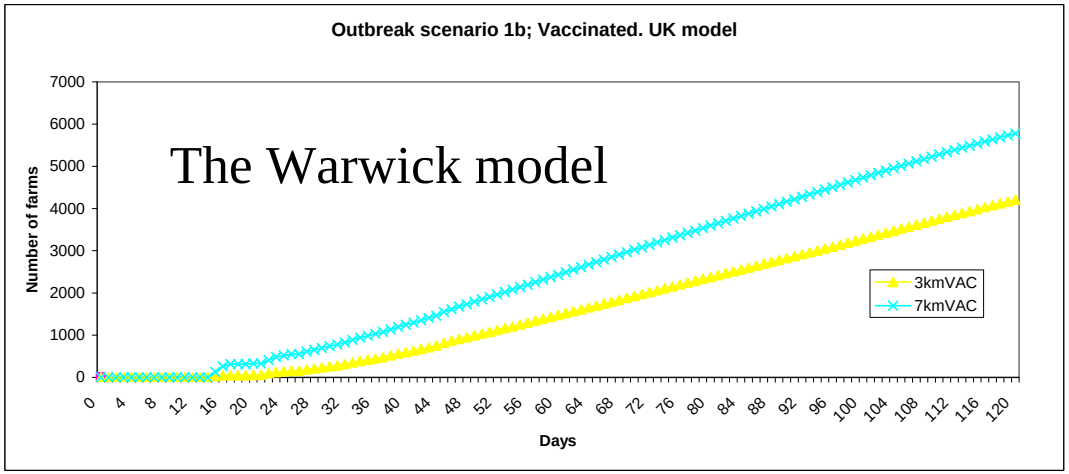
Number of vaccinated herds in the small outbreak scenario after 120 days







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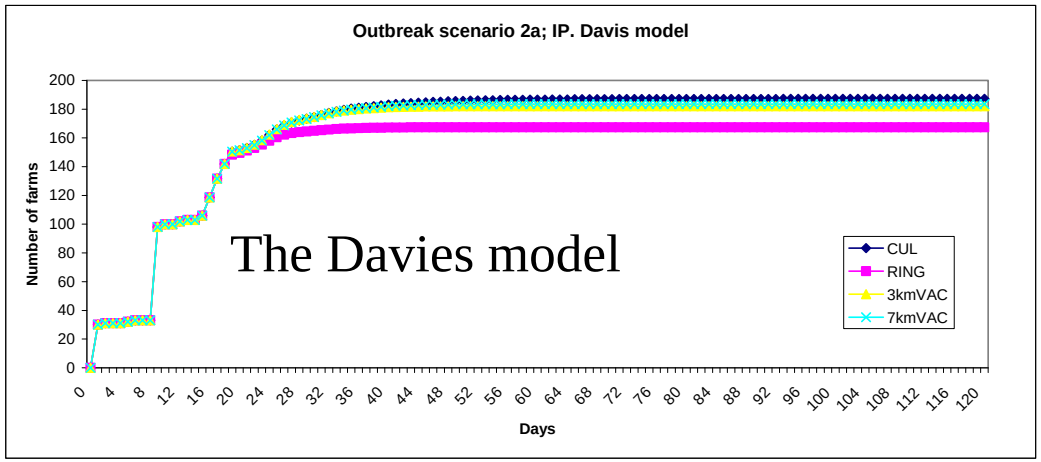
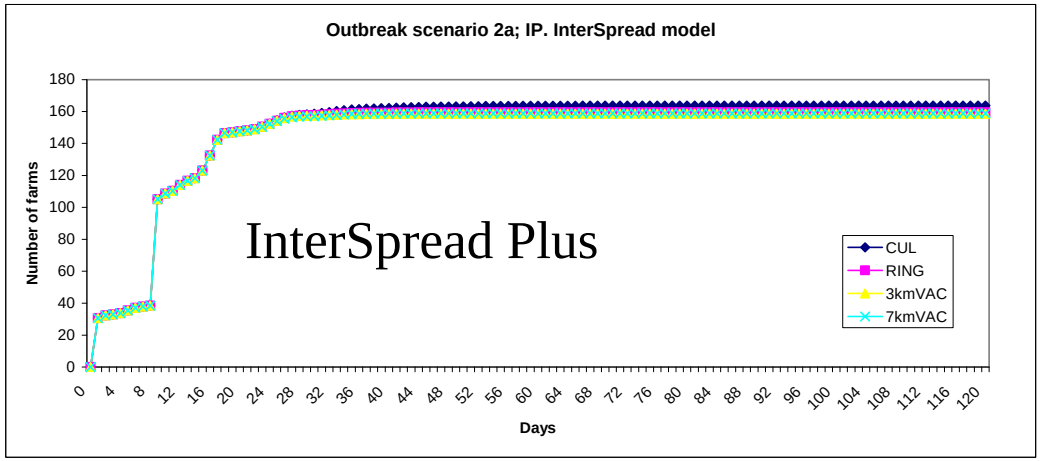
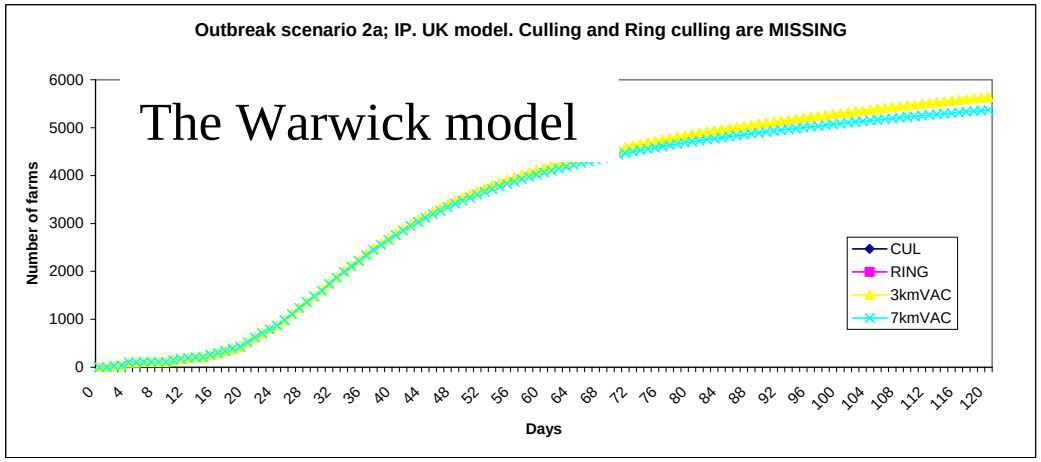
Number of infected herds in the large outbreak scenario after 120 days







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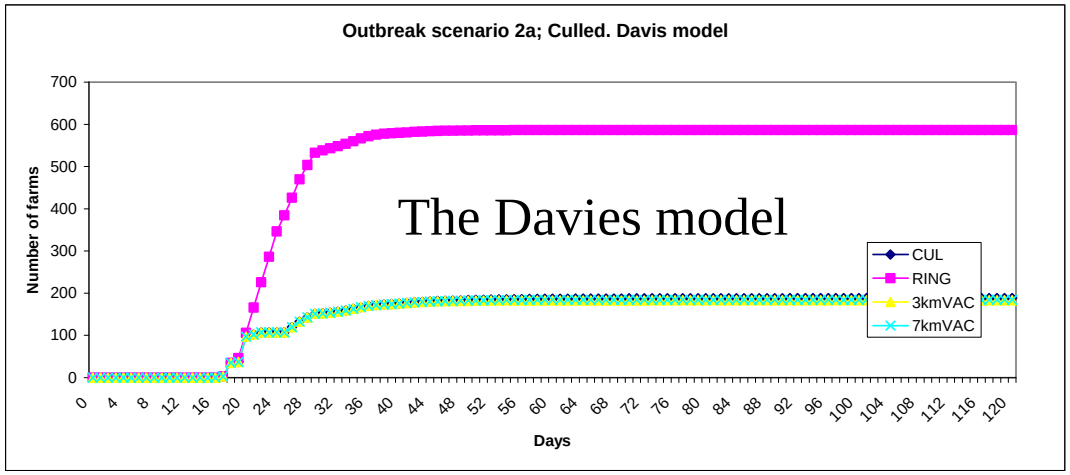
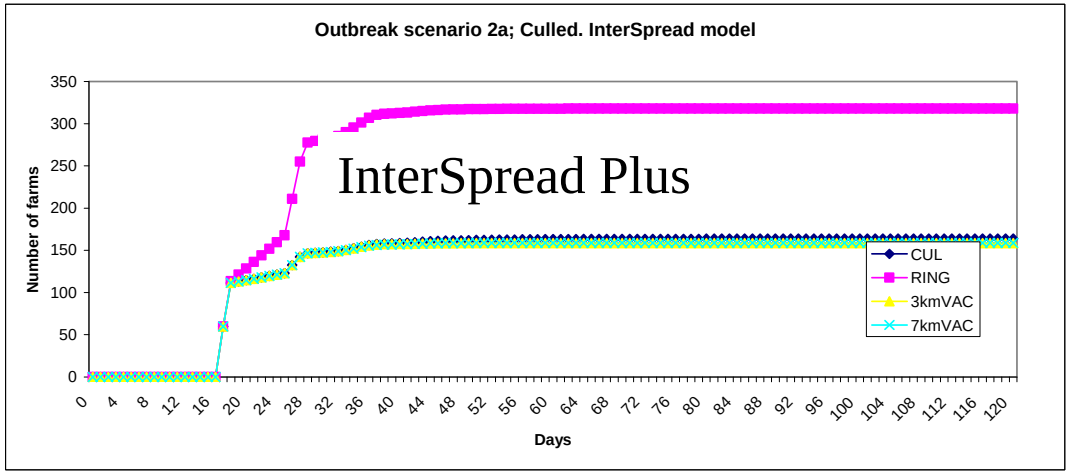
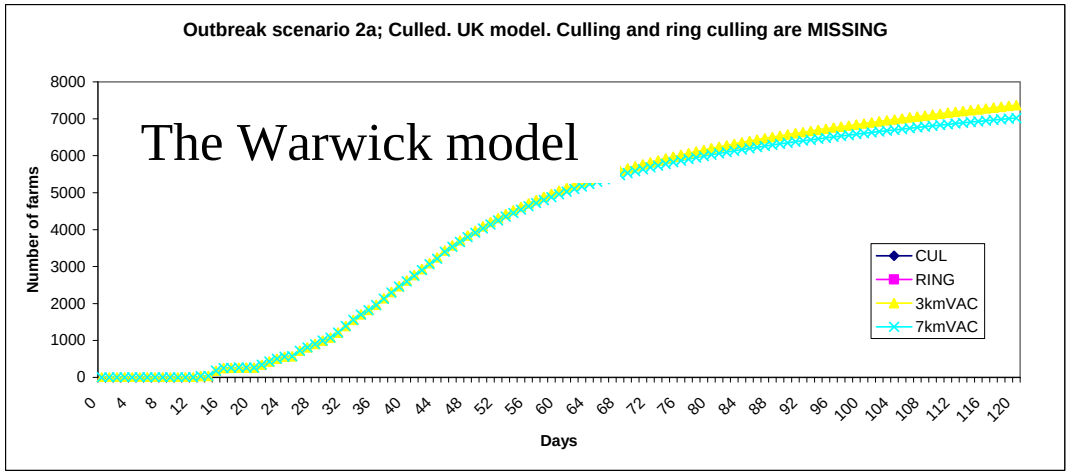
Number of culled herds in the large outbreak scenario after 120 days







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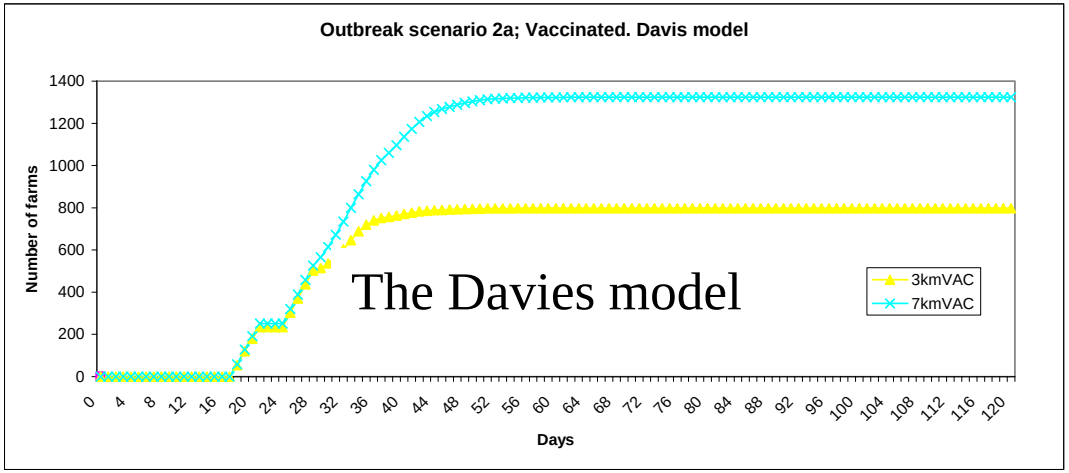
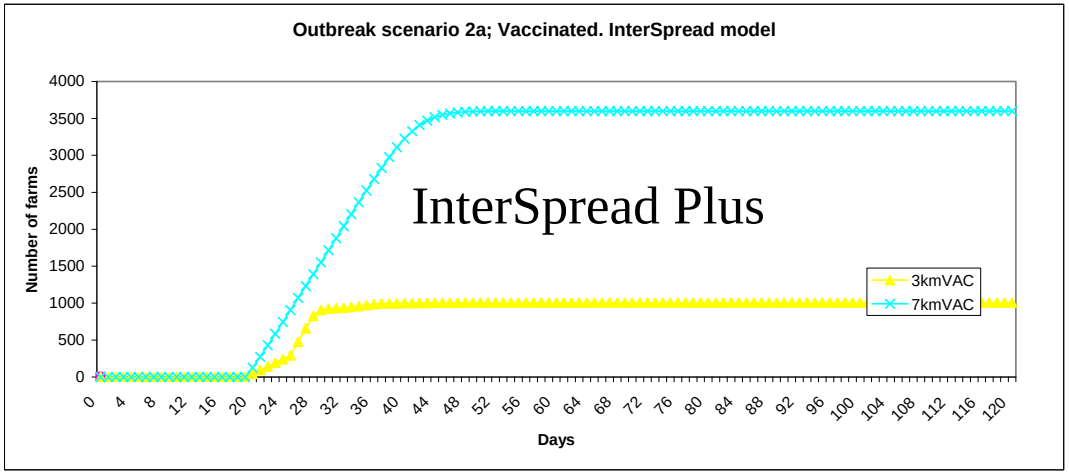
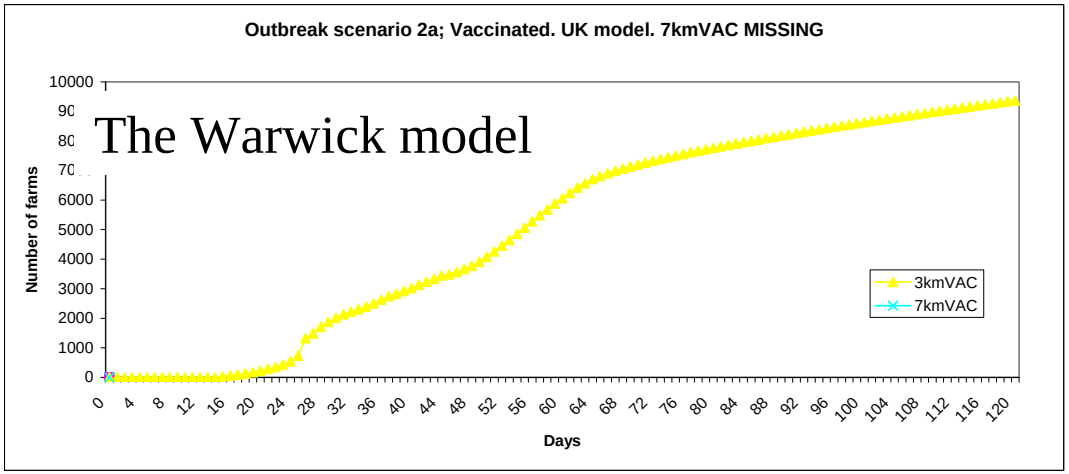
Number of vaccinated herds in the large outbreak scenario after 120 days







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General conclusions

- Significant different in the behaviour of the outbreak
  - The Warwick model gave relatively long lasting outbreaks
  - The Warwick model gave relatively large outbreaks with many infected herds
- Interaction between type of scenario (seed, initial conditions) and model.
  - Some ‘seeds’ did not generated large differences

Critical aspects of the Davies model and InterSpread Plus

- You have to believe in the parameter estimates used in the model.
- The values of the parameters used in the models are very often based on gut feelings and not obtained from experimental and observational studies
- Need to understand the biological process in disease transmission

Critical aspects of the Warwick model

- Parameter estimates theoretical based on the transmission pattern in real outbreaks – UK 2001.
- Limited flexibility
  - Assuming this was an average outbreak
  - Transmission curve includes the effect of: virulence of the FMD virus, windborne spread, illegal movement, indirect contact
  - The transmission curve can not be adjusted given specific knowledge to some of the parameters
- Driven by herd density – high herd density increase the spread.

Important aspects of FMD epidemiology that the models ignore

- The effect of quantity of virus: relation between amount of infectious particles and incubation time
- Do not include specific details about transmission between pig-pig, pig-cow, cow-pig, pig-sheep and sheep-pig because of missing knowledge
- Susceptibility and transmission rates are not well known, and these have major influence on the transition probabilities. Small changes in these parameters may have dramatically effects on the output
- The character of any FMD epidemic is decided by a series of stochastic events during the first days during the silent period. These events have large effect of the output of models.

Experience gained from the project - I

- Importance of output parameters may differ depending on the country.
  - In Denmark we are focusing on the duration of the outbreak because of the possibilities to regain export opportunities
- No standardized approach to compare output of models

Experience gain from the project - II

- Interaction between the effect of control measures, ‘seed’ and model used in the simulation
- Depending on the reason for simulation, even if the models behave very different, the conclusion that is based on the model output can be the same

Acknowledgement

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