

## Epidemiological consequences of vaccination against Foot and Mouth Disease

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### Background

Outbreaks of Foot and Mouth Disease (FMD) in the Netherlands represent a major risk to the Dutch farming industry, as around 17 million cattle, pigs and sheep can be infected by the virus. To control an epidemic, emergency vaccination is now preferred to preemptive culling. This policy change raises the following questions:

- what is the most effective strategy for emergency (ring) vaccination?
  - what is the effect if pig farms were excluded from emergency vaccination?
  - what is the most efficient end screening strategy to declare the affected area free of infection?
- These issues are addressed by a model analysis that evaluates the effectiveness and safety of vaccination strategies in controlling an FMD epidemic.

### Model

A stochastic individual-based model was developed that describes the transmission dynamics at two distinct levels.

The within-herd module:

- describes the virus transmission between animals
- takes differences between animal species into account
- describes the effect of vaccination on individual level
- is parameterized using vaccination and transmission experiments

The between-herd module:

- describes the probability of virus transmission between herds depending on the interherd distance
  - is parameterized using the outbreak data of the 2001 epidemic in the Netherlands (virus strain O/NET/2001)
  - distinguishes four farm types (assumed relative infectivity and susceptibility)
- The overall model is used to simulate the course of a hypothetical epidemic.

The model uses location coordinates and herd sizes of the Dutch farm data of 2006 (see Fig.1); simulations start in a densely populated livestock area in a cattle herd that infects 10 other herds during the High Risk Period.

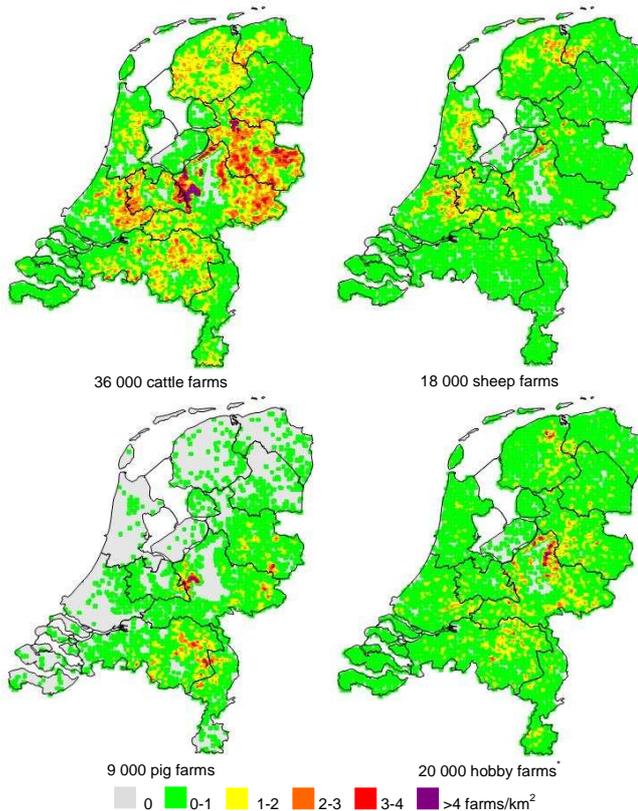


Fig.1 Farm densities of Dutch farming structure in 2006  
 hobby farms are here small sheep flocks held for recreational purposes

### Results

The results of six control strategies are shown in Tab.1 and Fig.2

Tab.1 Results of six control strategies: median values (5%-95% percentiles)

control strategy	duration (days)	# detected farms	# preemptively culled farms	# vaccinated farms
minimal (EU)	259 (181 - 390)	1640 (1126 - 2145)	0 (0 - 0)	0 (0 - 0)
1 km ring culling	67 (30 - 124)	45 (17 - 97)	974 (342 - 1870)	0 (0 - 0)
2 km ring vaccination	76 (41 - 133)	72 (23 - 162)	165 (76 - 300)	2416 (706 - 4400)
2 km vaccination except pig farms	85 (40 - 152)	85 (23 - 215)	165 (76 - 300)	2159 (574 - 4624)
5 km ring vaccination	52 (34 - 91)	43 (19 - 89)	165 (76 - 300)	4065 (1935 - 7469)
5 km vaccination except pig farms	55 (33 - 106)	45 (19 - 105)	165 (76 - 300)	3509 (1542 - 7516)

The minimal control strategy as required by the EU: culling of detected infected herds, tracing of their dangerous contacts and regulation of transport.

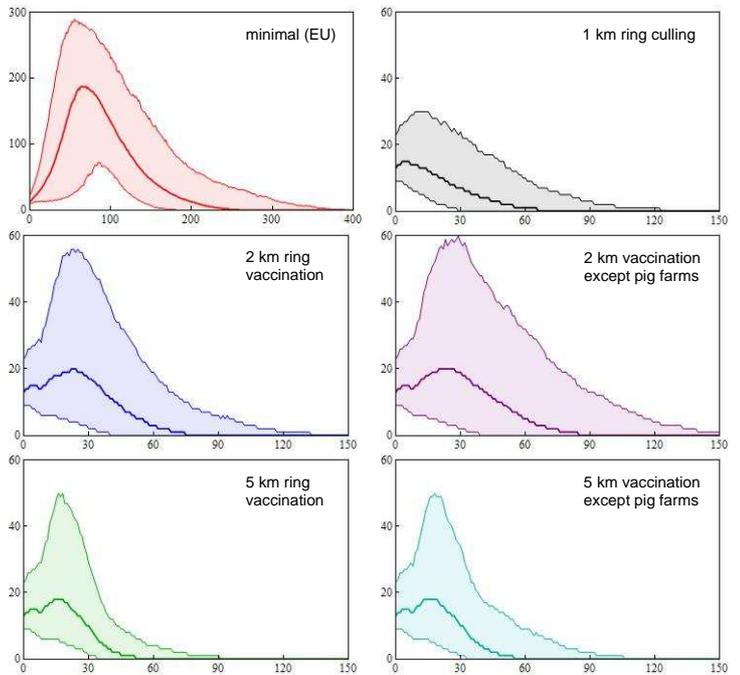


Fig.2 Epidemic curves for six control strategies: number of infectious farms as a function of time since the first detection; median curves (thick line) and 5%-95% interval (shaded area)

A fraction of the infected herds are not clinically detected during the epidemic; undetected animals are mainly present on sheep herds and vaccinated cattle herds, and should be detected serologically during the end screening.

### Conclusions

- In sparsely populated livestock areas (2 farms/km<sup>2</sup>) the EU control strategy suffices (not shown here), but in densely populated livestock areas (4 farms/km<sup>2</sup>) additional measures are necessary to control the epidemic
- 2 km ring vaccination is much more effective than the minimal strategy required by the EU but less effective than 1 km ring culling
- 5 km ring vaccination and 1 km ring culling are equally effective (with unlimited vaccination capacity)
- Under the model assumptions hobby farms have a negligible effect on the epidemic size and duration (not shown here)
- Excluding pig farms from vaccination has a significant but limited effect on the epidemic size and duration (for the virus strain under study)
- End screening should be targeted to sheep farms and vaccinated cattle farms
- With the current EU end screening guidelines, the risk of infected animals remaining after the epidemic and end screening is comparable for vaccination and culling strategies (not shown here)