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Comparison of different control strategies of two highly infectious animal diseases – results of a simulation model

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Highly infectious animal diseases

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Characteristics:

- Serious and rapid spread
- Serious socio-economic or public health consequences
- Major importance in the international trade

Two candidates are:

- Foot-and-Mouth Disease (FMD)
- Classical Swine Fever (CSF)

Disease characteristics of foot-and-mouth disease (FMD)

Agent: Aphtovirus of family picornaviridae

Host: cloven-hooved animals (cattle, sheep, goats, pigs, wild relatives)

Clinic: morbidity up to 100%, mortality low in adults (higher in young animals)

- Blisters on the mouth (tongue, lips, nose) with hypersalivation
- Blisters on feet (between toes, above hooves)
- Fever, apathy, milk reduction



Source: US Department of Agriculture, Plum Island Animal Disease Center (PIADC)



Disease characteristics of Classical Swine Fever (CSF)

Agent: Pestivirus of the family flaviviridae

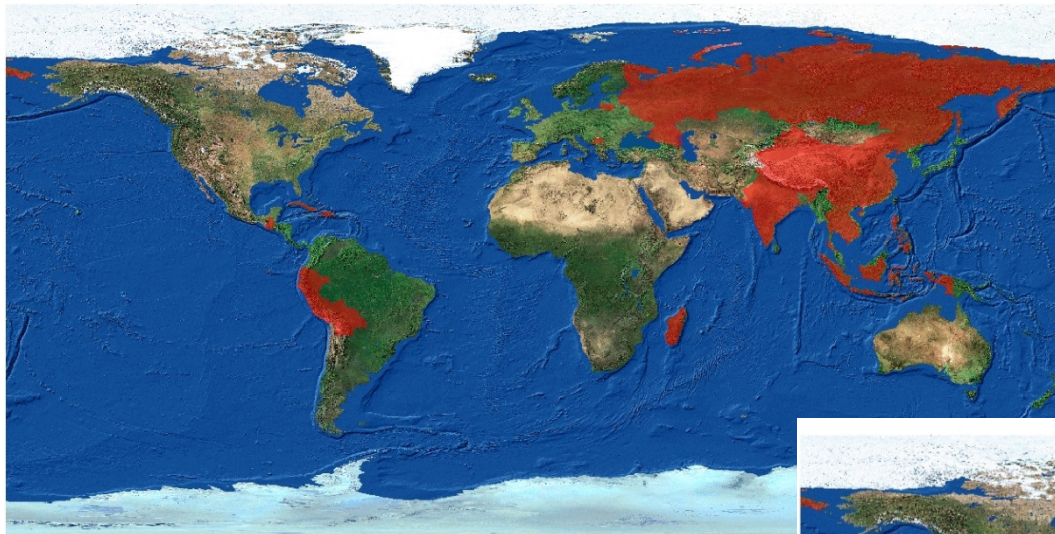
Host: Domestic and wild pigs

Clinic:

- peracute form (mortality up to 100%) or acute form (typical symptoms) → more in young pigs
- subacute form (unspecific syndroms) or chronic form → more in adults

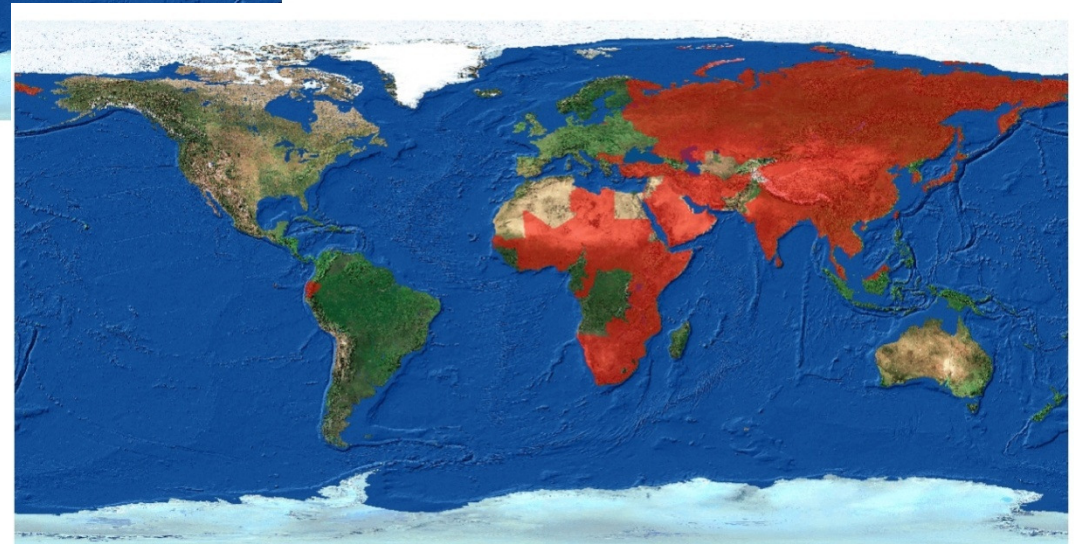


Global situation of FMD and CSF in 2010/2011



Classical Swine Fever

■ Countries with classical swine fever:



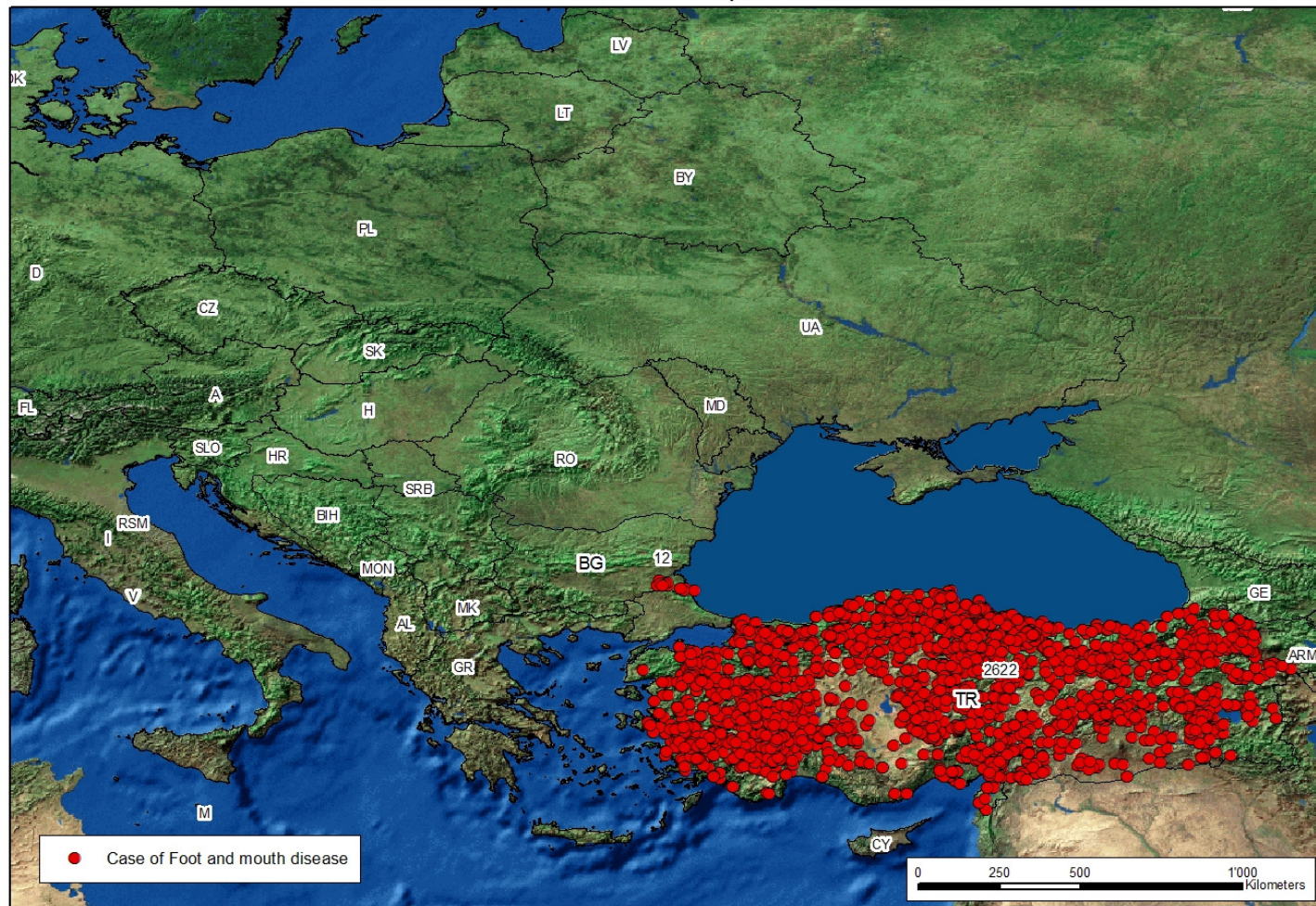
Foot-and-mouth disease

■ Countries with foot and mouth disease:

FVO, August 2011 - mbi

Situation of FMD in Europe (2009/2010)

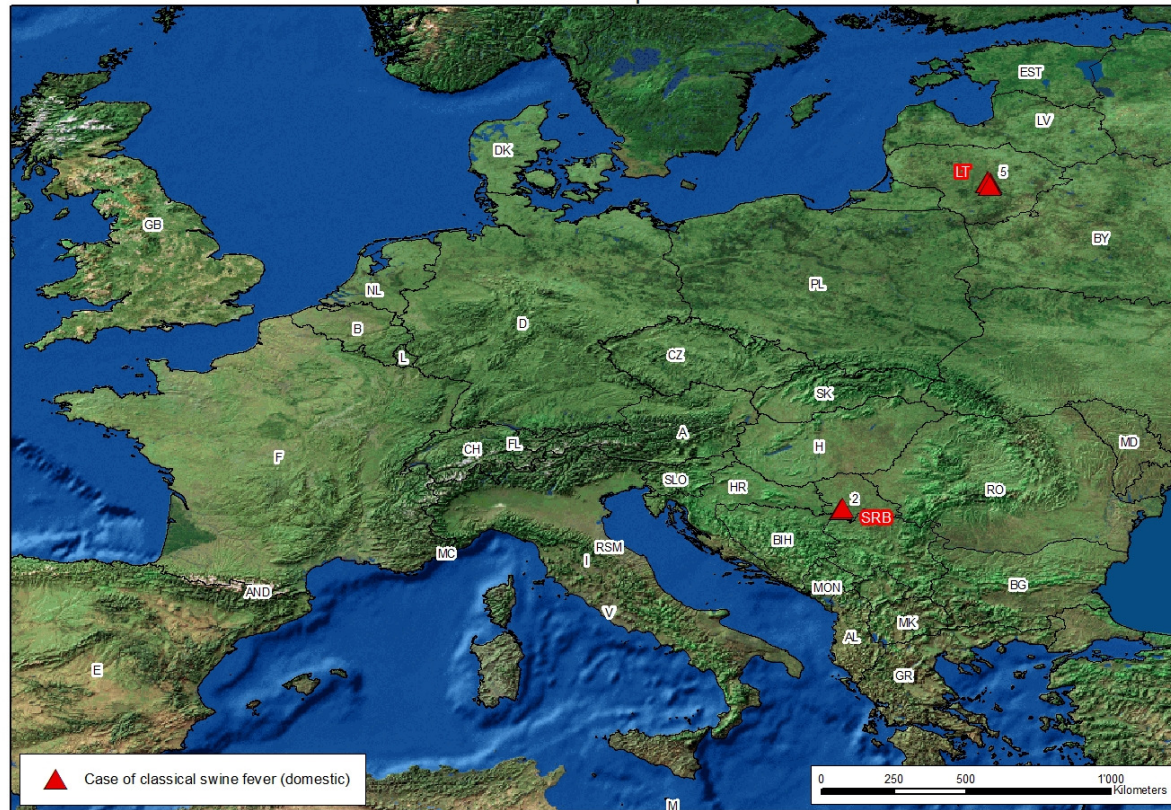
Foot and mouth disease in Europe 2010 und 2011



FVO, July 2011 - mbi

Situation of CSF in Europe (2009/2010)

Classical swine fever in Europe 2010 and 2011



FVO, July 2011 - mbi

Transmission modes:

- Direct animal-to-animal contact
- Feeding of contaminated meat
- By living (people, unsusceptible animals) or inanimate (lorries, cloths) vectors
- Aerosol spread

Examples of outbreaks in previously free countries: FMD outbreak in UK in 2001



Thompson D. et al., Rev Sci Tech, 2002

2000 outbreaks

Animals slaughtered:

- 4 million because of disease control
- 2 million because of animal welfare reasons

Economic loss of £3.1 billion



Examples of outbreaks in previously free countries: CSF outbreak in the Netherlands in 1997/8

430 outbreaks

Animals slaughtered:

- 2 million because of disease control
- 8 million because of animal welfare reasons

Economic loss of US\$ 2.3 billion



Possible control strategies

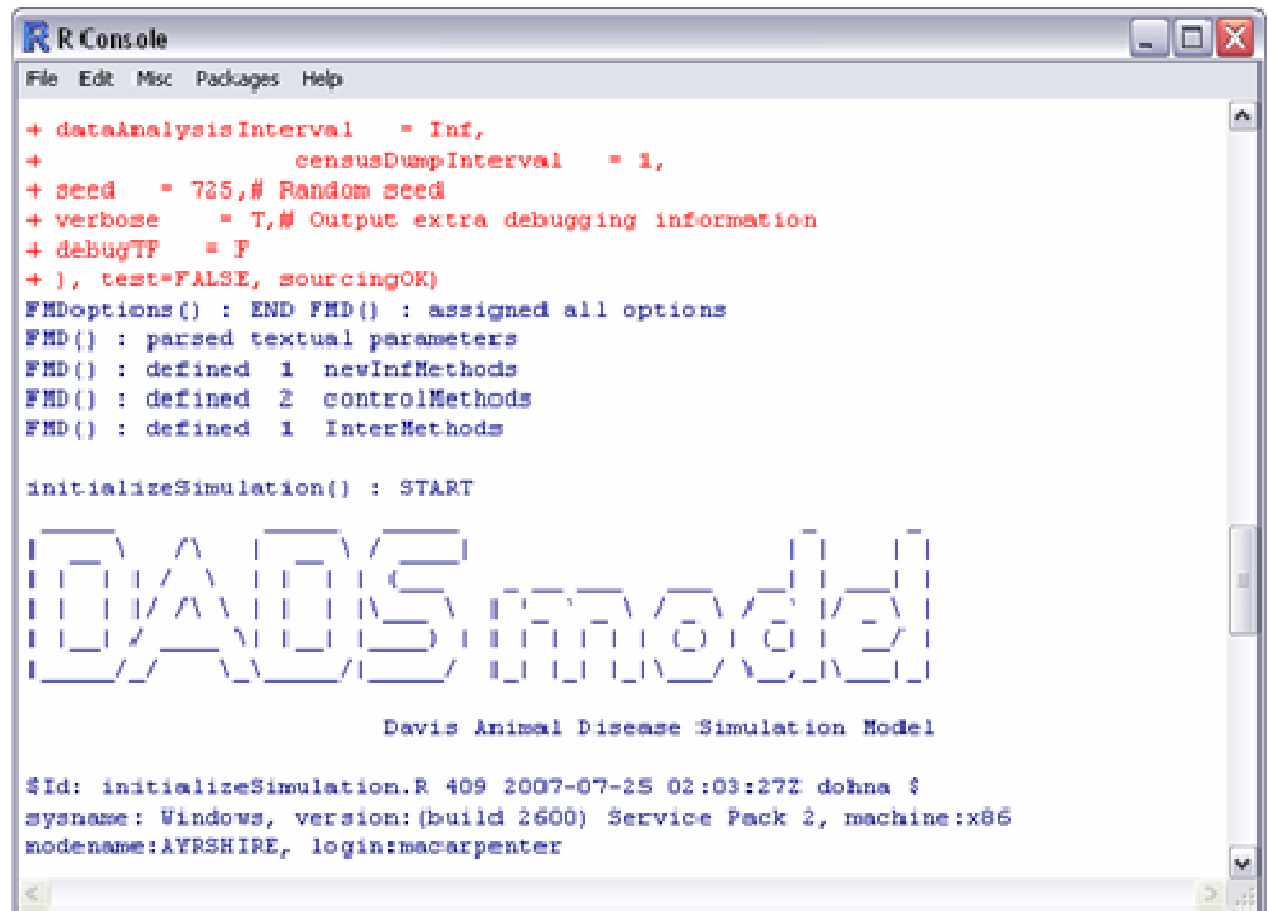
Control strategy	Effect
Prescribed control strategy by legislation	
Movement restrictions of animals, material and persons	Reduction of effective contacts
Tracing backward/forward	Find the infected
Culling of infected premises (stamping out)	Reduction of infected
Additional options	
Vaccination	Reduction of suseptibles
Pre-emptive culling	Reduction of suseptibles

Do additional strategies like **vaccination or pre-emptive culling** result in any benefit regarding the duration and size of the outbreaks in a country like Switzerland with a **low animal density**?

Davis Animal Disease Simulation (DADS) model

Characteristics:

- Within-herd and between-herd transmission
- Individual animal-based
- Stochastic
- Spatial and temporal analysis



```
R Console
File Edit Misc Packages Help

+ dataAnalysisInterval = Inf,
+   censusDumpInterval = 1,
+ seed = 725, # Random seed
+ verbose = T, # Output extra debugging information
+ debugTF = F
+ ), test=FALSE, sourcingOK)
FMDoptions() : END FMD() : assigned all options
FMD() : parsed textual parameters
FMD() : defined 1 newInfMethods
FMD() : defined 2 controlMethods
FMD() : defined 1 InterMethods

initializeSimulation() : START

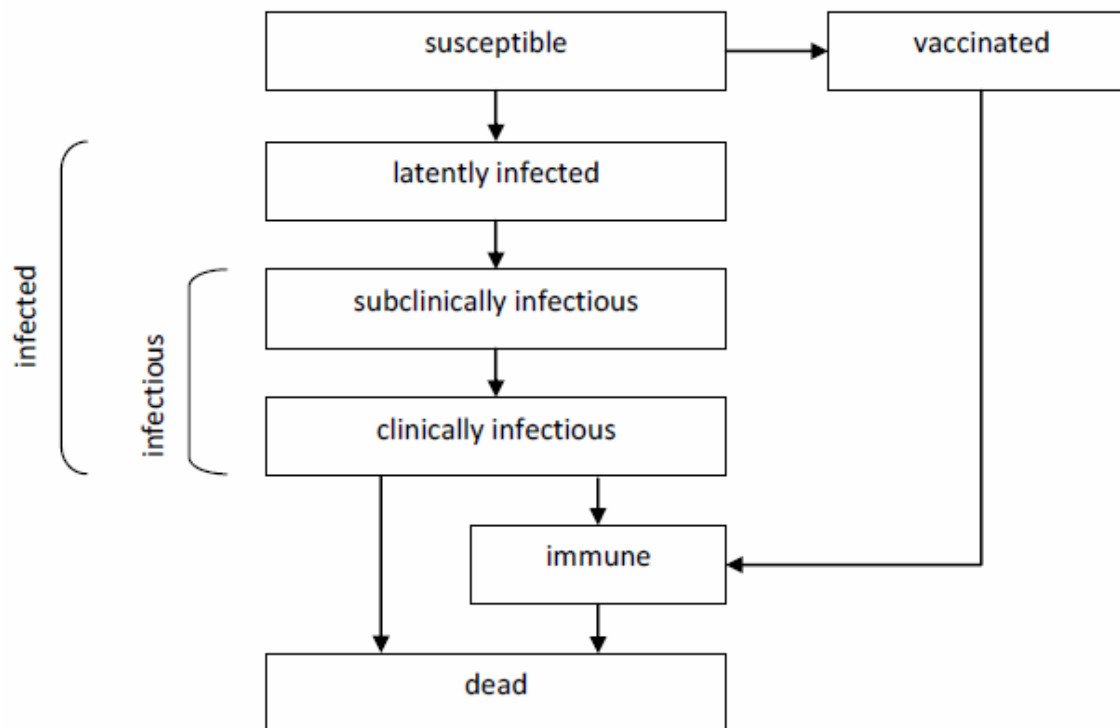
DADS model

Davis Animal Disease Simulation Model

$Id: initializeSimulation.R 409 2007-07-25 02:03:27Z dohna $
sysname: Windows, version: (build 2600) Service Pack 2, machine:x86
nodename:AYRSHIRE, login:macarpenter
```

Intra-herd disease spread

Individual disease stages:



Reed-Frost dynamic:

L_{t+1} = number of latent individuals for day $t+1$:

$$L_{t+1} = S_t \left(1 - \left(1 - \frac{k}{N-1} \right)^{I_t} \right)$$

S_t = number of susceptible individuals

k = number of daily contacts per animal

N = herd size

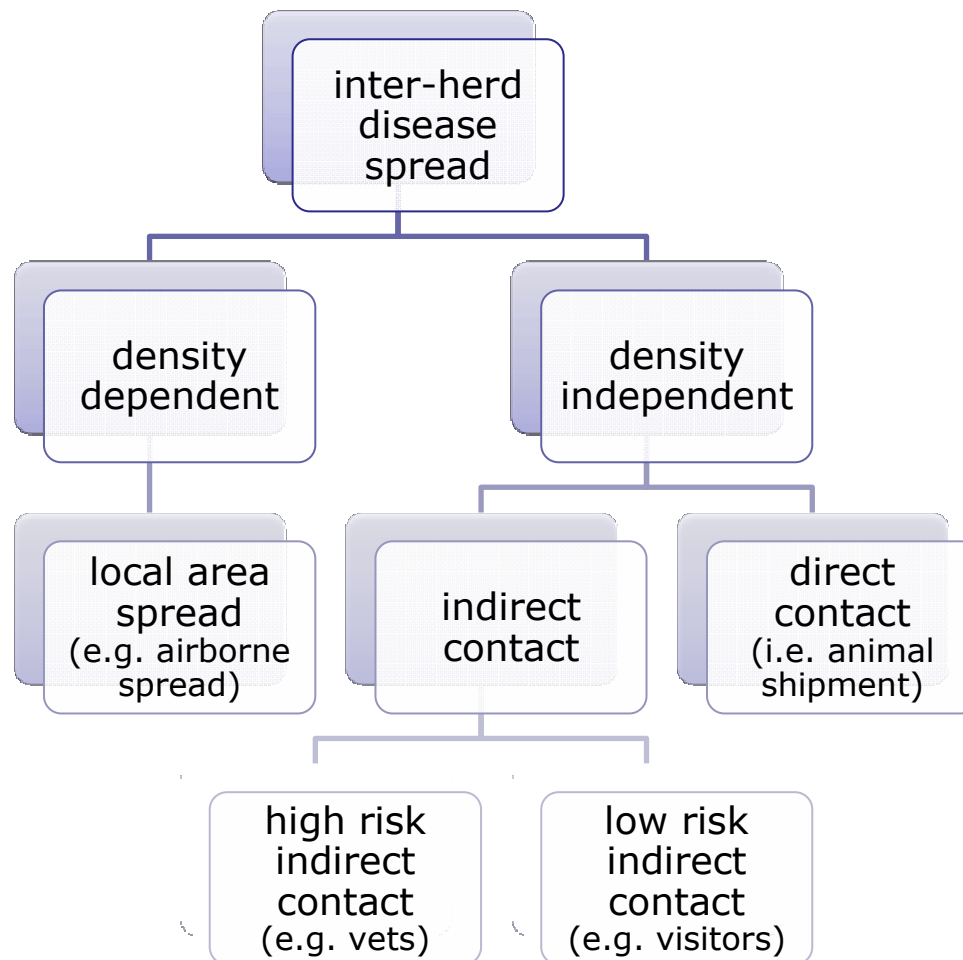
I_t = number of infectious individuals

Inter-herd disease spread

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Dependence of the contacts

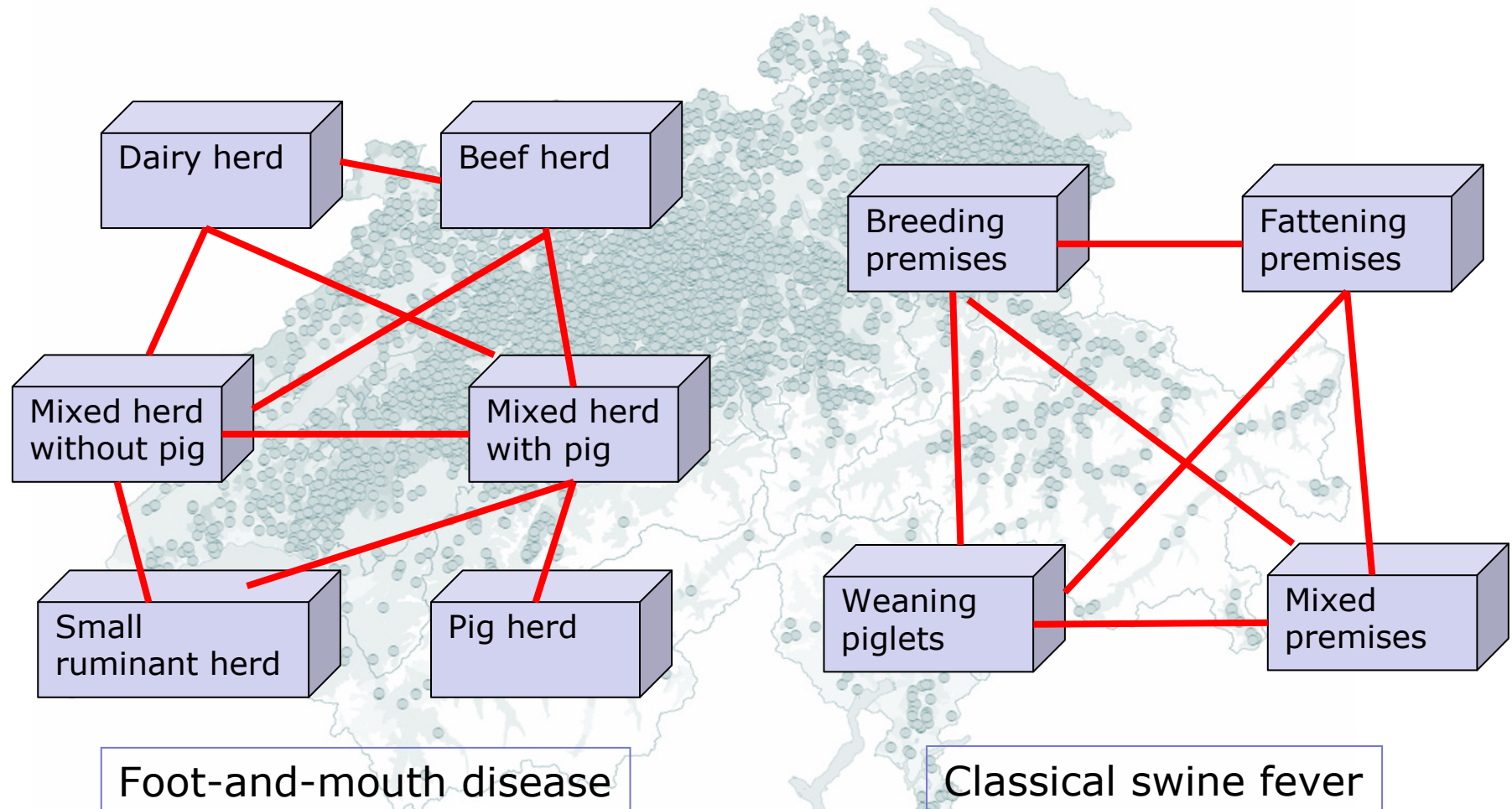
- Direct contact:
 - Contact rates of shipping and receiving herd
 - Distance between herds
 - Herd type
- Indirect contacts:
 - Contact rates
 - Distance between herds
- Local area spread:
 - Same for all herds
 - probability of daily transmission within a given radius around the infected herd

Herd types

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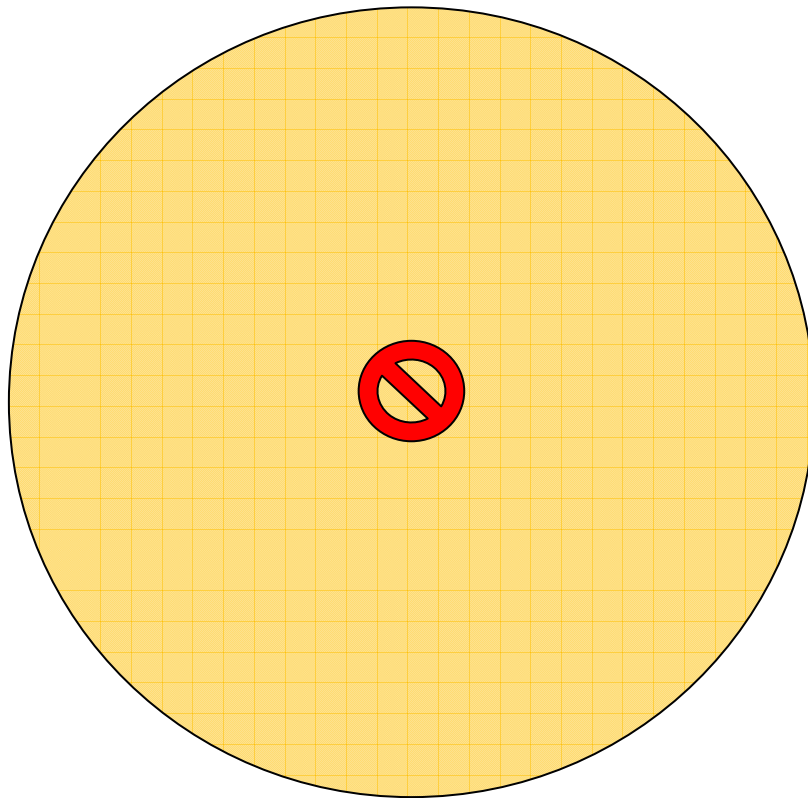
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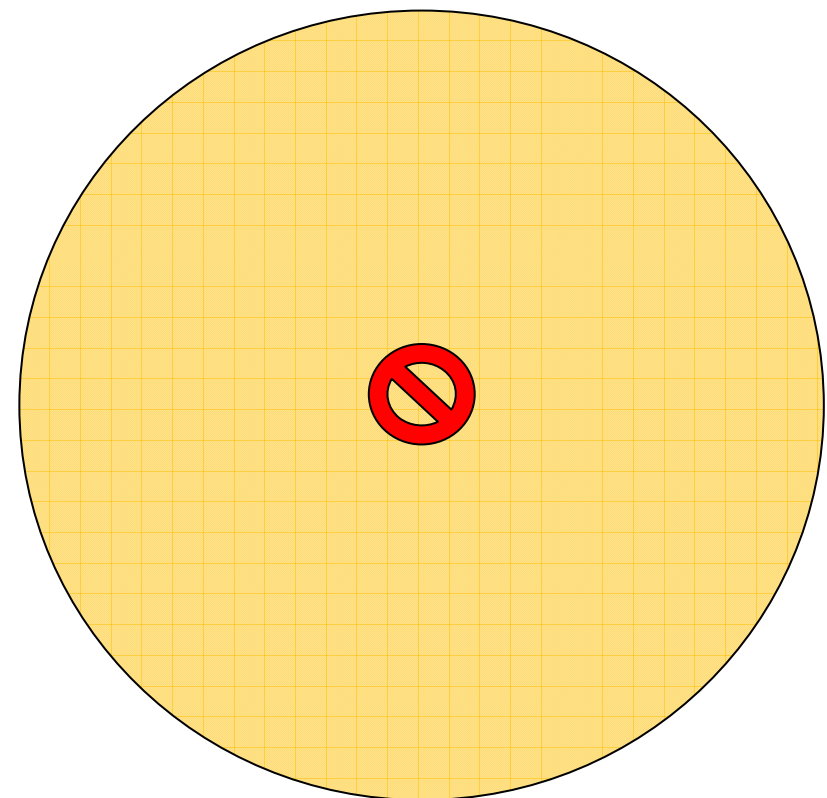
Control strategies: Baseline strategy

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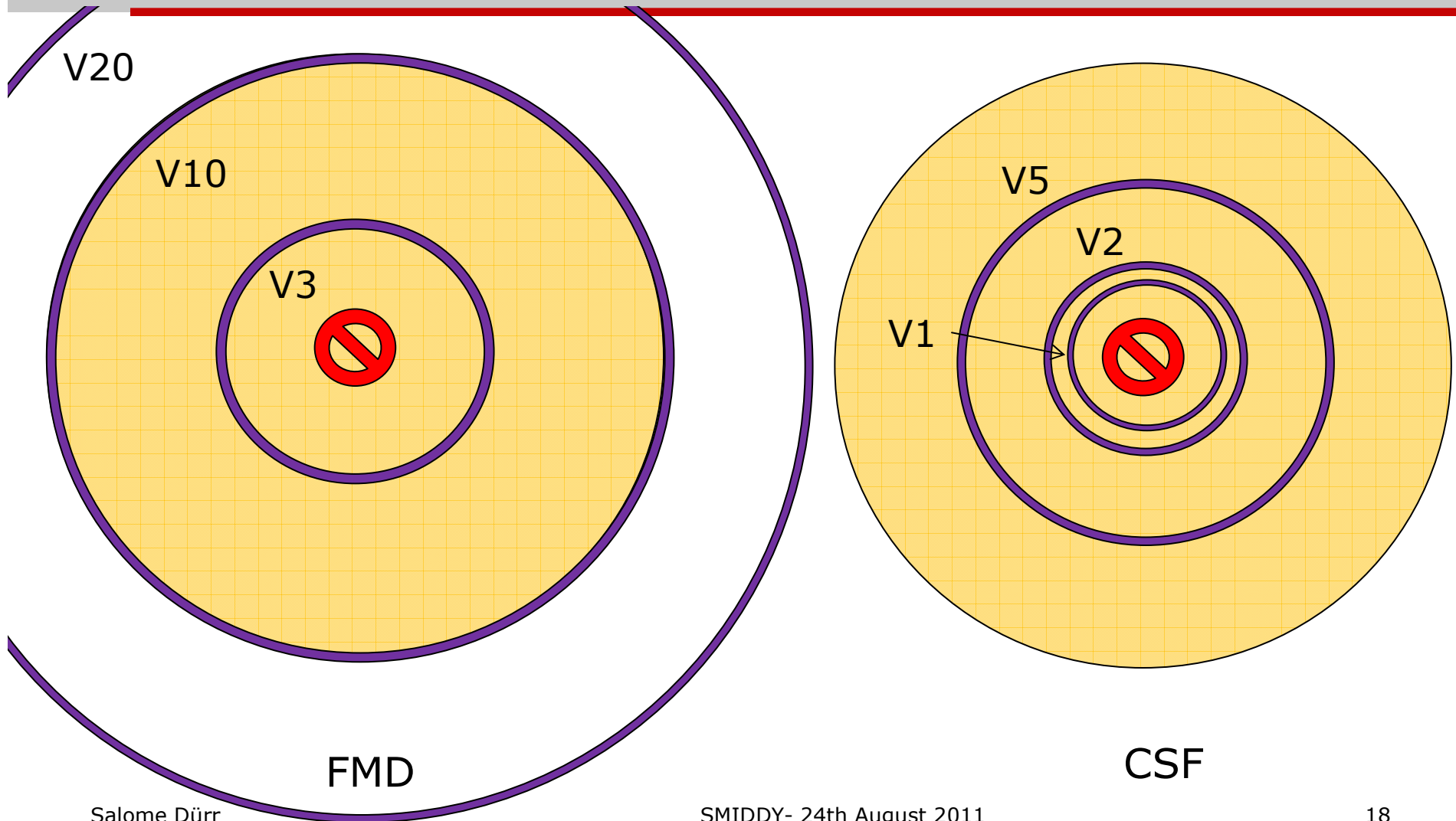


FMD

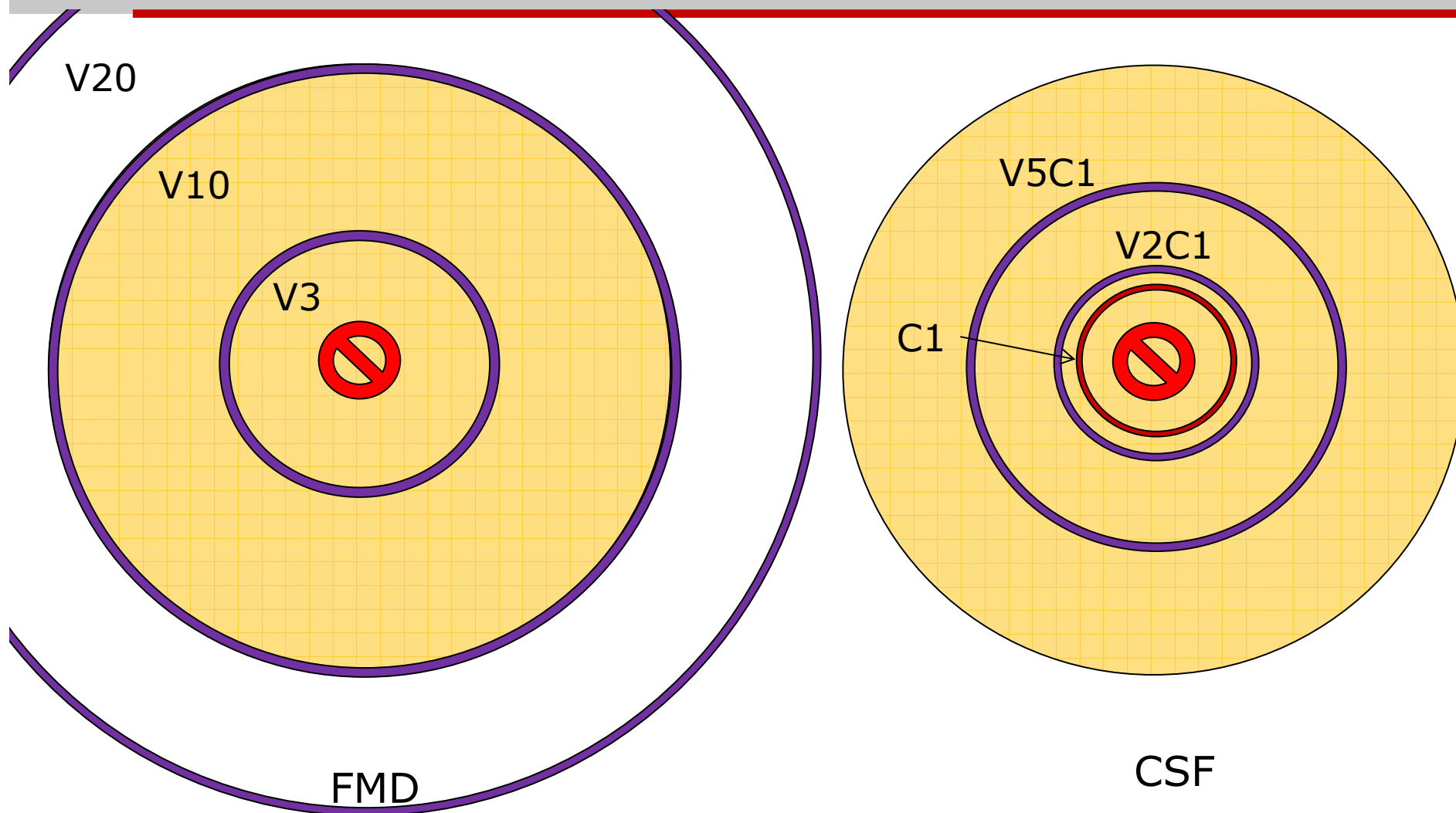


CSF

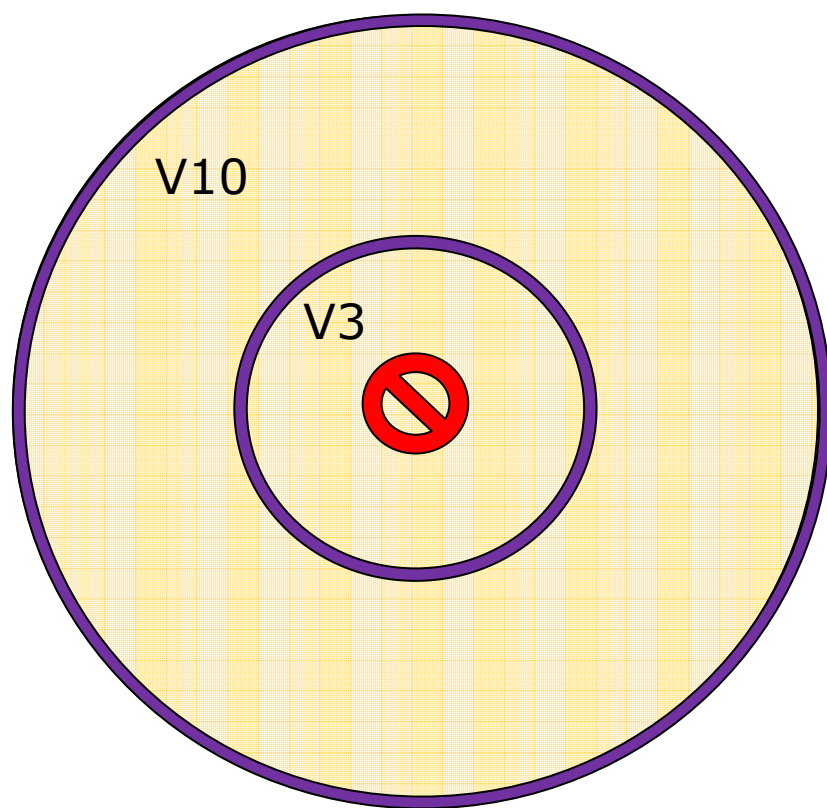
Control strategies: additional emergency vaccination



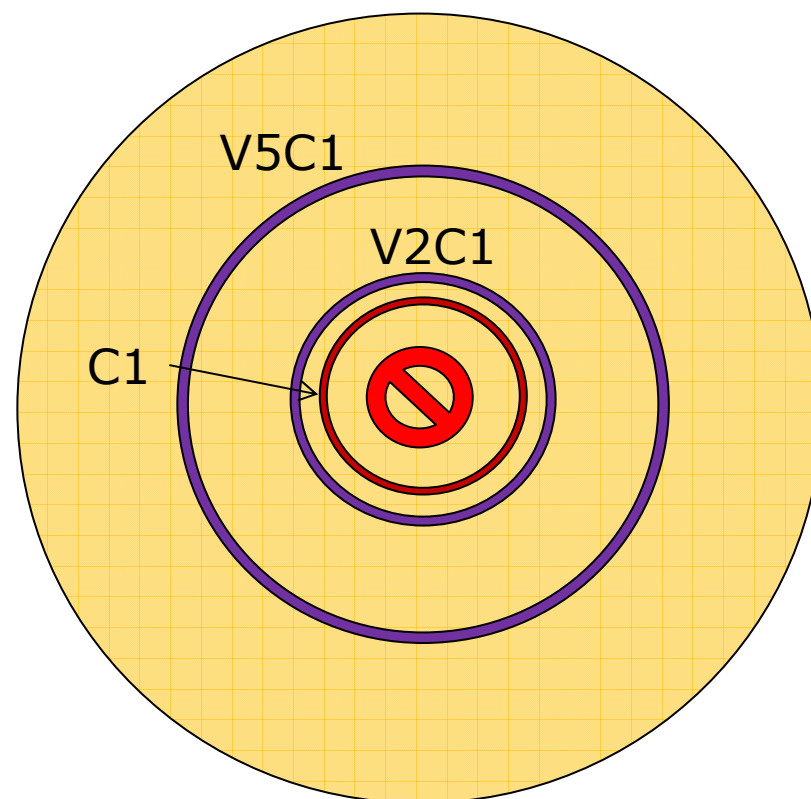
Control strategies: additional pre-emptive culling



Control strategies: reduced compliance of movement restrictions



FMD

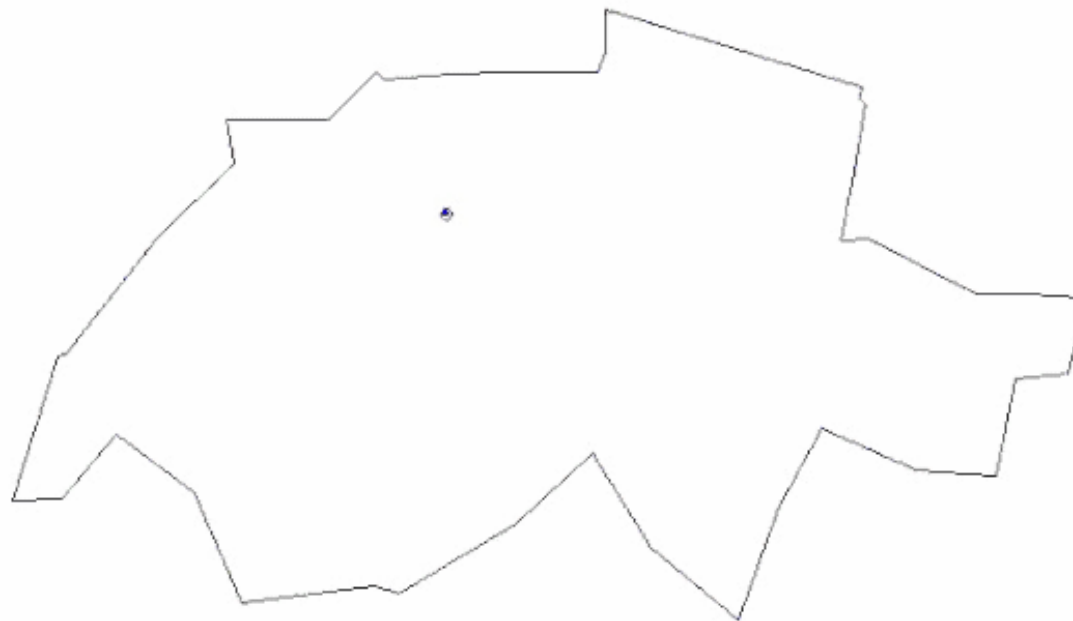


CSF

Outbreak of CSF

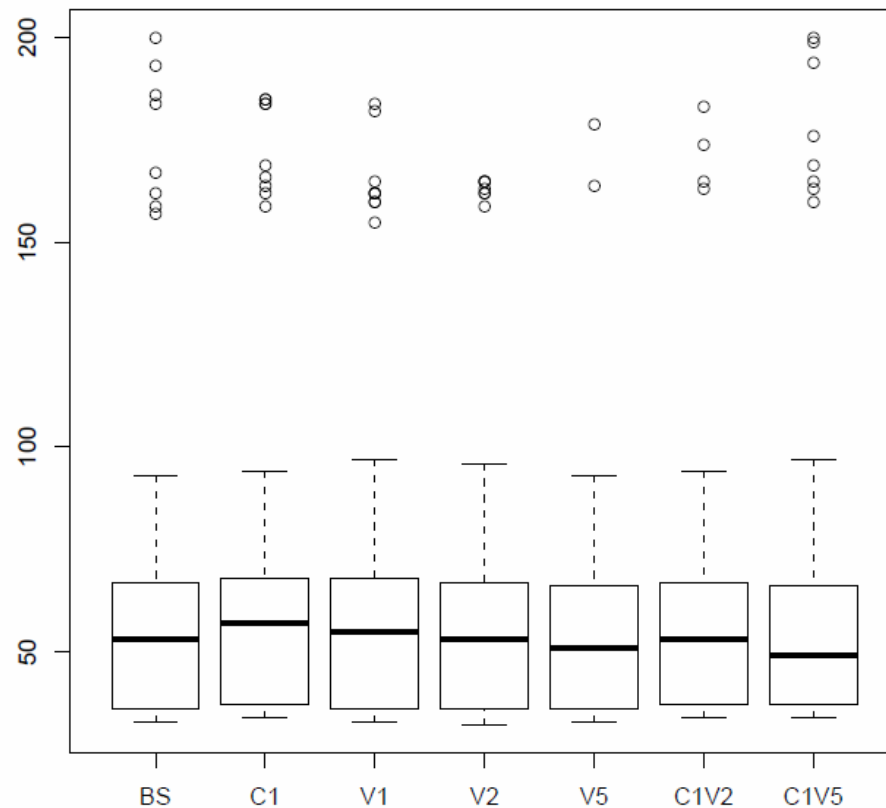
Day: 1

- Latent
- ♦ Subclinical
- Clinical
- ♦ Immune
- ◊ Index herd
- Movement restriction

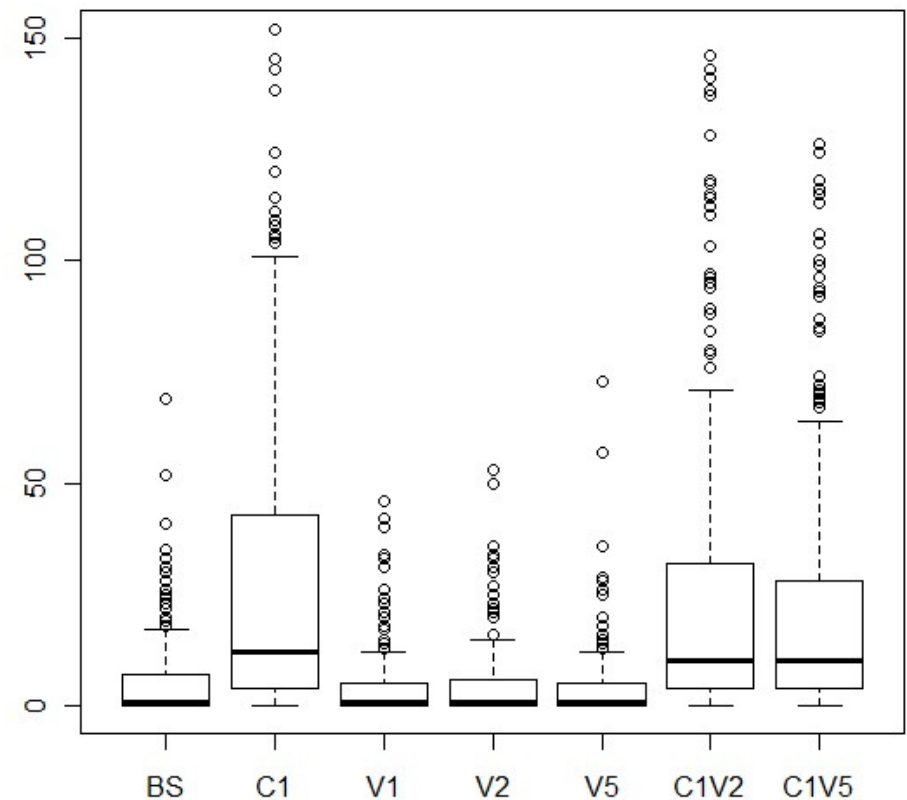


Results Classical Swine Fever

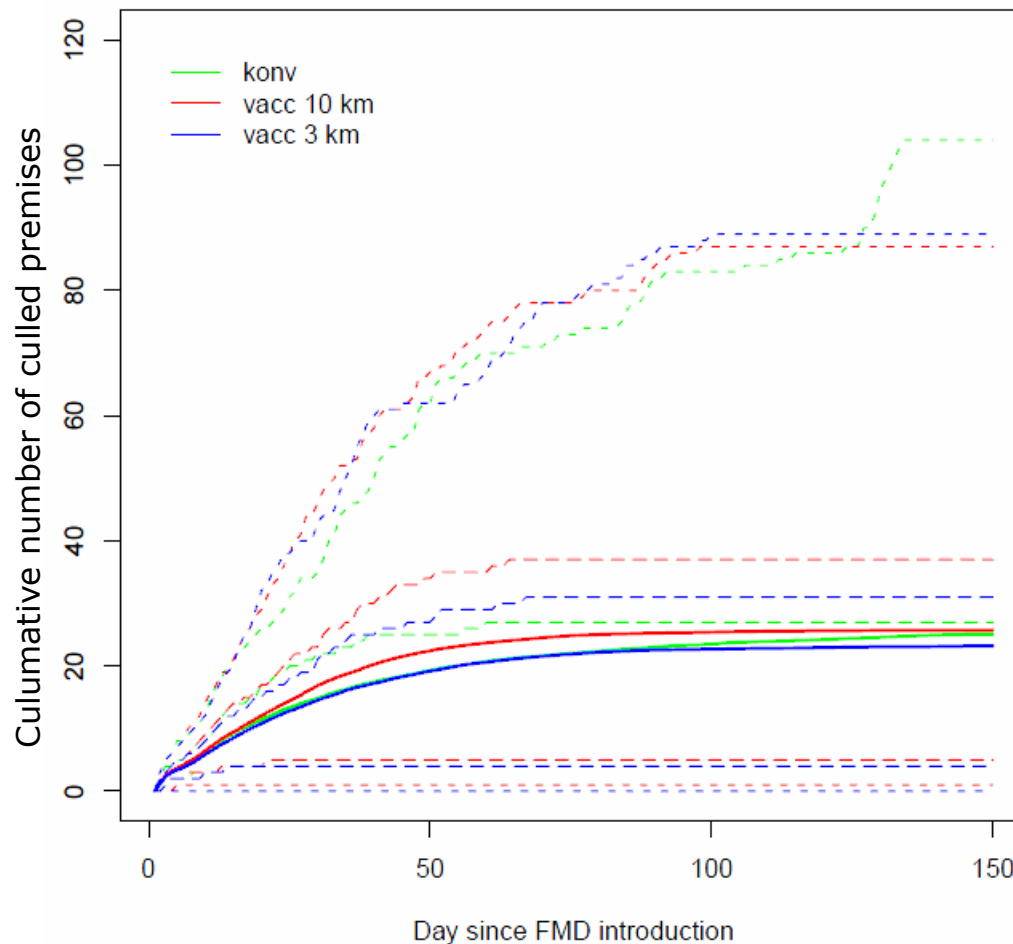
outbreak duration in days



number of culled premises



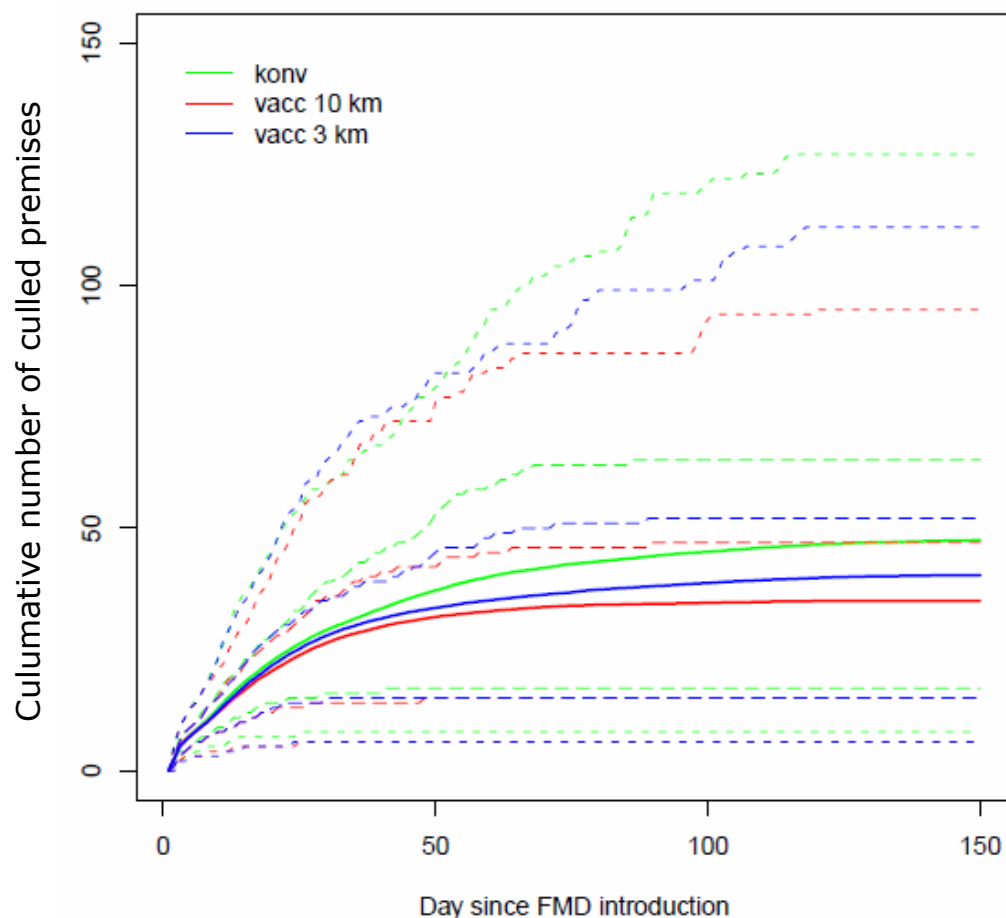
Results Foot-and-mouth disease I, 21 index herds



Cumulative number of culled premises during the outbreak, started with 21 index herds (mean, 75% C.I., 95% C.I):

- No advantage of the vaccination
- No statistical difference for the 25% longest and biggest outbreaks

Results Foot-and-mouth disease II, 50 index herds

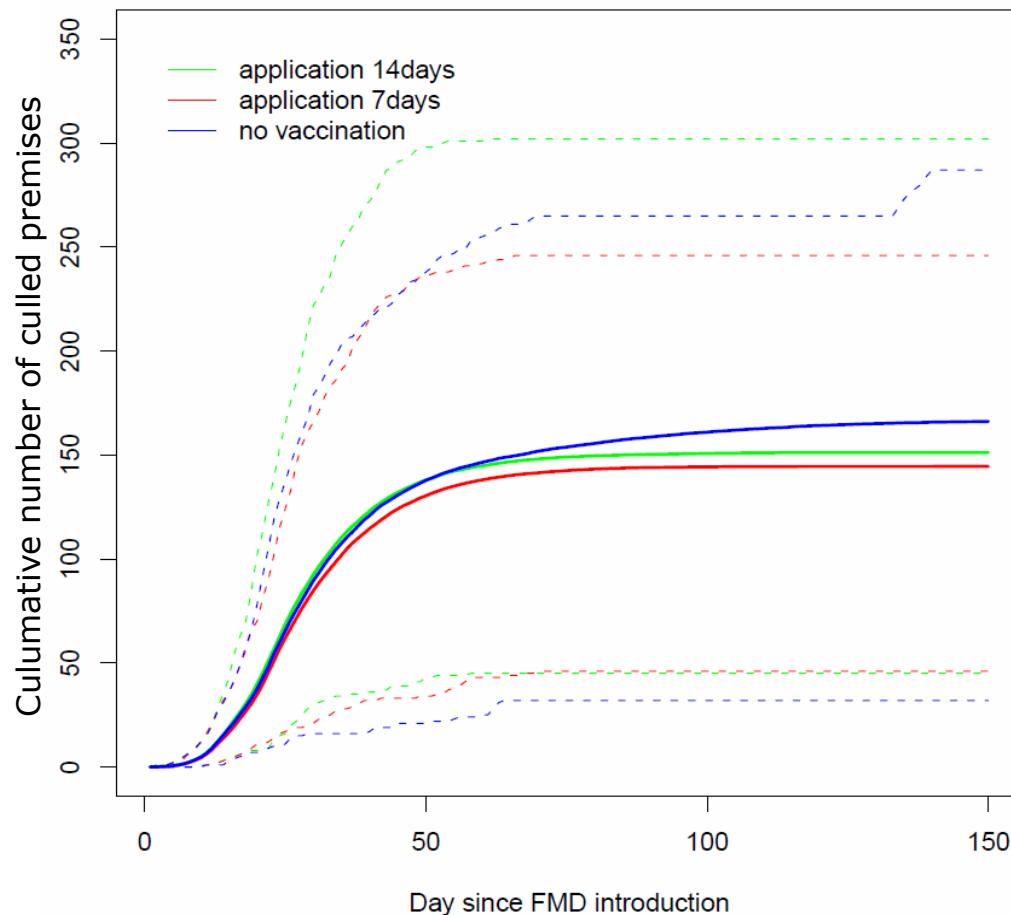


Cumulative number of culled premises during the outbreak, started with 50 index herds (mean, 75% C.I., 95% C.I):

- Vaccination shows a benefit
- 25% biggest outbreaks were significantly underrepresented in the V10 ($p=0.001$) and V3 ($p=0.027$) strategy

When starting later in an outbreak, emergency vaccination reduces the chance of big and long outbreaks

Results Foot-and-mouth disease III, 20km vaccination

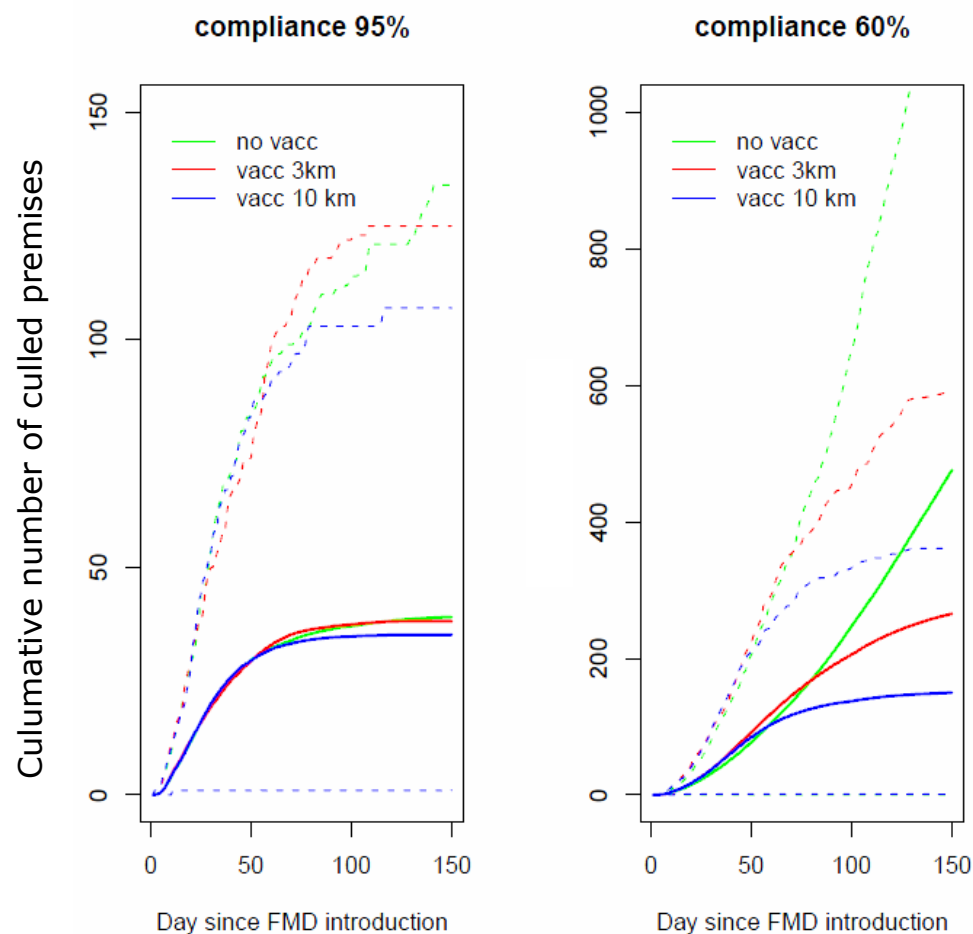


Cumulative number of culled premises during the outbreak, started with 1 index herd (mean, 95% C.I):

- Vaccination shows a benefit
- 25% biggest outbreaks were significantly underrepresented in the V20 ($p=0.011$ for 14 days application)

When applying an area-wide emergency vaccination, it reduces the chance of big and long outbreaks

Results Foot-and-mouth disease IV, reduced compliance

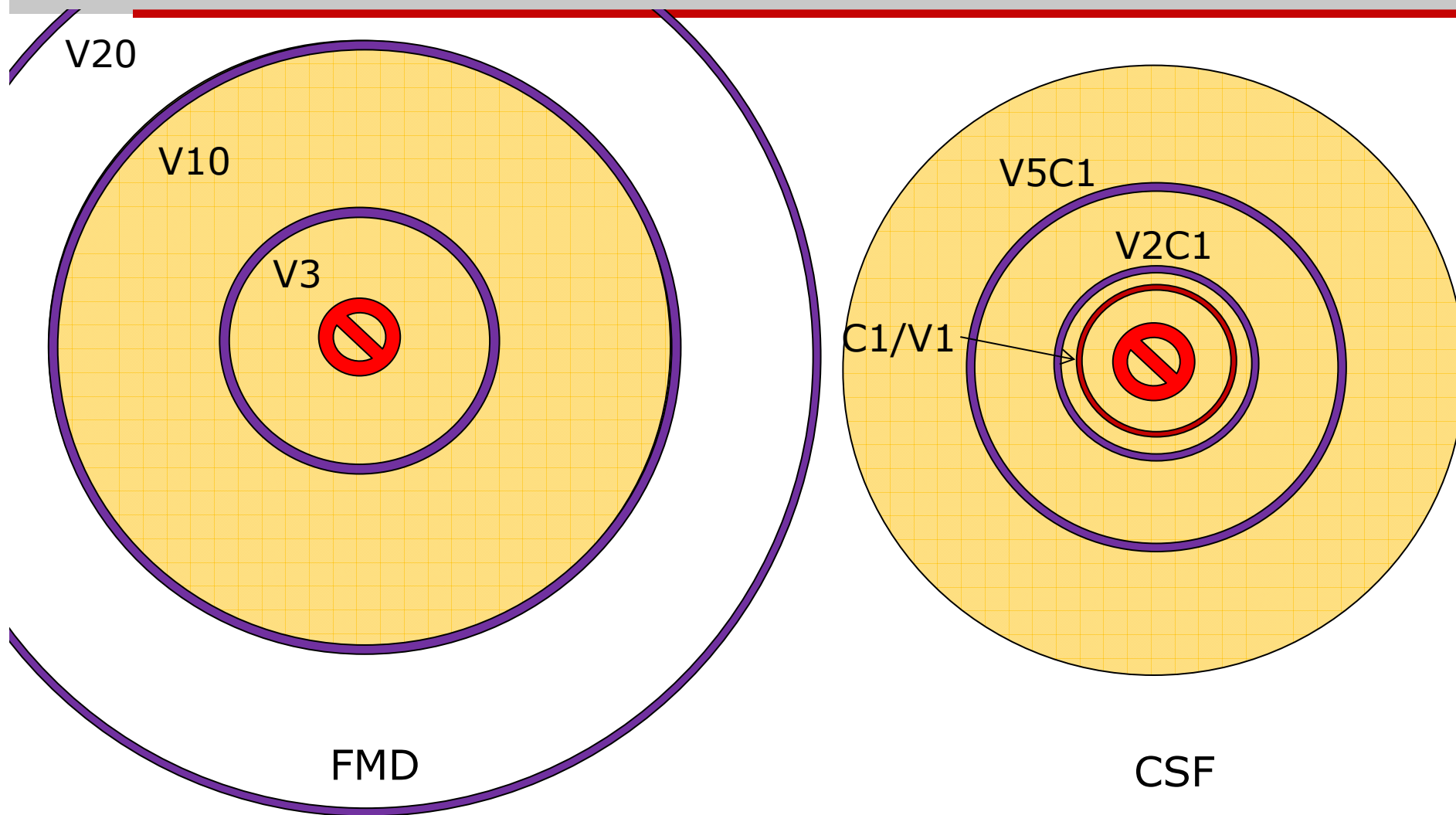


Cumulative number of culled premises during the outbreak, started with 1 index herd (mean, 95% C.I):

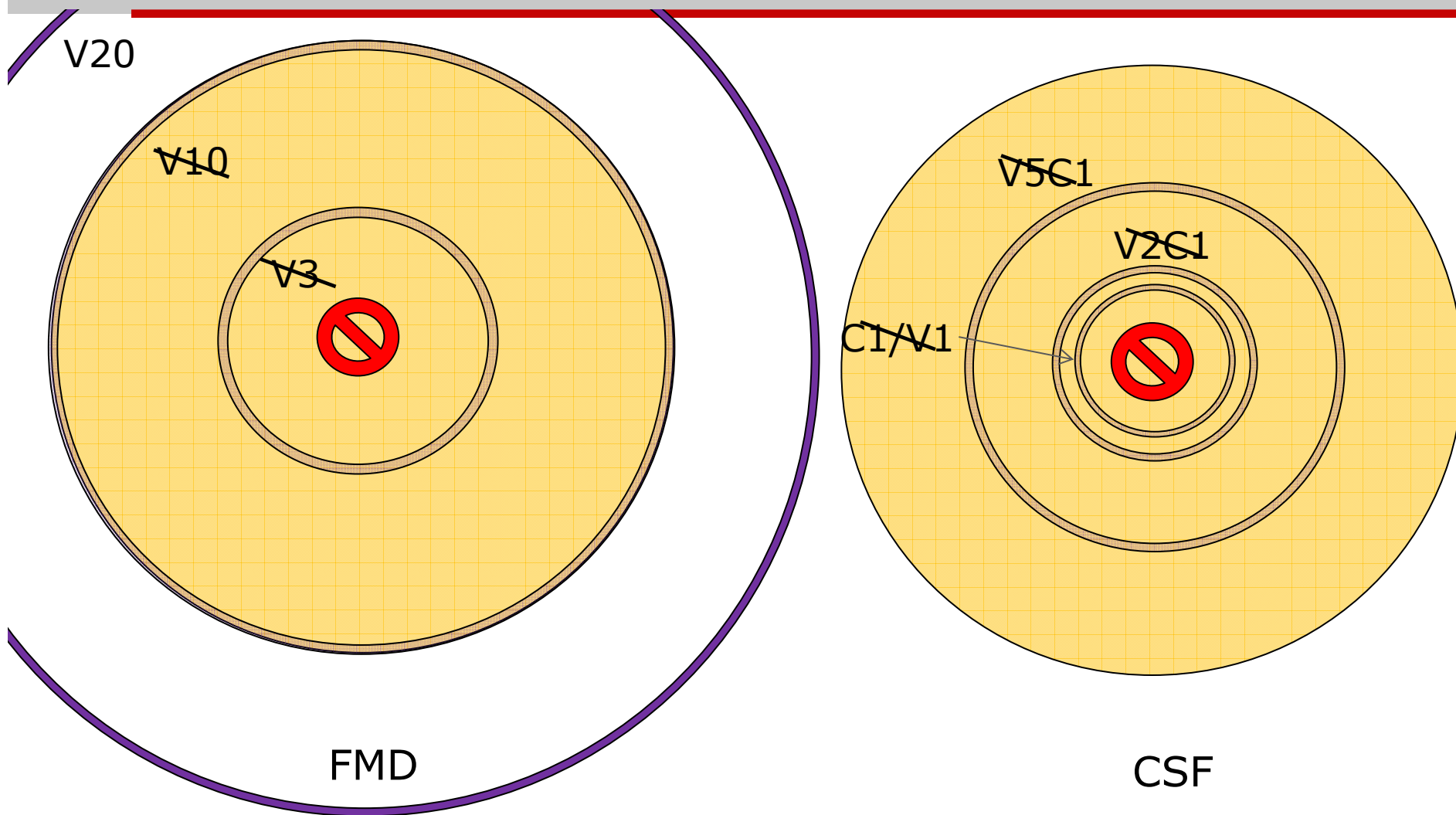
- Vaccination shows a clear benefit for low compliance
- Low compliance results in much bigger outbreaks

When the compliance is bad, emergency vaccination reduces the chance of big and long outbreaks

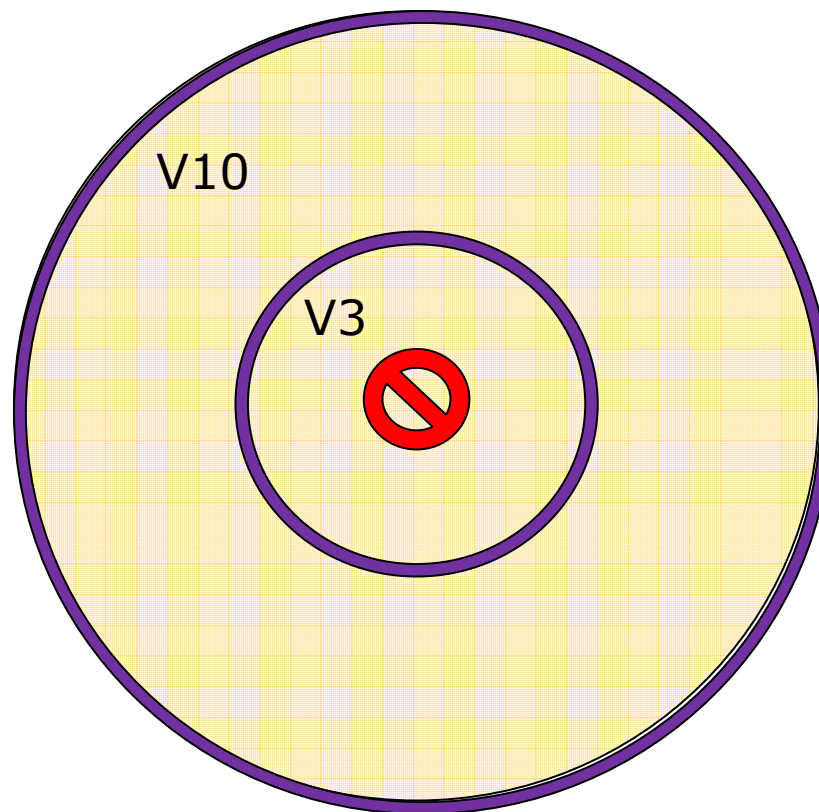
Summary results



Summary results



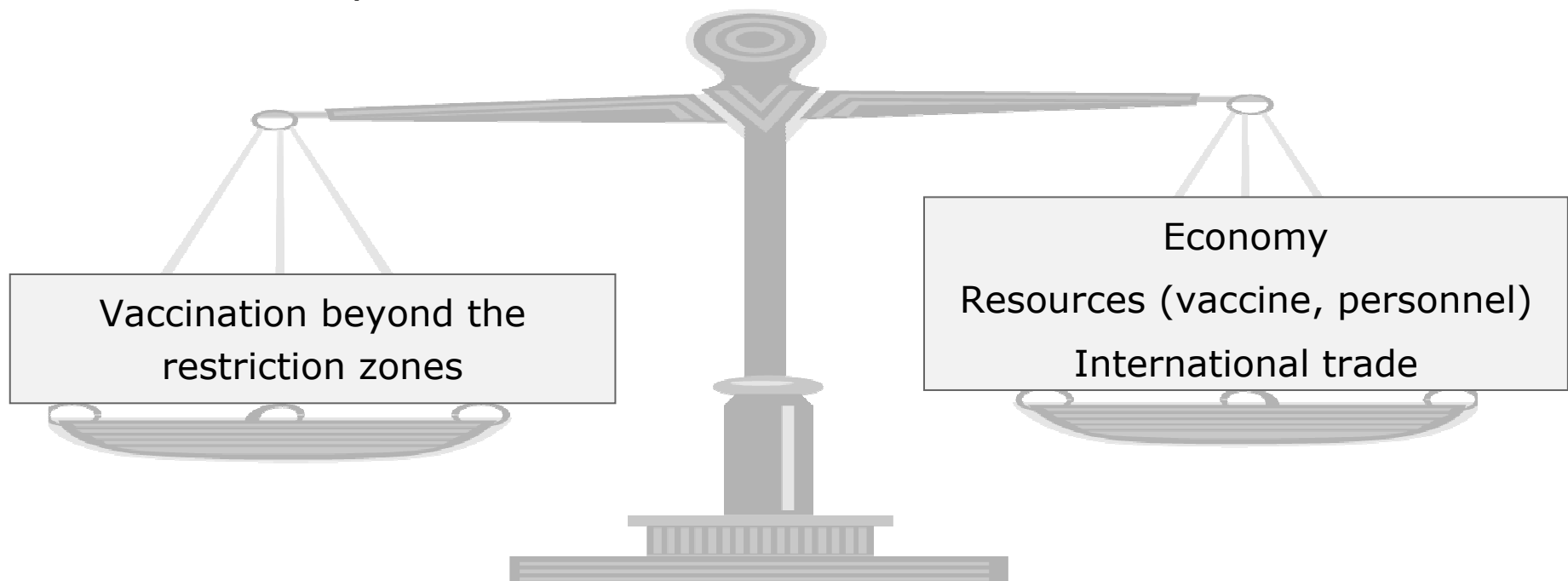
Summary results: reduced compliance of movement restrictions



FMD

Conclusions and further aspects

- Emergency vaccination and pre-emptive culling have no positive effect in settings with a rather low animal density
- but an area-wide application of vaccination outside the restriction zones may result in a benefit



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