How simulation models can help to design and update of control strategies

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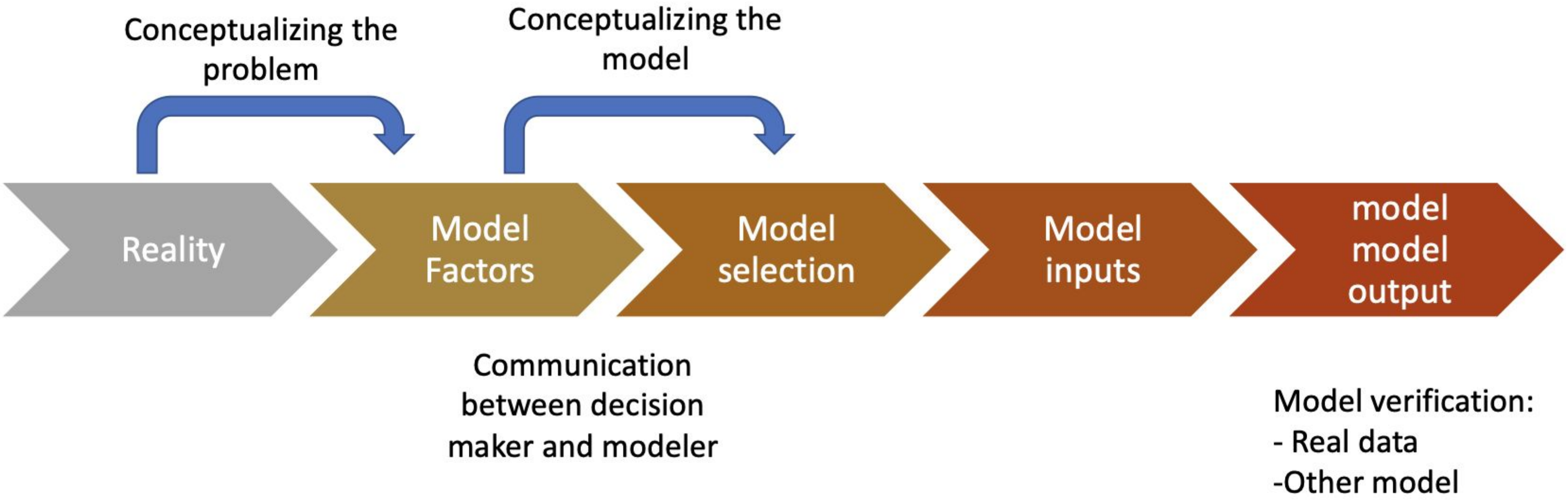
Initial considerations in the model

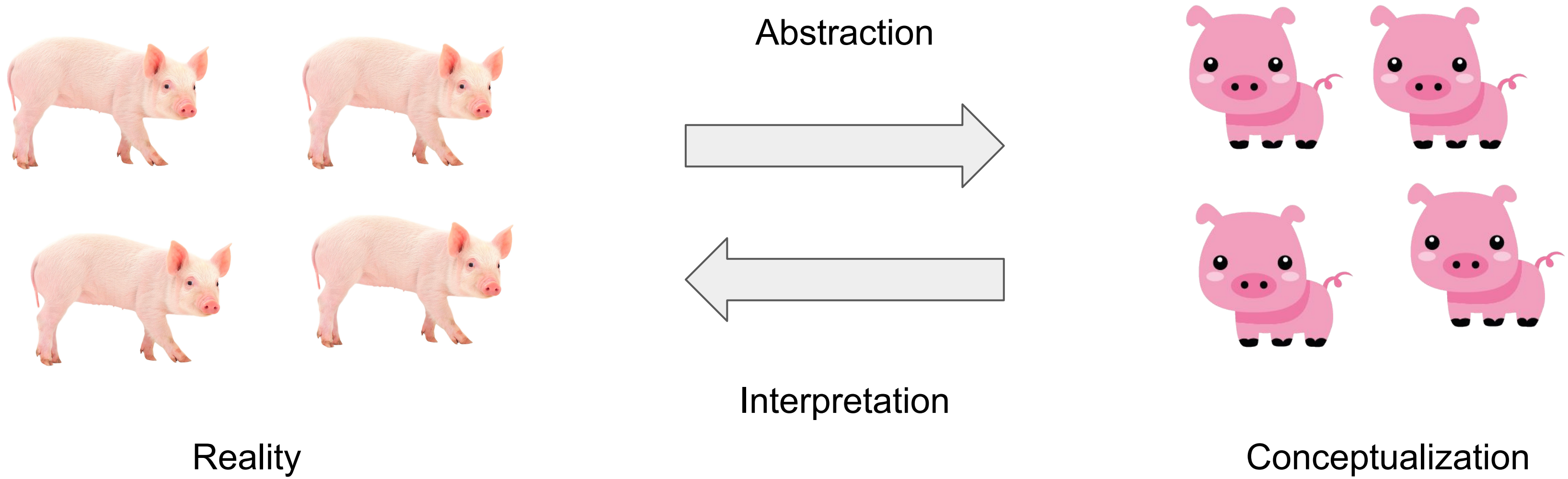
- Reality
  - Animal population, structure
  - Climate condition
  - Network connections
  - Pathogen
  - Immune / health population status

Initial considerations in the model

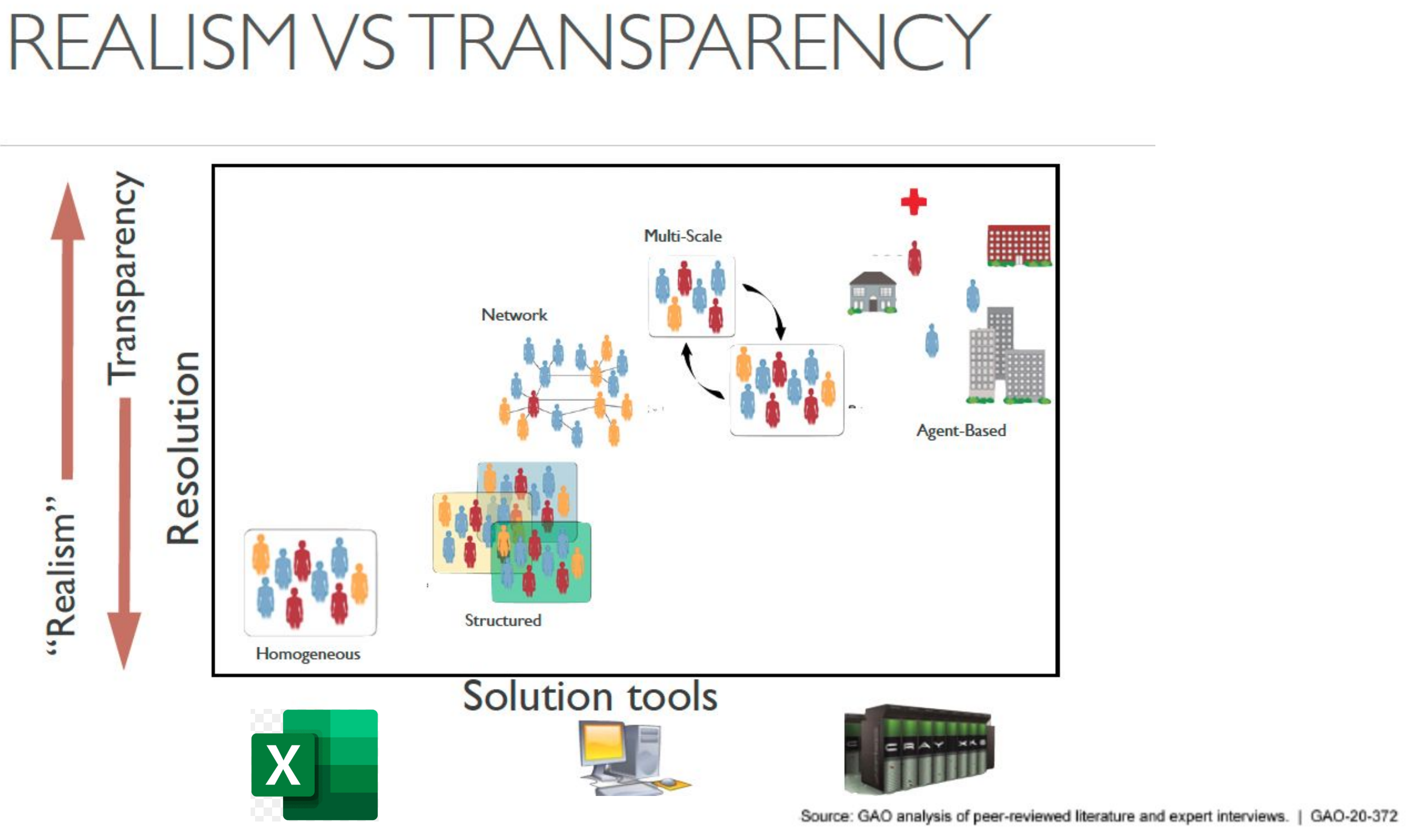
- Model factors
  - Data ability
    - Parameters
    - Population stats
  - Assumptions
    - Number of species
    - Animal in the same area
    - Routes transmission
  - Limitations
    - Parameters
    - variability in the pathogen individual, environment

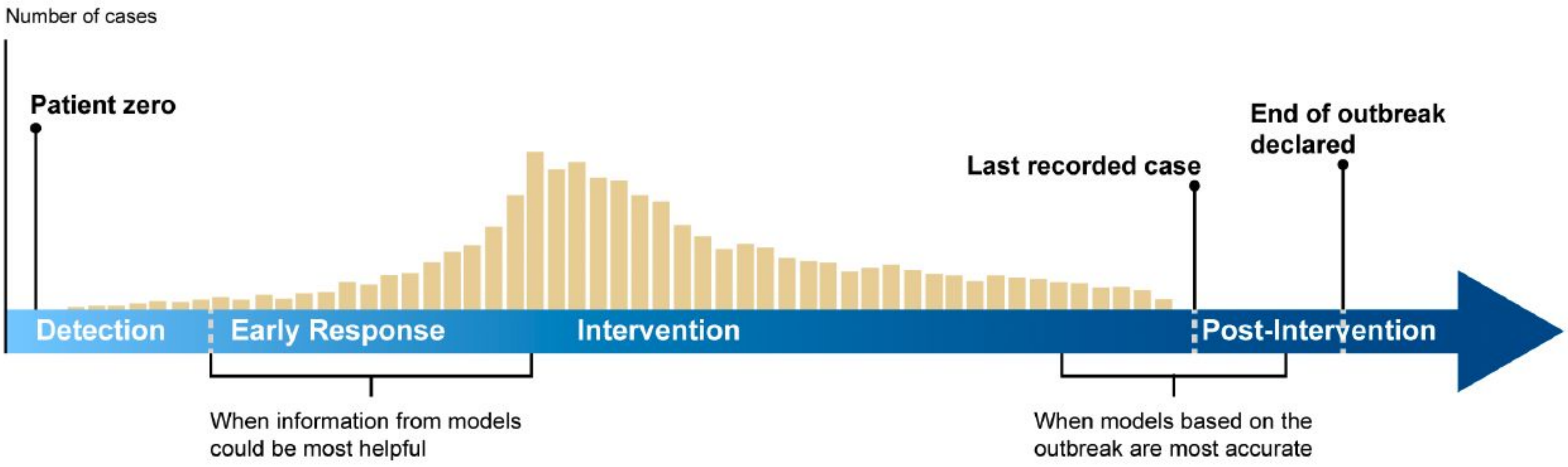

Conceptualizing the problem
Conceptualizing the model
Reality
Model Factors
Model selection
Model inputs
model model output
Communication between decision maker and modeler
Model verification:
- Real data
-Other model

Abstraction of real systems



Abstraction of real systems





Early response actions could include:
- Mobilization of personnel and resources
- Drafting/signing of agreements for data sharing

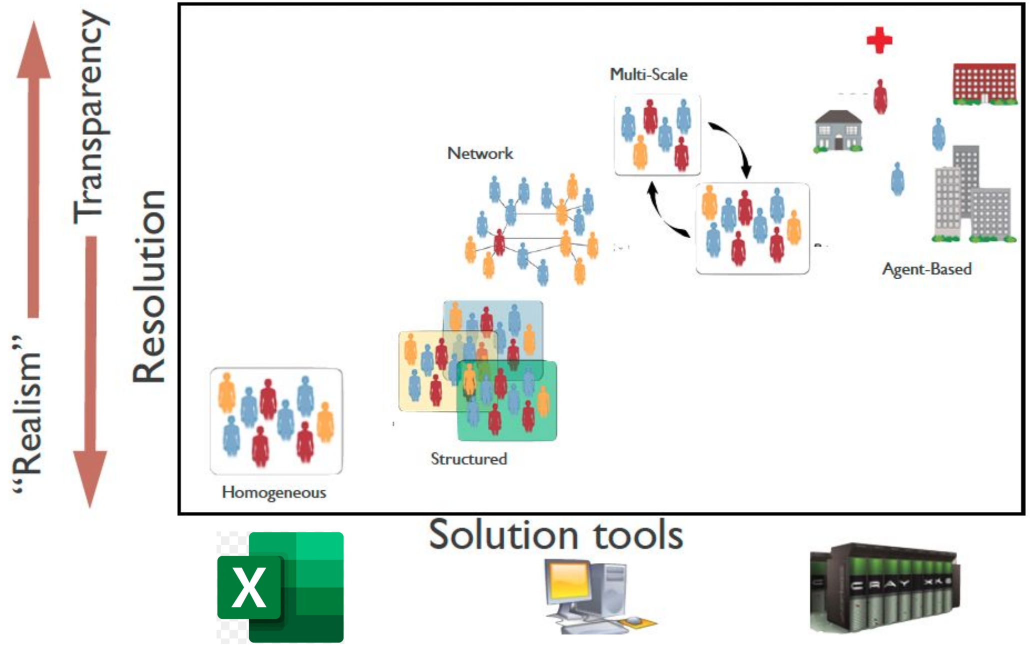
Intervention actions could include:
- Quarantine of infected persons
- Application of vaccines to non-infected persons

Post-intervention actions could include:
- Assessment of response in formal reports
- Validation of infectious disease models

Source: GAO analysis of peer-reviewed literature and expert interviews. | GAO-20-372

Abstraction of real systems

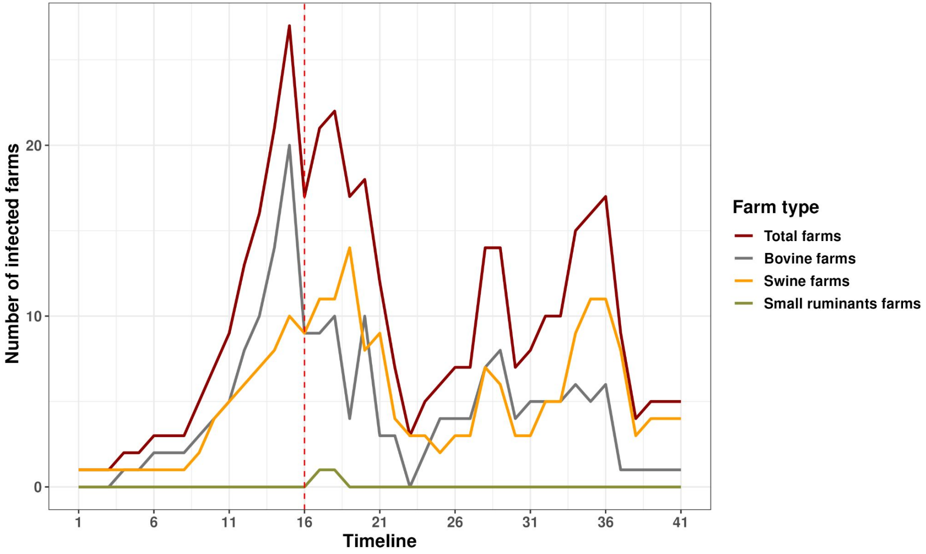
REALISM VS TRANSPARENCY



Source: GAO analysis of peer-reviewed literature and expert interviews. | GAO-20-372

Control actions implications:

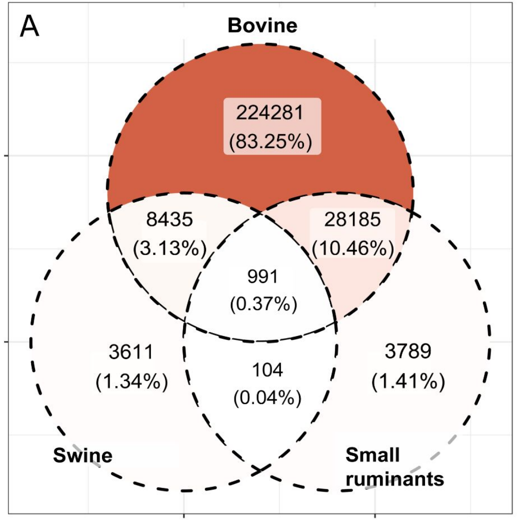
- How to prevent a spread?
- How to prevent disease introduction/ re introduction?
- How to prevent the spatial transmission?
- When is the best to implement control actions?
    - Evaluate the effectiveness of each action
- How drastic?
    - Variate the level of the control action

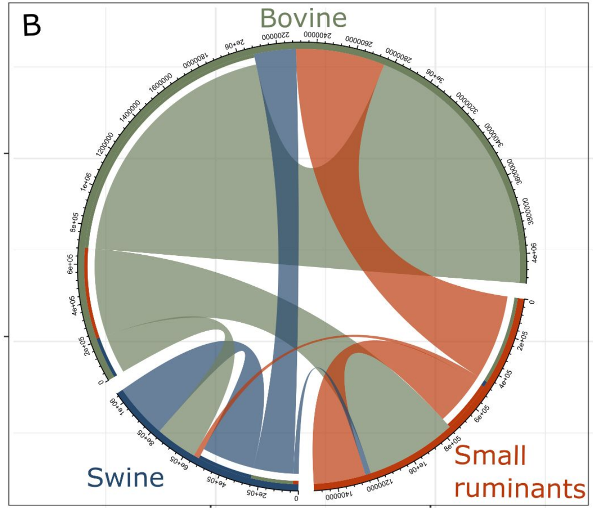


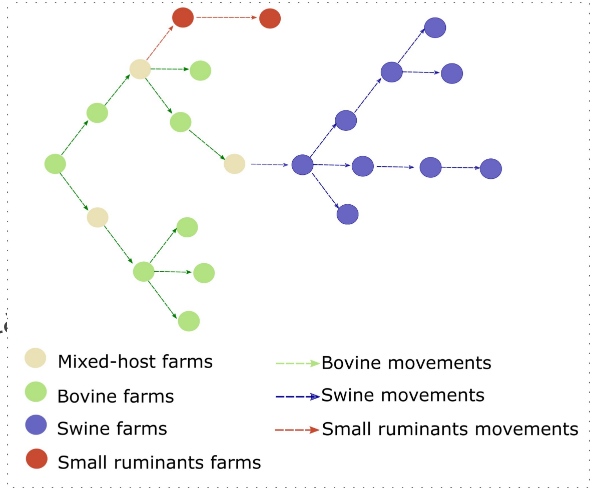
- Depopulation
- Movement ban
- Vaccination

Model definition

Why more than one species is really important ?







Cardenas, N.C., Sykes, A.L., Lopes, F.P.N. et al. Multiple species animal movements: network properties, disease dynamics and the impact of targeted control actions. V
https://doi.org/10.1186/s13567-022-01031-2

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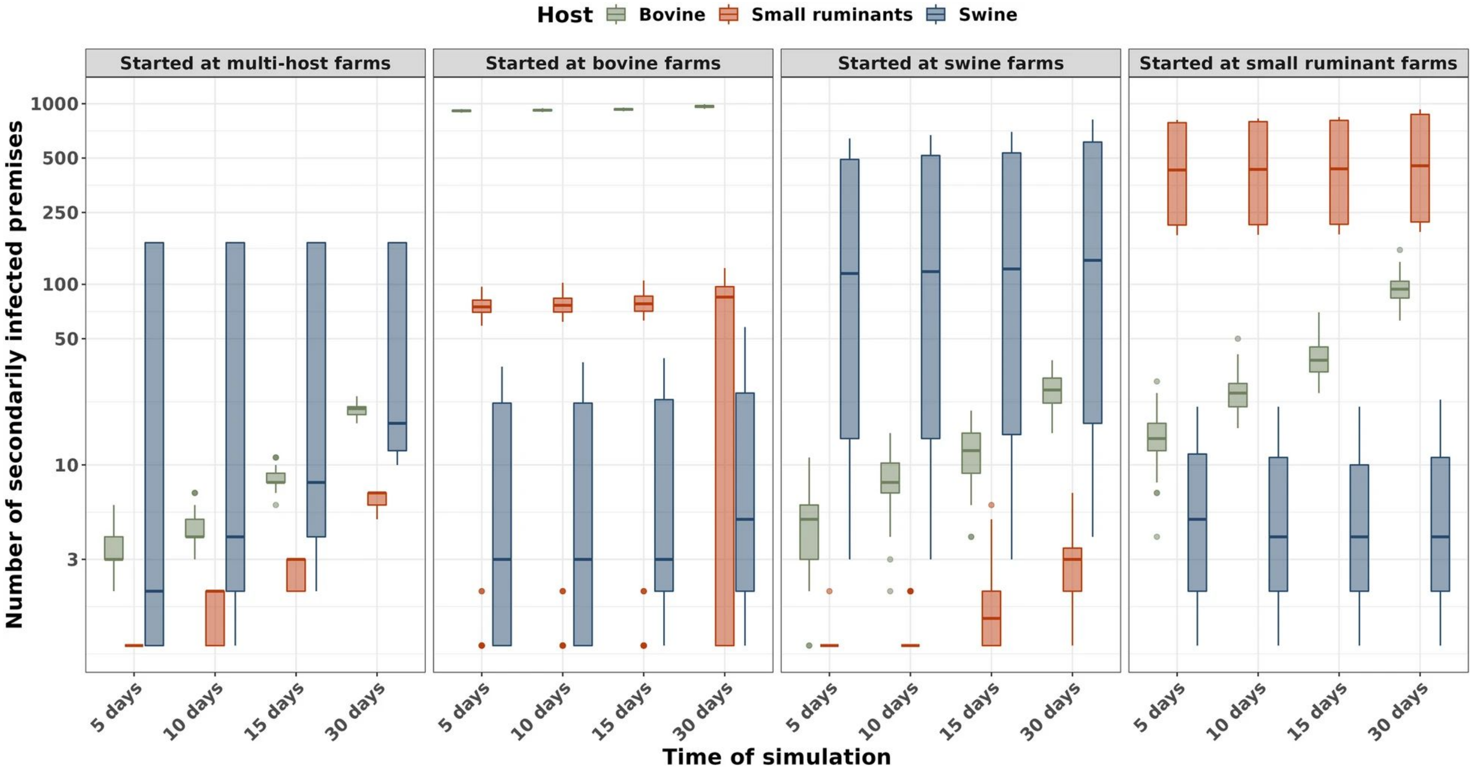

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Material and methods: Databases

- Livestock movements included the daily between-farm movements of farms containing:
  - **Bovine.**
  - **Swine.**
  - **Small ruminants.**
- **Birth** and **death** records.
- Data covering **three years**.

1,564,487

Movements farm to farm and/or slaughterhouses

409,655

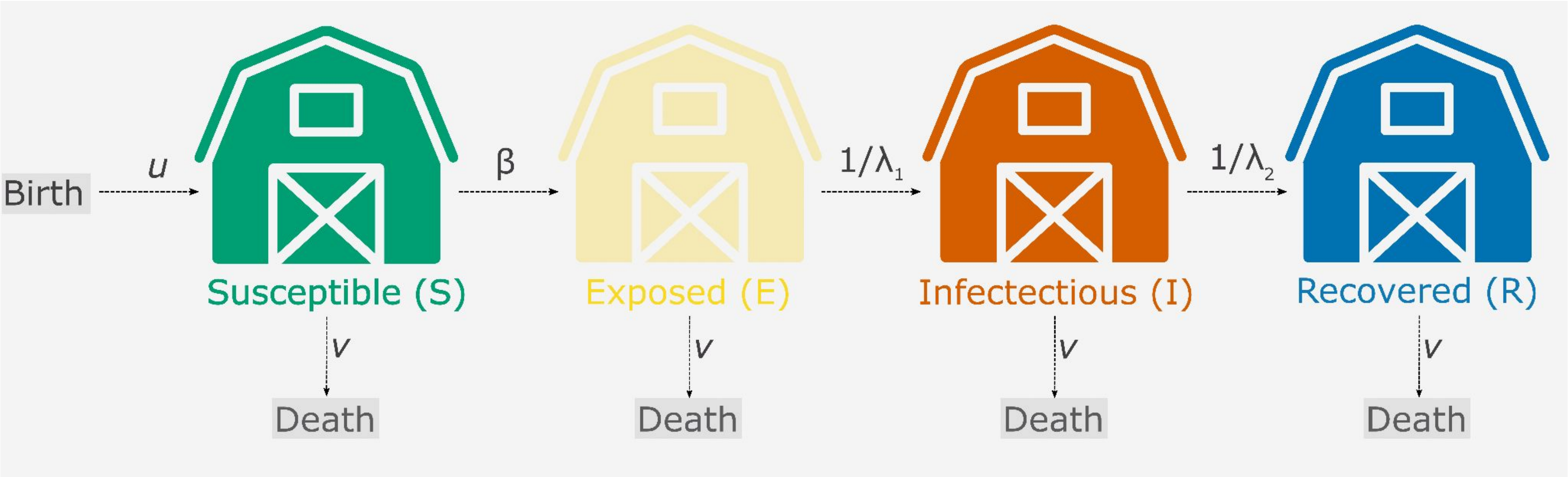
Farms

19,267,676

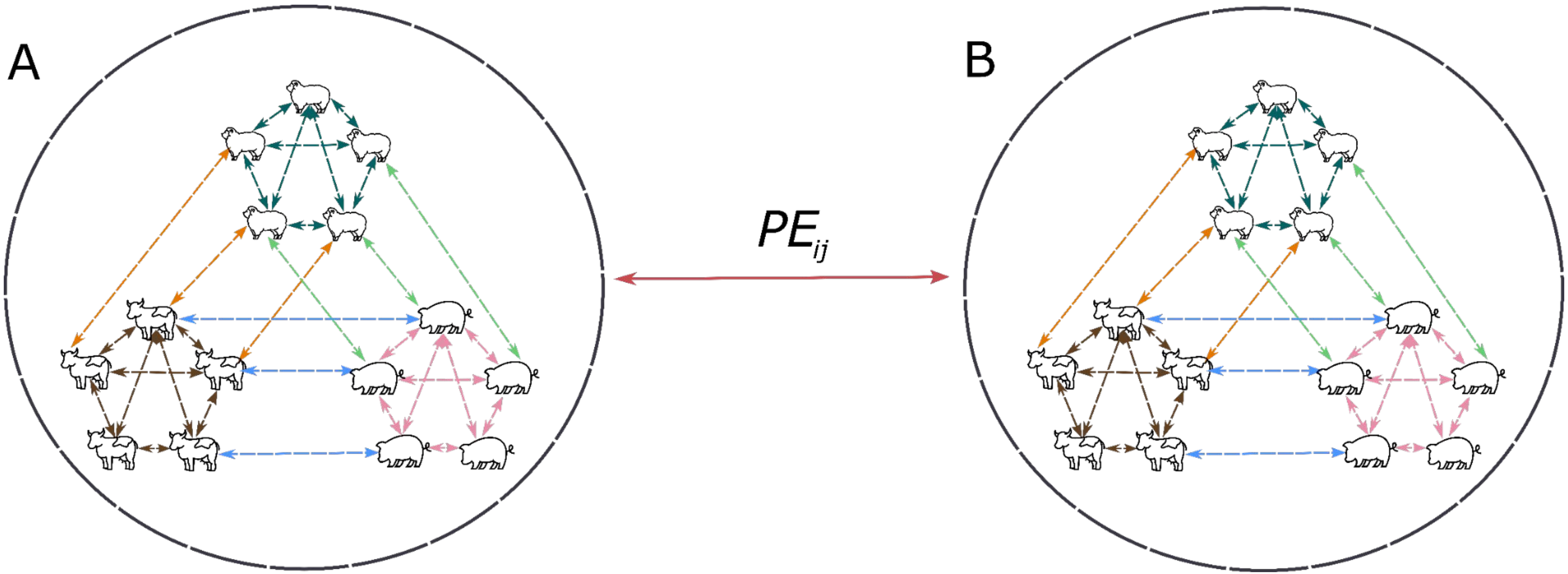
Bovine + swine + small ruminant population.

Spoiler alert: No real data

Model definition: infection dynamics

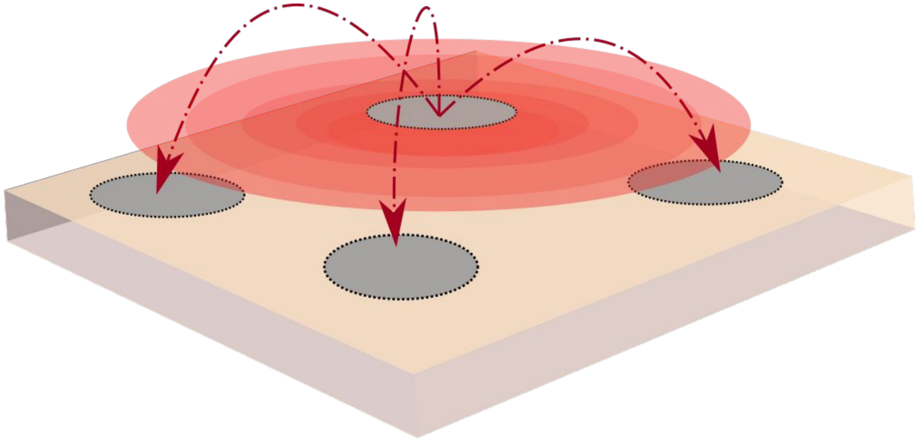


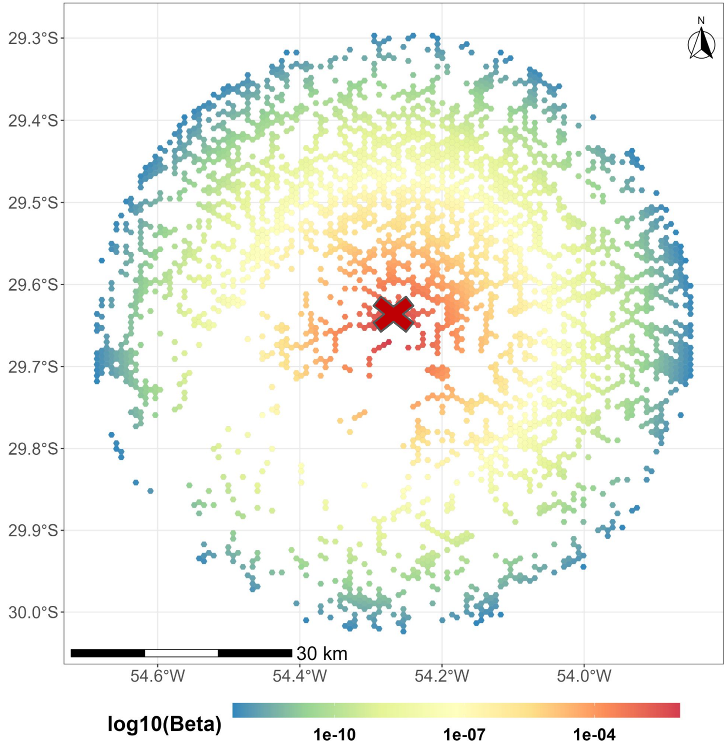
Model definition: infection dynamics



Material and methods: Transmission routes

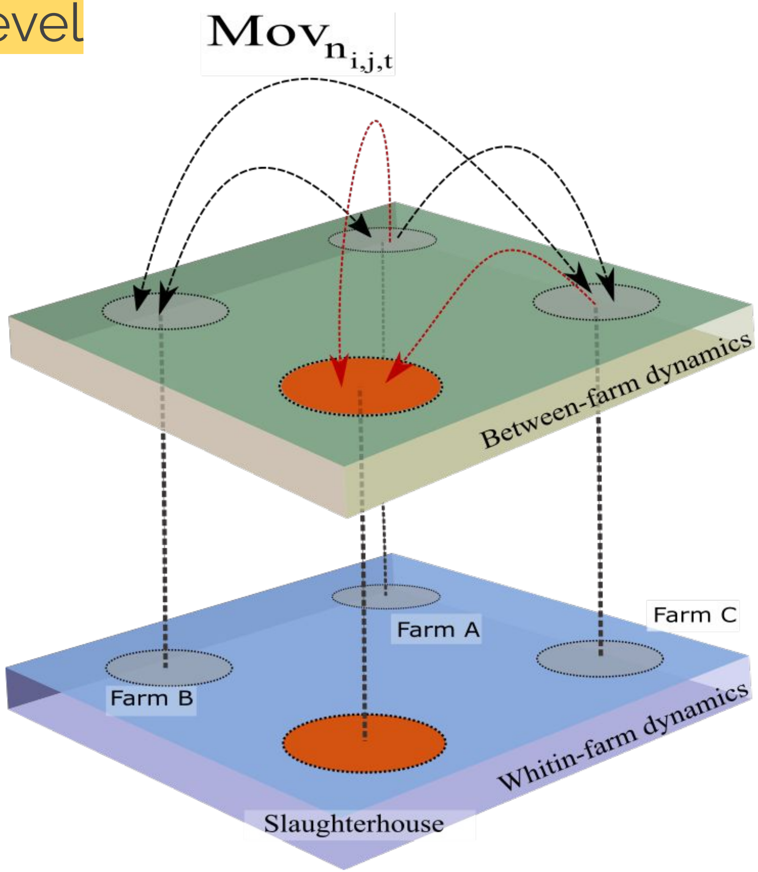
Spatial transmission



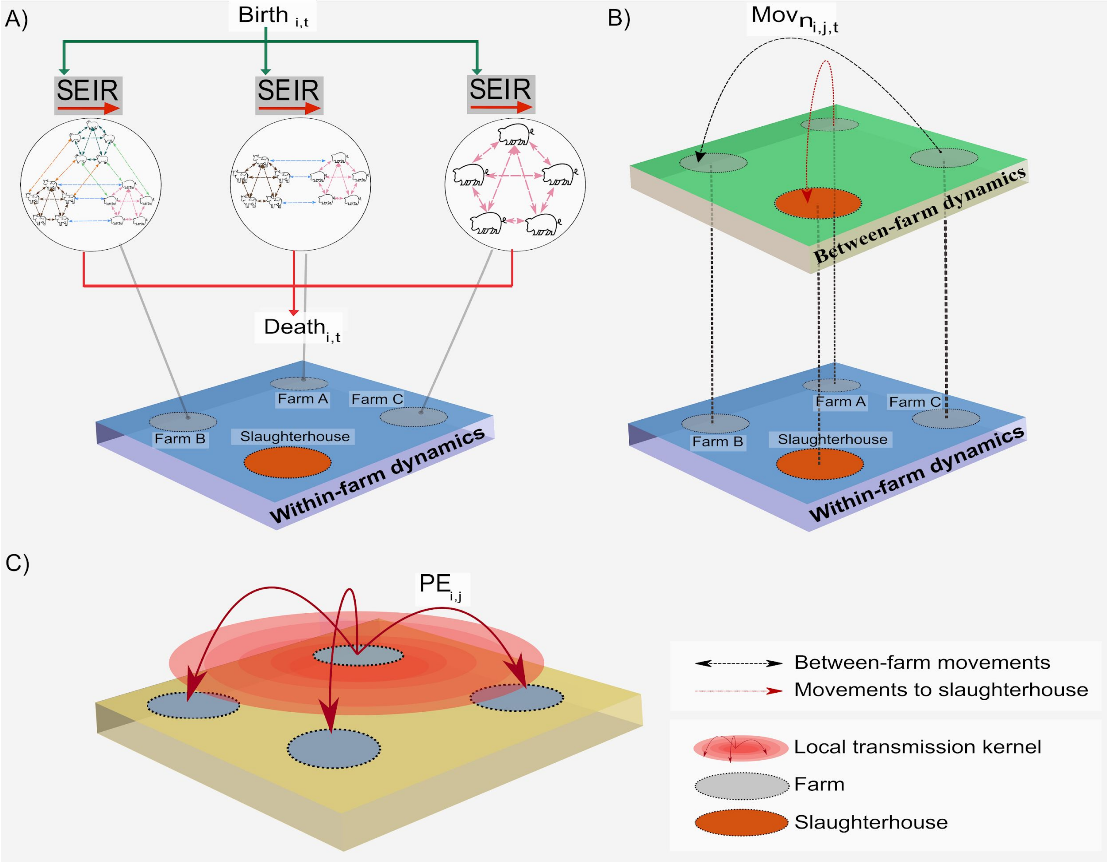


Global dynamics: Contact network level

- Farm to farm movements
- Farm to slaughterhouses



Material and methods: Model definition



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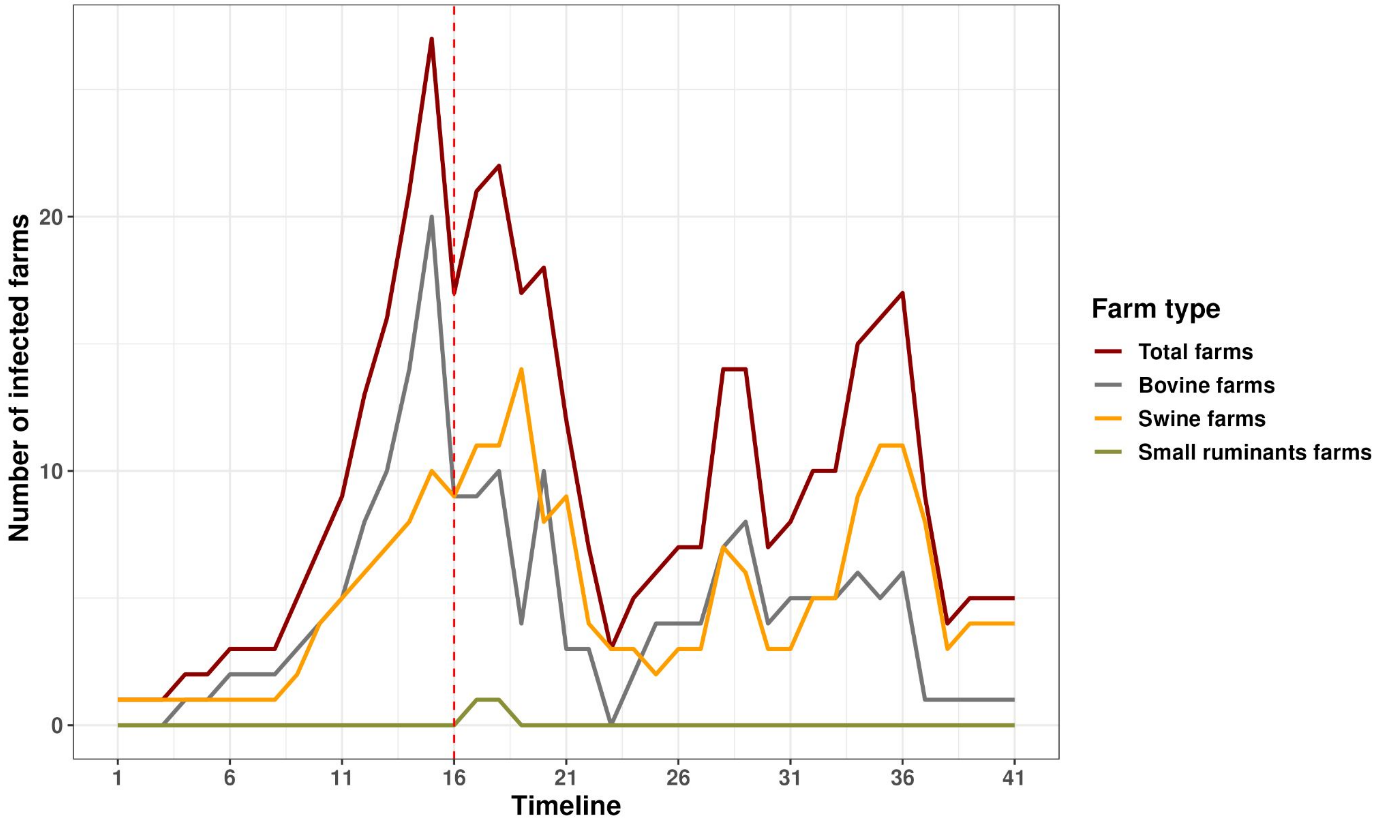
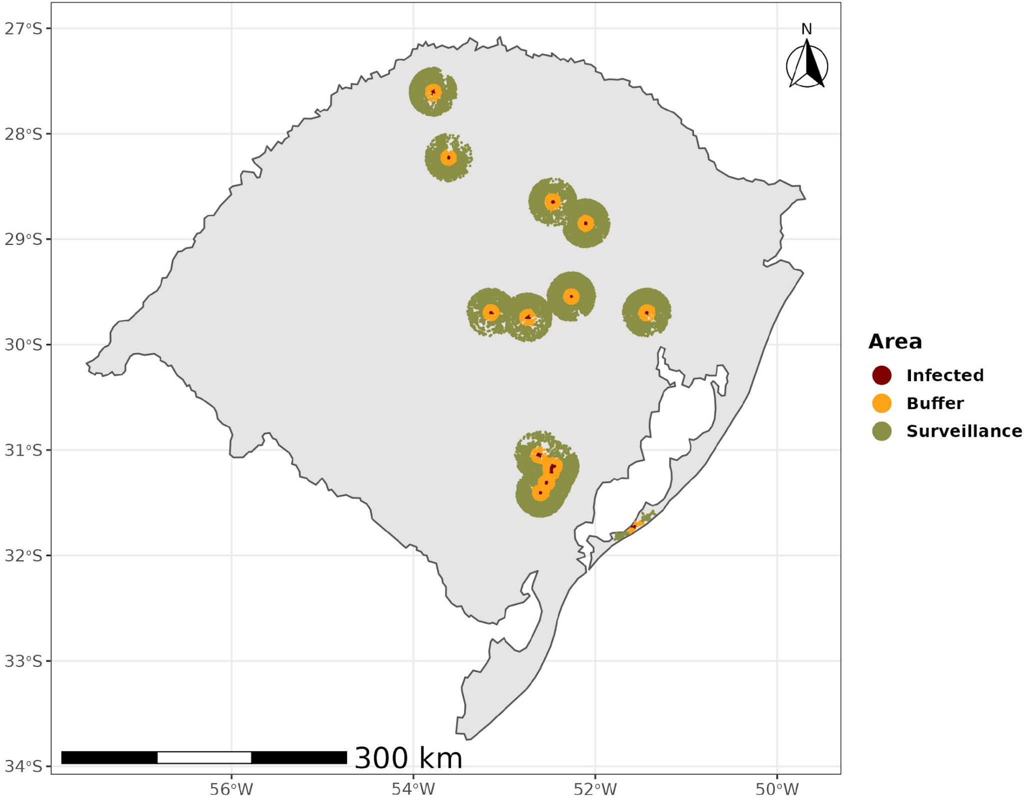
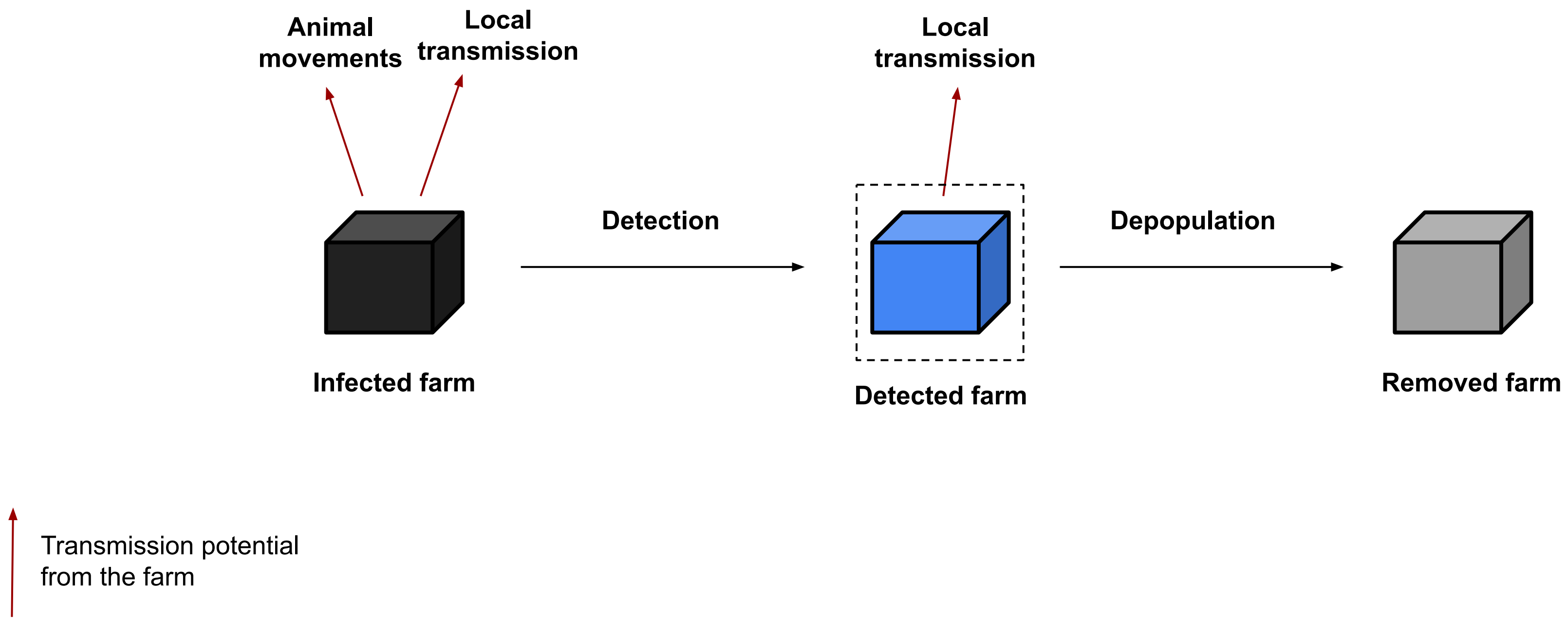


Control areas and zones



Depopulation



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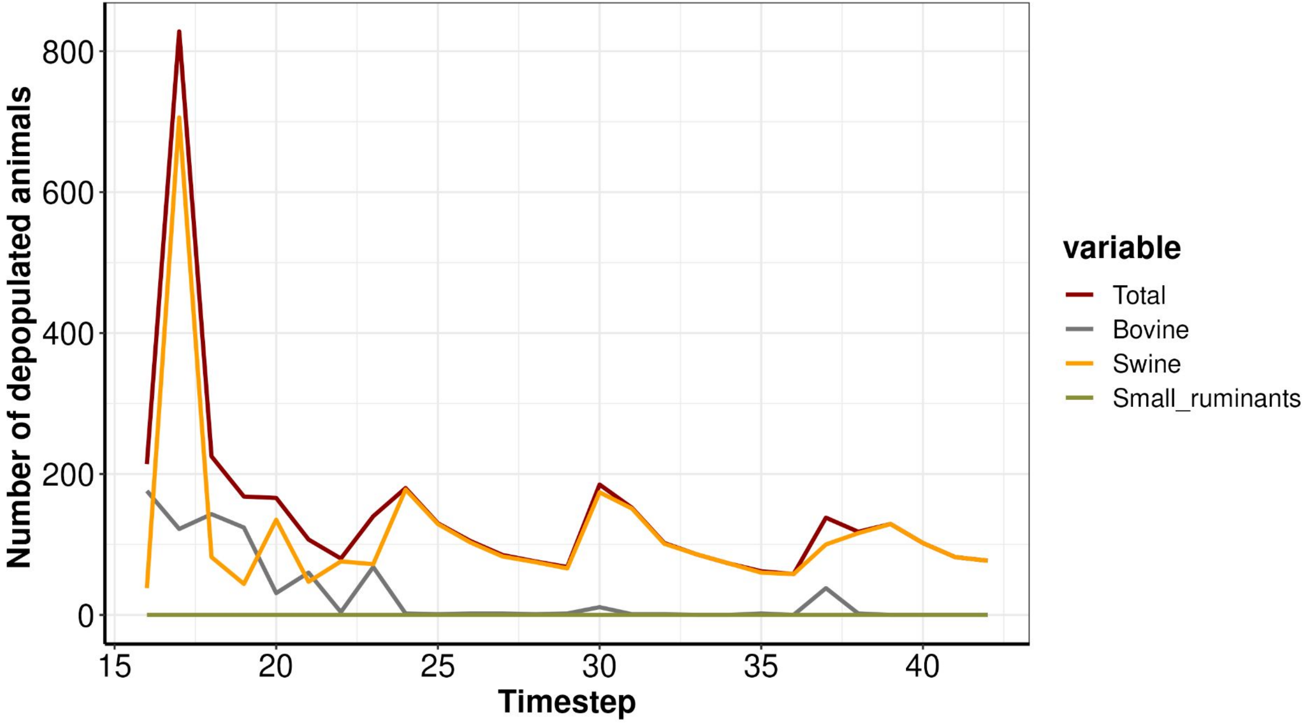
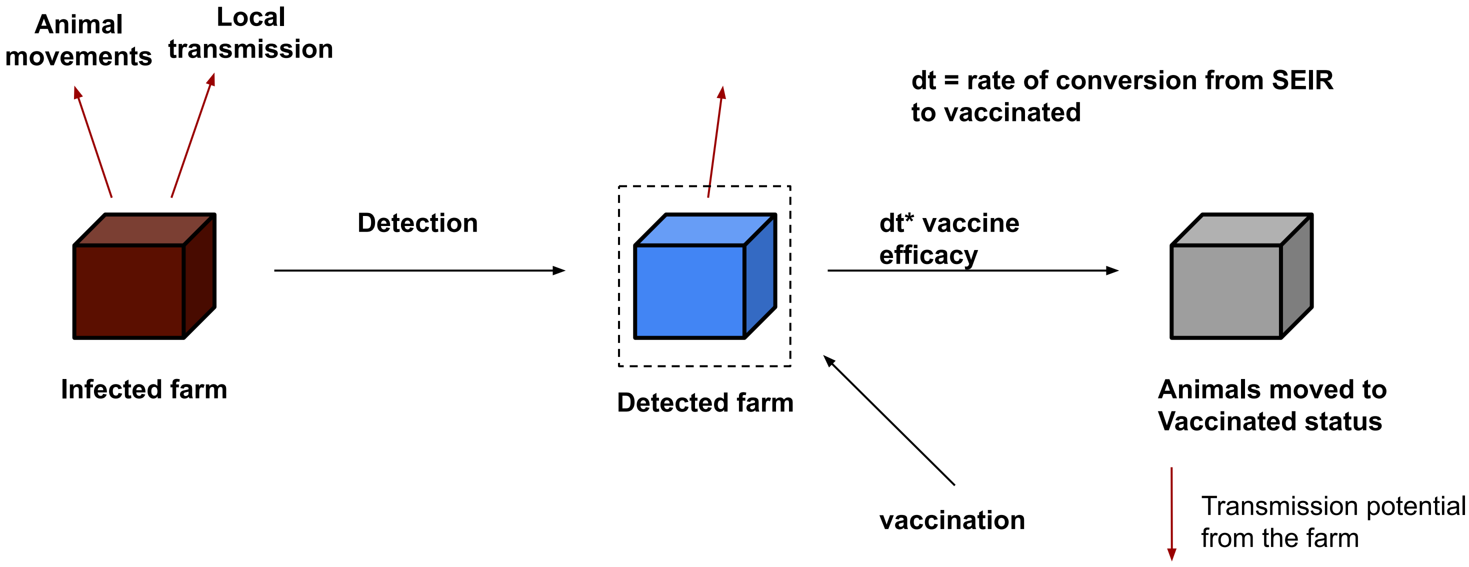


Vaccination



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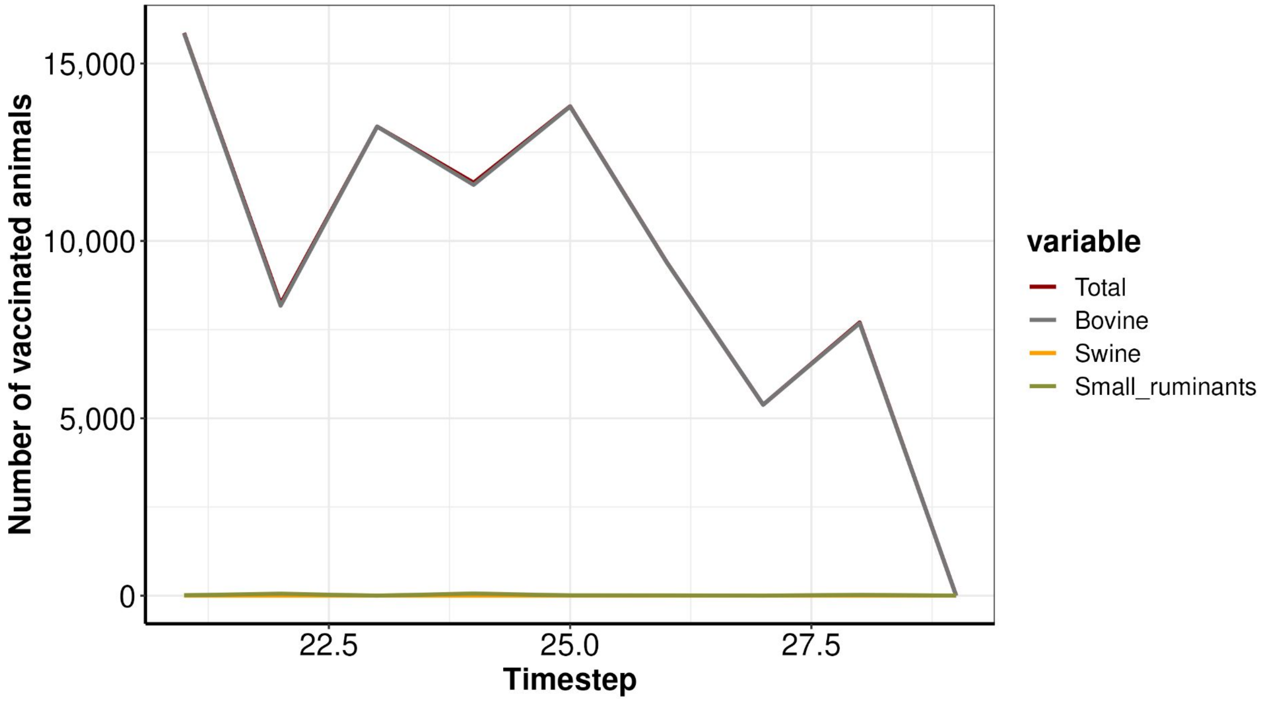
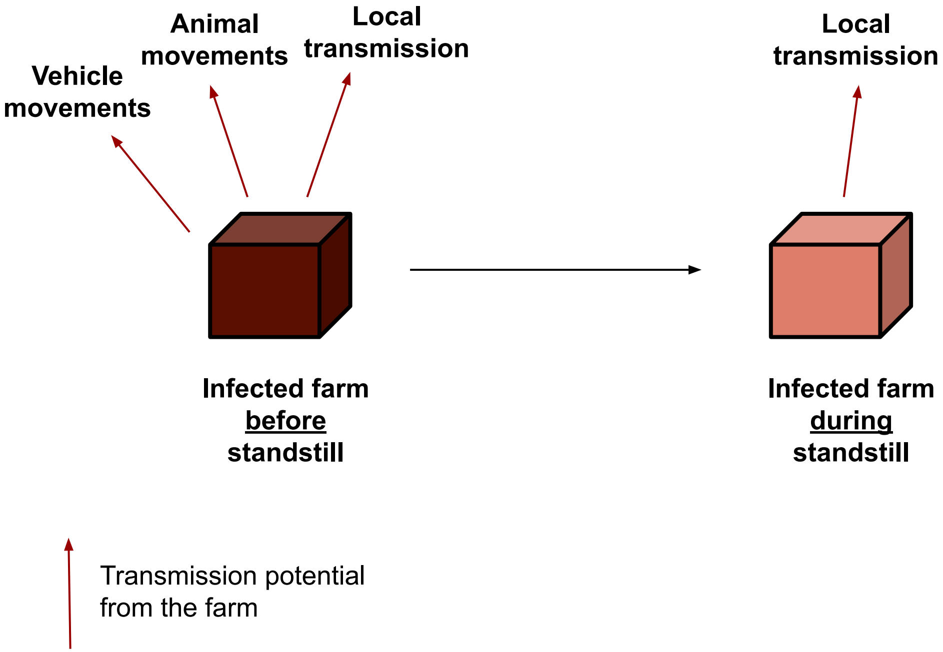
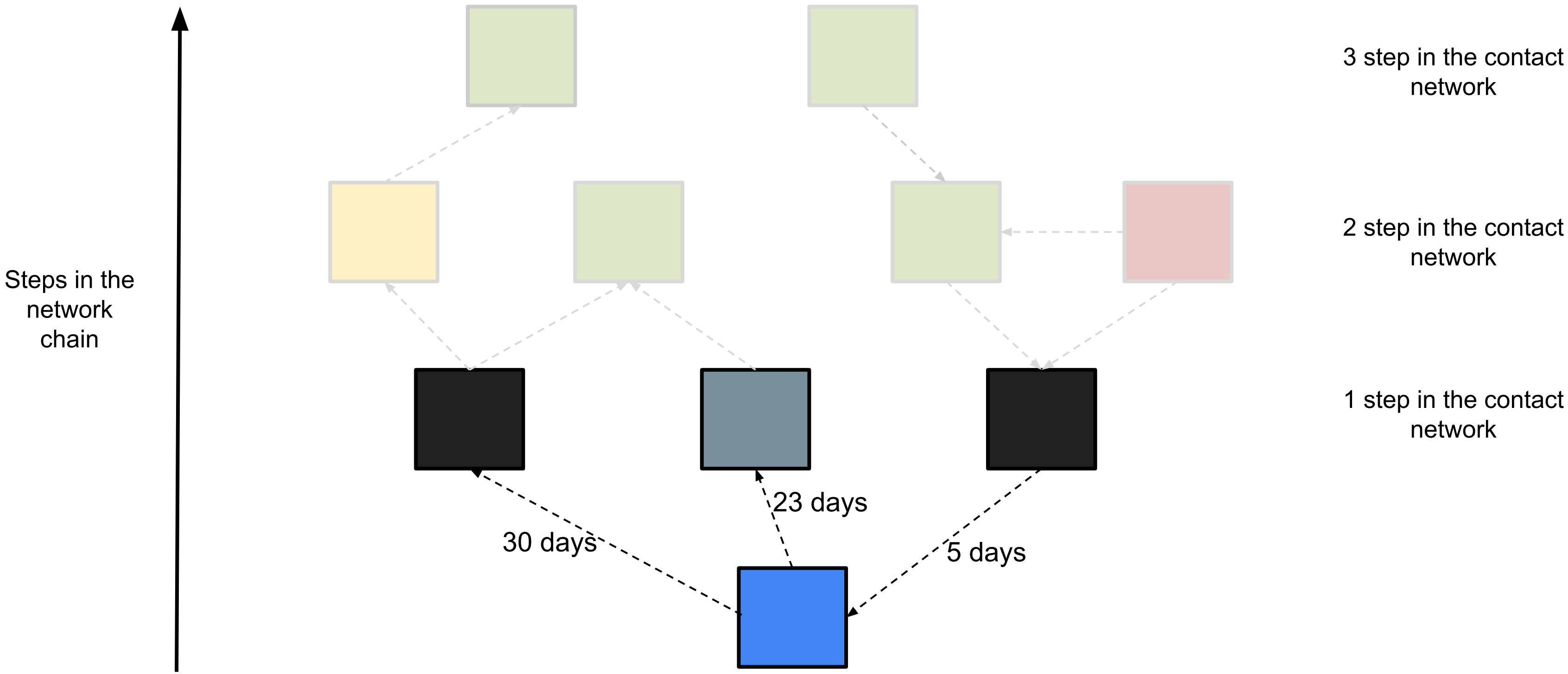


Movements standstill



Contact tracing—direct and indirect



Material and methods: Host to host transmission coefficients

Species	Species	Transmission coefficient (β)	References
Bovine	Bovine	Pert (0.018, 00.24, 0.056)	Calculate from the FMD outbreaks 2000-2001 in the state of Rio Grande do Sul (da Costa et al., 2022).
Bovine	Swine	Pert (0.018, 0.024, 0.056)	Assumed.
Bovine	Small ruminants	Triangular (0.020, 0.026, 0.031)	(Cabezas et al., 2021; Chis Ster et al., 2012)
Swine	Bovine	Pert (0.014, 0.044, 0.033)	(van Roermund et al., 2010)
Swine	Swine	Pert (0.044, 0.14, 0.33)	(Kinsley et al., 2018; van Roermund et al., 2010)
Swine	Small ruminants	Pert (0.014, 0.044, 0.033)	(van Roermund et al., 2010)
Small ruminants	Bovine	Pert (0.012, 0.031 0.065)	(Bravo de Rueda et al., 2014)
Small ruminants	Swine	Pert (0.006, 0.024, 0.09)	(Goris et al., 2009)
Small ruminants	Small ruminants	Pert (0.018, 00.24, 0.056)	Assumed

Material and methods: The distribution of each host latent and infectious period

FMD parameters	Species	Distribution parameters	Reference
Latent period	Bovine	Weibull (a = 1.78, b = 3.97)	(Mardones et al., 2010)
	Swine	Log logistic (shape = 7.60; scale = 1.06)	(Moreno-Torres et al., 2022)
	Small ruminants	Pert (m = 3.96, a = 0, b = 13.98)	(Mardones et al., 2010)
Infectious period	Bovine	Gamma (a = 3.97, b = 1.11)	(Mardones et al., 2010)
	Swine	Weibull (shape = 7.16; scale = 11.04)	(Moreno-Torres et al., 2022)
	Small ruminants	Pearson 5 (a = 6.19, b = 17.19)	(Mardones et al., 2010)

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