Adaptive strategy for controlling a pathogen spread within a group of herds

A.-F. Viet [a,b,*], L. Jeanpierre [a], M. Bouzid [a]

[a] GREYC, CNRS, Université de Caen Basse-Normandie, BP 5186, 14032 Caen Cedex, France
[b] UMR1300 BioEpAR, INRA,ONIRIS, BP 40706, 44307 Nantes Cedex 03, France

Context and objective

Modelled strategies often consist in a systematic use of an action and sometimes on an adaptive use depending on the pathogen spread. Adaptive strategies are less studied and often defined within a herd. An optimisation model such as a Markov Decision Process (MDP) may be used to define an adaptive strategy. Given an objective function, possible actions and model dynamics, a policy can be computed: each model state is associated to an action.

Objective: *To define an adaptive vaccination strategy for a group of herds to control a theoretical pathogen spread which is endemic in the area.*

Model

- Group: N herds with homogeneous contacts
- Available actions : Doing Nothing and Vaccinating
- Stochastic compartmental model (Fig 1)

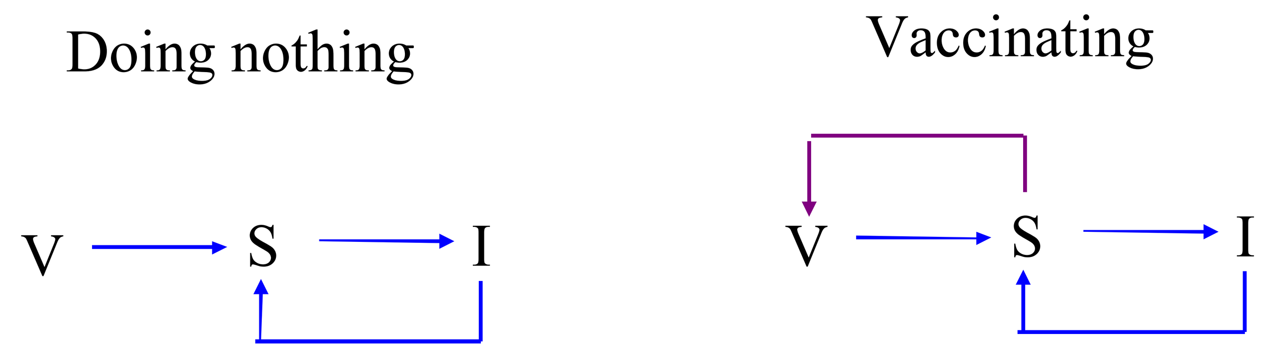

Fig 1. Representation of the individual transitions between health statuses according to available actions (V: vaccinated, S: susceptible, I: infected)

- Transmission
  - Between herds: frequency-dependent
  - External risk of pathogen introduction
    4 levels: High, Medium, Low, Null
    Risk values: 2r, r, r/2, 0
    Transitions between levels: Uniform probability over contiguous levels
- Vaccination : efficiency < 100%
- Objective of the group :
  minimising (Cost(disease)* I+ Cost(Vaccine)* (S+V))
  with Cost(disease)=-1/month and
  Cost(Vaccine)=-7/year when vaccinating

- Markov Decision Process (MDP):
  - model states: *{(e,(k,i,j))}* with *e* an external risk level and *(k,i,j)* a repartition of herds in the statuses S, I and V
  - Computing the policy (action for each model state): *ValueIteration* algorithm (infinite horizon, actualisation rate of 3% / year)
- Evaluation of the efficiency: simulation of the pathogen spread over 20 years for 3 strategies (Do Nothing, MDP Policy, Systematic vaccination).

Results

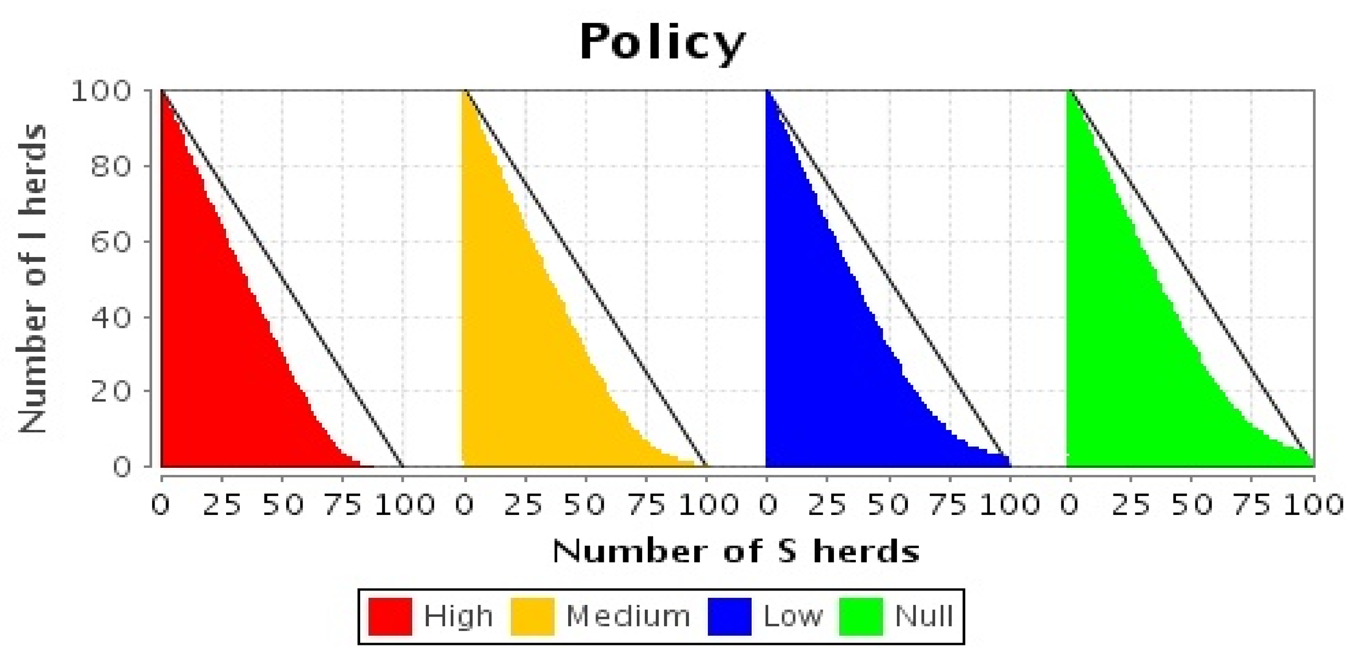

Fig 2. Representation of the MDP Policy: model states where the action Doing nothing is selected

- MDP Policy (Fig.2) : few model states with vaccination
- Efficiency of the strategy based on the MDP policy:
  - Vaccination is not used in all replications (Fig 3)
  - Reduction of the pathogen spread compared to the Do nothing strategy (dotted vs. heavy lines, Fig 4) but less than the Systematic vaccination one (thin line)

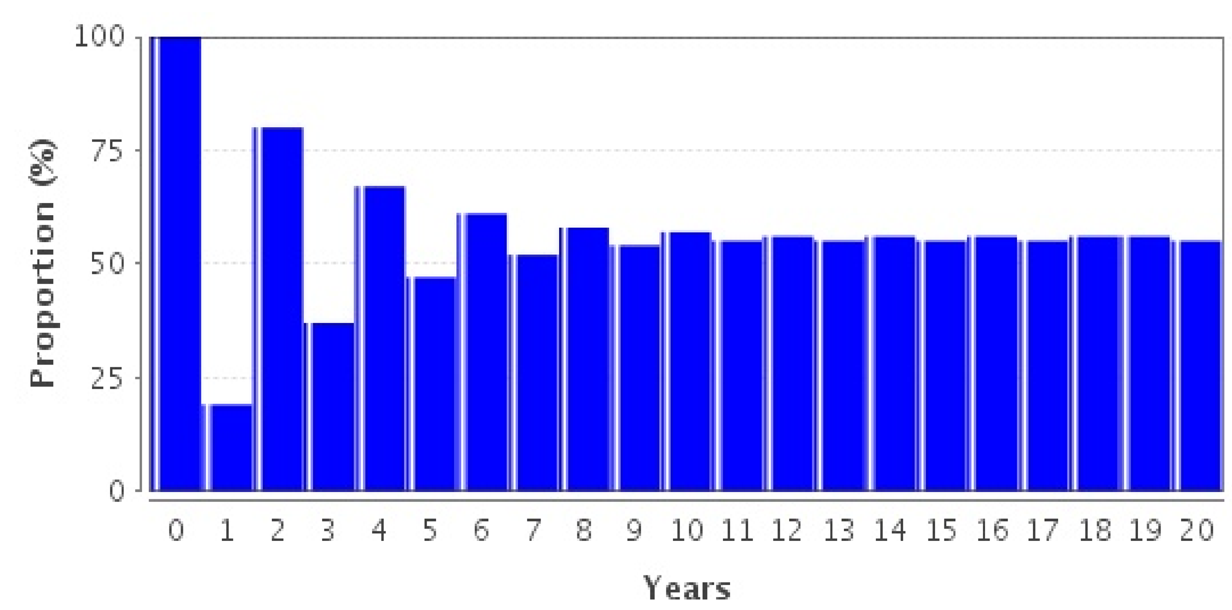

Fig 3. Proportion of vaccination every year when using the MDP policy (100 000 simulations)

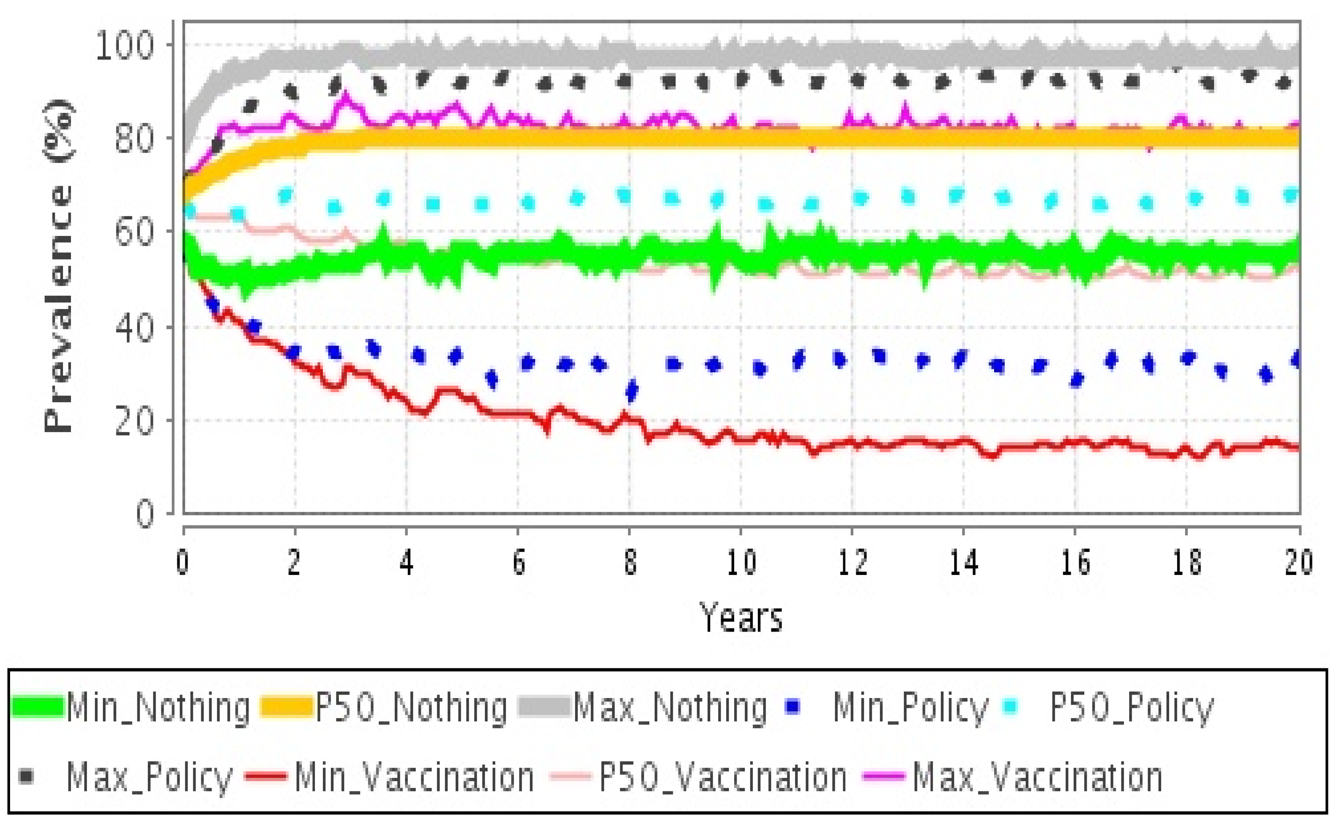

Fig 4. Prevalence of infected herds over time with the strategies Do nothing, MDP policy and Systematic vaccination – maximum (Max), median (P50) and minimum (Min) values.

Conclusion

With the MDP model, we proposed a strategy reducing the prevalence of infection but with a total cost less than the one of the systematic vaccination strategy. The model can be extended to consider:
- other actions (biosecurity, depopulation, …),
- other herd statuses (chronically infected, …),
- partial observations of herd statuses.

Acknowledgement: This work was carried out with the financial support of the "PSDR GO" program, project SANCRE.