Modelling framework to coordinate disease control decisions: example of PRRS

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CONTEXT

Non notifiable diseases in livestock populations

– Control measures at farmers' initiative
– Transmissible infectious disease => impact of decisions on the prevalence in an area
– Groups/associations of farmers: try to coordinate individual decisions
  • To achieve a global objective
  • Through advices or financial incentives

Tool helpful to coordinate individual decisions at group levels
PRRS (Porcine Reproductive and Respiratory Syndrome)

- Viral disease of pigs
- Endemic in many pig producing areas
- Responsible for significant economic losses in pig industry
  \(4.67\text{€/hog}\) (Holtkamp 2013)
- Infection of herds: purchase of infected animals, airborne transmission (manure)
- Persistent within a contaminated herd
- Control measures: vaccines, biosecurity, control of animal movements
**Objective:** proposing a strategy at the group level to limit the total cost of the PRRS within a group of farms
Herd PRRS statuses and individual actions

Herds:
- S $\Leftrightarrow$ Susceptible
- Sd $\Leftrightarrow$ Susceptible with biosecurity
- C $\Leftrightarrow$ Contaminated without any control
- C0 $\Leftrightarrow$ Contaminated with recent control action
- CC $\Leftrightarrow$ Controlled contaminated
AT GROUP LEVEL

Strategy a

Herds:
- $S \Leftrightarrow$ Susceptible
- $Sd \Leftrightarrow$ Susceptible with biosecurity
- $C \Leftrightarrow$ Contaminated without any control
- $C0 \Leftrightarrow$ Contaminated with recent control action
- $CC \Leftrightarrow$ Controlled contaminated

Biosecurity

Depopulation

Biosecurity + vaccination

Diagram:

- $S$ (Susceptible) connected to $Sd$ (Susceptible with biosecurity)
- $Sd$ connected to $CC$ (Controlled contaminated)
- $CC$ connected to $C$ (Contaminated without any control)
- $C$ connected to $C0$ (Contaminated with recent control action)
- $C0$ connected to Biosecurity + vaccination

The diagram illustrates the flow between different herd statuses under the implementation of biosecurity and depopulation strategies.
Strategic Strategy b

**Herds:**
- S ⇔ Susceptible
- Sd ⇔ Susceptible with biosecurity
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AT GROUP LEVEL

Strategy c

Biosecurity

Depopulation

Herds:
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Biosecurity + vaccination
Objective: Minimising the total costs
   - Cost of the disease
   - Cost of actions

Deadline: None

=> Optimisation to propose rules to decide which strategy to retain at each time step to achieve the objective (Markov Decision Model)
RESULTS

Scenario

- Group of 50 herds (40% S+Sd, 40% CC)
- Simulation over 50 years (time-step of 6 mo)

Rules depending on the epidemiological situation at the group level
Use of each strategy over time when following rules – Time 0:

<table>
<thead>
<tr>
<th>S</th>
<th>Sd</th>
<th>C</th>
<th>C0</th>
<th>CC</th>
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<td>5</td>
<td>5</td>
<td>20</td>
</tr>
</tbody>
</table>
RESULTS

Epidemiological impact

Do nothing

Follow the Rules

CC herds

S+Sd herds

Min  P5  P10  P25  P50  P75  P90  P95  Max  Ney

Min  P5  P10  P25  P50  P75  P90  P95  Max  Ney

Min  P5  P10  P25  P50  P75  P90  P95  Max  Ney

Min  P5  P10  P25  P50  P75  P90  P95  Max  Ney
Data/Compliance

- Parameters based on literature and expert knowledge
- Heterogeneity of farmers regarding risk attitude
  - Previously infected $\Rightarrow$ compliance $\gg$
- Estimation
  - Based on previous collective management
  - Evaluation with game-theory experiments (Chapman et al., 2012) on a set of representative farmers
Approach

- **Adaptive** coordination
  - Combination of strategies
  - Adaptation to the current epidemiological situation

- Perspectives
  - Multi-objective (minimal cost and prevalence target at a given time step)
ACKNOWLEDGMENTS

Members of the

- MODEC Team, UMR BioEpAR
- MAD Team, UMR GREYC

Financial supports

- French Research Agency program Investments for the future, project ANR-10-BINF-07 (MIHMES)
- INRA, Cemagref, Basse-Normandie, Bretagne, Pays de le le Loire and Poitou-Charentes regional councils under SANCRE project, in the framework of “For and about regional development” programs
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