Incorporating heterogeneity in farmer disease control behaviour into a livestock disease transmission model

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Interdisciplinary team

Infectious disease modelling


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Farmer-led Epidemic and Endemic Disease-management (FEED)

UKRI Biotechnology and Biological Sciences Research Council

Project motivation

FEED project webpage:
https://feed.warwick.ac.uk

- Control of infectious disease in livestock can be farmer-led or government-led.
- There is a knowledge gap on the different factors that drive farmer behaviour in response to an emerging disease.
- Mathematical models traditionally treat farmers as passive bystanders and omit variation in disease management behaviours.

Study aims

1. Elicit farmers vaccination decisions to an unfolding epidemic and link to their psychosocial and behavioural profiles (within Great Britain)

2. Refine mathematical disease models to capture psychosocial & behaviour change heterogeneities

3. Assess how psychosocial & behaviour change factors impact epidemiological outcomes given a fast-spreading livestock disease

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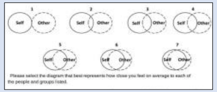
Study aim 1: Elicit farmers vaccination decisions

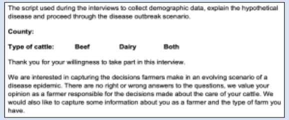
1. **Elicit farmers vaccination decisions to an unfolding epidemic and link to their psychosocial and behavioural profiles (within Great Britain)**

1 **Design of a Graphical User Interface (GUI) to act as a core, interactive component of the interview exercise**

Visit https://feed.warwick.ac.uk

2 **Development and usage of an interview script to elicit farmer disease vaccination behaviours**





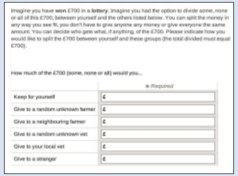
The script used during the interviews to collect demographic data, explain the hypothetical disease and proceed through the disease outbreak scenario.

County:

Type of cattle: **Beef** **Dairy** **Both**

Thank you for your willingness to take part in this interview.

We are interested in capturing the decisions farmers make in an evolving scenario of a disease epidemic. There are no right or wrong answers to the questions, we value your opinion as a farmer responsible for the decisions made about the care of your cattle. We would also like to capture some information about you as a farmer and the type of farm you have.



Imagine you have **won** £700 in a **lottery**. Imagine you had the option to divide some, none or all of this £700, between yourself and the others listed below. You can split the money in any way you see fit, you don't have to give anyone any money or give everyone the same amount. You can decide who gets what, if anything, of the £700. Please indicate how you would like to split the £700 between yourself and these groups (the total divided must equal £700).

How much of the £700 (some, none or all) would you...

	* Required
Keep for yourself	£
Give to a random unknown farmer	£
Give to a neighbouring farmer	£
Give to a random unknown vet	£
Give to your local vet	£
Give to a stranger	£

3 **Grouping of farmer vaccination behaviours in the elicitation exercise**

Elicitation results – GUI simulation

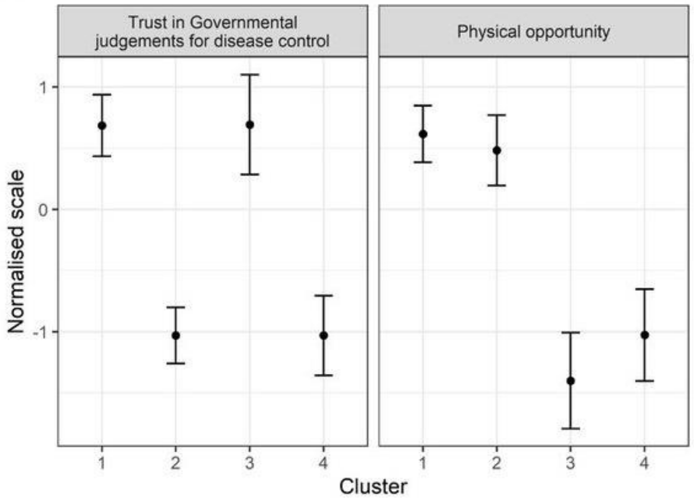
Stage of epidemic	Time since previous stage (weeks)	Number of infected herds (in GB)	Distance to nearest infected herd (km)	Number of farmers vaccinating (/60)
1	2	0	>500*	8
2	2	2	322	16
3	1	10	322	5
4	1	40	161	14
5	1	100	161	1
6	1	150	48	10
7	1	450	16	3
8	1	600	5	1
*Epidemic confined to southern-central France				

- Sixty farmers (39 beef & 21 dairy) participated.
- Variability in when they would use preventative vaccination.

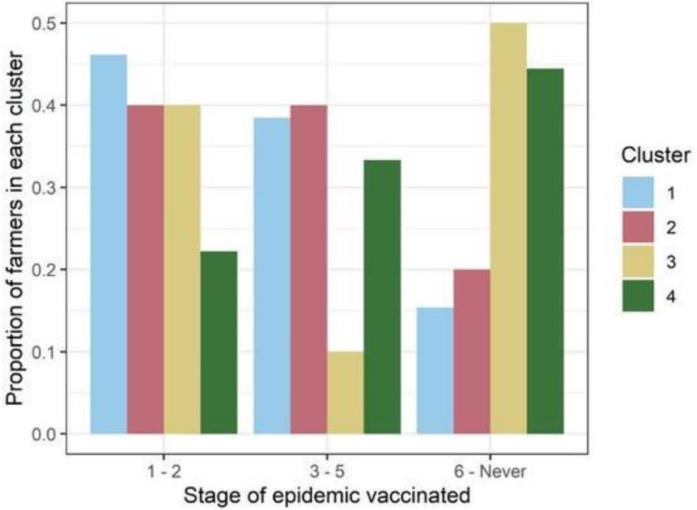
Elicitation results – farmer groupings

- Using k-means clustering, four groups gave best fit when clustering by two most stable covariates (trust in Governmental judgements for disease control, high physical opportunity)

Farmer groups from k-means clustering conducted on the two most stable covariates.



Proportion of farmers in each group that vaccinated in different stages of the outbreak.



Study aim 2: Refine the livestock disease model

1. Elicit farmers vaccination decisions to an unfolding epidemic and link to their psychosocial and behavioural profiles (within Great Britain)

2. **Refine mathematical disease models to capture psychosocial & behaviour change heterogeneities**

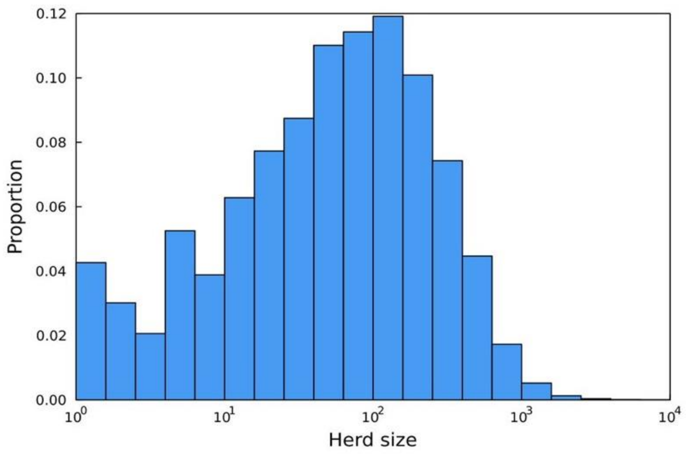
➢ Data-driven spatial model framework with epidemiological and behavioural layers.

3. Assess how psychosocial & behaviour change factors impact epidemiological outcomes given a fast-spreading livestock disease

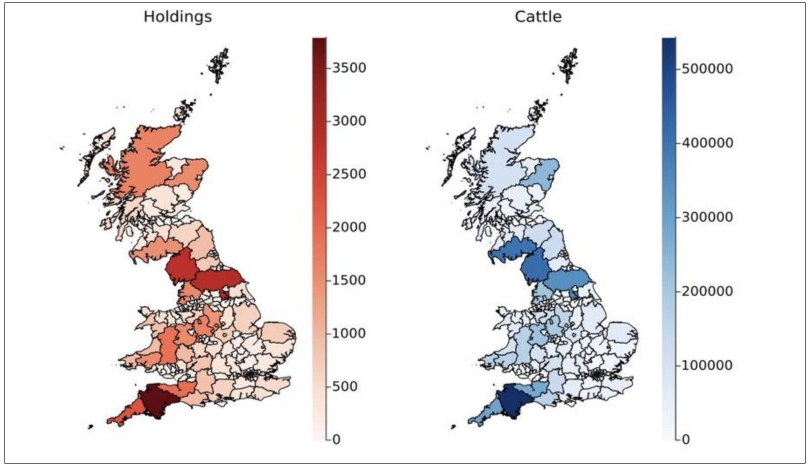
Modelling methods - Cattle data

- Data from the **Great Britain Cattle Tracing System** (from 2020 ; approx. 60,000 holdings)
- **Cattle demography:** Per holding, average cattle herd size
- **Cattle holding locations:** Per holding, easting-northing co-ordinates.

Distribution of cattle herd sizes

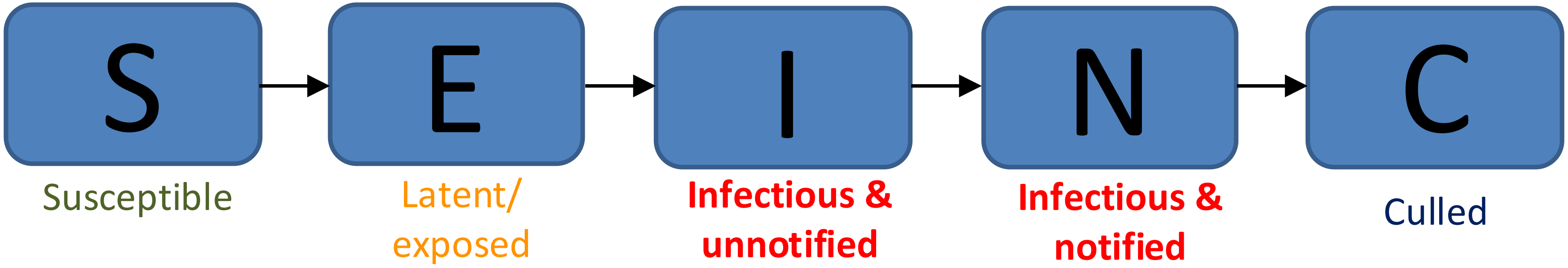


Per region, number of holdings with cattle & cattle population



Modelling methods – Disease states

- **Epidemiological unit:** Cattle holding (farm).
- **Spatial model**, based loosely on the dynamics of FMD.
  - **Force of infection dependencies:** Number of livestock, livestock type specific transmissibility and susceptibility, distance between premises.
  - **Infection to infectiousness (latent period):** 5 days
  - **Infection to notification:** 9 days
  - **Infection to culled:** 13 days



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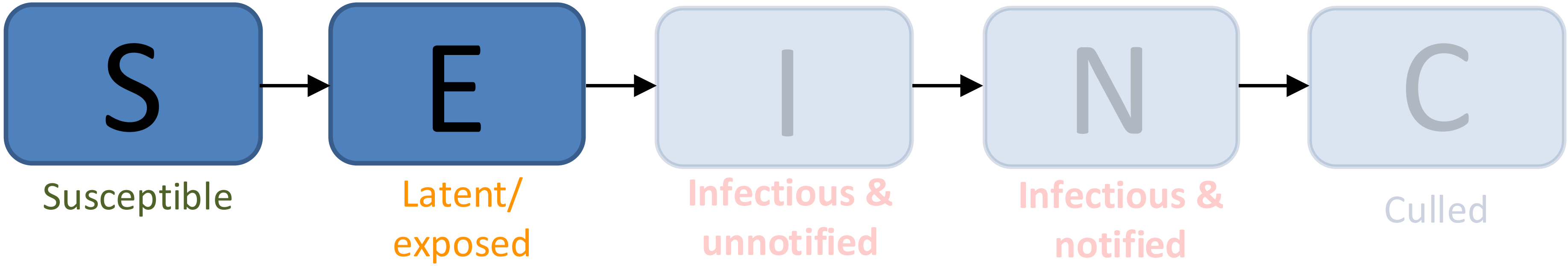

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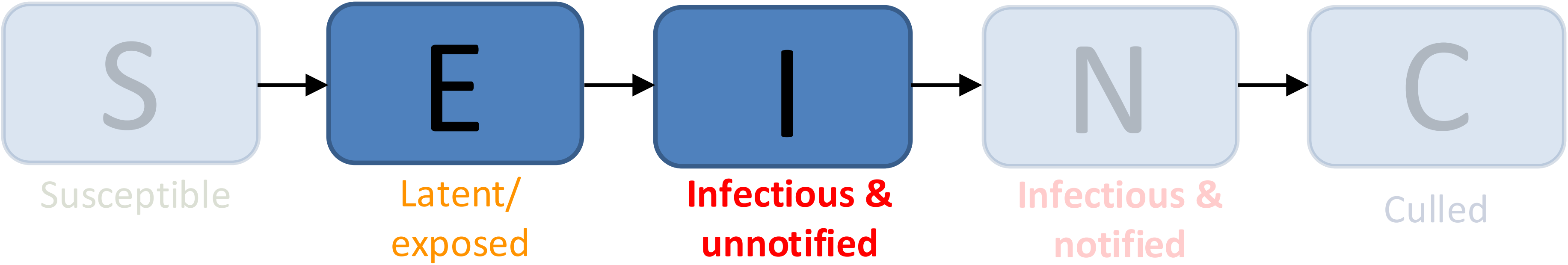

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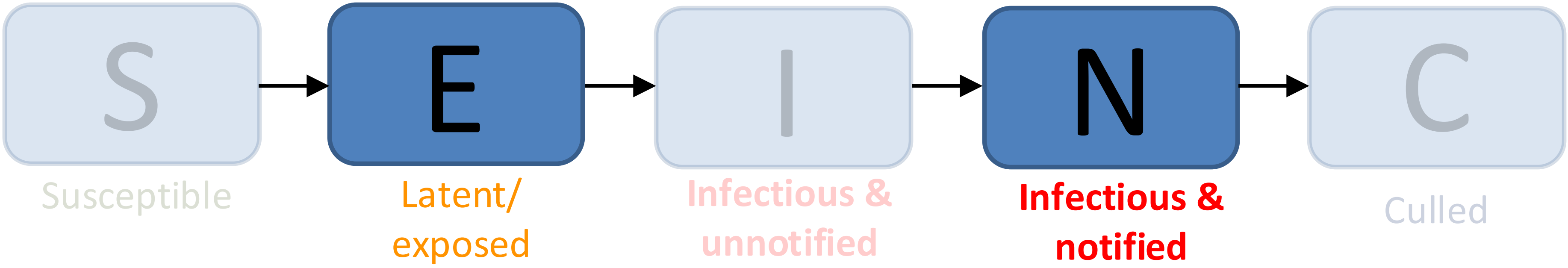

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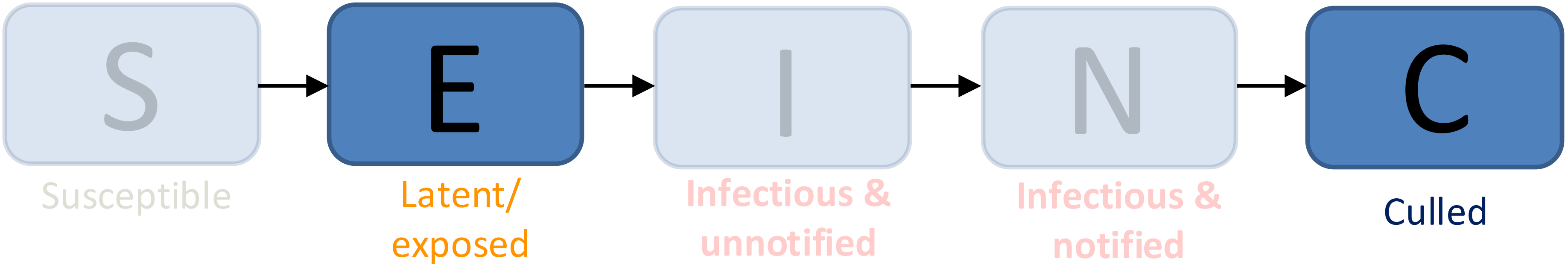


Modelling methods – Behavioural configurations

Uncooperative Only control is cattle being removed at holdings with confirmed infection. i.e. No holdings apply vaccination.

Homogeneous:
Non-data informed

Each farmer has same risk threshold - will vaccinate when infection is within a given distance.

Heterogeneous:
Non-data informed

Even split across different groups.

Heterogeneous:
Data informed

Parameterised using interview results

Study aim 3: Assess impact of behaviour assumptions

1. Elicit farmers vaccination decisions to an unfolding epidemic and link to their psychosocial and behavioural profiles (within Great Britain)

2. Refine mathematical disease models to capture psychosocial & behaviour change heterogeneities

3. **Assess how psychosocial & behaviour change factors impact epidemiological outcomes given a fast-spreading livestock disease**

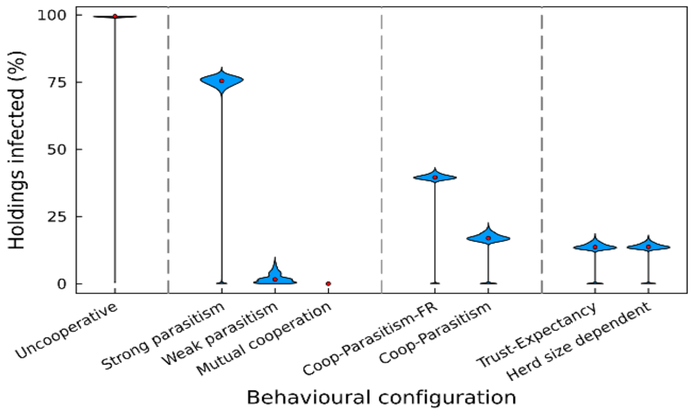
Spatial stochastic simulations of a fast-spreading epidemic in Great Britain cattle holdings:

- Per behavioural configuration, ran 500 replicates per 89 seed region locations.
- Per simulation replicate, seeded infection seeded in randomly selected cluster of three premises.

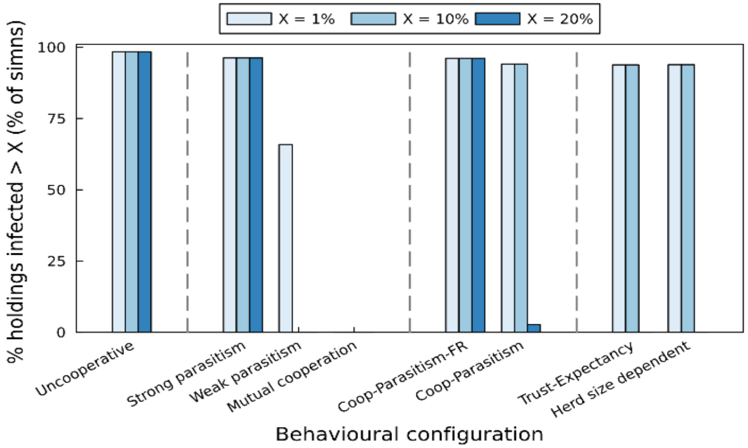
Modelling results – Epidemiological metrics

Figure: For each behavioural configuration: **(a)** Distribution of percentage of holdings infected; **(b)** Percentage of simulations exceeding the stated final size.

(a)



(b)

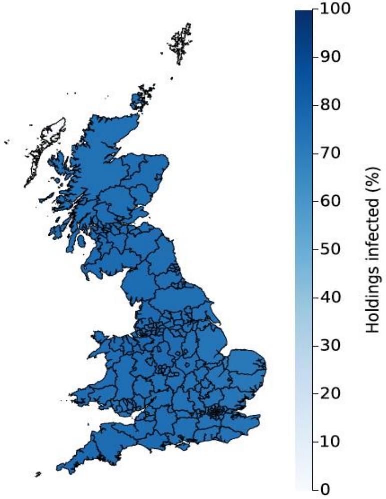


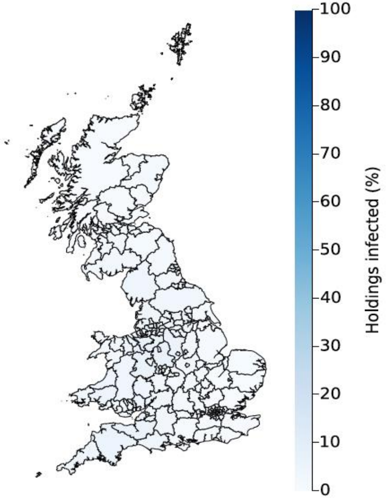
- Comparing homogeneity in farmer behaviour vs data-informed heterogeneity in farmer behaviour: **Disconnect in outcomes**

Modelling results - Role of seed infection region

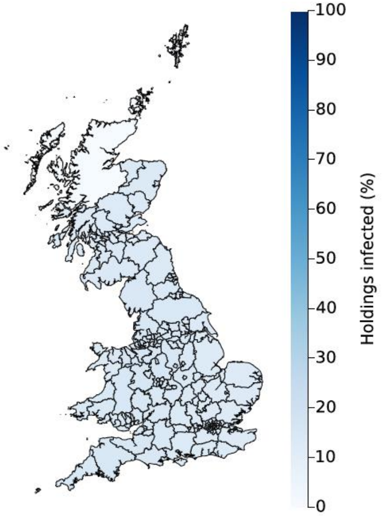
Median percentage of holdings infected, dependent on region of outbreak emergence and behavioural configuration. Statistics computed from 500 replicates per scenario.

Homogeneous behaviour (non-data informed)





Heterogeneous behaviour (data informed)



Vaccinate when infection within:

50km

320km

Study implications

Demonstrated a conjoined epidemiological and socio-behavioural workflow in action!

Encourage consideration of actions of individual farmers in policy frameworks for tackling future livestock disease outbreaks

Acknowledgements

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