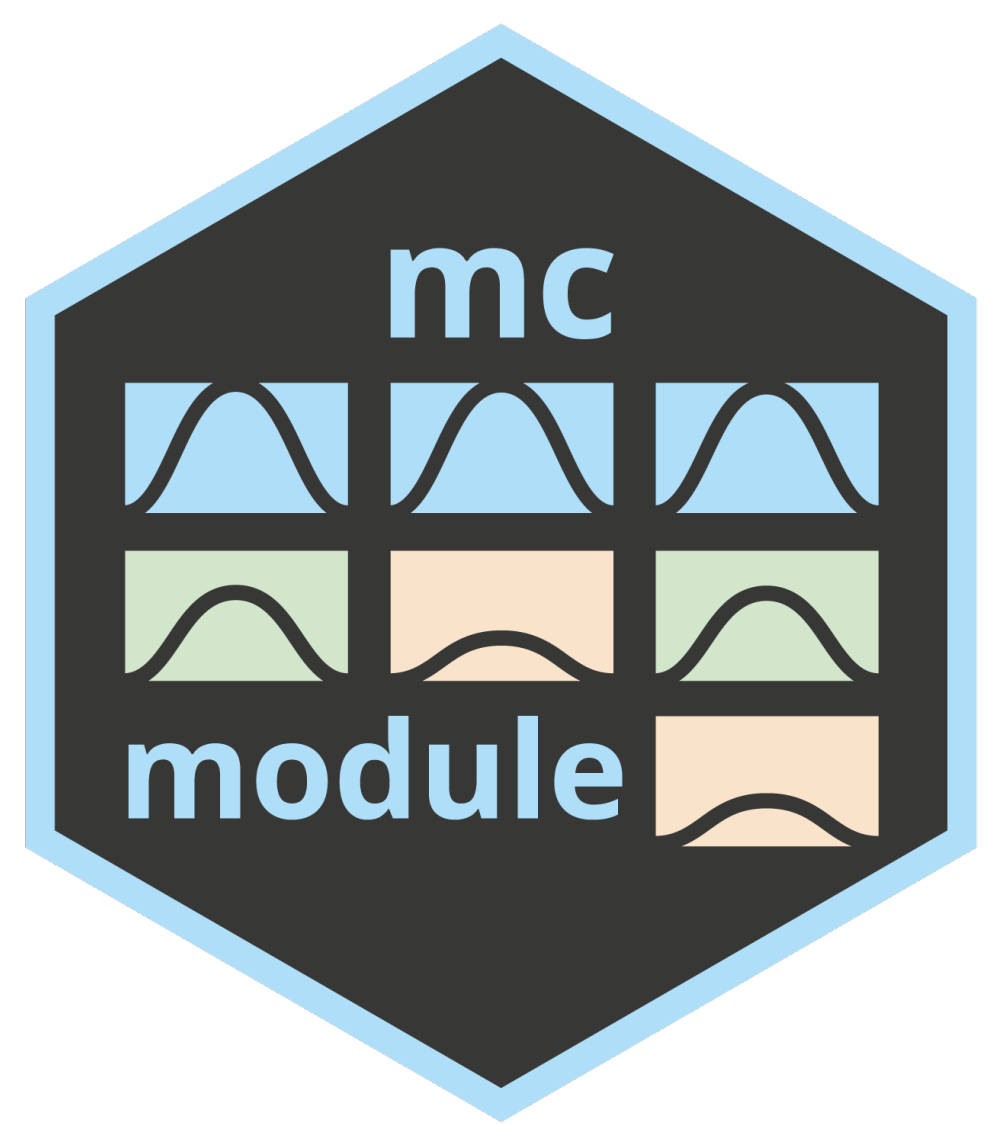




Modular, multi-scenario, multi-pathway Risk assessment in R

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Complex risk models limitations

Breaking risk into probability steps helps produce analyses that are easy to interpret. R packages such as mc2d can represent both parameter uncertainty and distinct parallel model units, known as variates (Fig.2). But real risk pathways are messy (Fig.2), and aggregating pathways with inputs with different variates is difficult to implement cleanly.

Fig. 2 – Introduction of sheep and goat pox into a country through two risk pathways, with a probability assigned to each step.

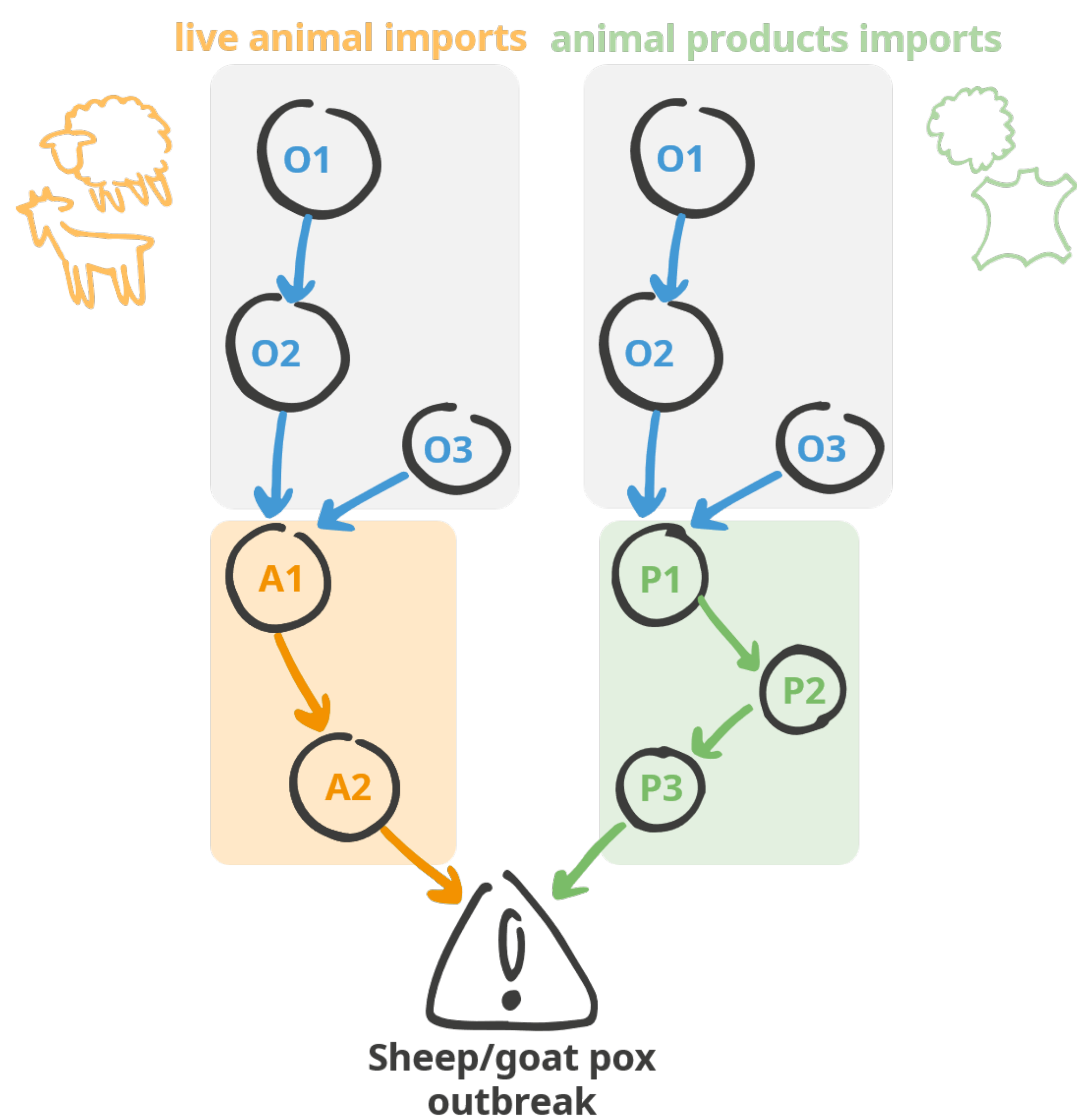


Fig. 4 – Building and evaluating a module with mcmodule

```
imports <- eval_module(
  exp = c(imports = origin_inf_exp), # Model expressions
  data = imports_data, # Input data
  mctable = imports_mctable, # Node definitions
  data_keys = imports_data_keys # Data keys for matching
)
```

Fig. 6 – Multilevel sampling structures, e.g. probabilities of an event occurring in at least one animal at least one farm

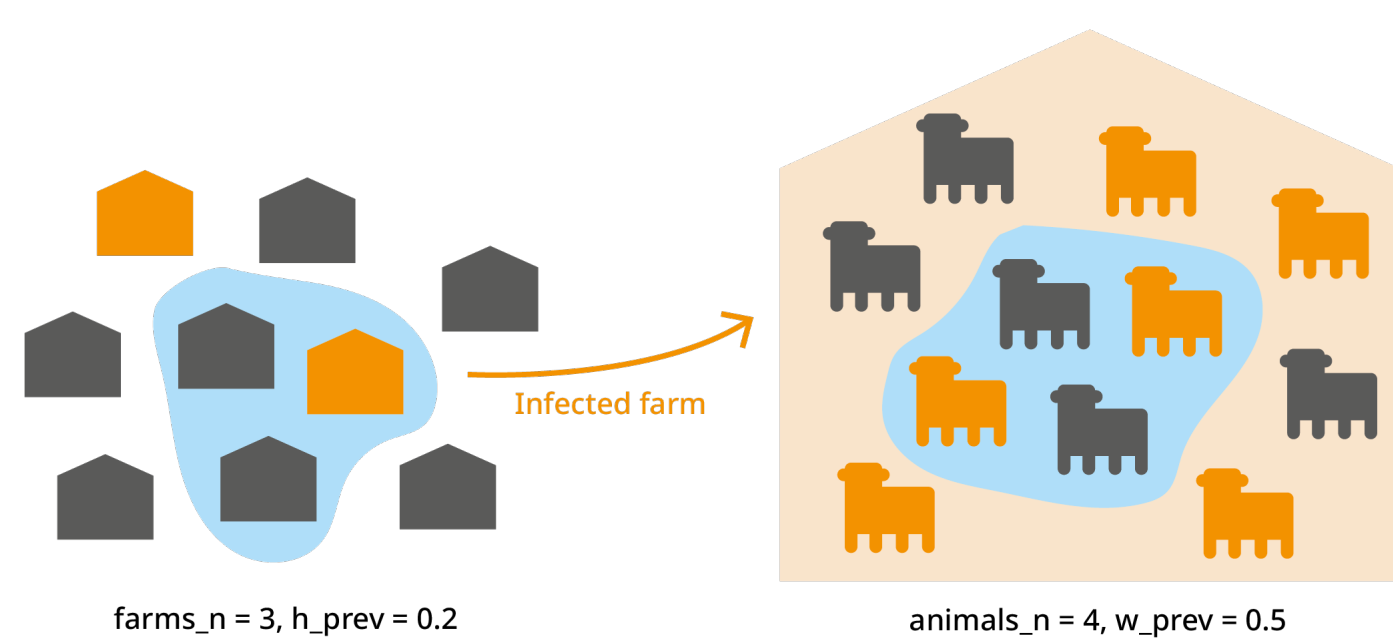
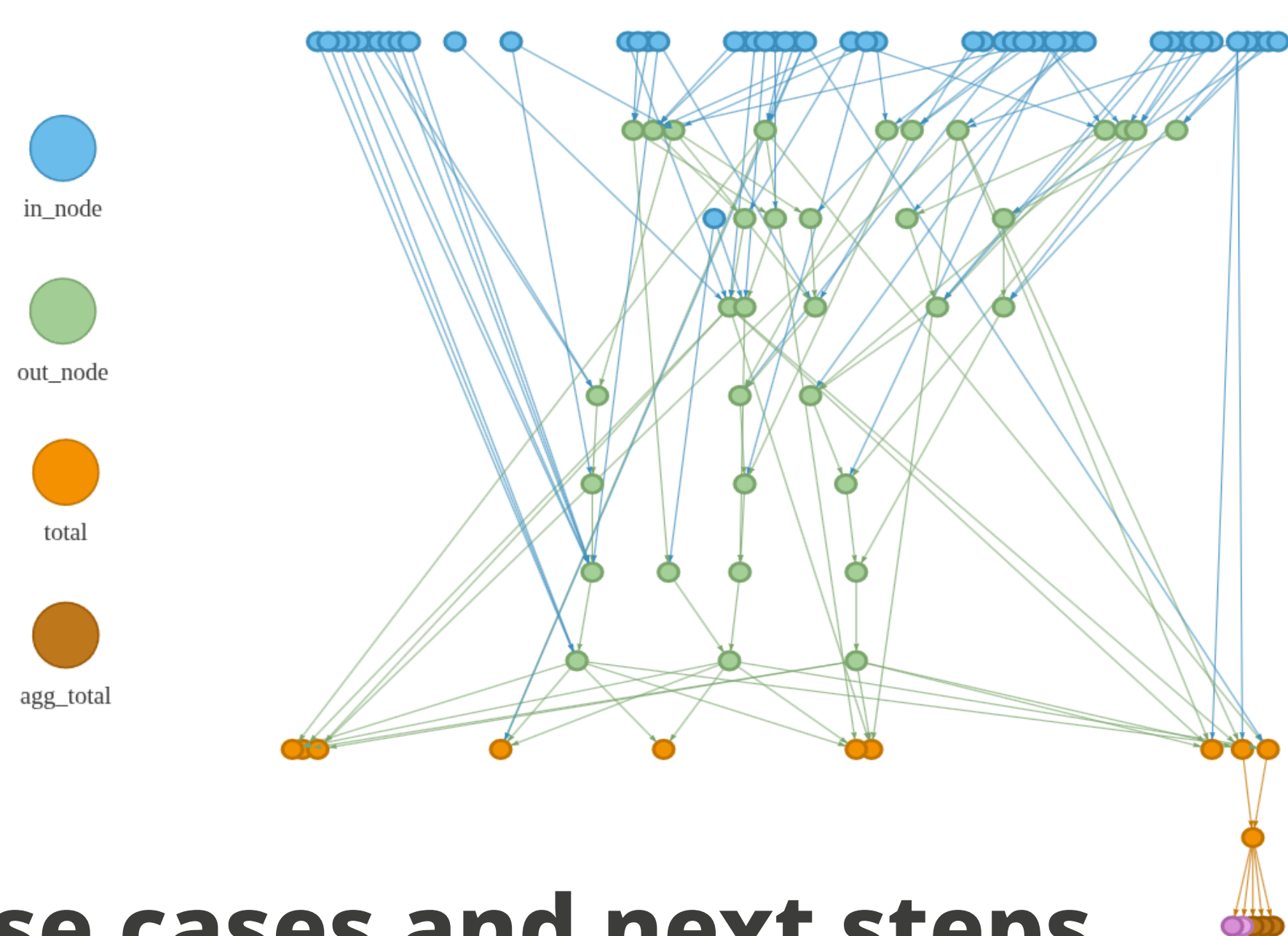


Fig. 7. – Visualizing model parameters as a network.



Use cases and next steps

This package has been used in to simulate the introduction of pathogens to a farm through different pathways (Fig. 10). Future applications will include estimating import risks. mcmodule is actively maintained on CRAN and Github.

Fig. 1 – Uncertainty (u) and the variates (i) propagated through model operations using two dimensional Monte Carlo tools (mc2d).

node_x						node_y						node_xy					
1	2	3	...	u		1	2	3	...	u		1	2	3	...	u	
1	0.01	0.02	0.01	...	0.02	1	0.005	0.001	0.002	...	0.003	1	5E-05	2E-05	2E-05	...	6E-05
2	0.02	0.02	0.01	...	0.01	2	0.001	0.002	0.004	...	0.002	2	2E-05	4E-05	4E-05	...	2E-05
3	0.39	0.37	0.41	...	0.4	3	0.55	0.53	0.58	...	0.54	3	0.21	0.2	0.24	...	0.22
4	0.42	0.38	0.4	...	0.37	4	0.17	0.2	0.18	...	0.15	4	0.07	0.08	0.07	...	0.06
...	0.25	0.56	0.32	...	0.69	...	0.02	0.03	0.02	...	0.02	...	0.01	0.02	0.01	...	0.01
i	0.61	0.42	0.28	...	0.33	i	0.03	0.02	0.02	...	0.02	i	0.02	0.01	0.01	...	0.01

Modular risk simulations

mcmodule R package provides tools to represent risk processes as mathematical expressions (Fig. 3). and evaluate them in independent flexible modules (Fig. 4). It assigns metadata to model parameters, making it easy to identify which variate corresponds to which data row. This enables combining probabilities across pathways (Fig. 5) and calculating event probabilities on hierarchical sampling structures (Fig. 6). Other features are included to facilitate the creation of complex risk analyses, for example, to automate the creation of stochastic parameters, visualize the model structure (Fig. 7), compare what-if scenarios (Fig. 8), and perform model diagnostics, such as sensitivity analysis (Fig. 9).

Fig. 3 – Model expressions representing the probability of the exporting country being infected (blue), and the probability of infection through product imports (green) and animal imports (orange)

```
origin_inf_exp <- quote({
  # Proportion of years with documented outbreaks
  p_years_outbreaks
})
products_inf_exp <- quote({
  # Number of infected animals before detection
  n_products
})
animal_inf_exp <- quote({
  # Number of infected animals before detection
  n_animals_pos <- n_herds_pos * w_prev * (census_heads / census_holdings)
  # Probability an animal is infected
  p_inf_animal <- p_not_detected_origin * (n_animals_pos / census_heads)
})
```

Fig. 5 – Not all of the country-species combinations represented in the first parameter (orange) are available in the second parameter (green). However, we can perform operations after aligning their keys.

country_code	species	Row	1	2	3	...	u	country_code	species	Row	1	2	3	...	u	country_code	species	Row	1	2	3	...	u
AUS	sheep	1						null	null	1						AUS	sheep	1					
BGR	sheep	2						null	null	2						BGR	sheep	2					
GRC	sheep	3						GRC	sheep	3						GRC	sheep	3					
GRC	goat	4						GRC	goat	4						GRC	goat	4					
ITA	sheep	5						ITA	sheep	5						ITA	sheep	5					
ITA	goat	6						ITA	goat	6						ITA	goat	6					
null	null	7						PRT	sheep	7						PRT	sheep	7					

Fig. 8 – Comparing the risk of sheep and goat pox introduction by commodity and scenario. Points represent uncertainty simulations.

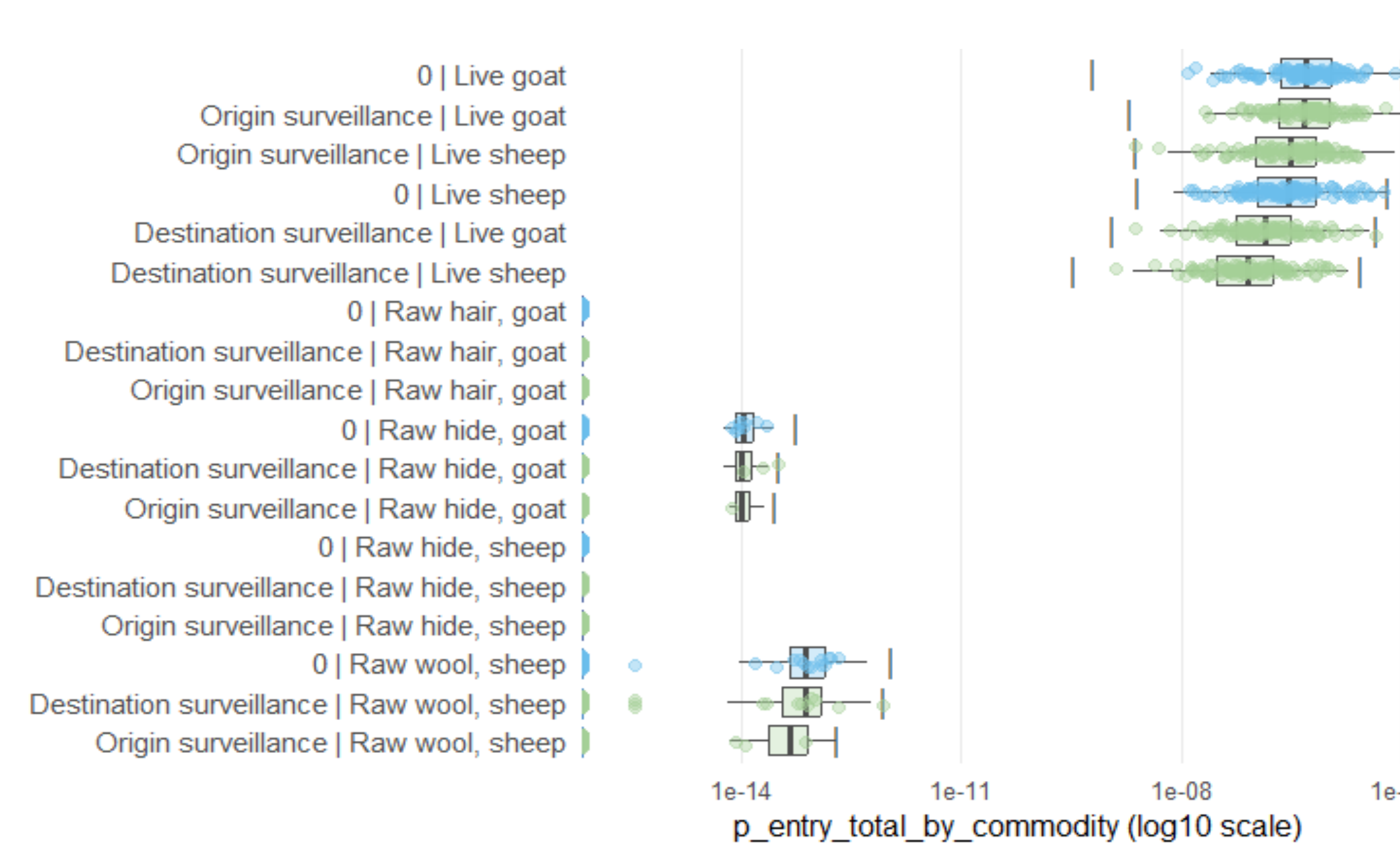


Fig. 10 – FarmRISK model diagram

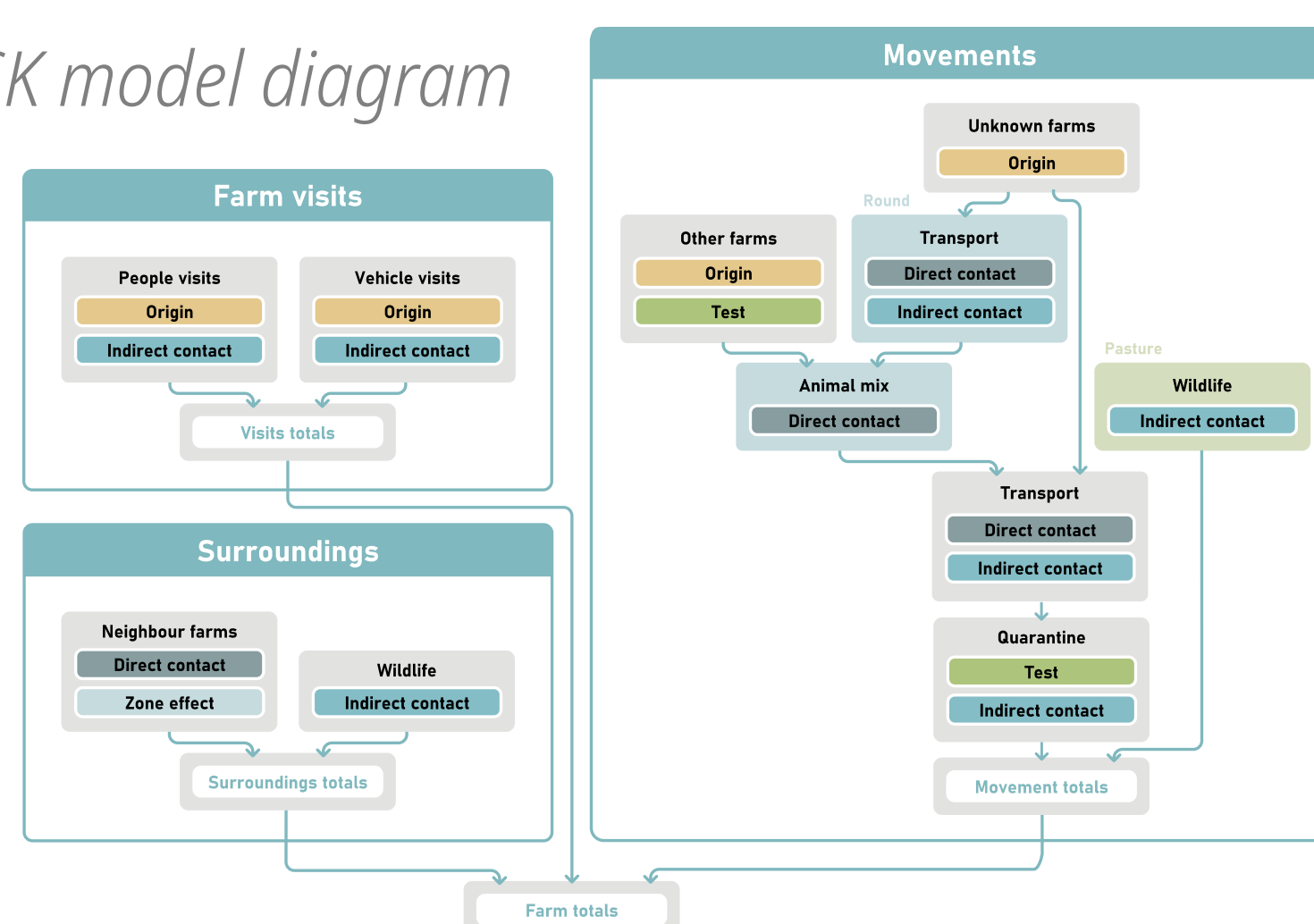
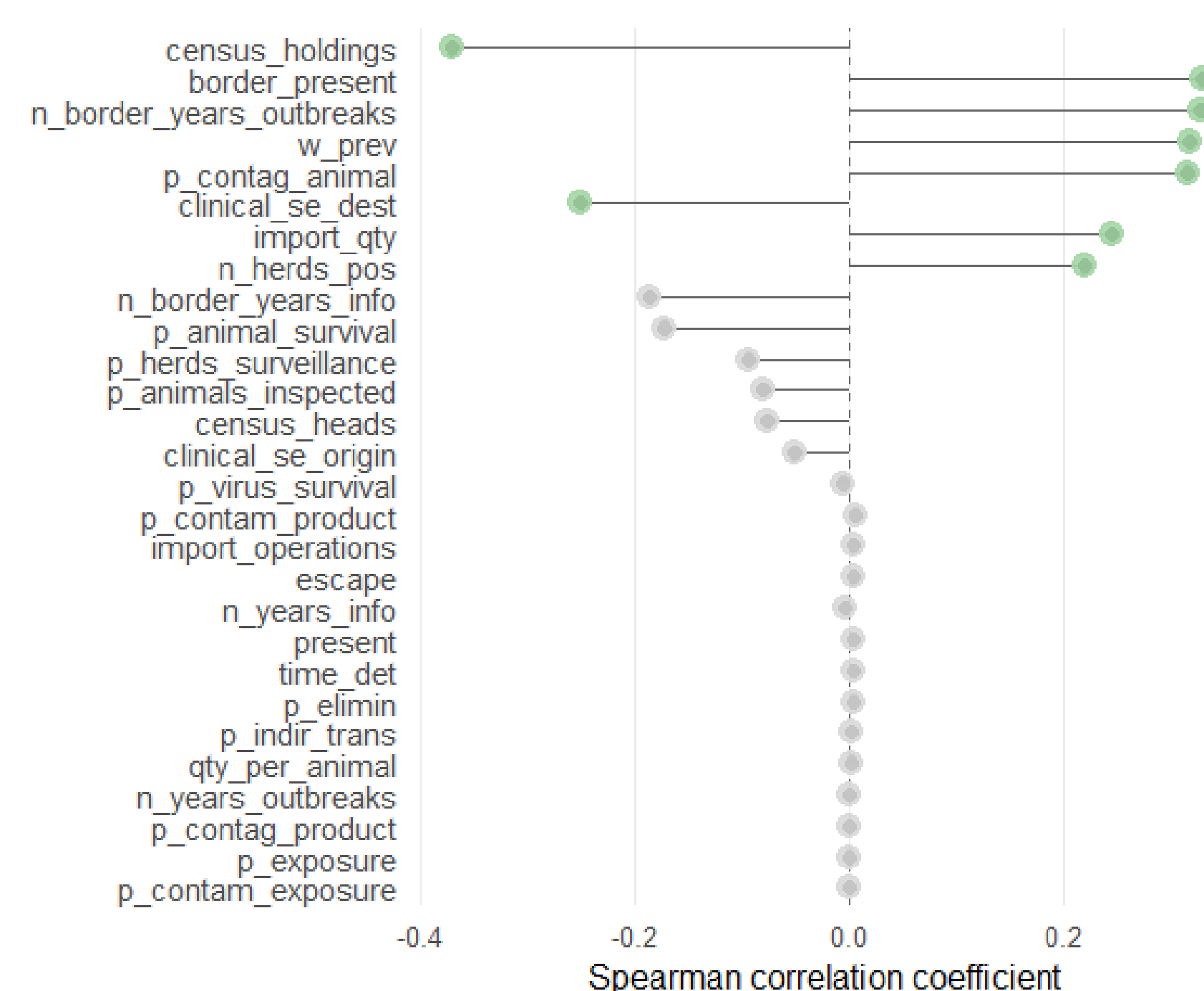


Fig. 9 – Correlation between inputs and outputs, based on the inputs sampling space.



Tutorials and more info

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