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THE UNIVERSITY of EDINBURGH
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Assessing the potential impact of environmental land management schemes on emergent infectious disease risks

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UKRI Biotechnology and Biological Sciences Research Council

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How do land management decisions affect disease?

- To improve biodiversity and carbon sequestration, we offer land owners incentives to plan new woodland.
- This is good!
- But are there unintended consequences?
- If we increase biodiversity, how does that affect contact between wildlife and agriculture?
- And how does that affect disease transmission?

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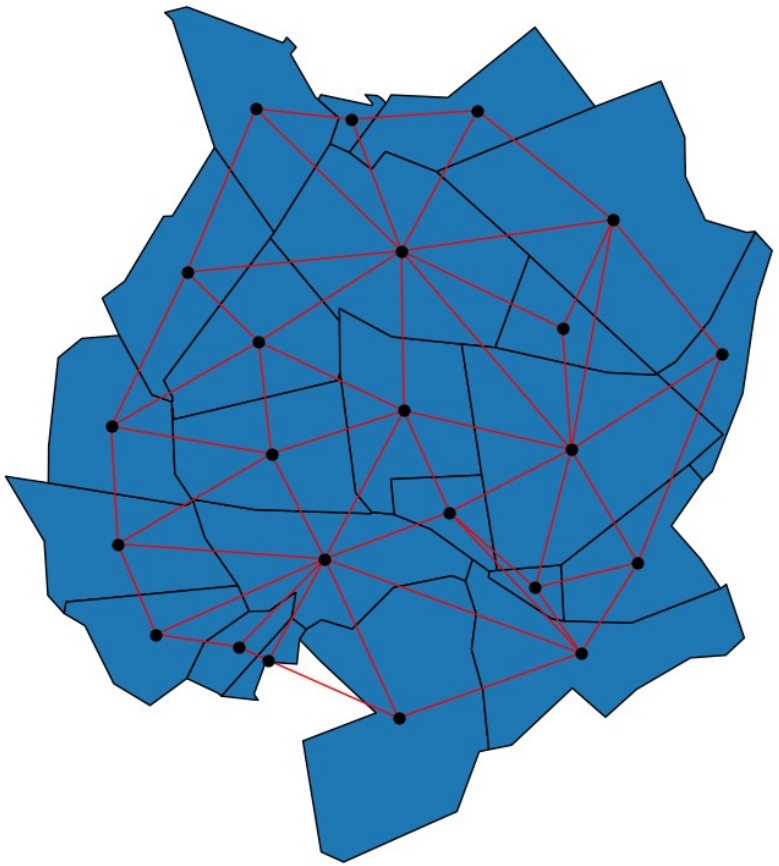
Why is this a network problem?



- Parcels of land are arbitrary polygons that can be connected to multiple others
- We can consider adjacency of land parcels to be a network.
- Edges represent the potential for contact between species inhabiting each land parcel.
- Scotland has 1,441,962 land parcels
  - with 4,221,802 edges between them!

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Land use/ Species distribution

Existing land use and species distributions are taken as input.

Economic model

Economic model of woodland subsidies predicts the conversion of existing land use into new woodland.

New species distribution

Species distribution model predicts the new distribution of wildlife given the changes in land use and new woodland.

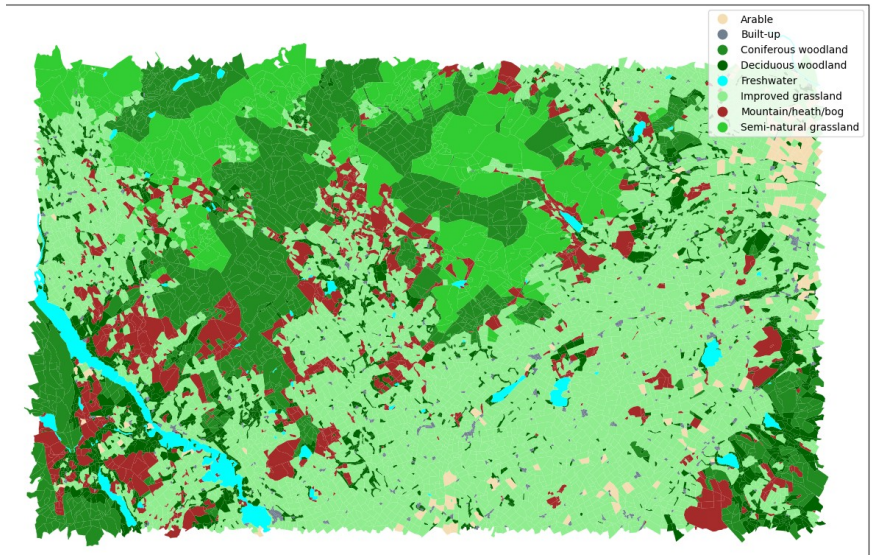
Wildlife/ livestock network

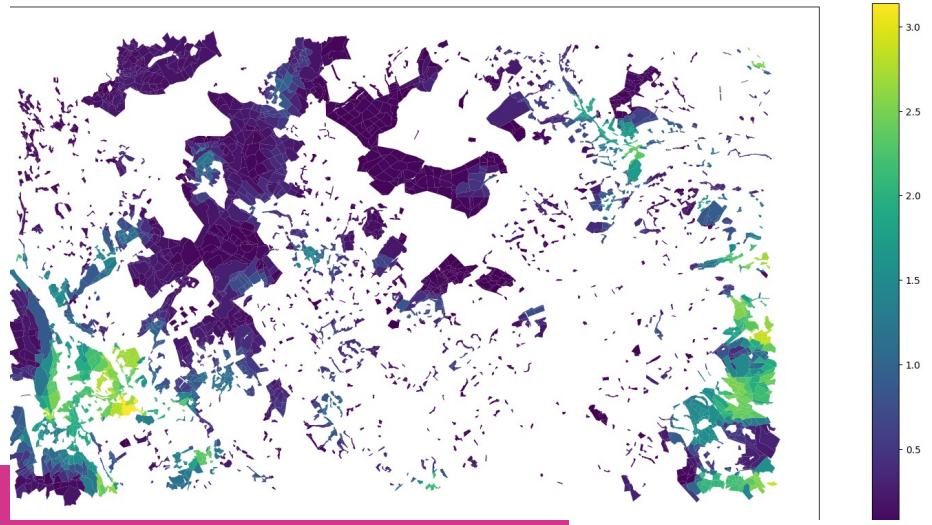
Proximity network models the relationship between land with wildlife and land with agricultural holdings.

Disease transmission risk

Change in disease risk is estimated from the network before and after land use change.

Existing land use / species distribution





- For a test area in Dumfries and Galloway, Scotland:
  - UK Centre for Ecology and Hydrology (UKCEH) Land Cover maps
    - Land parcels covering UK represent discrete units of land dominated by one land cover type.
  - Deer distribution taken from existing study (Croft et al., 2017).
  - Cattle locations taken from Cattle Tracing System (CTS) of the British Cattle Movement Service (BCMS).
  - Around 36,000 cattle in the area.

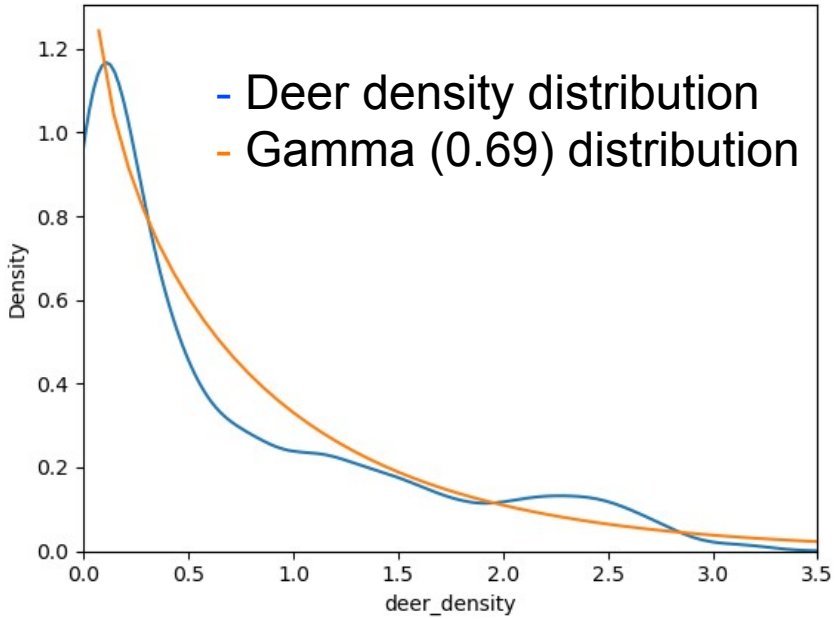
Economic model

Land type/subsidy	Margin/subsidy
Oilseed rape	£1,340
Potatoes	£1,393
Spring barley	£773
Spring field beans	£835
Spring oats	£422
Winter barley	£1,079
Winter wheat	£1,315
Grass (without livestock)	£0
Maize	£∞
Other crops	£∞
Woodland plantation subsidy	£1,104

Subsidy > Margin => New woodland

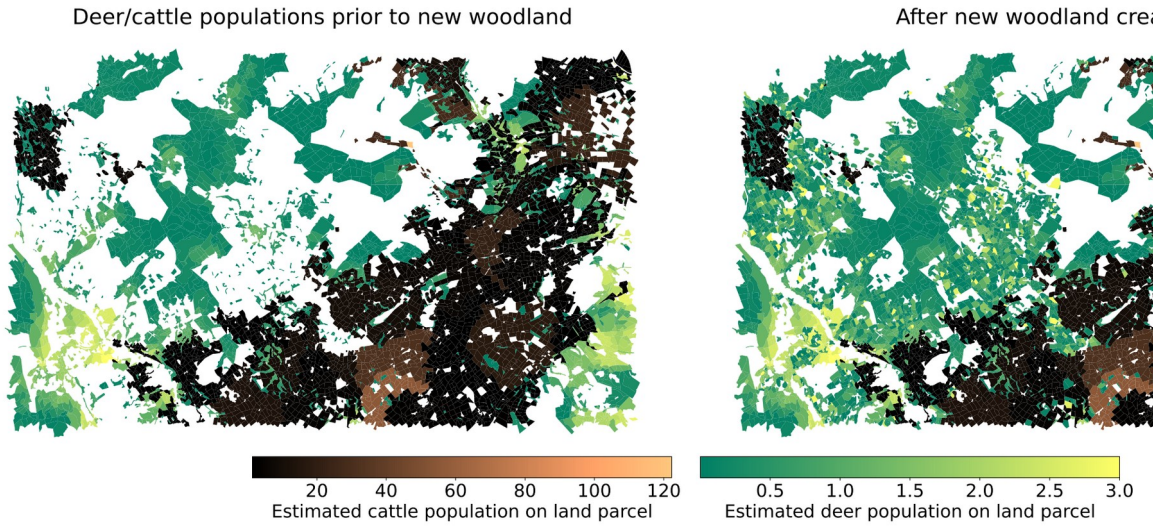
- Current agricultural returns are estimated for each land parcel.
- Gross margin per hectare was taken for each land type from the Farm Management Handbook (Beattie, 2022).
- Current forestry subsidies taken from Scottish Government Forestry Grant Scheme (Scottish Government, 2019).
- Simple model applied: if subsidy is greater than margin then new plantation is likely.
- Test a range of subsidy values.

New species distribution



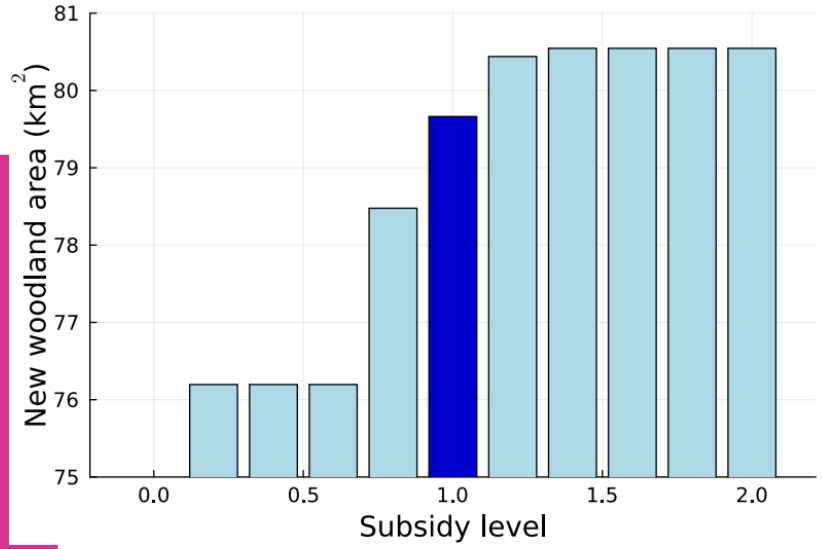
- Estimate spread of deer into new woodland areas:
  - Existing population distribution in deciduous woodland fits Gamma distribution.
  - New woodland populated with deer by drawing from that distribution.

Wildlife / Livestock network



- To estimate disease transmission risk we build the adjacency network between land parcels with deer and with cattle.
- Edges between parcels denote adjacency of deer and cattle, and thus risk of transmission.
- Networks built before and after new woodland creation.

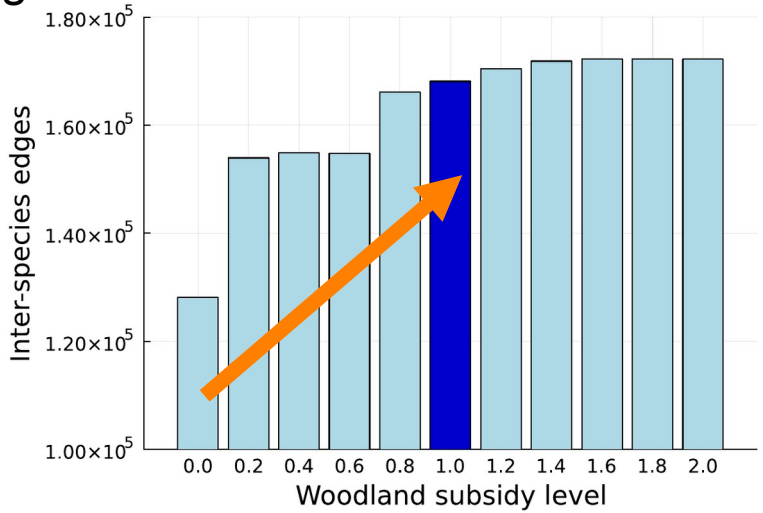
How can land management decisions affect disease?



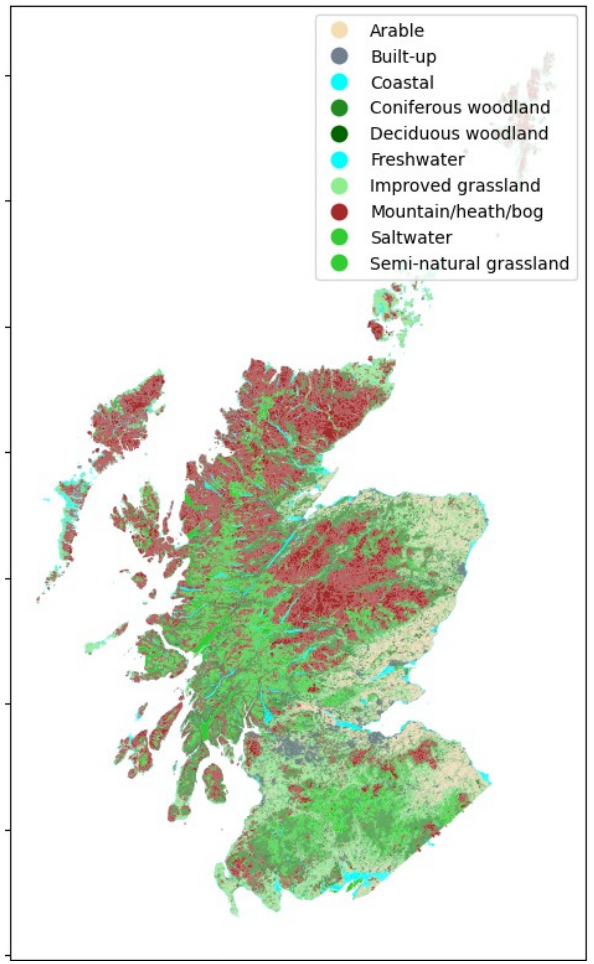
Modest increase in woodland area

- Area of **woodland created only varies by around 3%** between the low and high subsidy scenarios.
- But can allow up to a 57% increase in deer population.
- Overall **26%--35% increase in contact risk** between cattle and deer, depending on the level of subsidy provided.

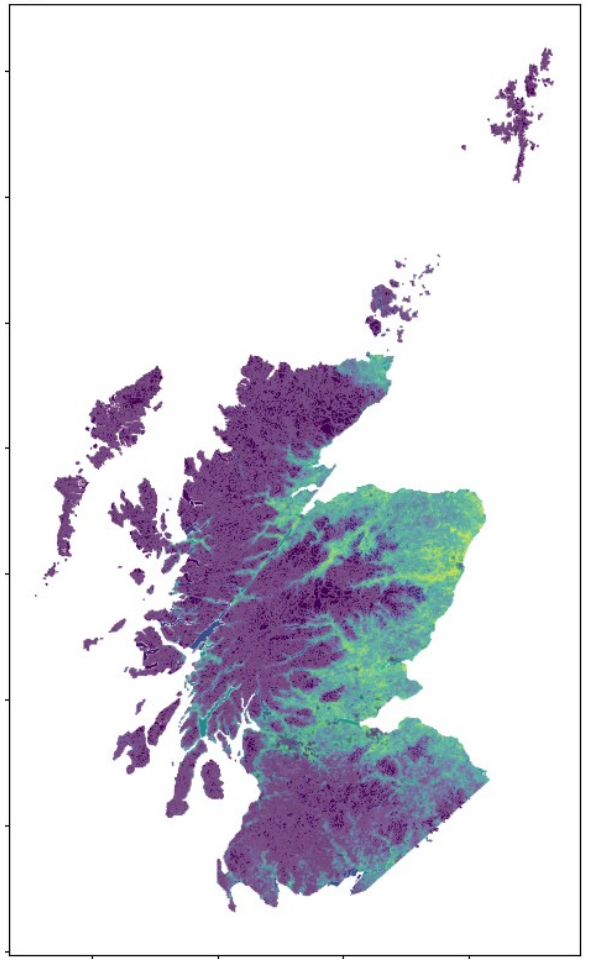
Significant increase in deer/cattle contact



Where from here?



- National scale
- Economic model:
  - Budget cap
  - Landowner choices (value curve)
    - (also non-econ decisions)
- Deer distribution model:
  - Machine learning-based
  - Better spatial distribution
- Carbon impact
- Disease model
  - From contact to disease process
  - Cattle movements



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Thank you

Preprint available:

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Full paper under review: J. Environmental Management