

Influence of Feedbacks in Food System Models: Exploring the Relevance of Biodiversity and Other Cross-System Feedbacks

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Food System? Isn't this a Biodiversity Conference??

The food system is a key policy space for both **climate** and **biodiversity**.

Existing models are biased towards **climate** (Neumann et al. 2026).

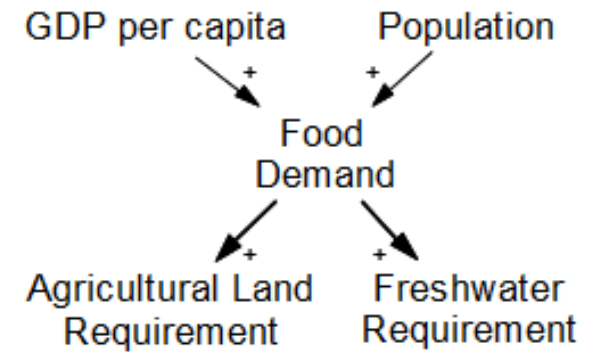
Models should support a more **integrated** perspective for biodiversity and other sustainability outcomes.

Conceptualisation of the Food System

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Food Demand



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Conceptualisation of the Food System

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Agricultural Resource Allocation

1) Water Stress Response ☉

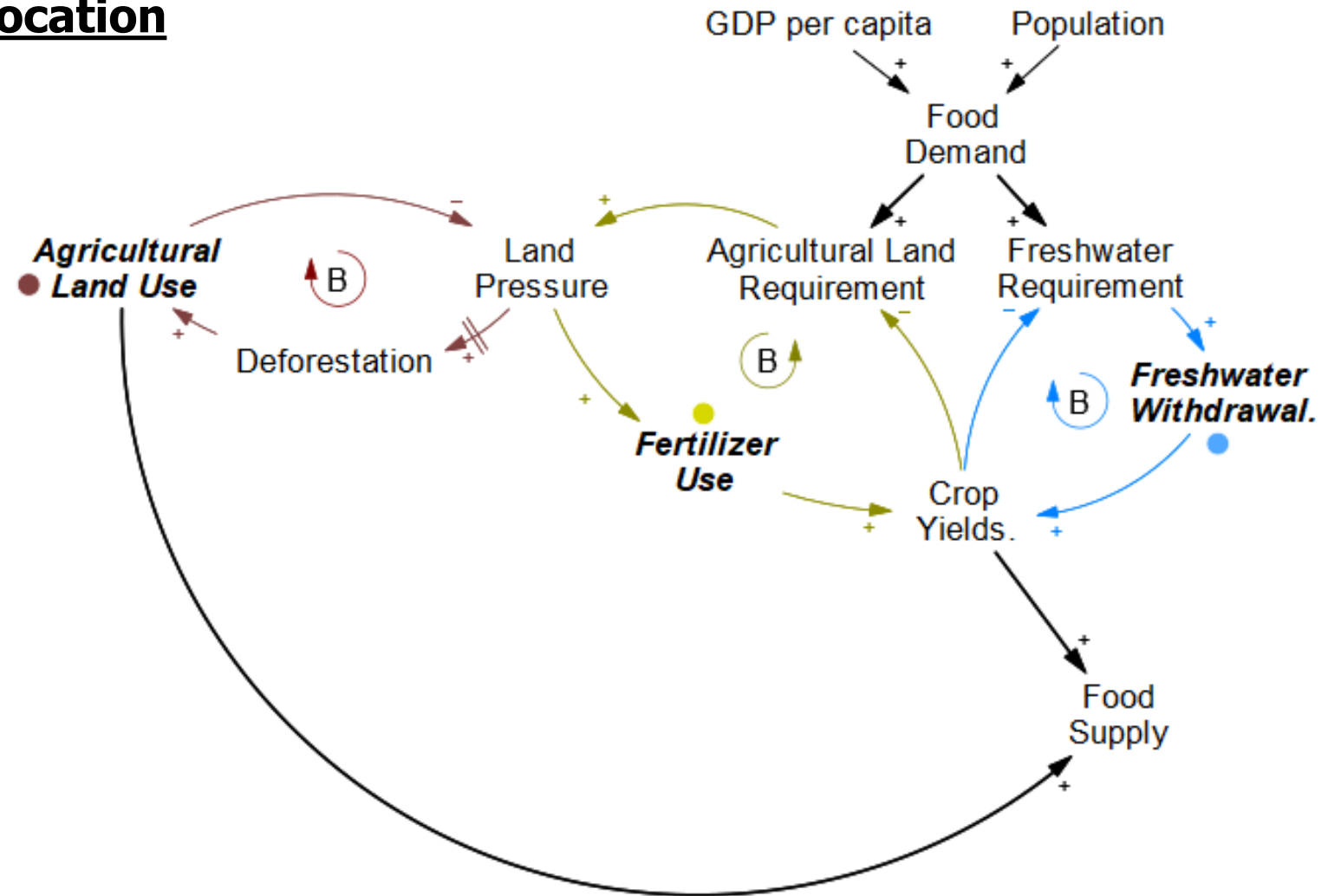
(Yield → Water Use → Yield)

2) Land Use Response ☉

(Yield → Land Use → Yield)

3) Fertiliser Intensification ☉

(Yield → Fertiliser Use → Yield)



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Conceptualisation of the Food System

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Environmental Feedbacks

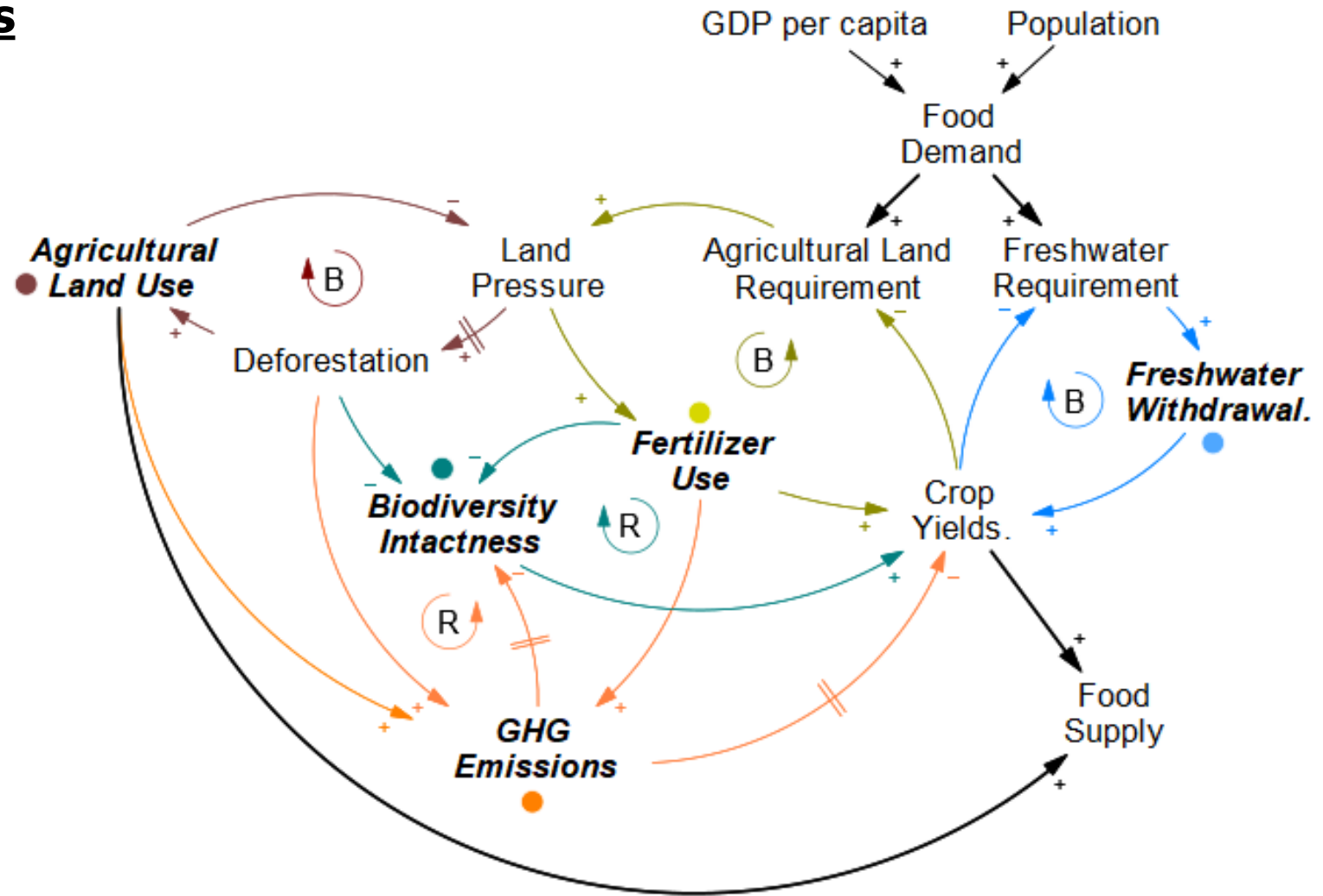
4) Biodiversity Feedback

(Biodiversity → Yields → ...)

5) Climate Feedbacks

(Temperature → Yield → ...)

(Carbon → Yield → ...)



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Conceptualisation of the Food System

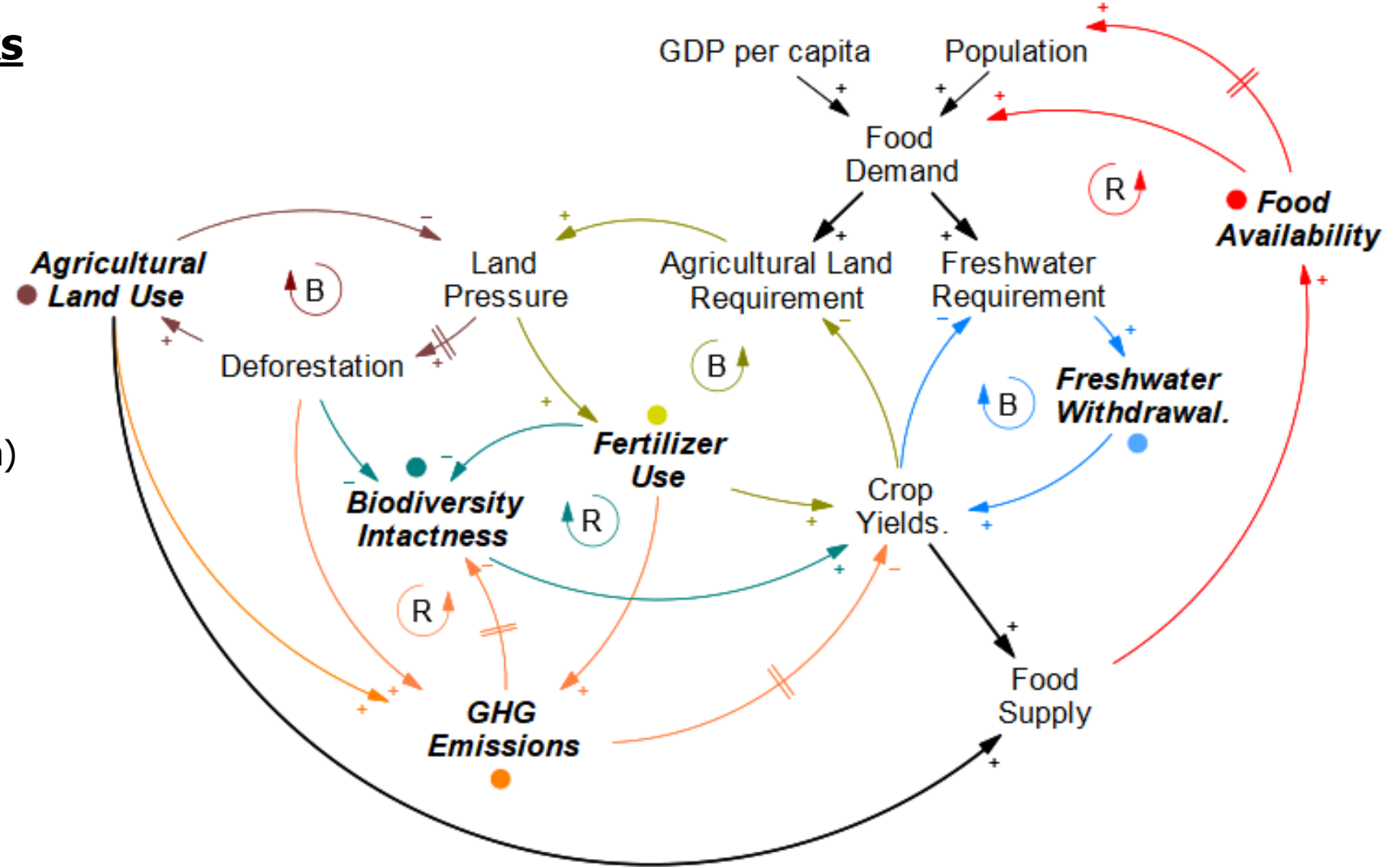
Socioeconomic Feedbacks

6) Market Feedback

(Supply → Price → Demand)

7) Population Feedback

(Supply → Availability → Population)



Limitations in Model Structures and Representation

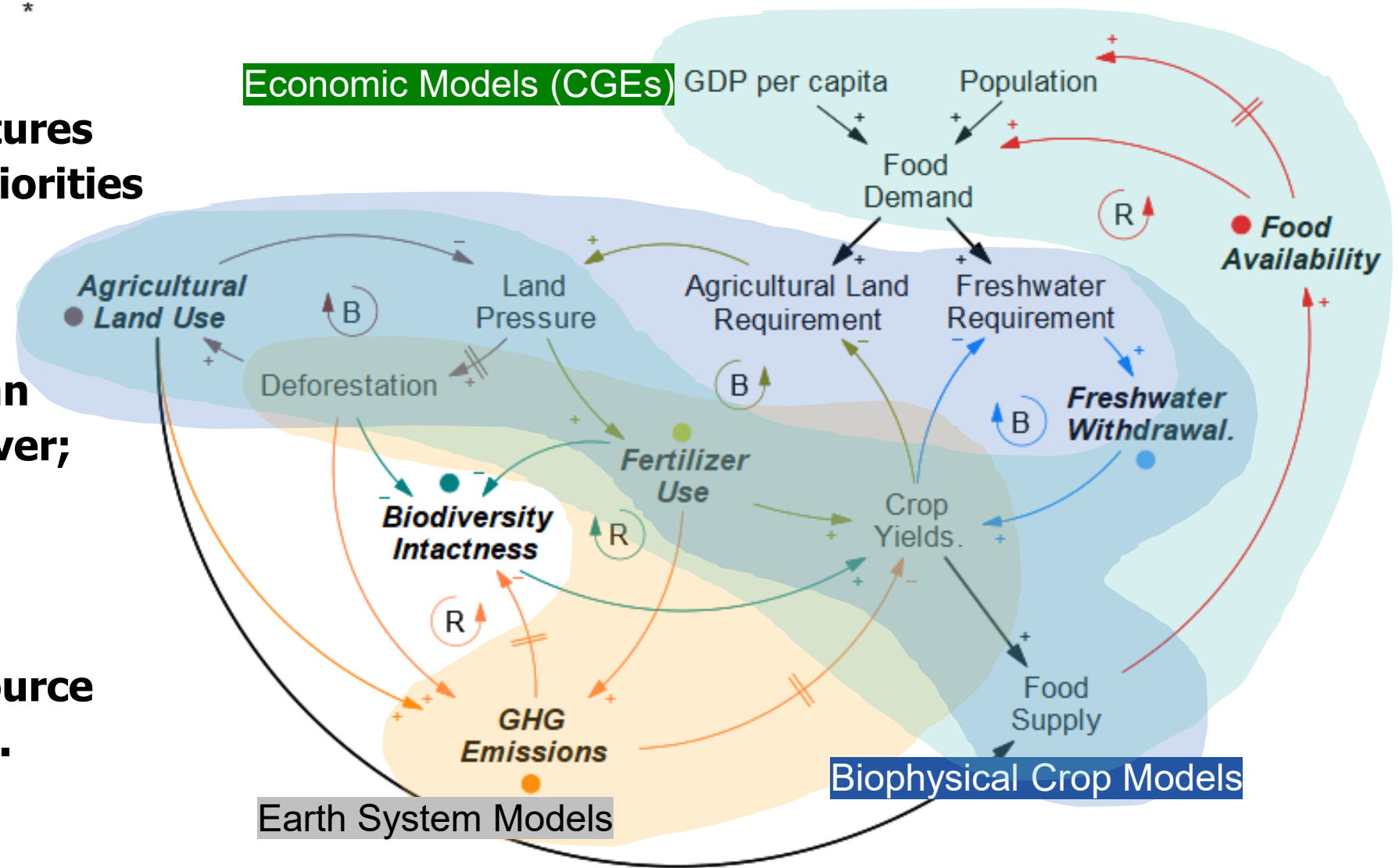
Models' differing structures biases towards their priorities

(Neumann et al., 2026)

Biodiversity is largely an endpoint, not a key driver;

(Kim et al., 2025)

Limitations in model representation are a source of bias and uncertainty.



What will we learn from having a fuller picture?

Experimental Setup

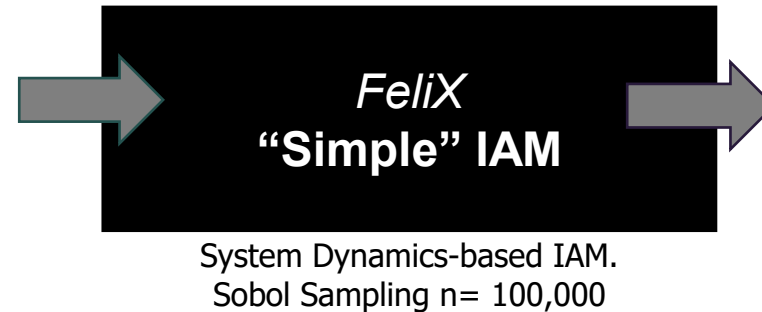
FEEDBACKS* as INPUTS

**Relatively underexplored feedbacks*

- **Biodiversity-Yield** Feedback
- **Climate-Yield** Feedback
- **Water-Yield** Feedback
- **Land-Fertiliser** Intensification
- **Food-Population** Feedback

Varying from “full feedback” to “no feedback”

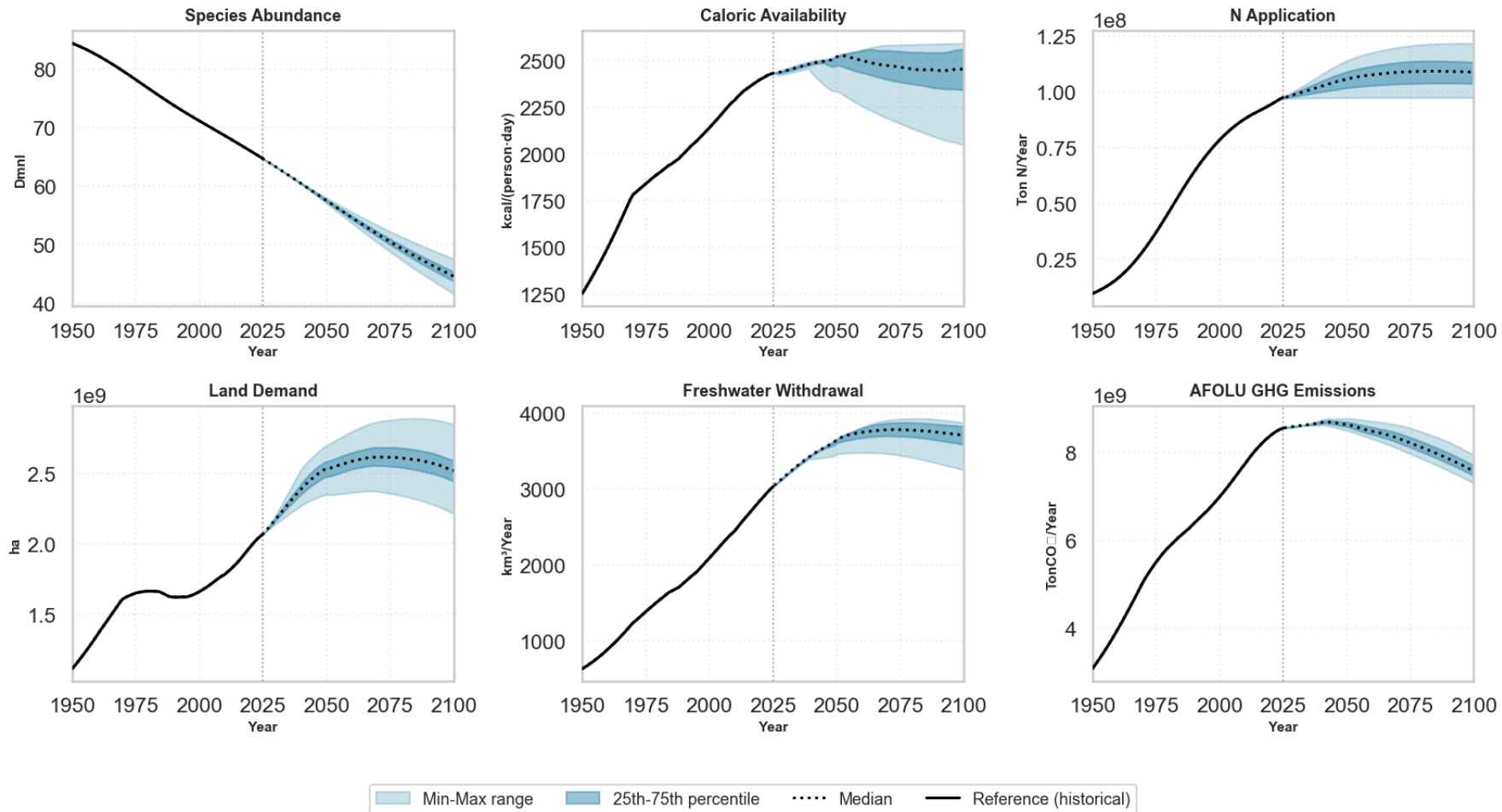
Global Sensitivity Analysis



OUTCOMES as OUTPUTS

- (**Biodiversity**) Species Abundance
- (**Climate**) GHG Emissions AFOLU
- (**Water**) Freshwater Withdrawal
- (**Land Use**) Agriculture Land Demand
- (**Fertilizer**) Nitrogen Application
- (**Nutrition**) Caloric Availability

Uncertainty Ranges of Outcomes (LHC Sampling)

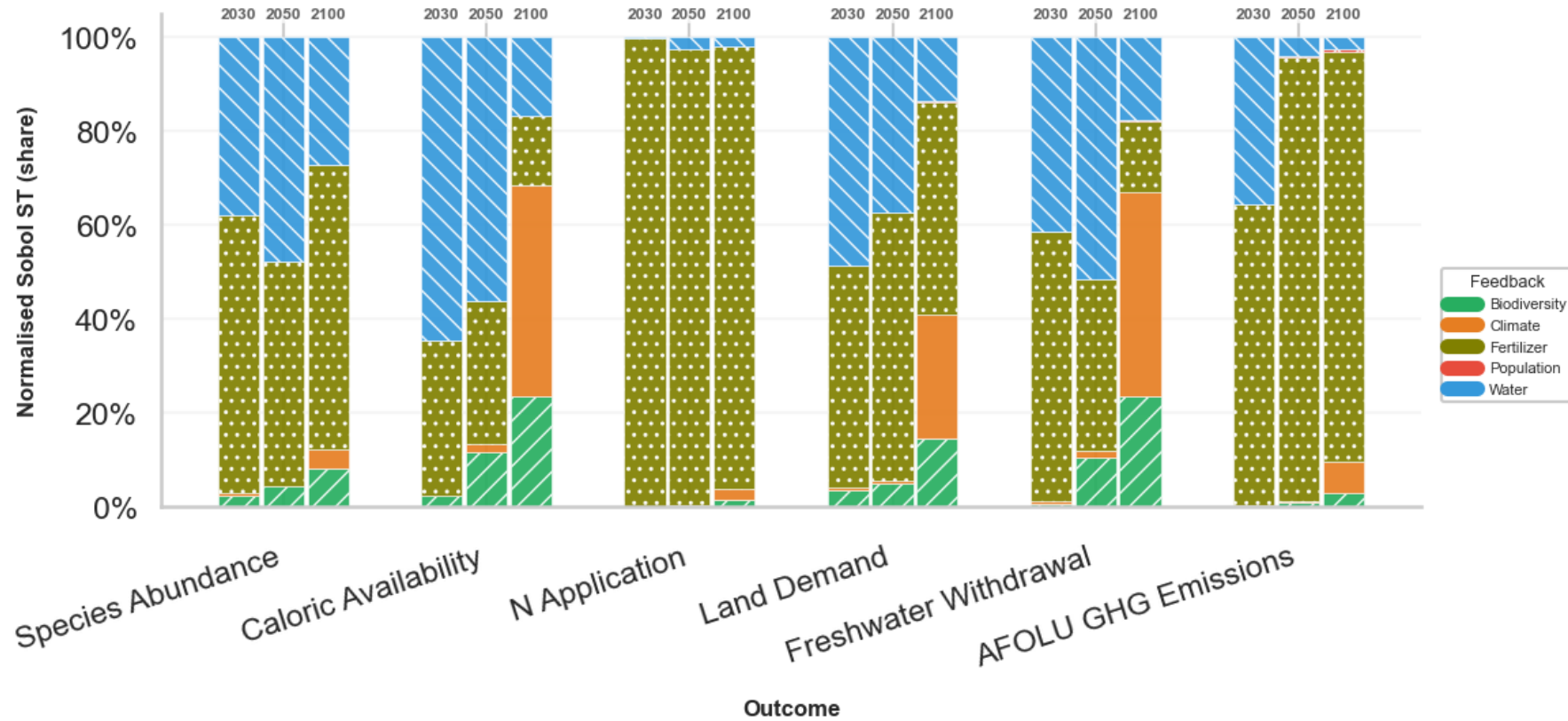


(1) Some outcomes are more “uncertain” than others

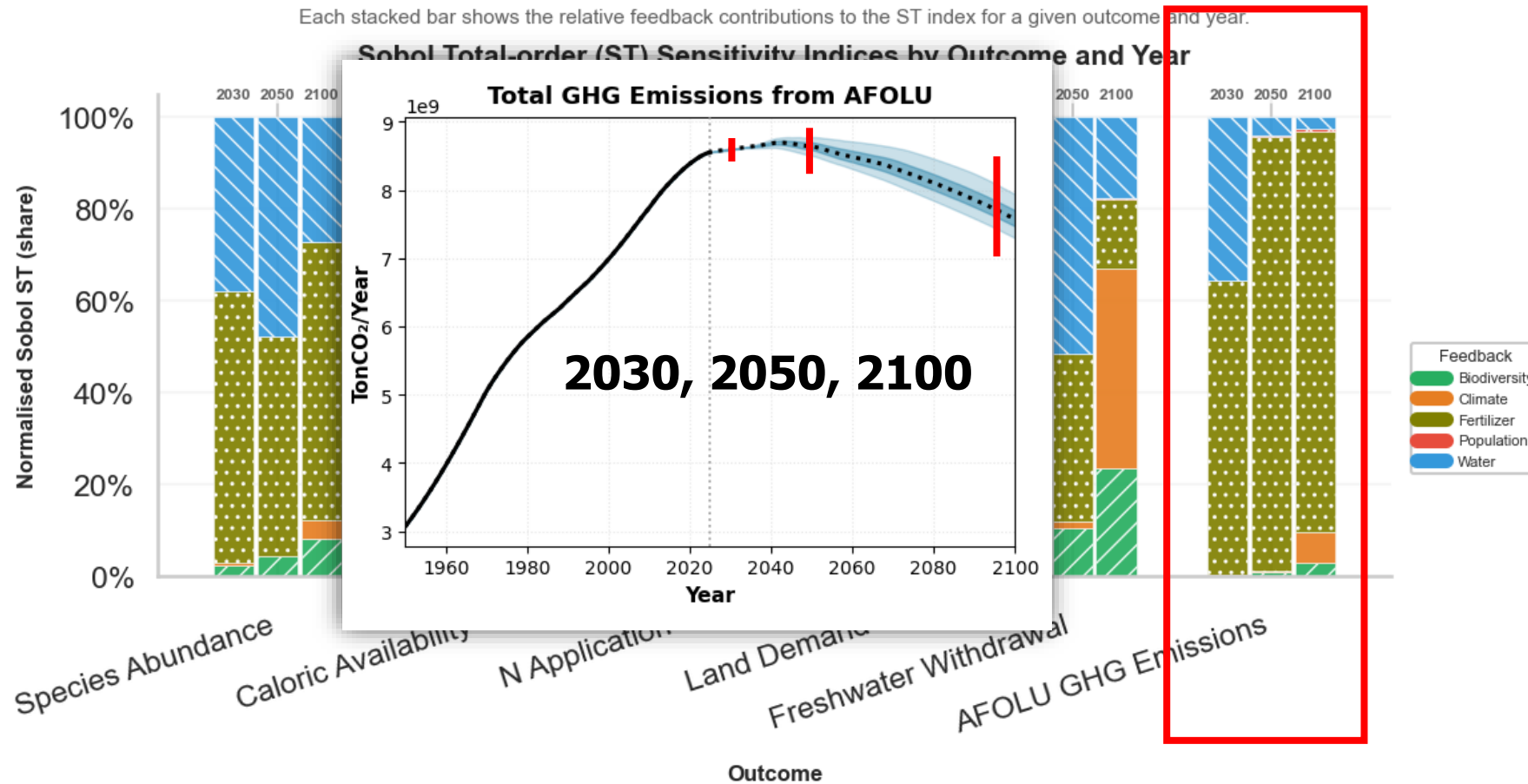
(2) Each outcome uncertainty is explained by different feedbacks

Each stacked bar shows the relative feedback contributions to the ST index for a given outcome and year.

Sobol Total-order (ST) Sensitivity Indices by Outcome and Year



(2) Each outcome uncertainty is explained by different feedbacks



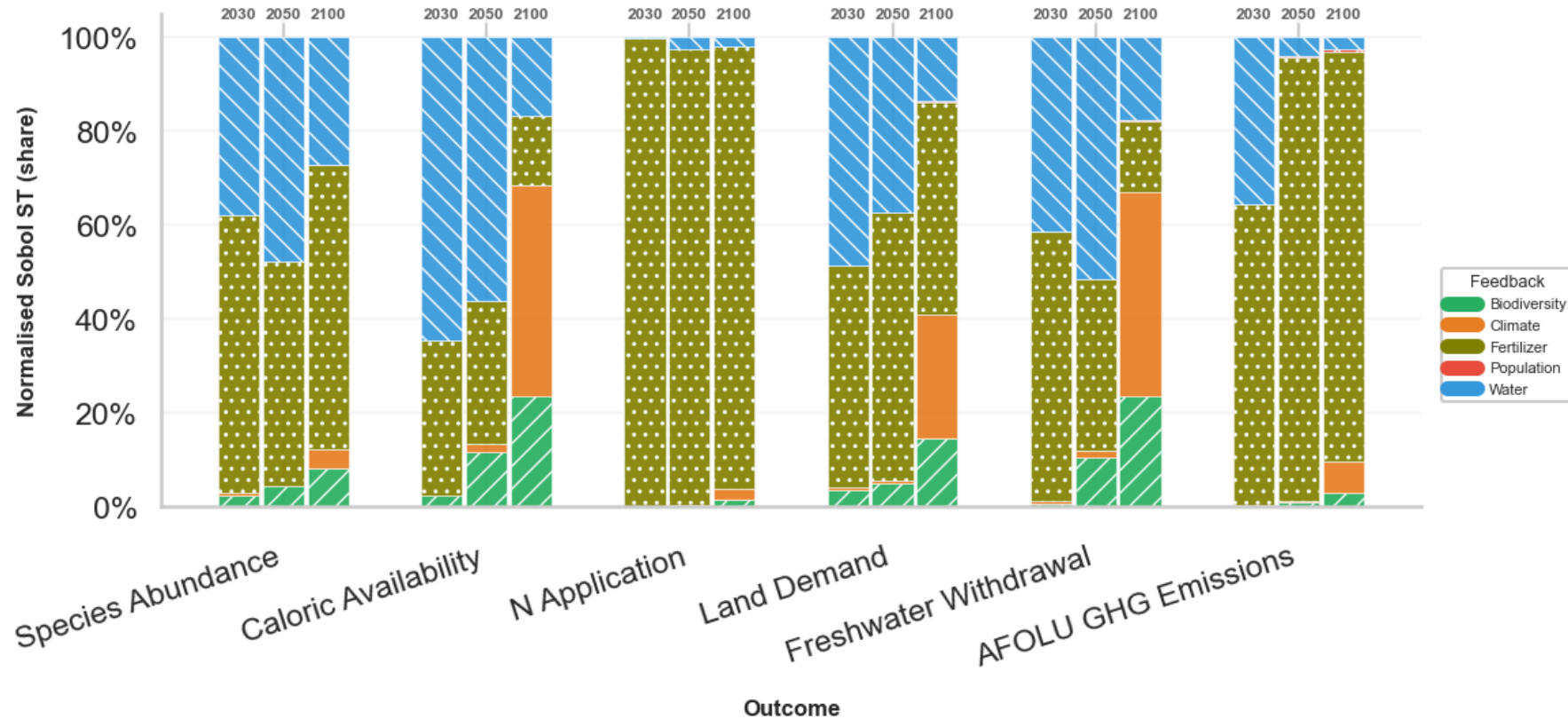
Different feedback matters for different outcomes.

(E.g. Models focused on emissions are concerned about agricultural activities, i.e. fertilizer use)

The model structure is biased to its **main outcome of interest.**

Each stacked bar shows the relative feedback contributions to the ST index for a given outcome and year.

Sobol Total-order (ST) Sensitivity Indices by Outcome and Year



Dominant Drivers are not static.

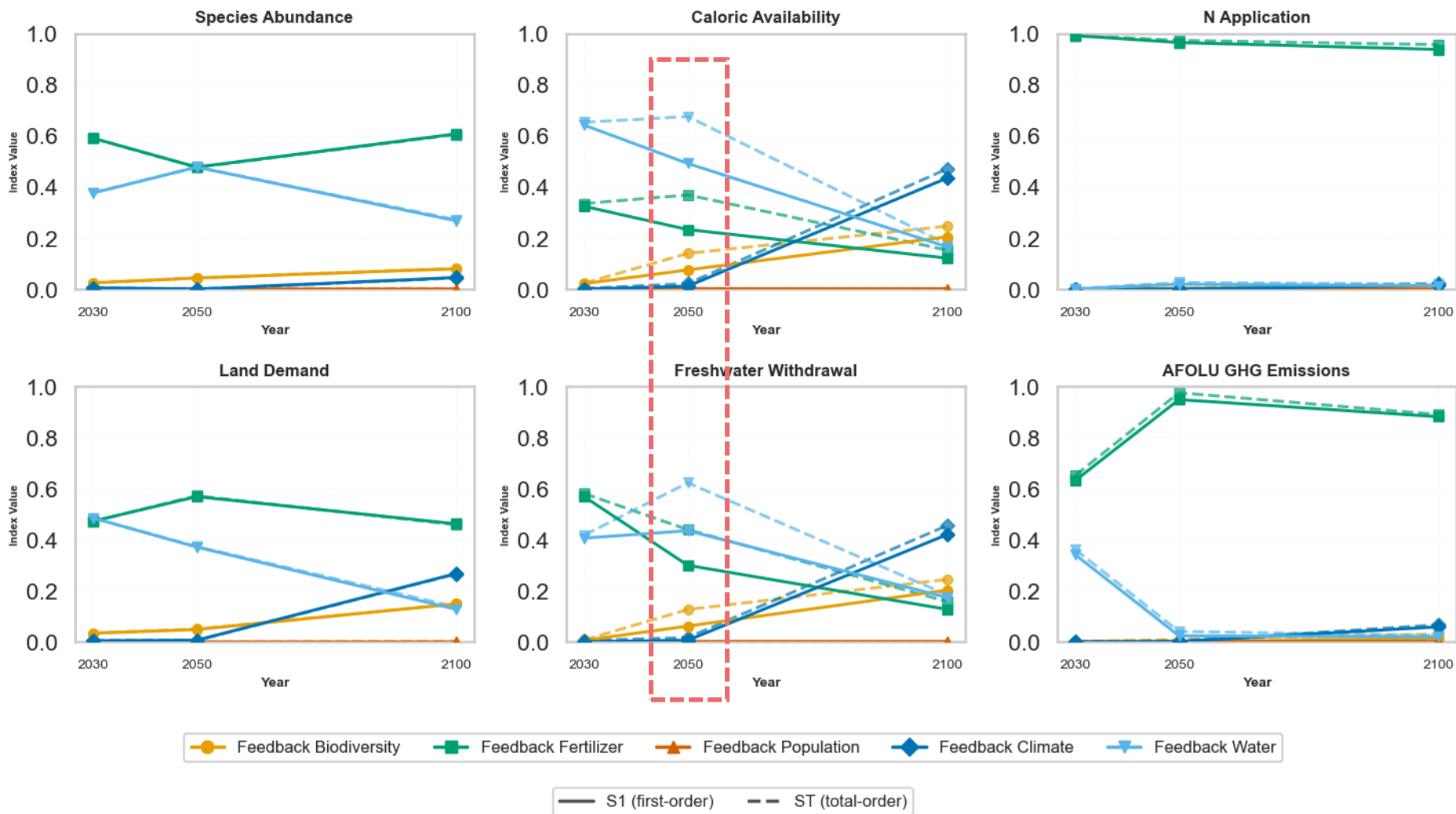
Fertiliser and **Water** are important near-term (production intensification)

Climate and **Biodiversity** Feedbacks are important in the long-term (environmental feedbacks)

(3) Feedback importance changes over time

(4) Interacting Effects are important in Medium-Term

Sobol Sensitivity Indices of Feedbacks over Time, by Outcome



Feedback interaction effects peaks in the mid-term future.

Caloric availability involves interactions between resource constraints and environmental responses

Growing system coupling (e.g biodiversity and climate) and presence of tipping behaviours

Conclusion

Feedback complexity shape **longer-term trajectories;**

Biodiversity plays an increasingly prominent role as a **driver.**

A single objective can work with a limited structure; **multiple objectives require a more holistic modelling structure.**

Future Work:

- 1) Link feedback uncertainty to **actions and policies** to assess robustness.
- 2) More accurate formulation and process representation to explore **interaction effects.**



Also, check out our interactive online simulator!
<https://climatechoice.github.io/felix/>



Thank You!
Any Questions
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