Balancing Nature and Economy: Ecological-Economic Modeling for Biodiversity-Friendly Policies

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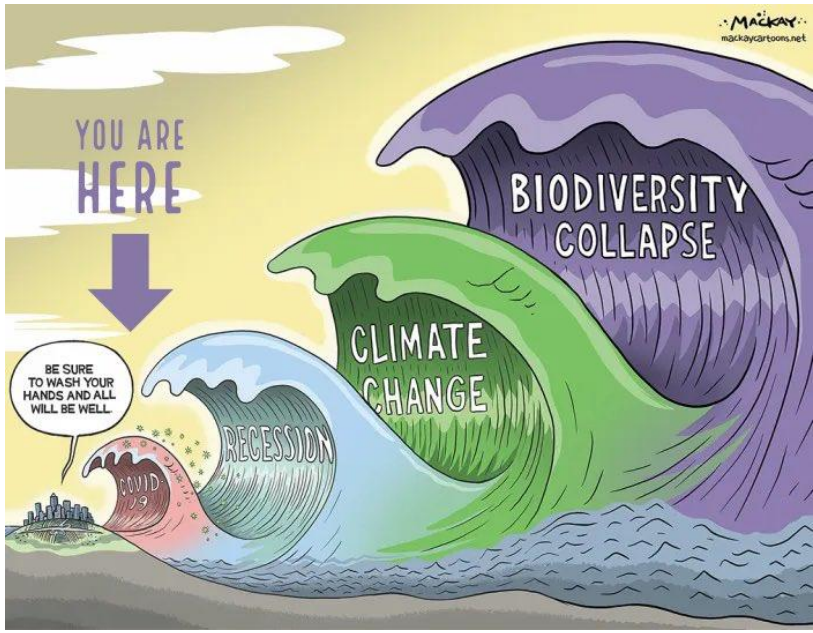
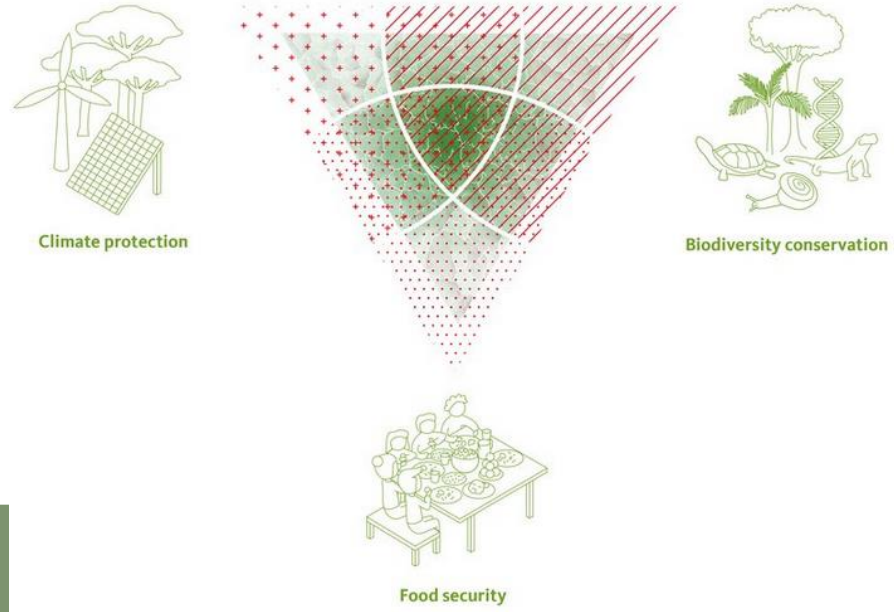
Agenda

- Why do we need integrated models?
- What is Ecological-Economic Policy Modeling?
- Biodiversity-friendly Policies in Germany
- Partial Declines of Cocoa Pollinators in West Africa
- Outlook

Why do we need integrated models?

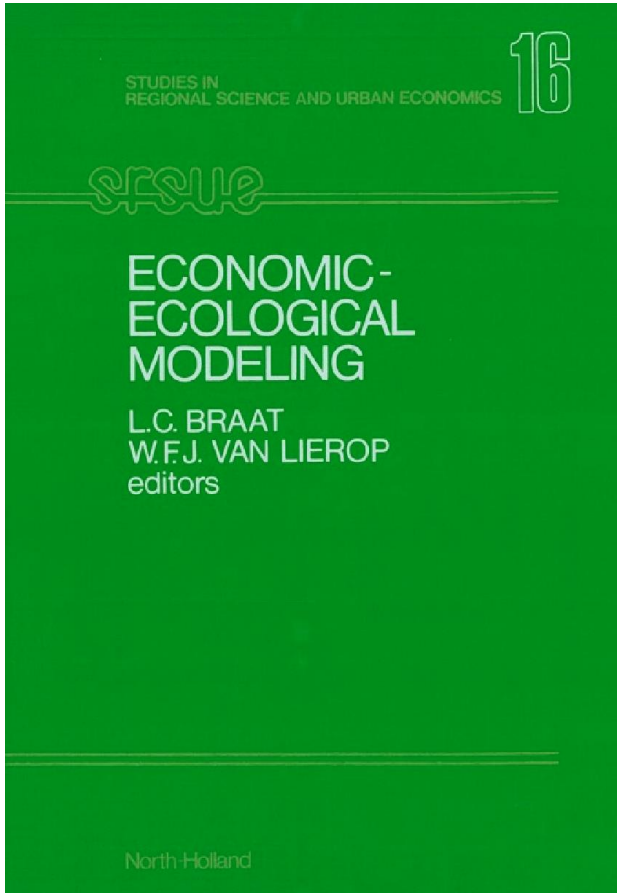
- World faces multiple crisis (”Polycrisis world”) which are highly interconnected
- Detrimental impacts of economic activity on climate change, pollution and biodiversity loss
- Trade-offs between addressing multiple challenges (Trilemma)
  - Risk of facing unintended consequences
  - Example: Policies promoting biofuels resulted in deforestation through indirect land-use change





What is ecological-economic modeling?*

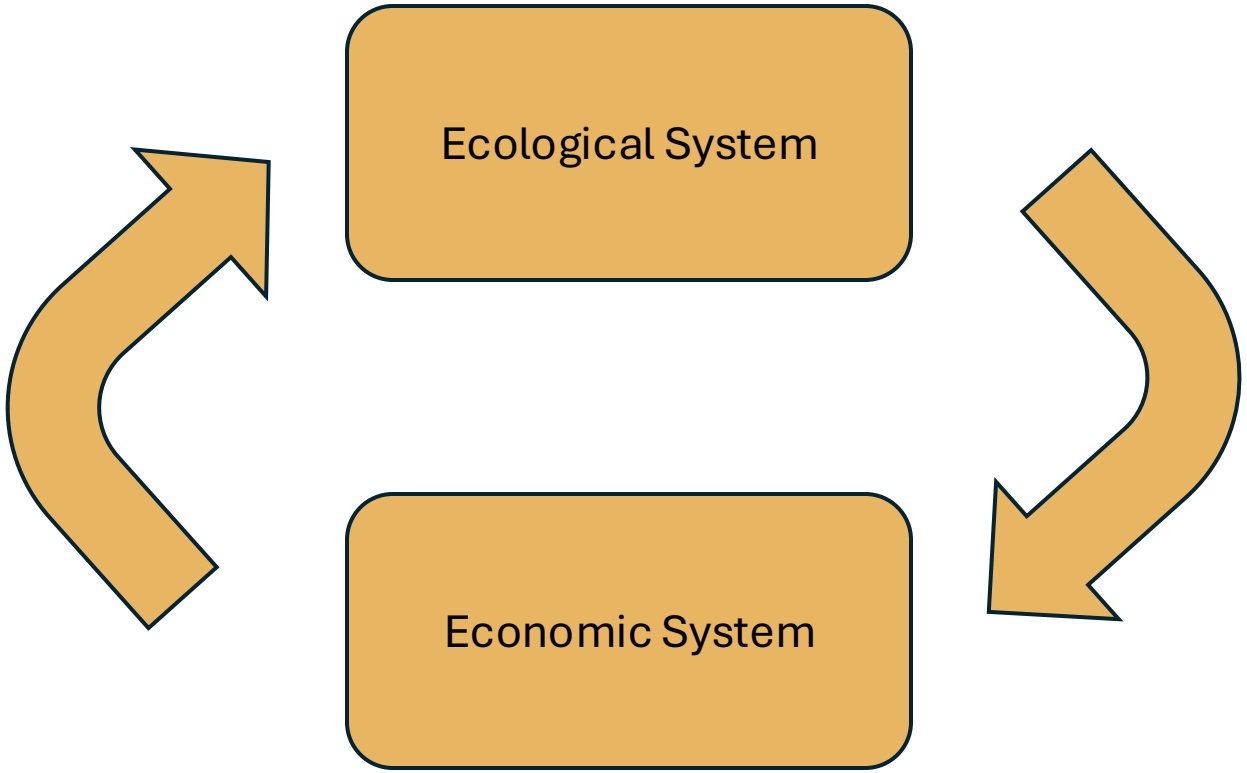
- Model that is
  - ”capable of assessing the relevant impacts of the socio-economic activities on ecosystems, as well as the relevant effects of the state and development of ecological systems on socioeconomic activity”
    (Braat and van Lierop, 1987, p. 49)



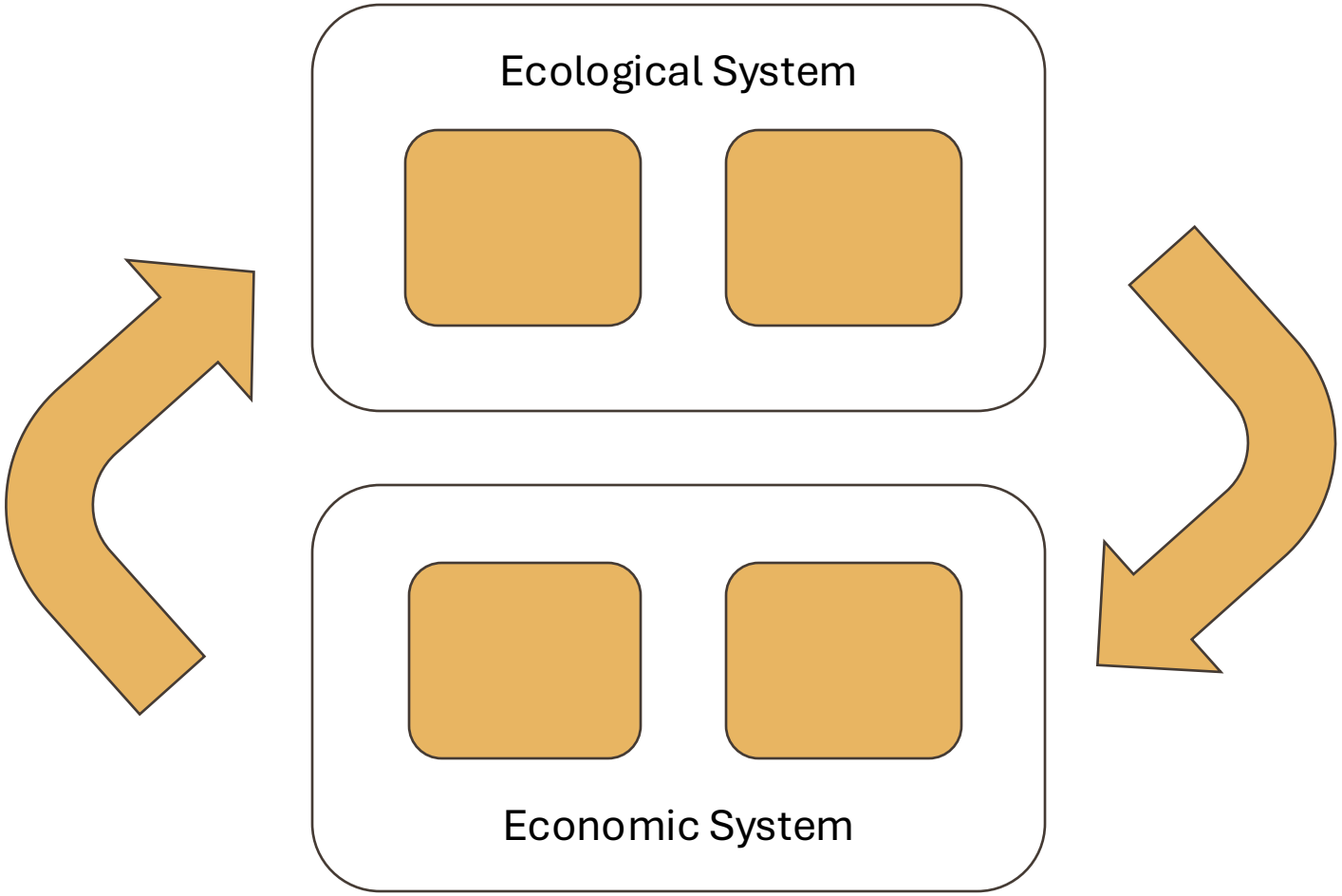
Braat and Van Lierop, 1987, Economic-Ecological Modeling, Amsterdam
https://pure.iiasa.ac.at/id/eprint/2902/1/XB-87-001.pdf

*or “Economic-ecological modeling”

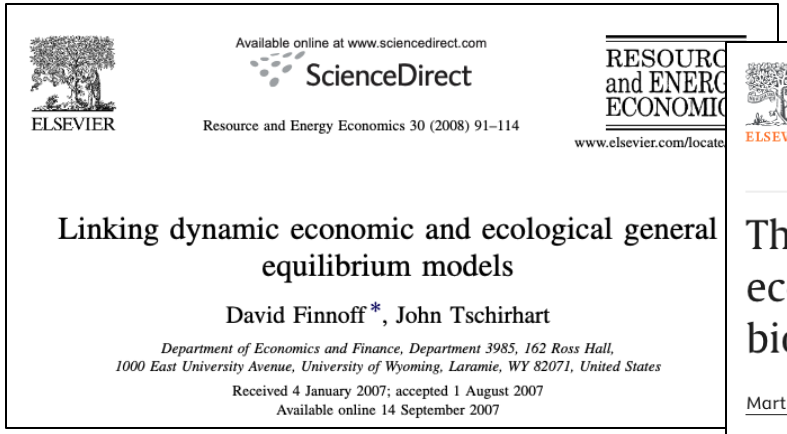
Linking ecological and economic systems



Linking ecological and economic systems



Different types of ecological-economic models



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Linking dynamic economic and ecological general equilibrium models

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The hitchhiker's guide to generic ecological-economic modelling of land-use-based biodiversity conservation policies

Martin Drechsler [a b], Frank Wätzold [b], Volker Grimm [a c]

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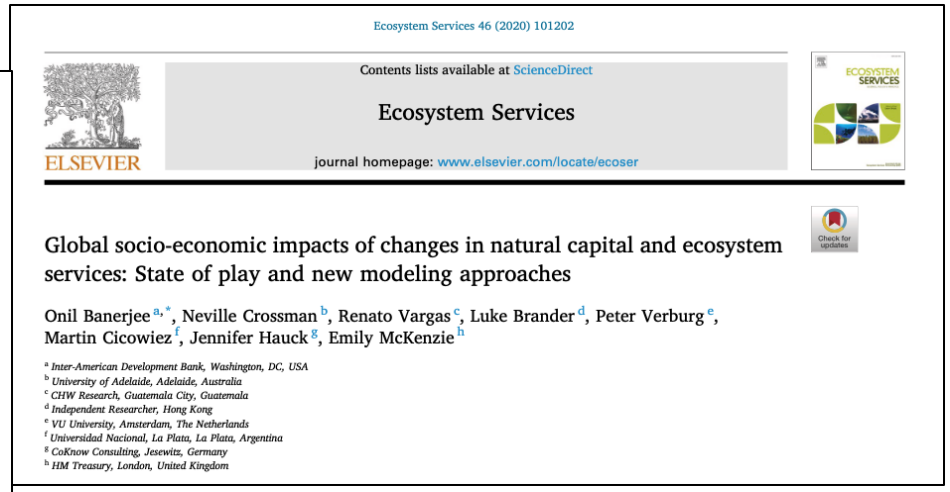

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Ecosystem Services

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Global socio-economic impacts of changes in natural capital and ecosystem services: State of play and new modeling approaches

Onil Banerjee [a,*], Neville Crossman [b], Renato Vargas [c], Luke Brander [d], Peter Verburg [e], Martin Cicowiez [f], Jennifer Hauck [g], Emily McKenzie [h]

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- Different model types:
  - ABM, market models (PE and GE) spanning over various spatial and temporal scales
  - Difficult to delineate from “bioeconomic models”, “integrated assessment models”, etc.

Ecological-economic policy modeling?

- Understanding the impacts of a policy on both ecological and economic systems
  - Capturing both the economic and ecological benefits and costs of a policy
- In our research group:
  - Use of market models instead of supply / farm models
  - Capture feedback from markets to analyze leakage, rebound and spillover effects

Social-ecological research

Evaluation of agricultural policy transformation pathways towards a biodiversity-friendly food system

01.07.2022 – 30.06.2027

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PROBLEM DEFINITION

Biodiversity decline in European agricultural landscapes

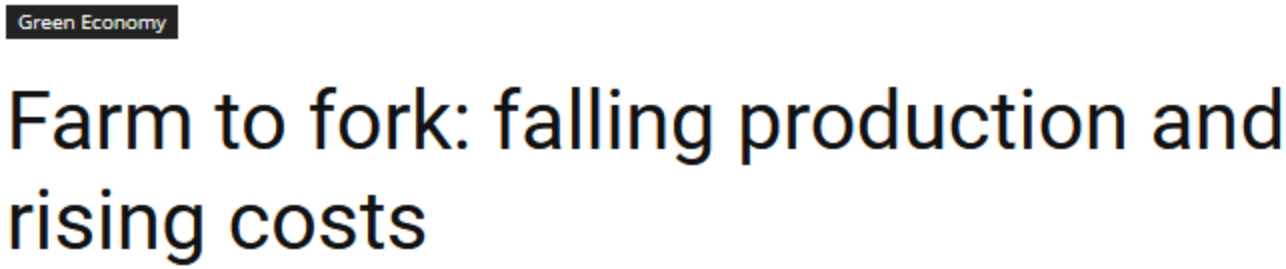
- Increase in political reforms for preserving biodiversity on European farmland.
- Initiatives to make agricultural land-use more biodiversity and insect-friendly

EU lays out roadmap to 25% organic farming

German climate, insect protection laws cross finish line

Bavaria to pass 'save the bees' petition into law in landmark move

..but these initiatives face many opponents, often citing unreasonable costs of conservation efforts



Overarching objective: bridging the intention–transformation gap

- ✓ Dramatic decline in biodiversity
- ✓ Increase in political reforms and targets for strengthening biodiversity
- ⇨ Intention for transformation

- ✗ Lack of knowledge about costs and benefits
- ✗ Economic models ignore ecological relationships
- ⇨ **Ecological–economic policy modeling can help to bridge this gap**

Project structure

Work packages

② Biodiversity & land use

Quantification of the contribution of insect pollinators to agricultural productivity

③ Ecological-economic modeling

Simulation model for analyzing biodiversity-enhancing measures in agricultural and food policy

④ National & local perspectives

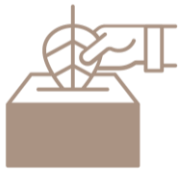
Participatory development of transformation scenarios and analysis of non-governmental instruments

⑤ Multi-criteria evalutation

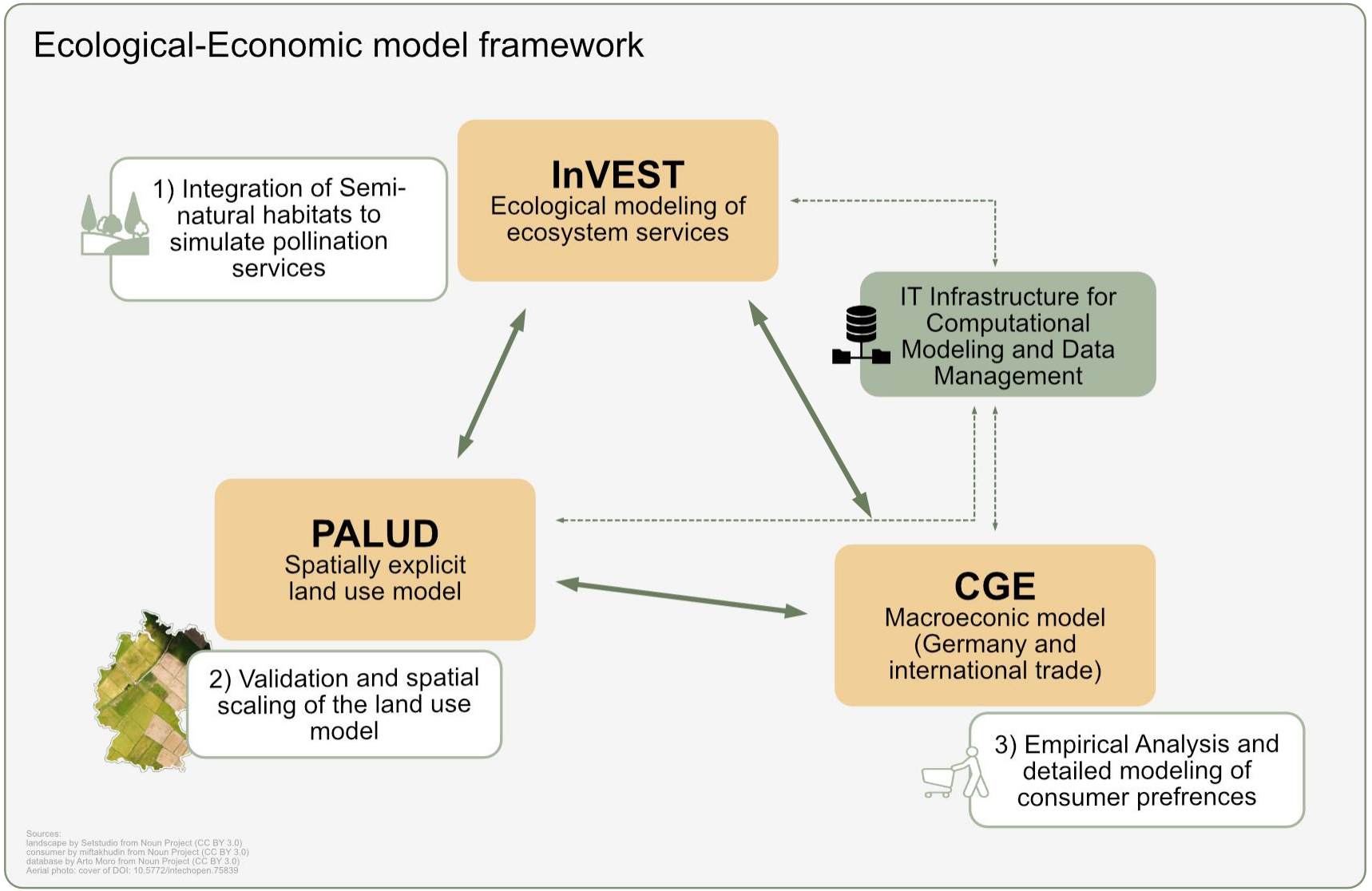
Collaborative scenario analysis with stakeholders using social, economic, and ecological indicators

Transdisciplinary research

Synthesis & policy implications



Model linkage in the BEATLE project



- Market results (production and prices) from CGE passed down to land-use model
- Land-use model will calculate land-use changes (incl. spatially explicit crop diversity)
- InVEST determines change in pollinator abundance, pollination service changes and changes in yields

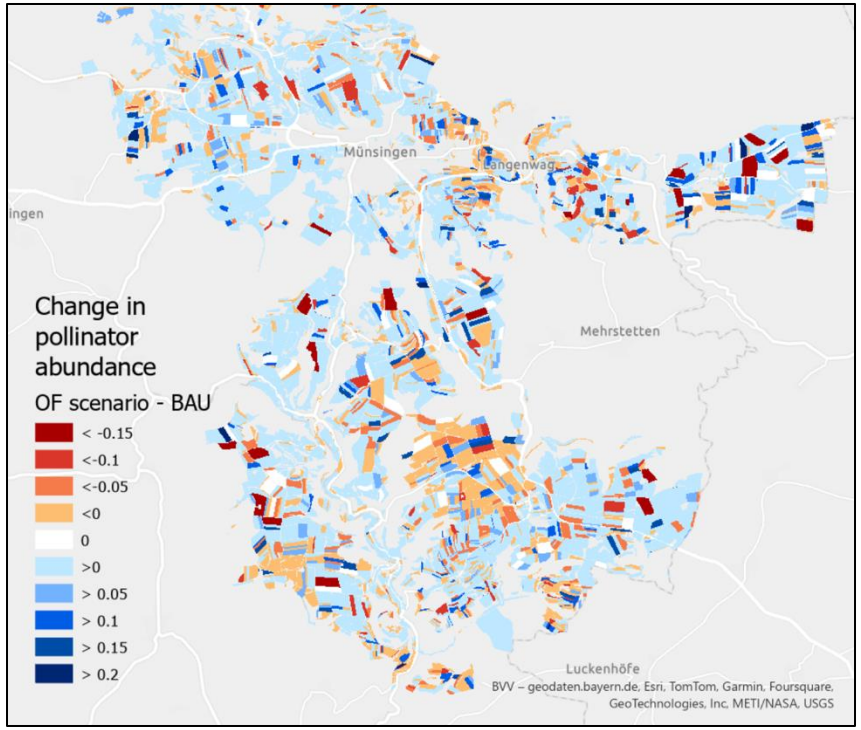
Modeling the economic and ecological impacts of a large-scale organic agricultural policy

Spatially explicit modeling

- Extension of the land-use model to include among others organic farming
- Coupling models to represent interactions between land use and ecosystem services
- Case study: *Ecological-economic modeling of organic farming expansion scenarios in Baden-Württemberg*

Next steps:

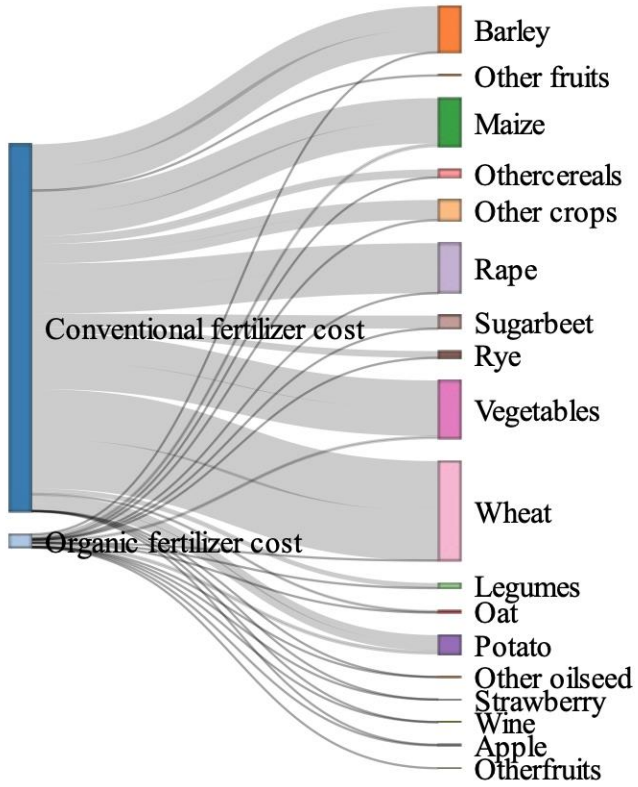
- Scaling from Baden-Württemberg to all of Germany
- Model coupling of CGE, PALUD & InVEST



CGE Model with detailed representation of the agri-food system

Market model (Computable-General-Equilibrium model)

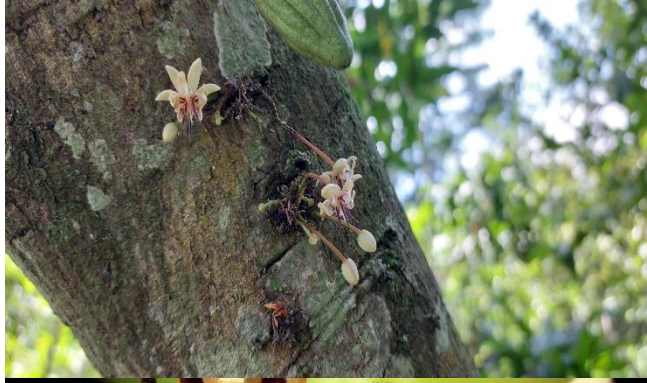
- Using novel dataset to depict organic and conventional food markets (demand, supply, processing, trade)
- Disaggregation of representative household groups
- Simulation of biodiversity-friendly policies
- Coupling with land-use and ecological model
    - Passing down changes in aggregate agricultural production
    - Capturing ecological feedbacks (change in pollination dependent yields)



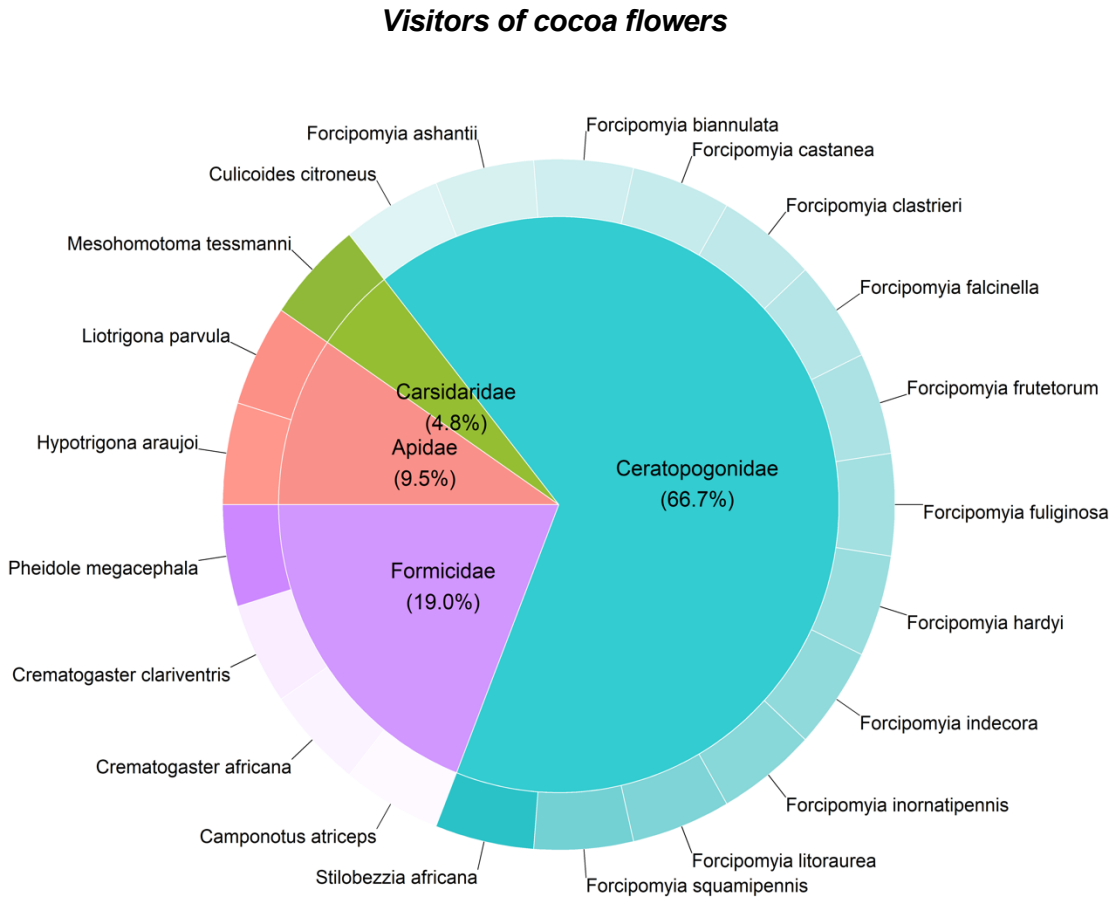
Small Midges, Major Consequences:
Partial Declines in Cocoa Pollination and Their Economic Impact in West Africa and Worldwide

Falk Krumbe, Camillus Wongnaa & Arndt Feuerbacher

Under review at *Agricultural Economics.*



Cocoa‘s dependence on pollination



- Cocoa production is entirely dependent on animal-mediated pollination (Siopa et al. 2024)
- Various different pollinator families, but *Forcipomyia* midges dominate in Ghana
  - Deposit of ≥35 pollen grains for successful pollination (Kaufmann 1975)

The mighty midge

~2.5 mm

Forcipomyia squamipennis

Research questions

1. What are the short-term economic impacts of partial changes in forcipomyia populations?
2. How do different spatial extents affect these impacts?
3. To what extent do impacts differ across households (poor↔ non-poor, rural ↔ urban) ?
4. How do impacts transmit to importing and non-affected producing regions?

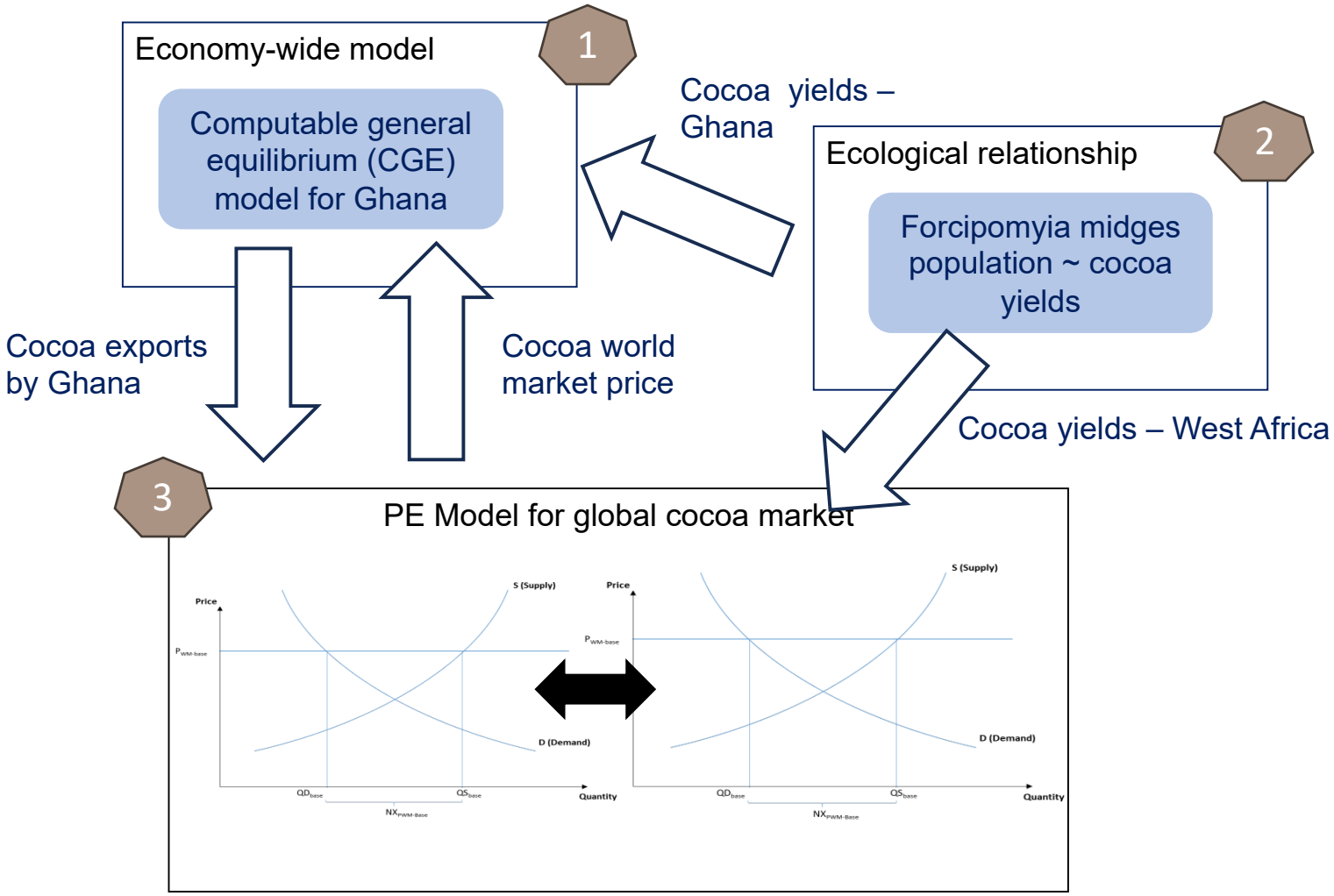
- Focus on Ghana (second largest cocoa producer)
  - Cocoa contributes 2% to national GDP in 2015 (11% of agricultural GDP)
  - 450,000 livelihoods depend on cocoa in Ghana (~15% of all farmers)
  - Western Region produces about 50% Ghana's cocoa production

Source: 2015 Social Accounting Matrix for Ghana, developed by JRC, Seville (Ferreira et al. 2021)

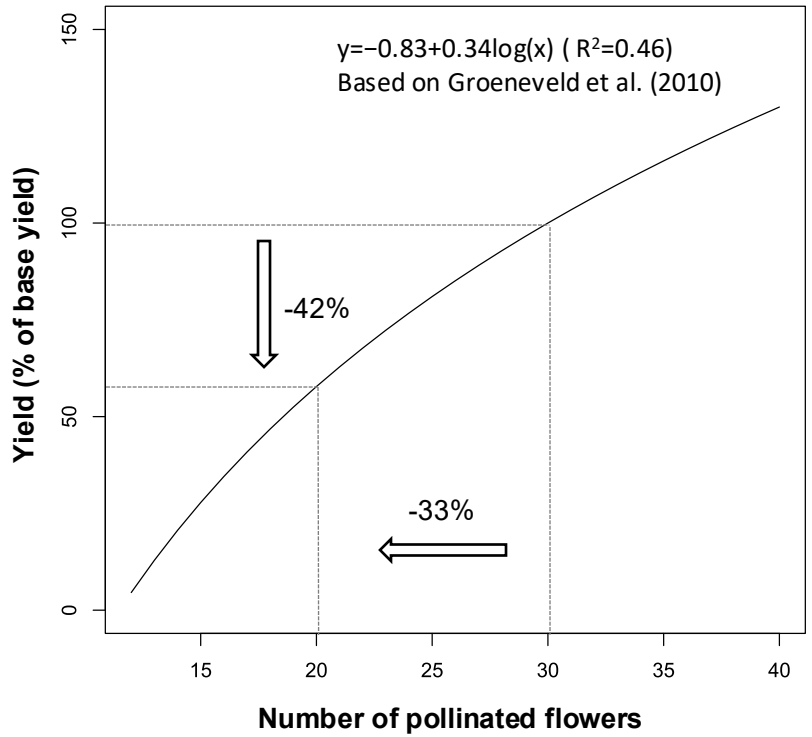
Scenarios of partial cocoa pollinator declines

- Consultation of cocoa pollination experts about likelihood of population changes in West Africa
- Scenarios: **Unexpected 33% decline** in cocoa pollinator population with different spatial extents
  - Scenario 1 - Regional decline: Western region of Ghana
  - Scenario 2 - National decline: Ghana – whole country
  - Scenario 3 - West-African decline: Ghana + Côte d'Ivoire (approximate whole of West Africa)

Ecological-economic model

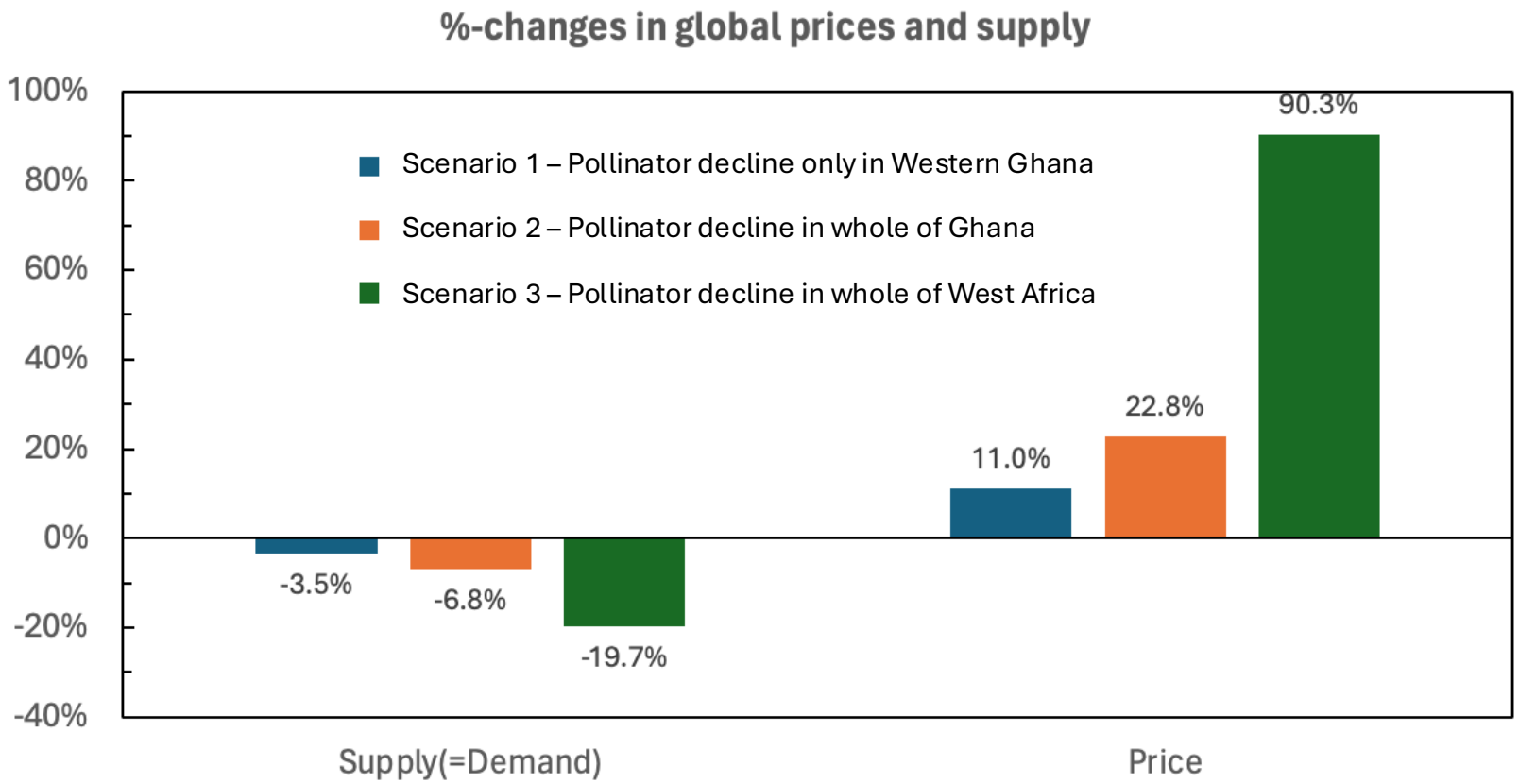


Changes in cocoa yields (Ecological model)



- No (known) monitoring of midge populations across time and space
- Experimental data from Groeneveld et al. (2010) about relationship between pollinated flowers and cocoa yield
- Assumption: Pollinator efficiency (pollinated flowers/pollinator) stays constant
  - Cocoa yields become a logarithmic function of pollinator populations

Changes on the global cocoa market (Partial Equilibrium Model)



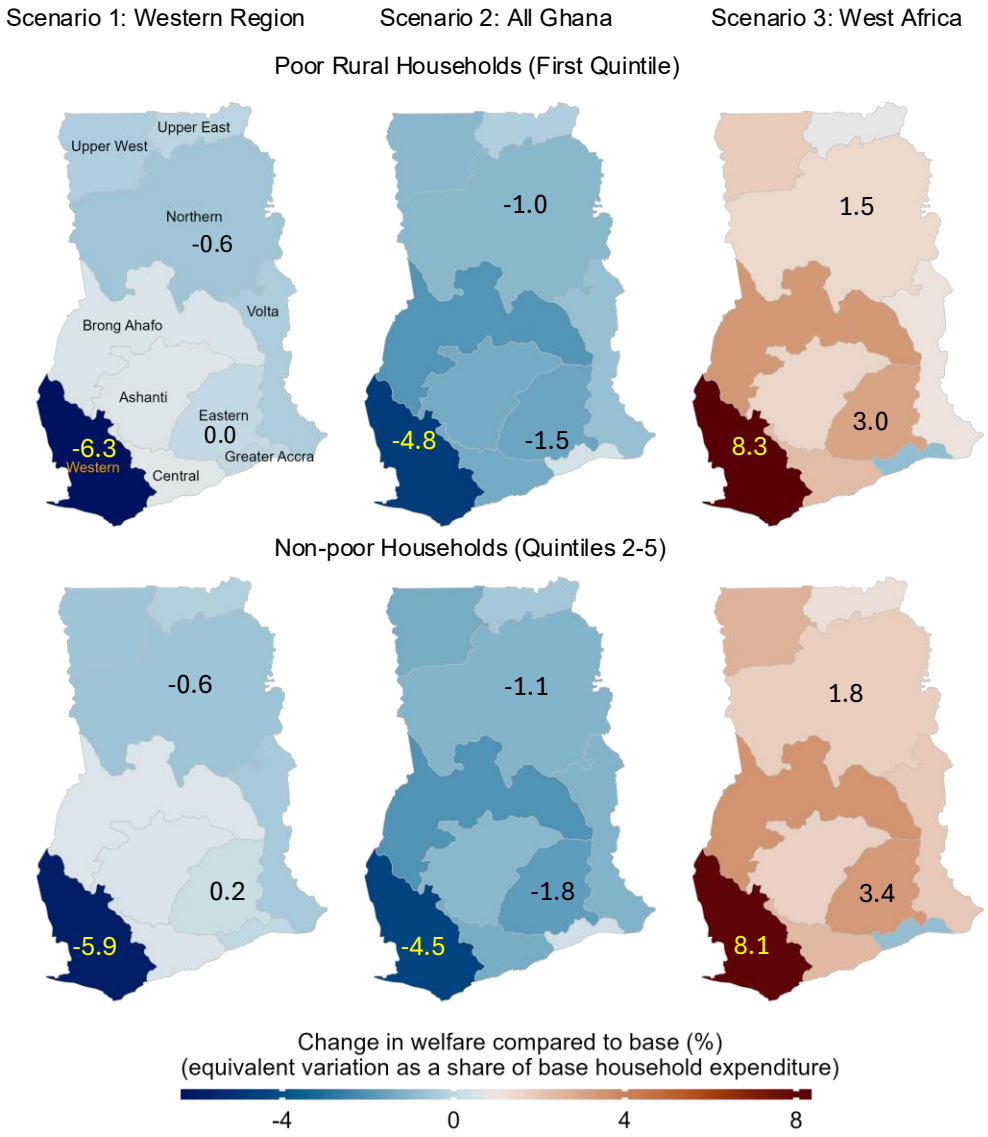
Welfare changes across rural households in Ghana (CGE model results)

Scenario 1 and 2:

- Poor households experience higher welfare declines
- Higher dependence on labor income
- Underemployment increases

Scenario 3:

- Except Greater Accra, all regions benefit from the 90% cocoa price increase



Outlook for Ecological-Economic Modelling for Biodiversity-Friendly Policies

- Ecological-economic policy modeling is still a “young field”
  - Review of related literature currently in progress (led by Tim Williams in our group)
- Ecosystem services are a good “bridge” to link ecological and economic systems
- Difficult to model biodiversity as a whole – data limitations
  - Focus on pollinators as a proxy – but sometimes only few species matter
  - Important to collaborate with ecology experts
- Important to capture feedback mechanisms
  - Example: More organic agriculture leads to higher local pollinator abundance and thus higher pollination dependent yields.
  - BUT: Possible adverse effects on biodiversity through trade leakages due to yield gaps between organic and conventional agriculture.

Thank you for your attention!

Do not hesitate to contact me in case of questions!

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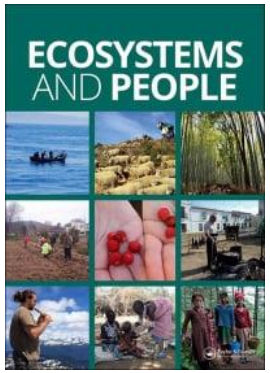
What is policy modelling?

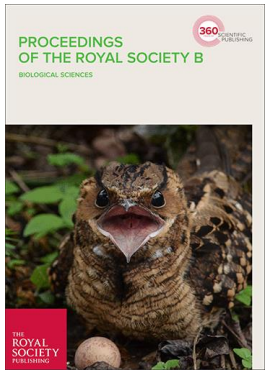
- In short “to model the past or future impacts of policies”
  - Ex-post or ex-ante perspective (what-if scenario analysis)
- Multiple purposes
  - How do policies impact different dimensions of an economic system
    - Households (welfare, consumption), production, international trade, government
  - Investigate impacts over time and space
  - Explore policy alternatives
- Approaches
  - Mostly quantitative, few qualitative approaches
  - Econometric modeling, simulation modeling (market models like PE and CGE models, agent-based modeling, I-O models) and others

BEATLE related Publications

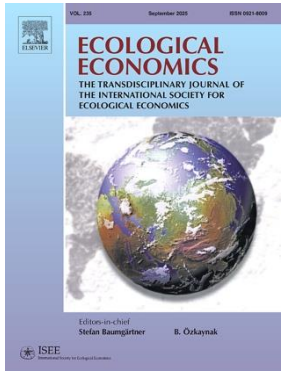


Bücheler, H., Bieling, C., **Feuerbacher, A.** (2024). Exploring private financing for biodiversity conservation: stakeholder perspectives and governance in case of wildflower strips in Germany

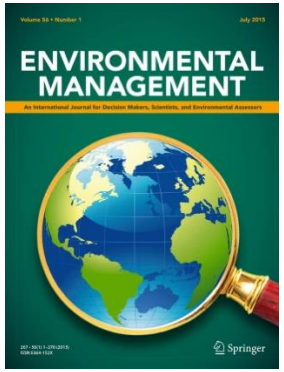
Feuerbacher, A., Herbold, T., **Krumbe, F.** (2024). The Economic Value of Pollination Services for Seed Production: A Blind Spot Deserving Attention.



Librán-Embid, F., Grass, I., Emer, C., **Alarcón-Segura, V.**, Behling, H., Biagioni, S., Ganuza, C., Herrera-Krings, C., Ani Setyaningsih, C., Tscharntke, T. (2024). Flower–bee versus pollen–bee metanetworks in fragmented landscapes.

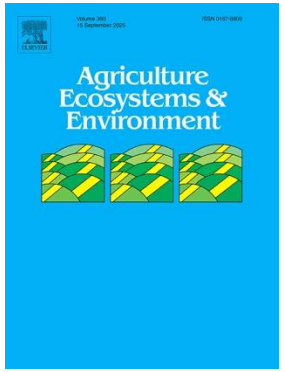


Feuerbacher, A. (2025). Pollinator declines, international trade and global food security: Reassessing the global economic and nutritional impacts

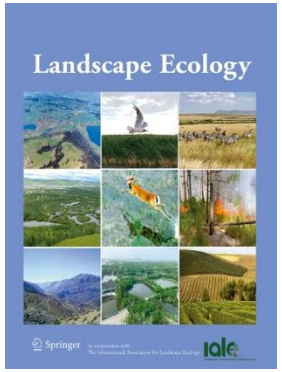


Streit, L., **Feuerbacher, A.**, Röhl, M. (2025) Market-Based Instruments for Biodiversity in Agricultural Landscapes: An Evaluation of Quality Criteria in a German case study

Mupepele, A.-C., von Königslöw, V., Bleile A.-M., Fornoff F., Fründ J., Klein, A.-M. (2025) Plant-pollinator interactions in apple orchards from a production and conservation perspective.



Krumbe, F., Melder, S., **Feuerbacher, A.** (forthcoming): The vital role of pollination services in seed production: A global review



Alarcón-Segura, V., Grass, I., **Feuerbacher, A.**, Gonzales-Chavez, A., **Mupepele, A.-C.** (2025). Semi-natural habitats and their contribution to crop productivity through pollination and pest control: a systematic review. *Minor revision*

Mupepele, A.-C., Hellwig, Niels., Dieker Petra, Klein, A.-M. (2025) Wild bee trends in Germany. *Minor revision*