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GLOBIOM

Understanding uncertainty
in market-mediated responses to US oilseed biodiesel demand

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Forestry and Agriculture Greenhouse Gas Modeling Forum
Session 4: Mitigation (Part 2) - Agriculture and Bioenergy
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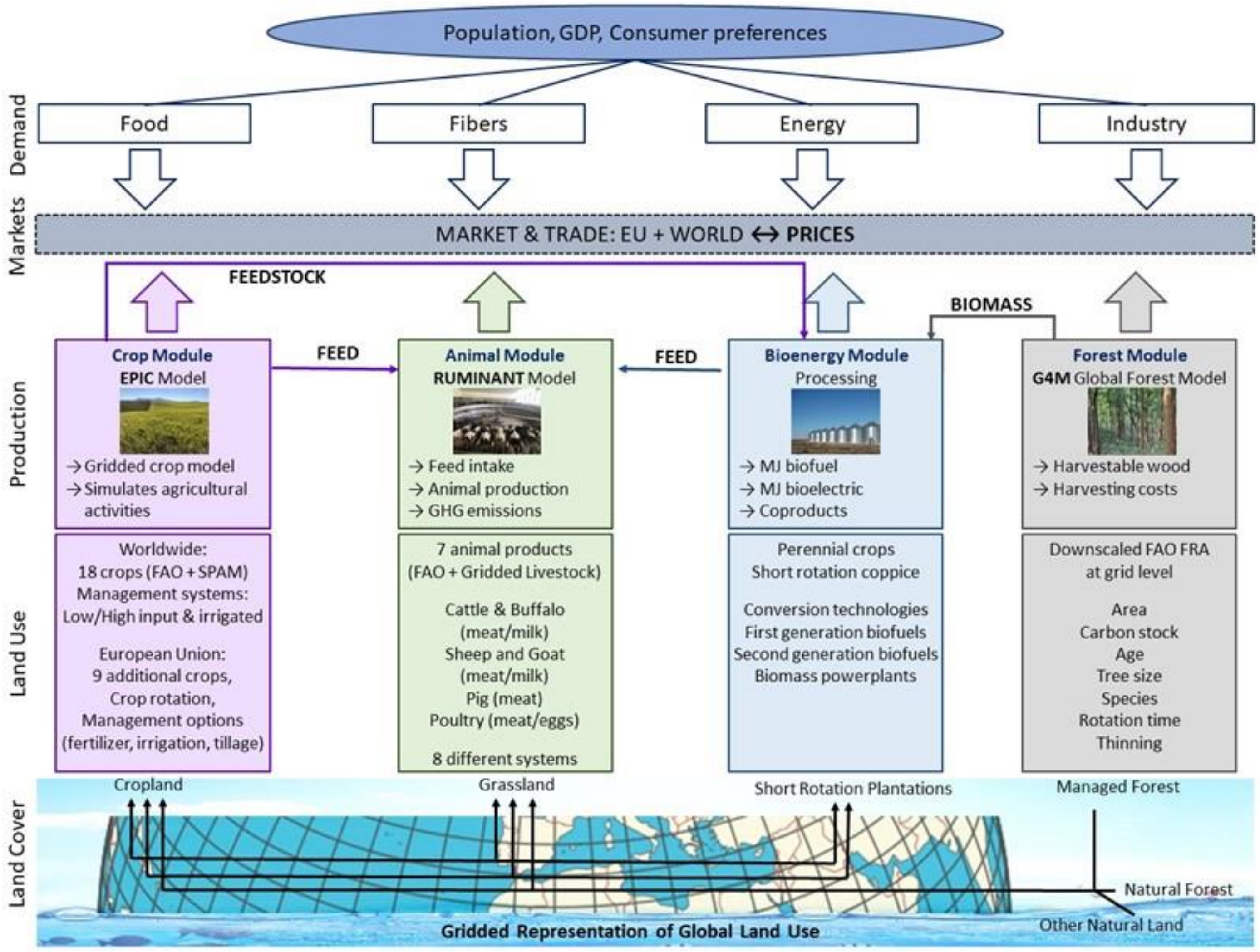
Agenda

1. GLOBIOM overview

2. GLOBIOM recent publications and developments

3. Understanding uncertainty in market-mediated responses to US oilseed biodiesel demand (paper under review)

The economic model GLOBIOM simulates land-use change and related emissions of multiple sectors



- Bio-economic land use **partial equilibrium** model integrating global agriculture, bioenergy, and forestry sectors
- **Recursively dynamic**: 10-year time steps (2000 calibration, 2000-2020 validation, up to 2100 projections)
- **Bottom-up** (spatially explicit land cover, land use, management systems and economic cost information) to the top (regional commodity markets)
- **Major, globally cultivated crops modelled** (ca. 85% of crop-derived calorie supply, ca. 84% of total harvested cropland)
- Comprehensive and detailed representation of **global livestock sector**
- **Food demand drivers**: population, income, response to prices and income, and price changes
- Various **bioenergy feedstocks** represented incl. their **co-products** (e.g., DDGS)

Huge media echo for GLOBIOM impact analysis of potential substitution of animal products by plant-based foods

nature communications

Article

https://doi.org/10.1038/s41467-023-40899-2

Feeding climate and biodiversity goals with novel plant-based meat and milk alternatives

Received: 14 December 2022

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Published online: 12 September 2023

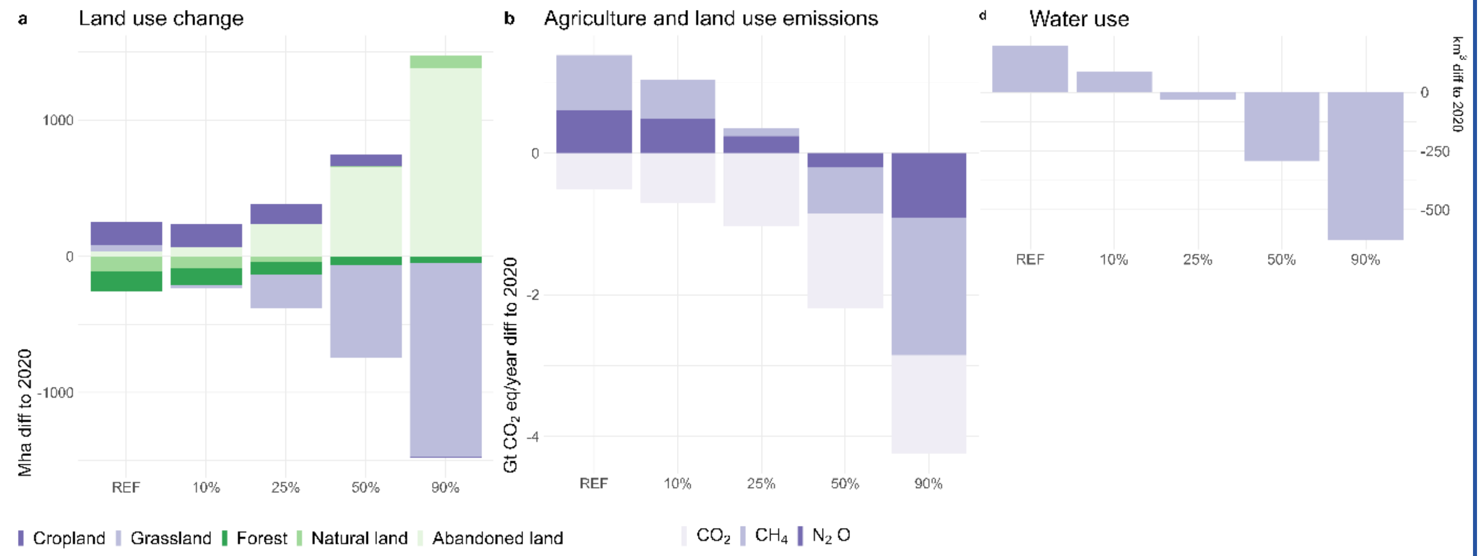
Marta Kozicka[1], Petr Havlík[1], Hugo Valin[1], Eva Wollenberg[2,3], Andre Deppermann[1], David Leclère[1], Pekka Lauri[1], Rebekah Moses[4], Esther Boere[1,5], Stefan Frank[1], Chris Davis[4], Esther Park[4] & Noel Gurwick[6]

Online attention

- 896 tweeters
- 2 Facebook pages
- 8 Redditors
- 93 Mendeley
- 8 blogs
- 163 news outlets
- 5 Wikipedia page

This article is in the 99th percentile (ranked 192nd) of the 344,353 tracked articles of a similar age in all journals and the 99th percentile (ranked 8th) of the 2,199 tracked articles of a similar age in *Nature Communications*

change 2050 vs 2020	**Reference**	**50% substitution**
Agricultural area	+4%	-12%
Forest & other nat. land	-5%	-1%
AFOLU GHG emissions	+15%	-31%
Water use	+6%	-10%



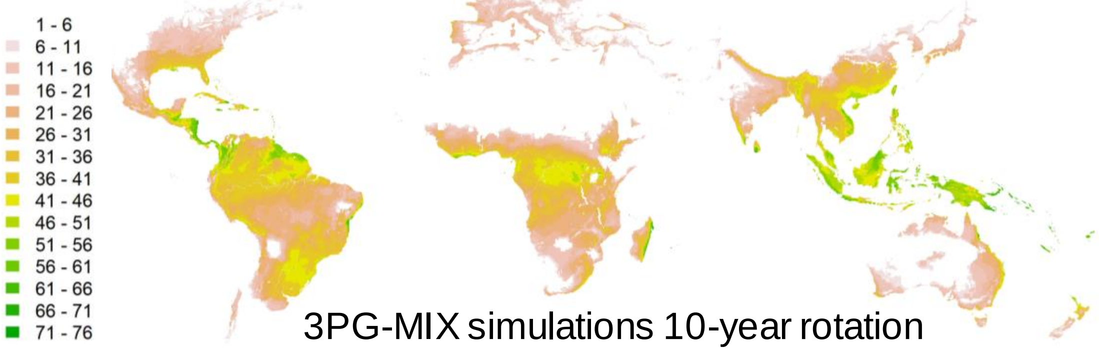
New agricultural CO_2 sequestration options in GLOBIOM

preliminary

Silvo-pastures

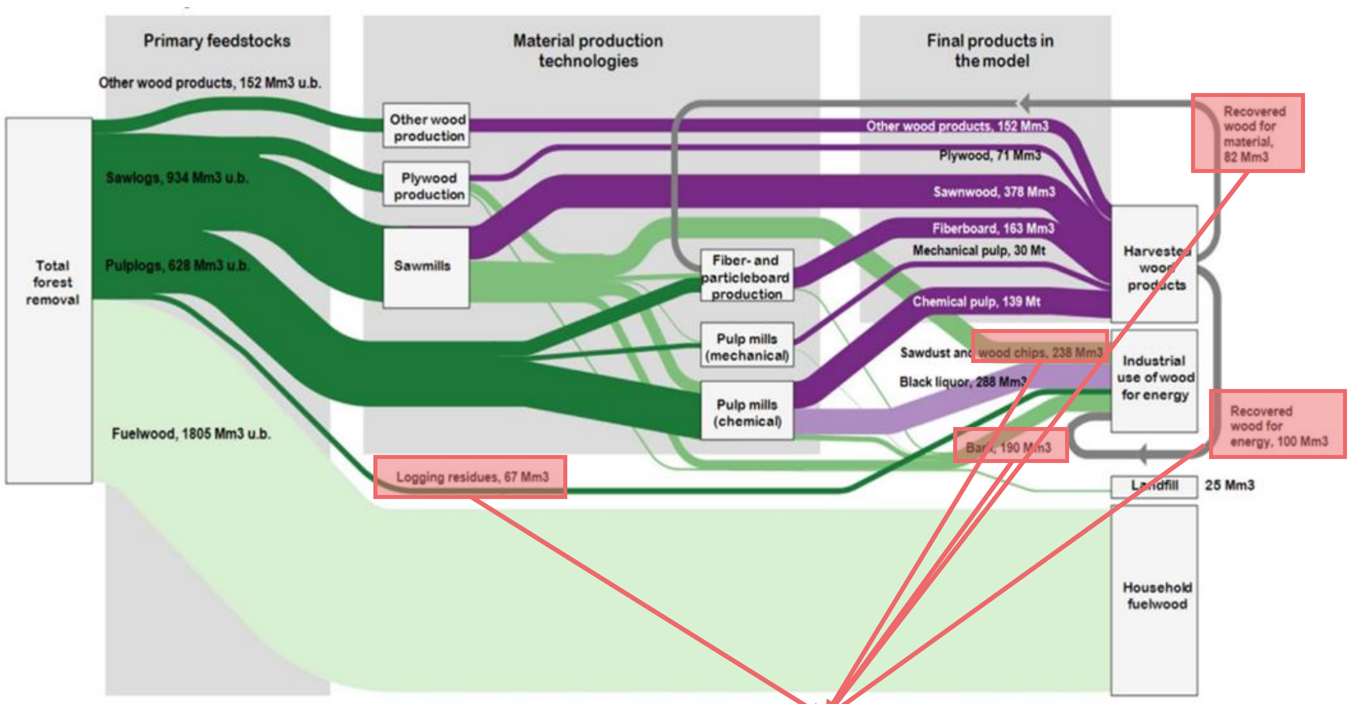
Pasture & CO_2 sequestration	**Pasture & biomass production**
Rotation ~25 years 400 trees/ha	Rotation ~10 years 2500 trees/ha

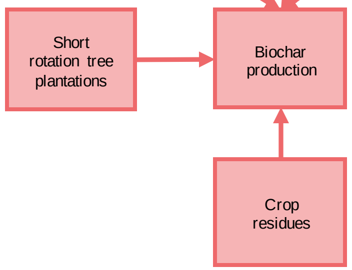
MAI [m³/ha]



3PG-MIX simulations 10-year rotation

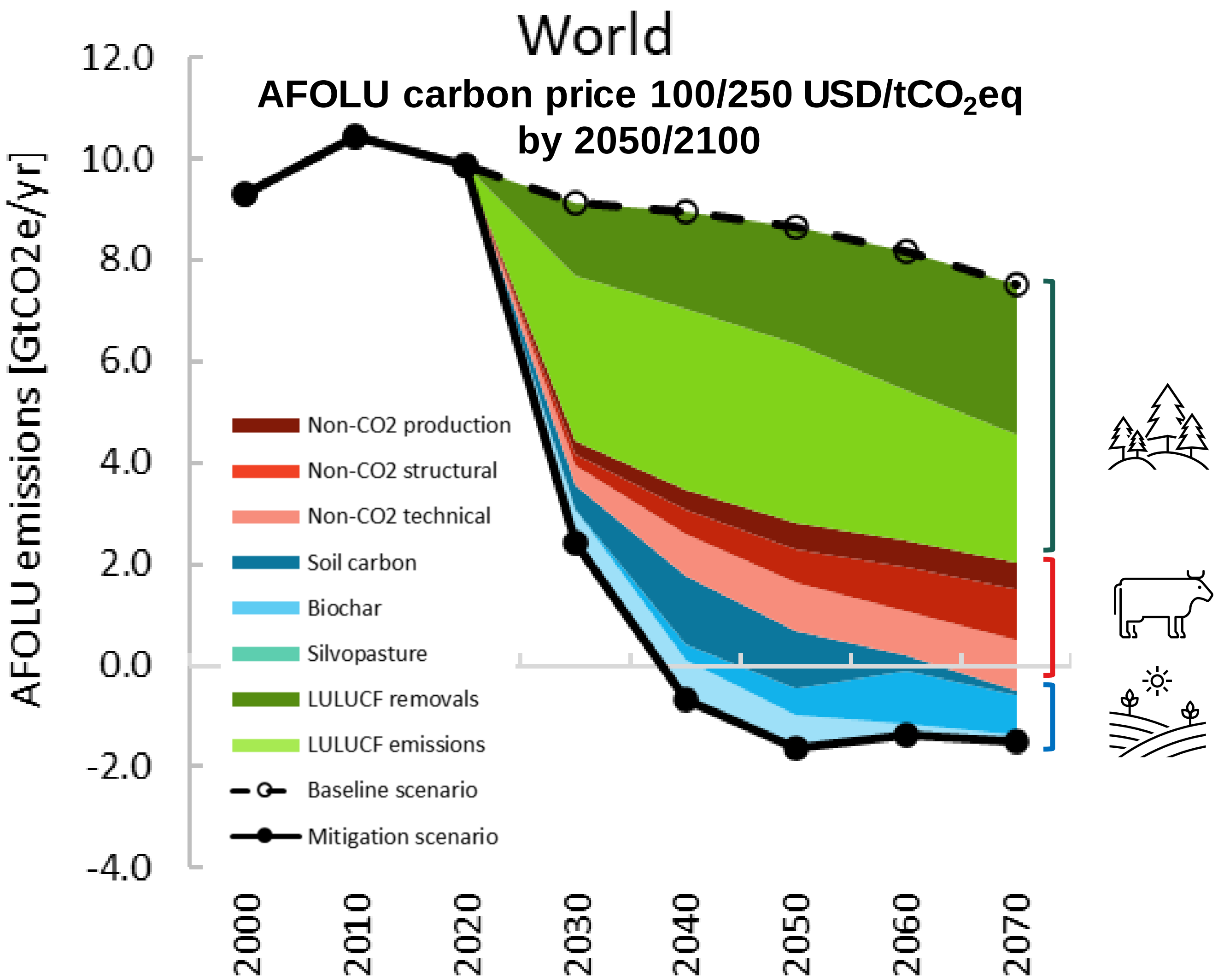
Biochar application





Frank et al. under review

Importance of ag. CO_2 sequestration for AFOLU mitigation



- FOLU emission reduction remains most cost-effective AFOLU mitigation options (60% of abatement by 2050)
- Carbon sequestration on agricultural land may deliver an important contribution to land-based mitigation efforts (20% by 2050)
- Represents around 30-35% of anticipated AFOLU abatement requirement in existing 1.5 C scenarios in 2050
- Across regions, highest potentials in Sub-Saharan Africa and Latin America

Frank et al. under review

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IIASA investigated uncertainties of soy-based biofuel ILUC values in cooperation with RTI International and the EPA

Understanding uncertainty in market-mediated responses to US oilseed biodiesel demand

under review

Neus Escobar[1,2], Hugo Valin[1], Stefan Frank[1*], Diana Galperin[3], Christopher M. Wade[4], Leopold Ringwald[1], Daniel Tanner[3], Niklas Hinkel[1], Petr Havlík[1], Justin S. Baker[5], Sharyn Lie[3], and Christopher Ramig[3]*

- Demand for oilseed-based biofuels is associated with particularly complex market and supply chain dynamics
- ILUC = induced land-use change = direct + indirect land-use change
- Investigation of market mediated impacts and ILUC emission uncertainty of increasing demand for soy-biodiesel in the USA over the coming decades

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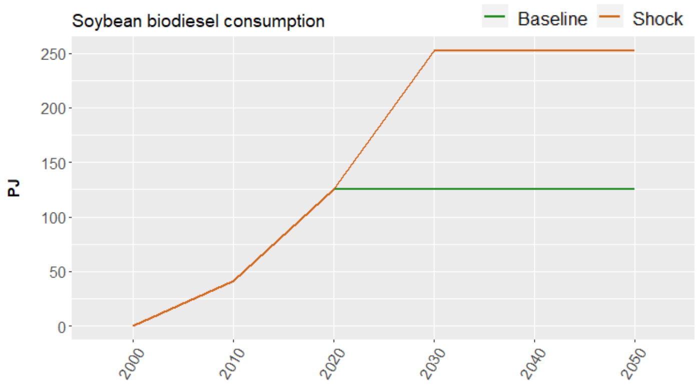
Multiple techniques are combined to assess uncertainties

- **Baseline:** global biofuel volumes constant at 2020 levels
- **Shock:** increased demand for soybean biodiesel in US 2020-2050, reaching total additional demand of 126.9 PJ/year in 2030 (= 1 BGGE ≈ current US consumption)



- Assessing influence of **varying key economic (7) and biophysical (4) parameters**:

Central Case	• **model default** • central values of varied parameters
One-at-a-time (OAT) sensitivity analysis	• **individual** effects of analyzed parameters • 4 values below, 4 above default → 89 combinations
Monte Carlo (MC) simulation	• ILUC **impact ranges** from **simultaneous variation** (distributions) of analyzed parameters • 1000 runs (baseline and shock)

- Assessing **uncertainty development** of ILUC **over time** by comparing two approaches:
  - **comparative-static** for 2030 → short term response to shock
  - **recursive-dynamic** through 2050 → development of response to shock over time

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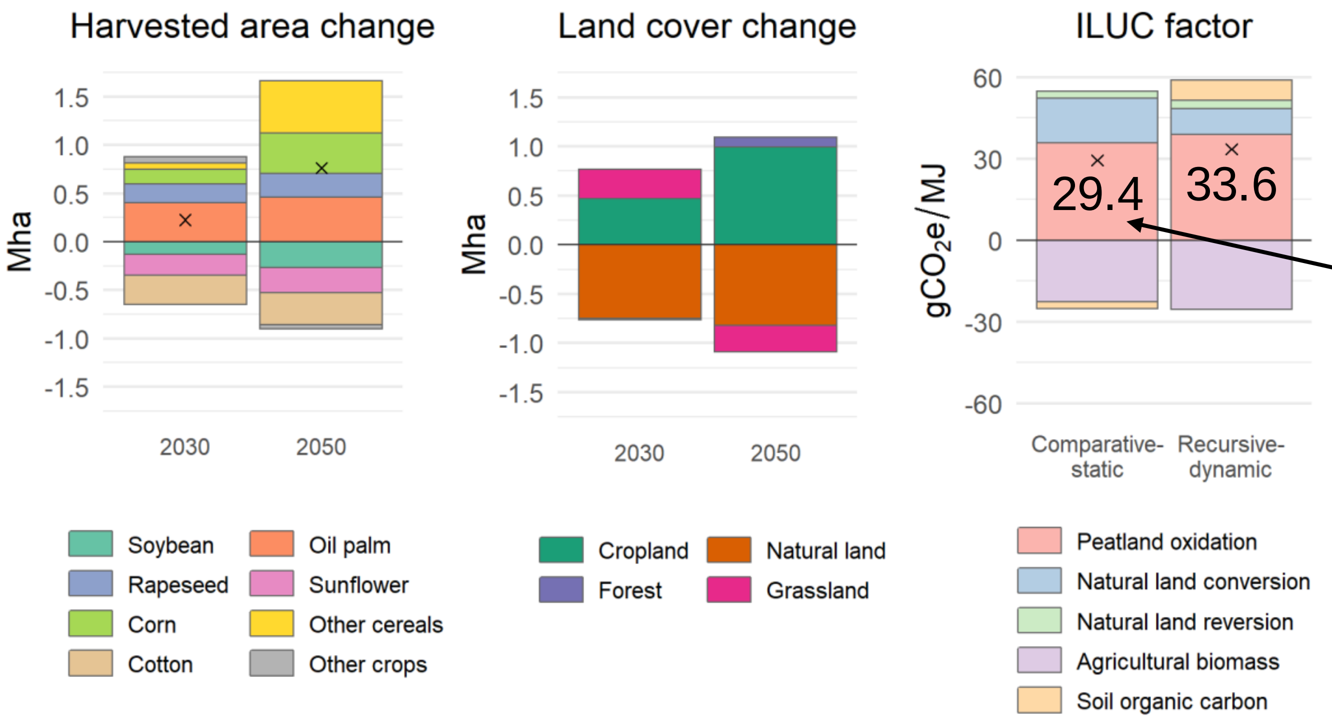
Central case compares baseline vs. biofuel shock scenario, given GLOBIOM default parameter values

Absolute changes: shock scenario vs. baseline



comparative-static 2030

Soya oil

↑ 3.5 Mt of US fuel use
- ↑ 1.9 Mt US production
- ↓ 1.2 Mt US net trade
- ↓ 0.3 Mt US non-fuel use

↑ 6% (3% other veg. oil) price globally

↓ 3.1 Mt global non-fuel use

↑ 1.8 Mt of palm and rapeseed oil use globally

Soya meal (co-product)

↑ 7.7 Mt US production

↓ 8% (3%) price in US (globally)

↓ production by other major producers, i.e., slower expansion from 2020 onwards in SAM

Livestock rebound effect

↑ livestock intensification

↑ 1.3 Mt complementary grains for feed

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OAT shows variabilities in ILUC estimates and increases of these variabilities over time

Comparative-static

Largest variations (mean ± std. dev. in gCO_2e/MJ):

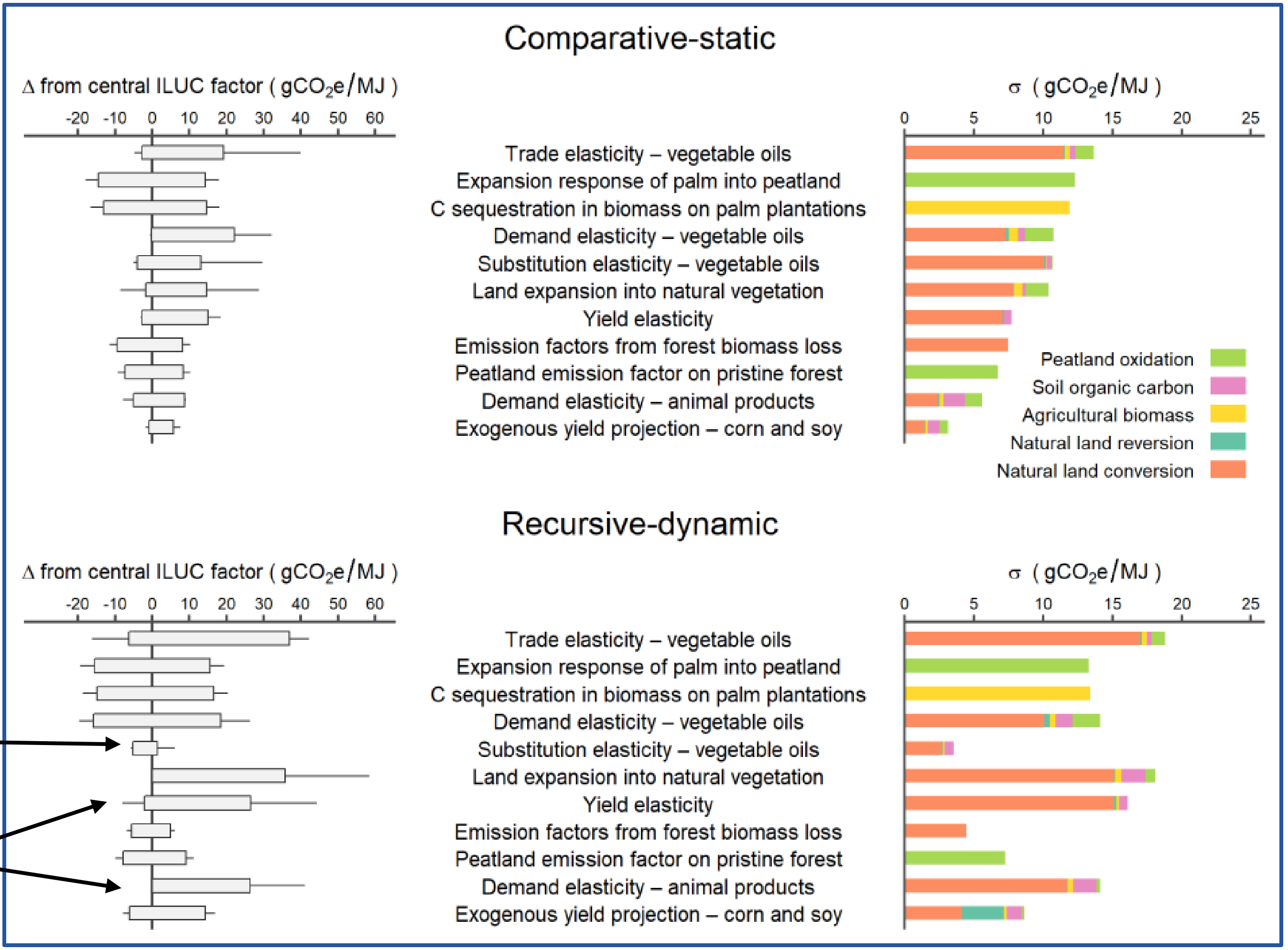
35.8 ± 13.6 trade elasticity of veg. oils

29.4 ± 12.3 expansion response of palm into peatland

29.9 ± 12.3 EF for C sequestration in BIOM of palm

Recursive-dynamic

- uncertainty mostly increases over time
  - ILUC factor ranges widen in recursive-dynamic setting
  - especially for economic parameters
    e.g., 44.2 ± 18.8 trade elasticity of veg. oils
- Substitution elasticity among veg. oils matters less
- Parameters determining the size of the livestock rebound gain influence (yield elasticity, demand elasticity for animal products)



Boxes represent the 10th and 90th percentile. Whiskers represent the minimum and maximum values.
Standard deviations are decomposed by emission source.

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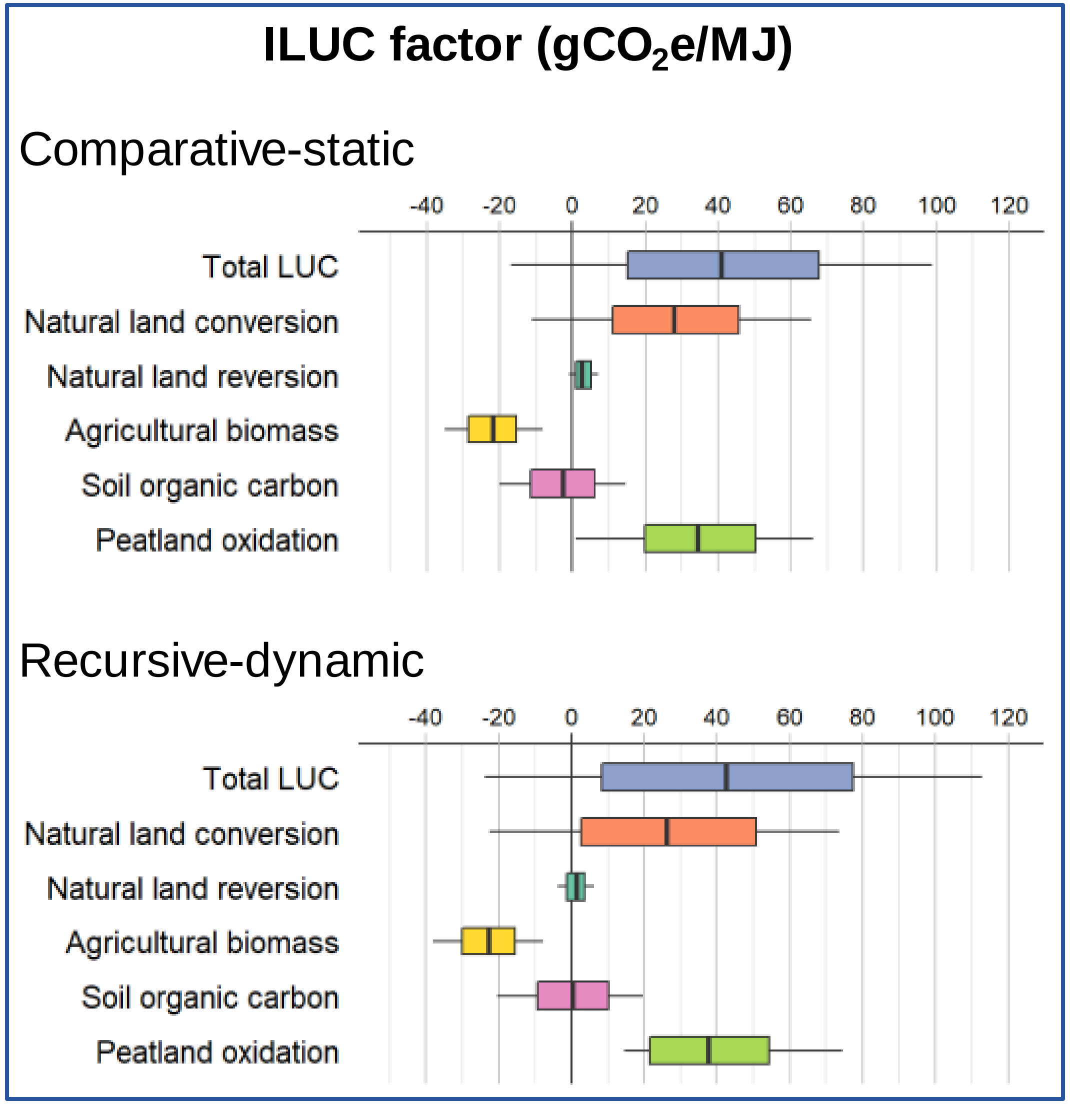
Monte Carlo simulations show ranges of ILUC estimates



- **ILUC factors** in gCO_2e/MJ for US soybean biodiesel **range** from 10th to 90th percentiles (total min. to max. excl. outliers)
  - **comparative-static: 15.1 to 67.7** (-17.0 to 98.7)
  - **recursive-dynamic: 8.4 to 77.4** (-23.7 to 112.8)
- Emissions from **natural land conversion and peatland** oxidation are most **influential** and have **widest distributions**
- **Agricultural biomass** changes leads to **net sequestration**, mostly in **palm plantations**
- **Spreads and means** are slightly higher in recursive-dynamic
  - **comparative-static: 40.8 ± 20.5**
  - **recursive-dynamic: 42.4 ± 25.9**
  - mostly due to peatland oxidation
- Simulations show almost always **positive ILUC**
  - 98.8% of simulations for 2030
  - 94.7% of simulations for 2050

Boxes represent the 10th and 90th percentile. Whiskers represent the minimum and maximum values, excl. outliers according to the 1.5 rule: Outliers are < Q1 - 1.5 x IQR or > Q3 + 1.5 x IQR, where IQR is the interquartile range.

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Conclusion and discussion

1. **Major market-mediated responses** related to vegetable oil markets require systemic analysis of uncertainty when estimating ILUC emissions
   - modeled soybean biodiesel ILUC factors are highly sensitive to economic and biophysical parameters
   - a strong driver of results is oil palm expansion in Southeast Asia
   - spillovers from US shock to Southeast Asia and South America depend strongly on vegetable oil substitution elasticity and vegetable oil demand elasticity

2. **Methodological considerations**
   - similar effects may be expected for other oilseeds with meal co-production (e.g., rapeseed)
   - further efforts are needed to better estimate biophysical parameters (e.g., emission factors)
   - Monte Carlo simulations varied a limited amount of parameters
     - crucial parameters might have been overlooked
     - including more parameters does not always change results as many parameters interact
   - other factors impact ILUC estimates (e.g., chosen modelling framework, amortization periods)

Thank you for your time.

Questions? Comments?

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