EPA Model Comparison Exercise for Biofuel Analysis

Presented by

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U.S. EPA Office of Transportation & Air Quality

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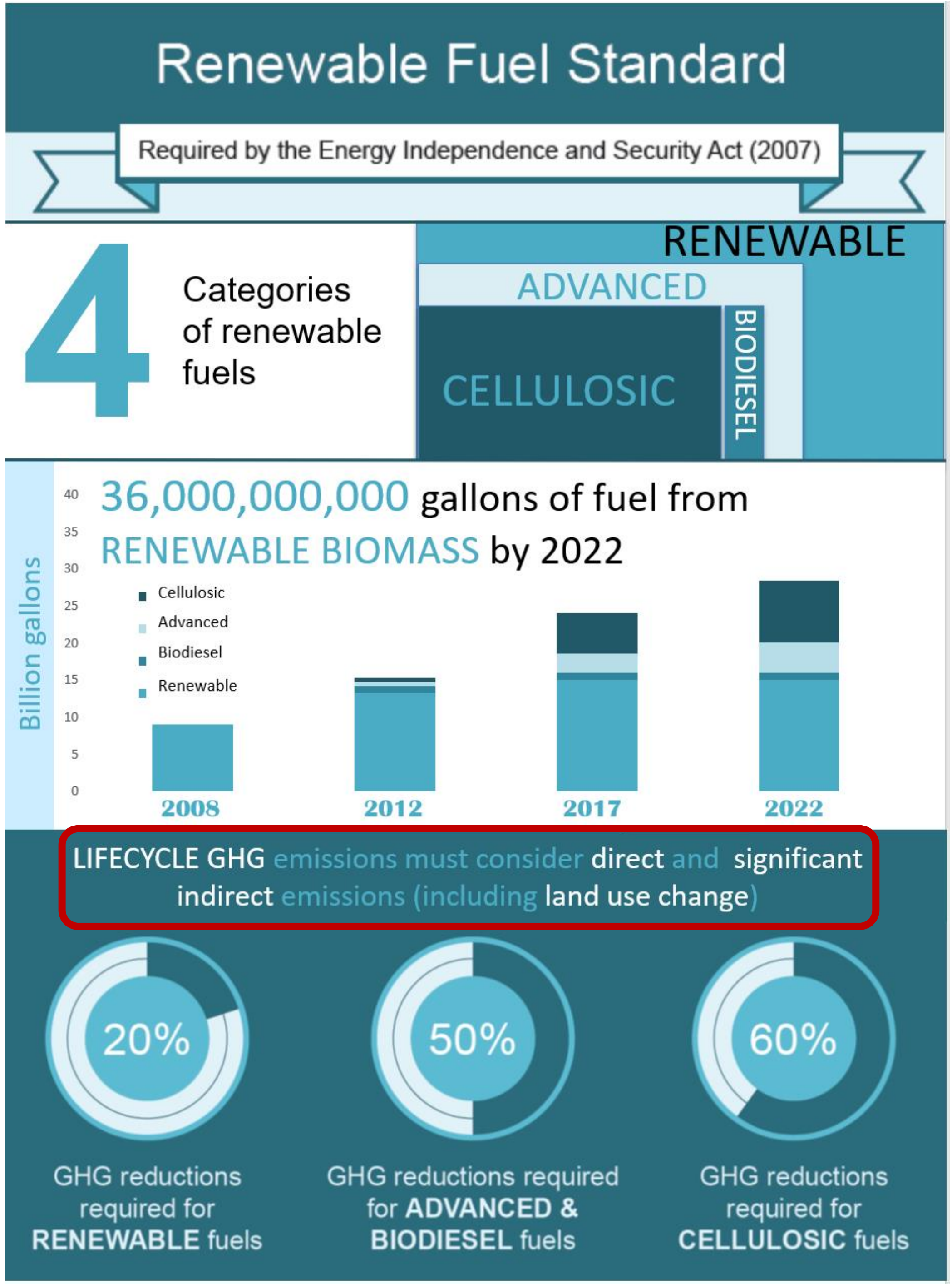
EPA Office of Transportation & Air Quality

Our Mission is to protect human health and the environment by…

- Reducing air pollution & GHGs from mobile sources and the fuels that power them
- Advancing clean fuels & technology
- Encouraging business practices & travel choices that minimize emissions

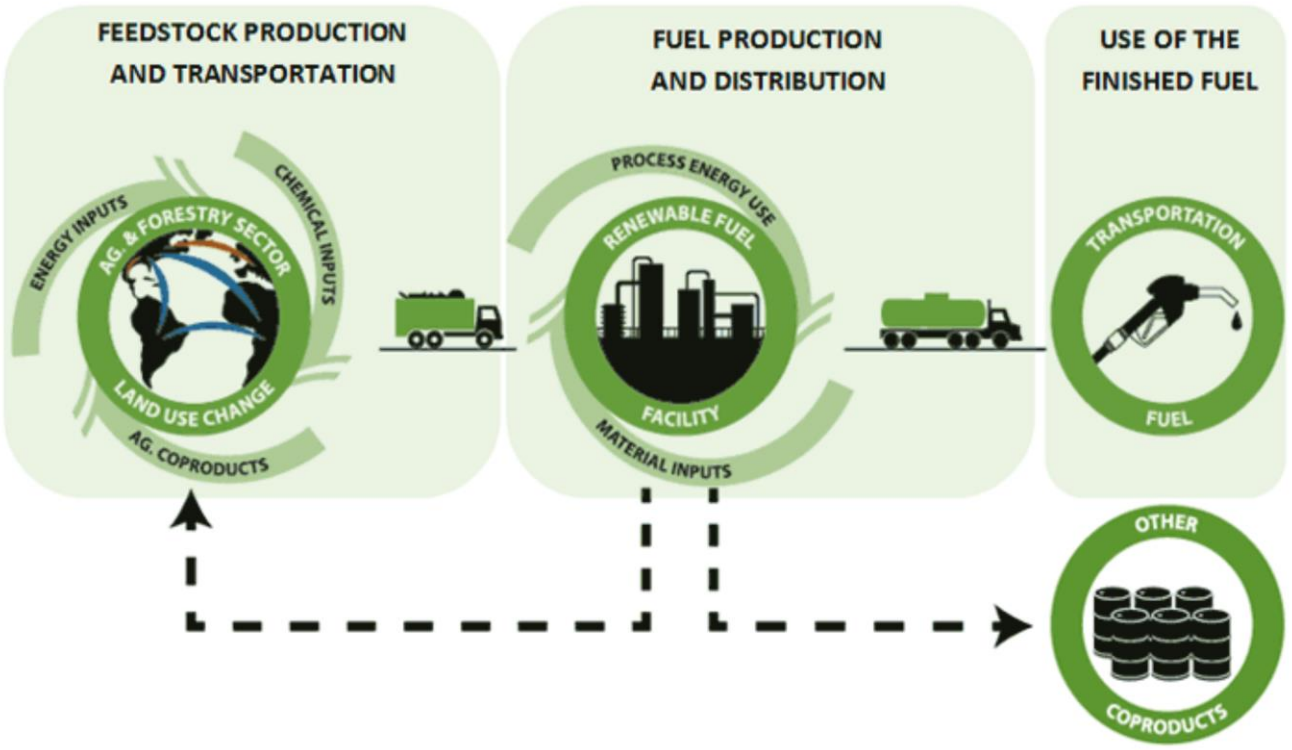
Our interest in land use change stems from implementation of the Renewable Fuel Standard Program



EPA is required by statute to consider land use change GHG emissions associated with biofuels

- EISA definition at CAA 211(o):
  - "The term 'lifecycle greenhouse gas emissions' means the aggregate quantity of greenhouse gas emissions **(including direct emissions and significant indirect emissions such as significant emissions from land use changes)…"**
- Since 2010, EPA has regularly published GHG lifecycle analyses for biofuels, including assessments of LUC impacts for crop-based fuels

Scope of EPA biofuel lifecycle GHG analysis methodology



In early 2022, we conducted a workshop…

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Workshop on Biofuel Greenhouse Gas Modeling

EPA hosted a virtual public workshop on biofuel greenhouse gas (GHG) modeling February 28 - March 1, 2022. This was a virtual meeting and open to the public. The purpose of this workshop was to solicit information on the current scientific understanding of greenhouse gas modeling of land-based crop biofuels used in the transportation sector. The meeting was conducted by EPA's Office of Transportation and Air Quality (OTAQ) in consultation with the Department of Agriculture and the Department of Energy. Thank you to everyone who attended the workshop and submitted comments to the docket.

EPA solicited comments through a docket that was open from March 1, 2022 - April 1, 2022. A copy of these comments can be found on the Federal eRulemaking Portal here. We reviewed the 29 comments that were received through the docket. After reviewing these comments we decided to conduct a model comparison exercise to advance our scientific understanding of available models.

Sessions included:

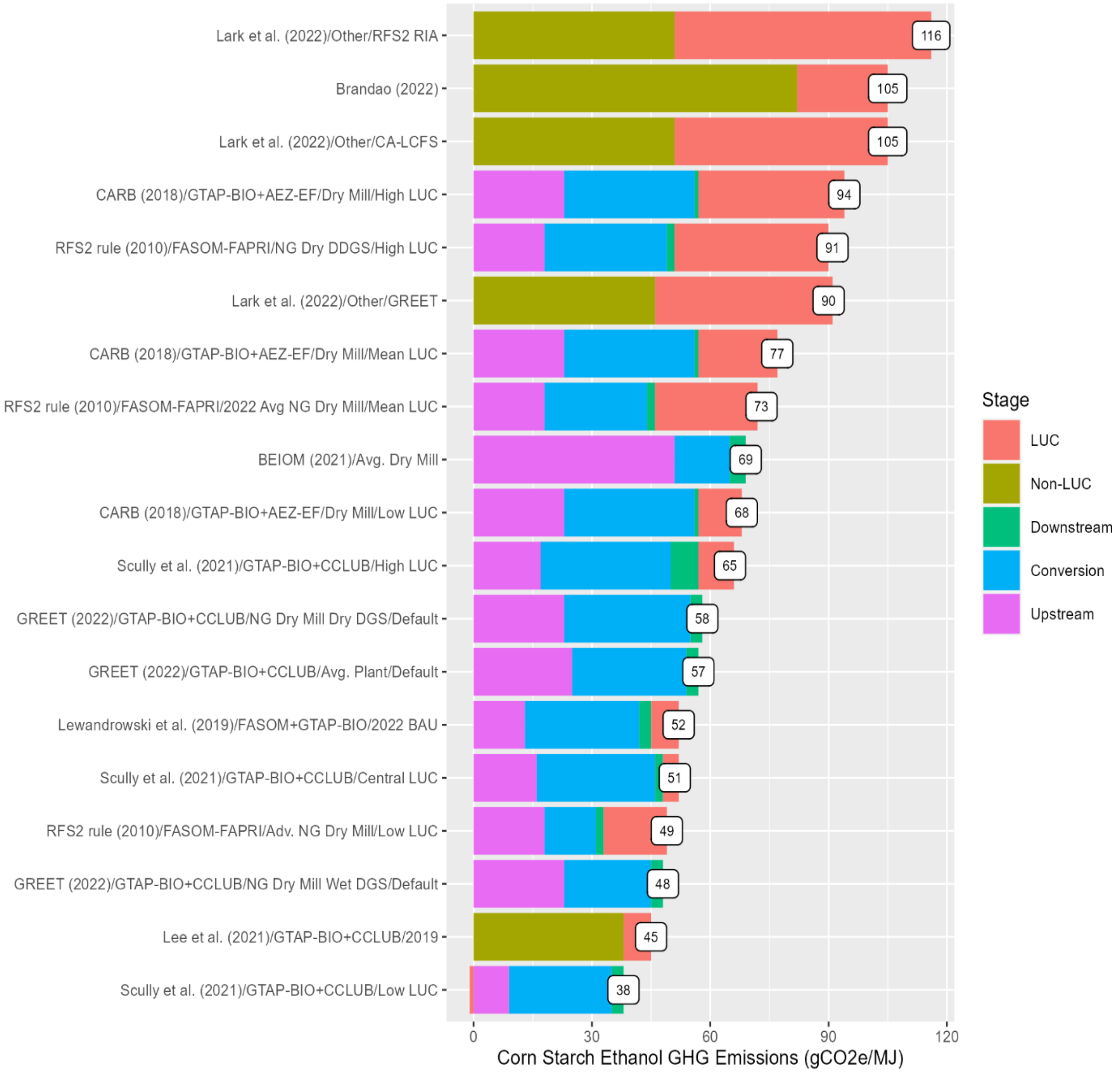
- Biofuel Greenhouse Gas Modeling Uses
- Recent Developments in Biofuel Production and Implications for Modeling Future Biofuel Impacts
- Feedstock Supply and Land Use Change
- Soil Carbon, Biomass Carbon, and Climate Smart Agricultural Practices
- Overview of Modeling Frameworks of Crop-Based Biofuels
- Sources of Uncertainty in Biofuel GHG Estimates

https://www.epa.gov/renewable-fuel-standard-program/workshop-biofuel-greenhouse-gas-modeling

Uncertainty persists in the literature…

Soybean Oil Biodiesel Lifecycle GHG Estimates

Corn Starch Ethanol Lifecycle GHG Estimates



Source: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017OW2.pdf (Chapter 4)
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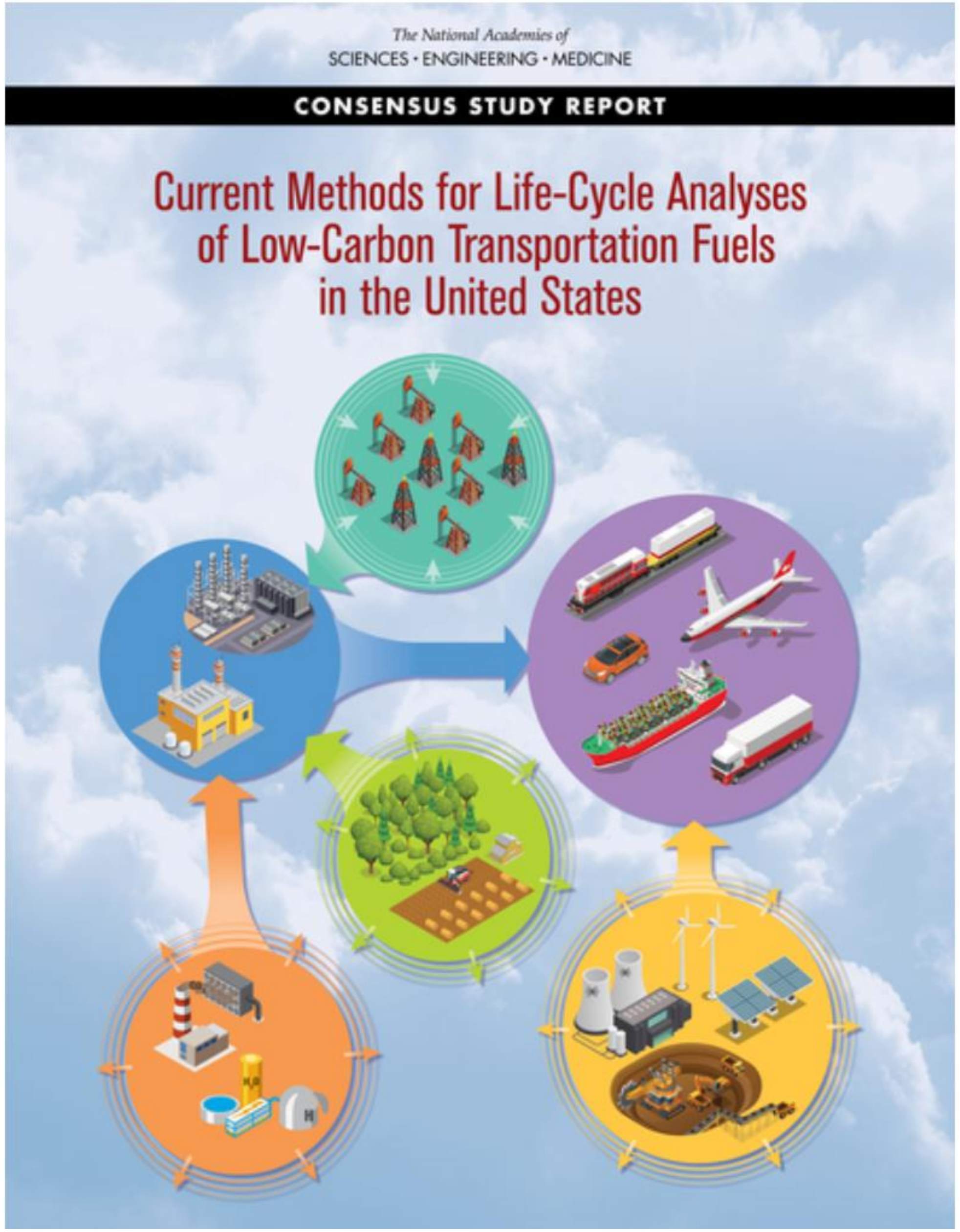
NASEM provides some helpful methodological guidance

"LCA studies used to inform policy should explicitly consider **parameter uncertainty**, **scenario uncertainty**, and **model uncertainty**" (Recommendation 4-3)



Source: https://nap.nationalacademies.org/catalog/26402/current-methods-for-life-cycle-analyses-of-low-carbon-transportation-fuels-in-the-united-states

EPA Biofuel GHG Model Comparison Exercise (MCE)

- Goals of the MCE:
  1) Advance the science
  2) Identify differences in models
  3) Understand how these differences affect biofuel GHG estimates

- Structure of the MCE:
  - Conduct common U.S. biofuel consumption shock scenarios across several models
    - Reference case – align USA biofuels background through 2020, biofuel conversion yield assumptions
    - Corn starch ethanol – 1 billion gallons
    - Soybean oil biodiesel – 1 billion gallons
  - To the extent possible, conduct scenario & parameter sensitivity analyses

Source: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017P9B.pdf

Model Types Evaluated

Computable General Equilibrium	Partial Equilibrium Model	Supply Chain LCA Model
Model of the entire global economy that simulates effects of economic policies or shocks	Economic model that focuses on key economic sectors, and holds other sectors constant	Tool that assesses environmental impacts of a product without taking economic impacts into account

Source: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017P9B.pdf

Models Considered

✓ = Represented in model. For GREET the checks are for the core model, not the ILUC module.

- All three categories of models are represented in the MCE.
- Models used for lifecycle analysis have differences in:
  - Structure
  - Sectoral representation
  - Time period
  - Parameter assumptions
- These differences lead to different results.

Model (Organization)	Model Type	Agriculture and Forestry Markets	Energy Markets	Biofuel Supply Chain Details	Time Period Modeled for MCE
ADAGE (RTI)	Computable general equilibrium	✓	✓		2020-2050
GTAP-BIO (Purdue)	Computable general equilibrium	✓	✓		2014
GCAM-T (PNNL)	Partial equilibrium	✓	✓		2020-2050
GLOBIOM (IIASA)	Partial equilibrium	✓			2020-2050
GREET (Argonne)	Supply chain LCA model + induced land use change (ILUC) from separate module			✓	2030

Source: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017P9B.pdf
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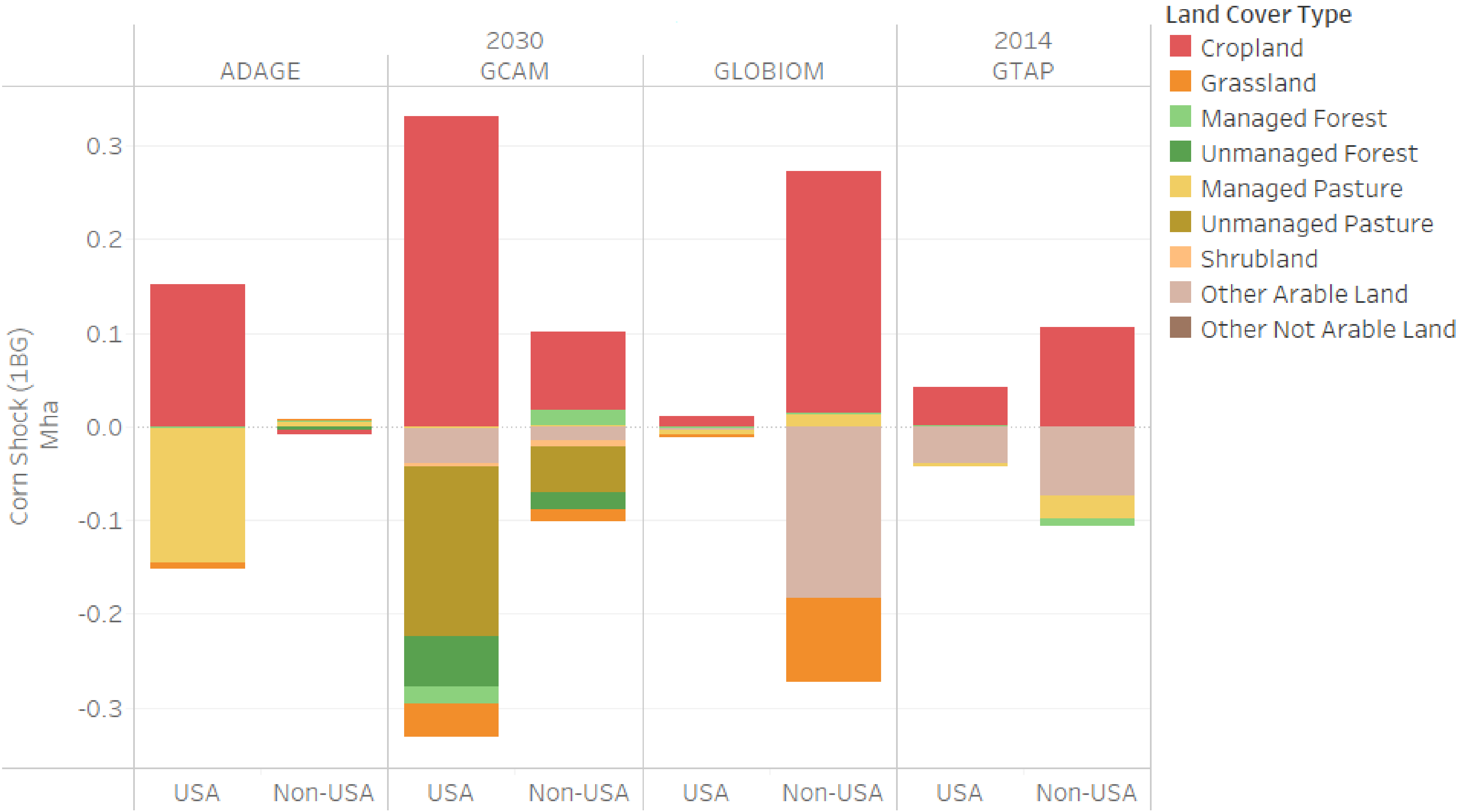
Corn Starch Ethanol

Land Use Change Results

Figure 6.6-2: Difference in land use (million hectares) in the corn ethanol shock relative to the reference case in 2014 (GTAP) and 2030 (ADAGE, GCAM, GLOBIOM)



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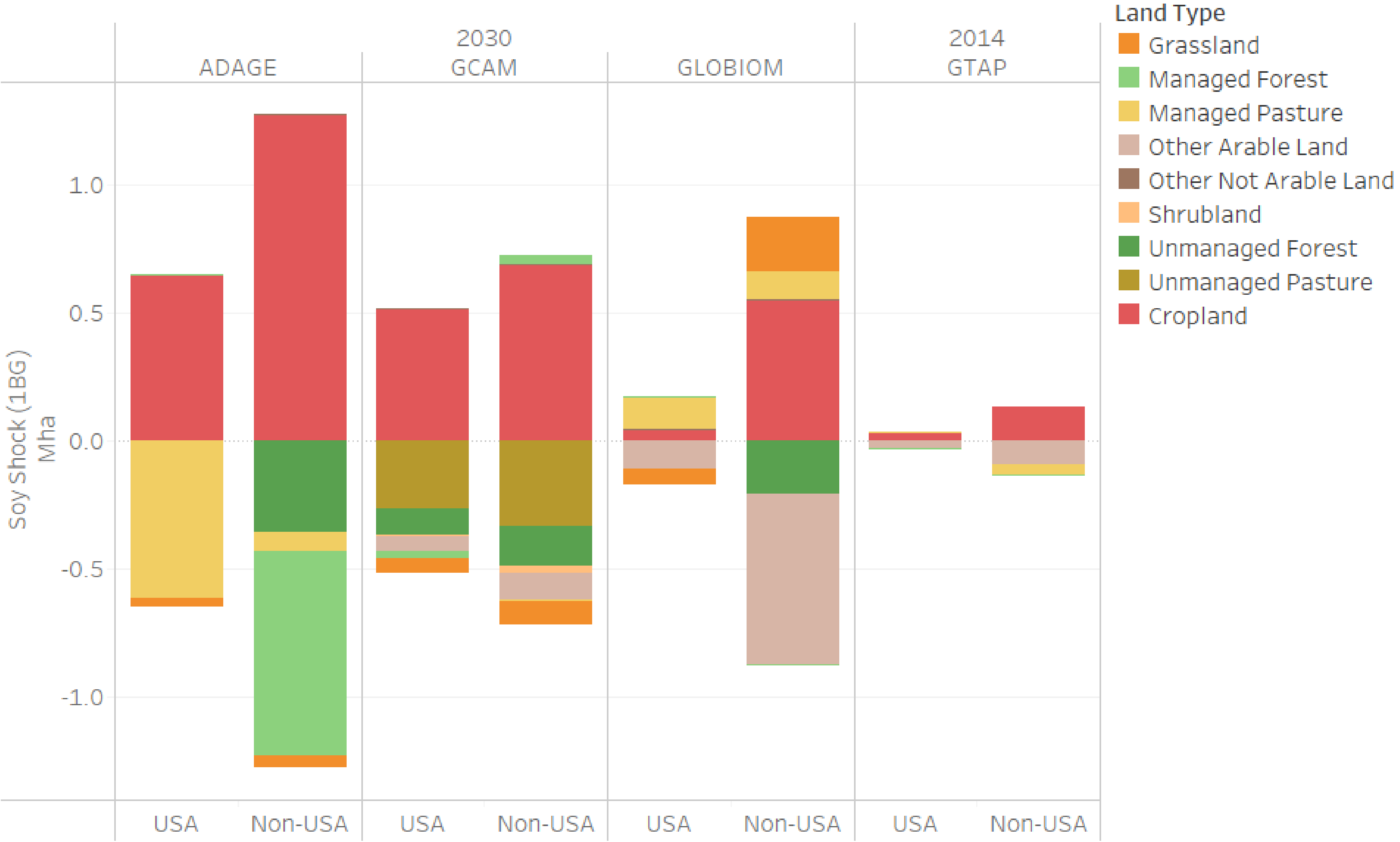
Soybean Oil Biodiesel

Land Use Change Results

Figure 7.6-2: Difference in land use (million hectares) in the soybean oil biodiesel shock relative to the reference case in 2014 (GTAP) and 2030 (ADAGE, GCAM, GLOBIOM)



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LUC emissions results vary significantly across models and scenarios

Table 6.7-1: Carbon intensity of corn ethanol (kgCO₂eq/MMBTU) calculated using emissions reported by each model[193]

	Models with Energy Markets				Models without Energy Markets		
		ADAGE	GCAM	GTAP		GLOBIOM	GREET
Sector/stage-specific emissions	Energy from Fossil Fuels	-15	-65	-15	Biofuel Production	x	29
	Crop Production	14	16	1	Crop Production	9	x
					Feedstock Production	x	16
	Livestock Sector	0.1	0.3		Livestock Sector	-1	x
	Other	1	-1		Fuel Use	x	0.4
	Land Use Change	-1	31	6	Land Use Change	13	8
Totals	Agriculture, forestry, and land use	14	47	7	Agriculture, forestry, and land use	21	24
	Global GHG Impact	-1	-19	-8	Global GHG Impact	x	x
	Supply Chain GHG Emissions	x	x	x	Supply Chain GHG Emissions	x	53

Table 7.7-1: Carbon intensity of soybean oil biodiesel (kgCO₂eq/MMBTU) calculated using emissions reported by each model[213]

	Models with Energy Markets				Models without Energy Markets		
		ADAGE	GCAM	GTAP		GLOBIOM	GREET
Sector/stage-specific emissions	Energy from Fossil Fuels	-28	-40	-46	Biofuel Production	x	13
	Crop Production	7	21	-6	Crop Production	11	x
					Feedstock Production	x	9
	Livestock Sector	0.7	-1.3		Livestock Sector	3	x
	Other	1	0		Fuel Use	x	0.4
	Land Use Change	295	62	10	Land Use Change	23	10
Totals	Agriculture, forestry, and land use	303	82	4	Agriculture, forestry, and land use	38	19
	Global GHG Impact	276	42	-42	Global GHG Impact	x	x
	Supply Chain GHG Emissions	x	x	x	Supply Chain GHG Emissions	x	32

Source: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017P9B.pdf
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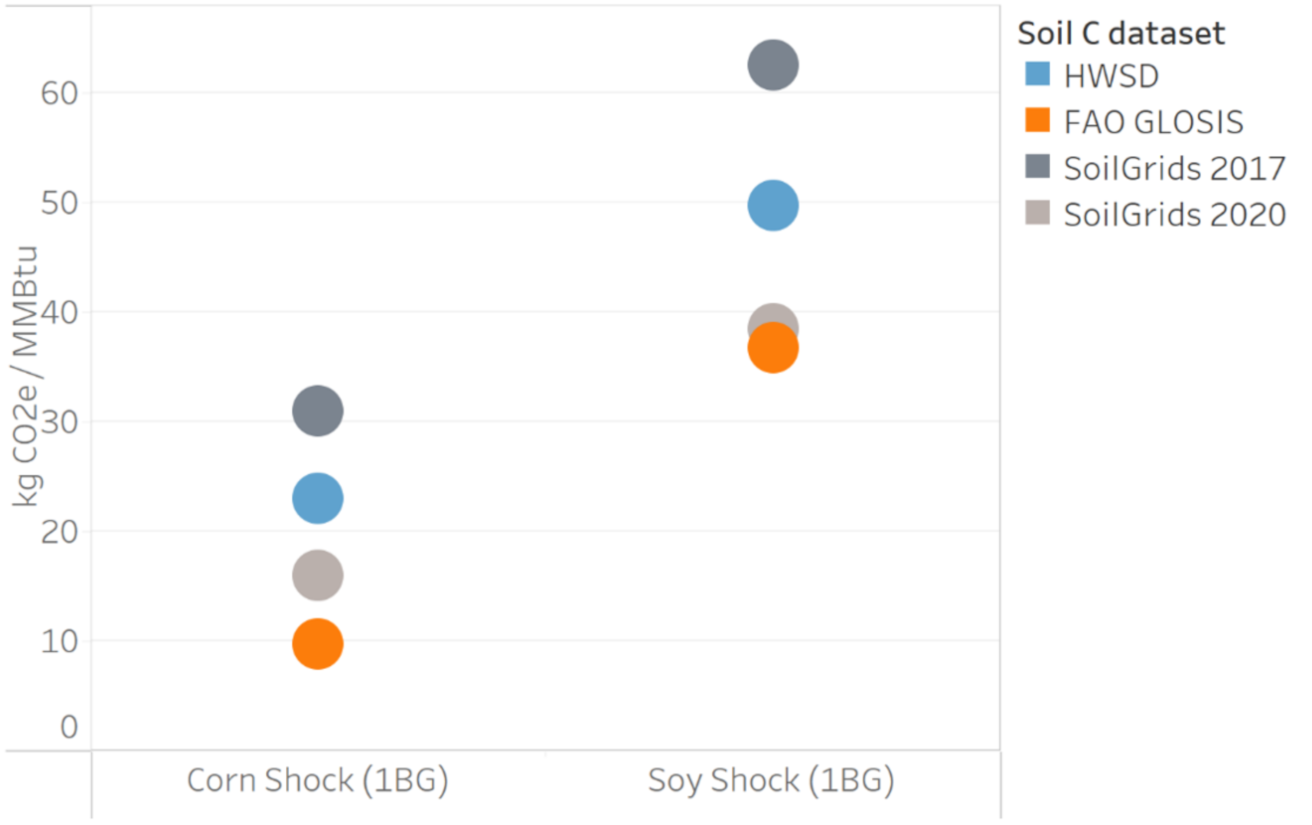
Parameter sensitivity analyses find additional variation within models

Figure 9.2-2: Carbon intensity from land use change emissions for the corn ethanol shock and the soybean oil biodiesel shock using a range of soil carbon datasets



Source: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1017P9B.pdf
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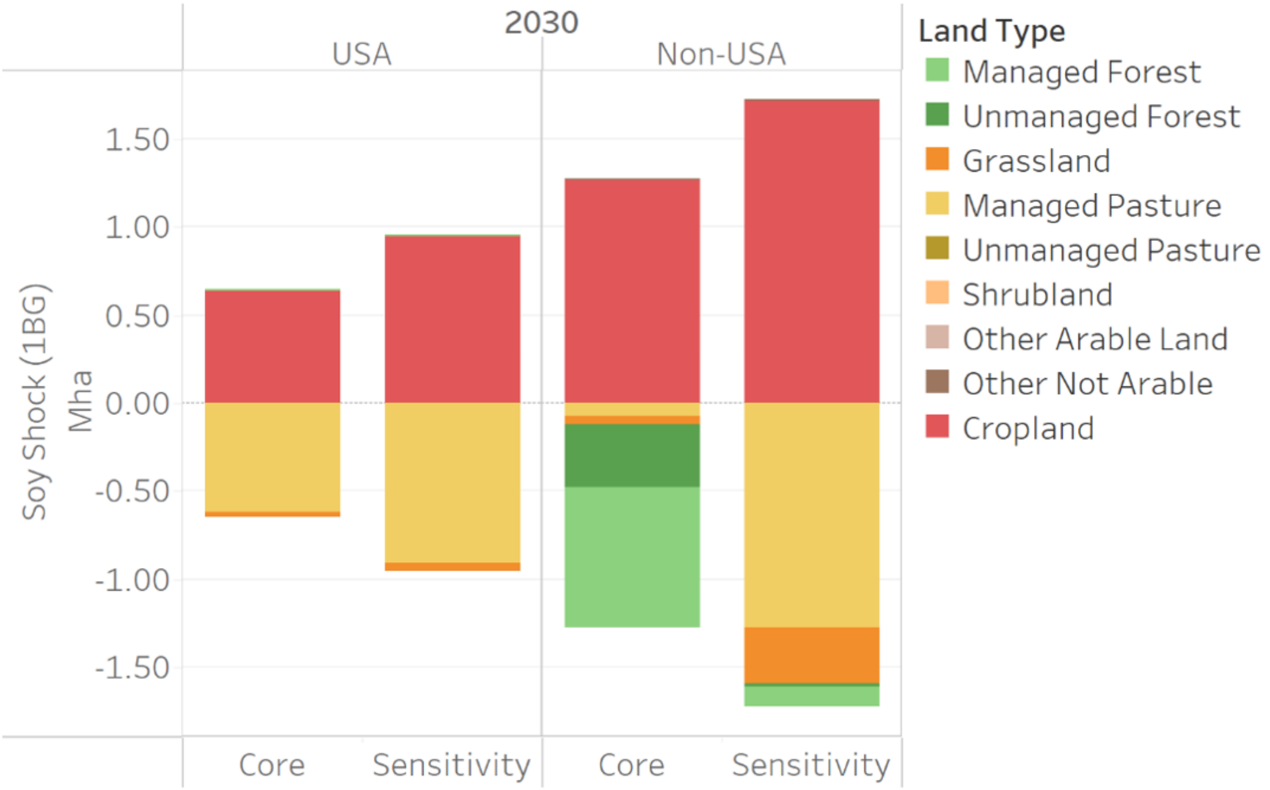
Parameter sensitivity analyses find additional variation within models

Figure 9.3-2: Difference in land use (million hectares) in the soybean oil biodiesel shock relative to the reference case in 2030 for the original ADAGE runs ("Core") and the fixed factor elasticity sensitivity runs ("Sensitivity")



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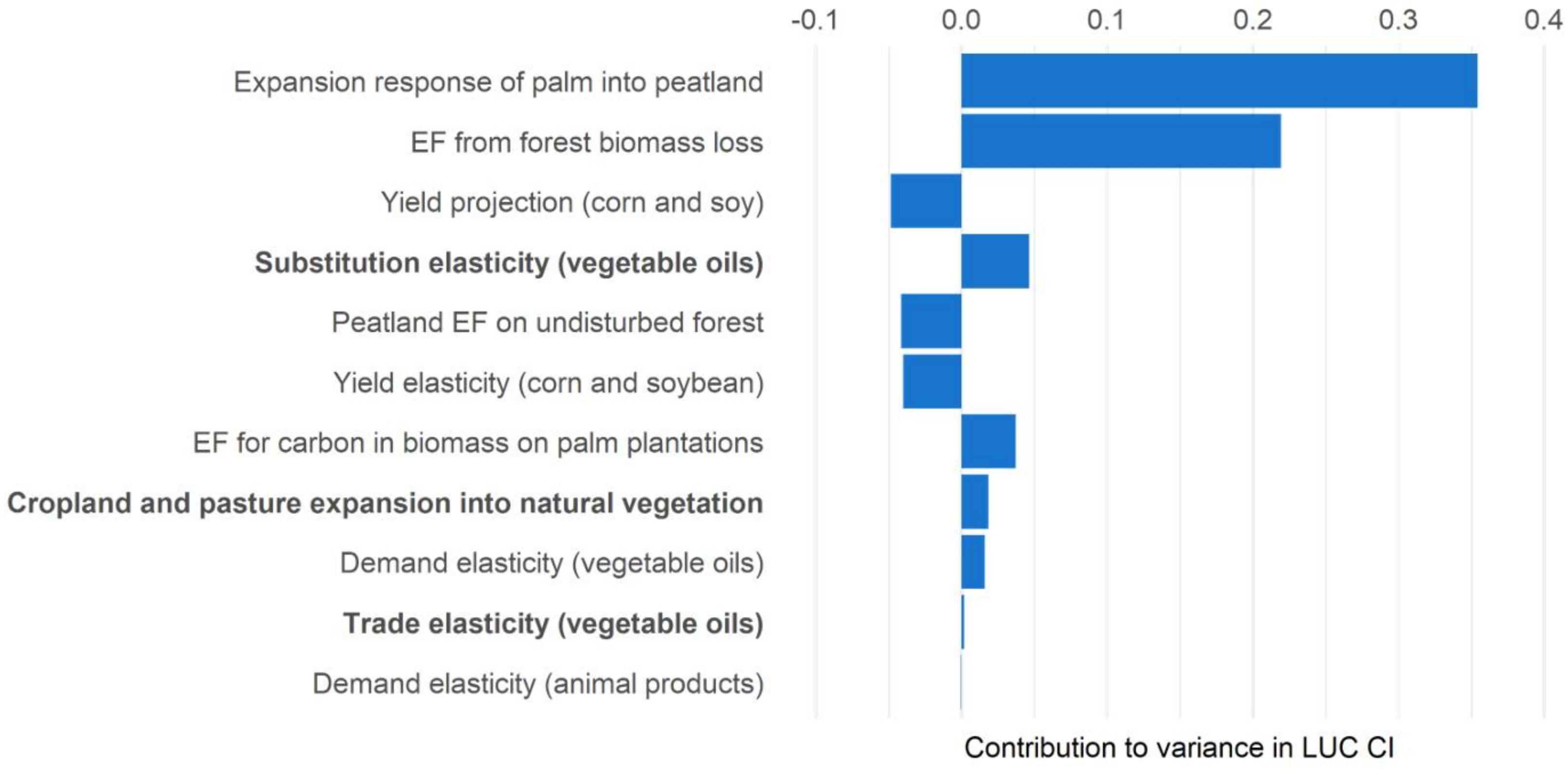
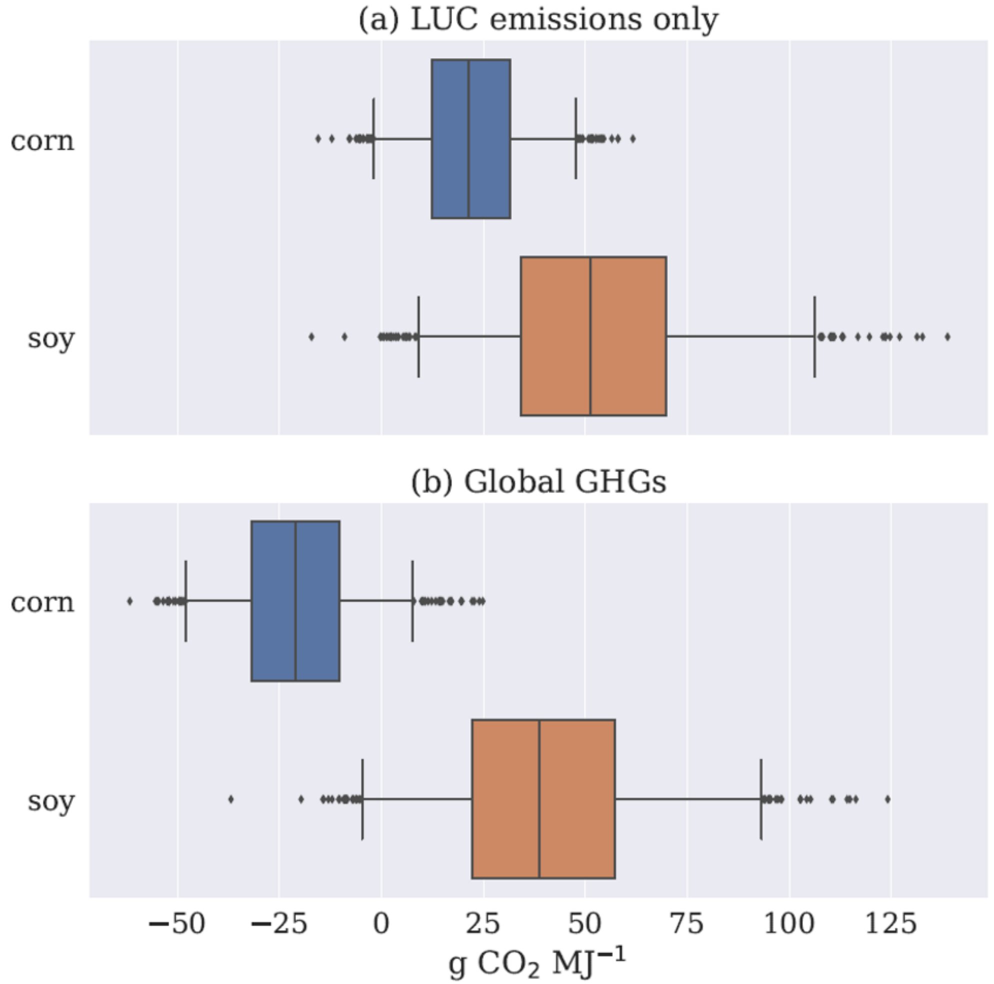
Parameter sensitivity analyses find additional variation within models

Figure 9.1.2-2: Tornado chart of most the influential parameters in GLOBIOM MCS on soybean oil biodiesel land use change carbon intensity.[236]



Parameter sensitivity analyses find additional variation within models

Figure 9.1.1-1: Distribution of GCAM (a) land use change carbon intensity and (b) overall carbon intensity estimates for corn ethanol and soybean oil biodiesel based on the MCS[225]



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Discussion

- After 15 years of research, land sector emissions impacts for crop-based biofuels remain uncertain
- Robust consideration of land sector emissions uncertainty should include analysis across models, assumption sets and scenario designs
  - **Scholarly model comparison efforts such as AgMIP, CMIP, and the Stanford EMF can play a critical role here**
- Parameter sensitivity analysis to date suggests areas of research into key model input values

- **Calling All Researchers! (We need your help)**
  - **Section 10** of our MCE identifies numerous suggested areas for **future research**

Thank You!

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