Decarbonization scenarios in the United States: Comparing biofuels growth in two models – GCAM and BSM

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Background

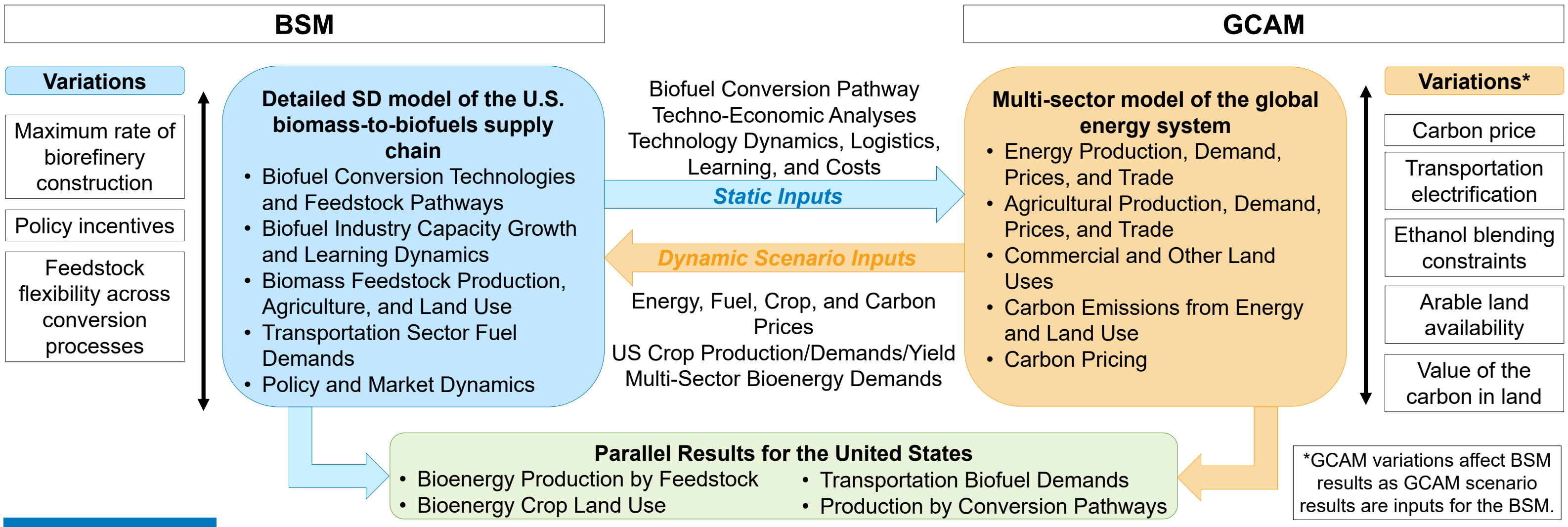
Land availability and technology transition rates lead to differences in model results for decarbonization scenarios using bioenergy with carbon capture and storage (BECCS)

Research Question

How are biofuels production and land use allocation affected by carbon prices, transportation electrification, land availability, value of carbon in land, industry growth rate, and policy incentives?

Methodology

We performed a coordinated analysis using the Global Change Analysis Model (GCAM),[1] an integrated assessment model (IAM), and the Biomass Scenario Model (BSM),[2] a biomass-to-biofuels system dynamics (SD) model



BSM

GCAM

Variations

- Maximum rate of biorefinery construction
- Policy incentives
- Feedstock flexibility across conversion processes

Detailed SD model of the U.S. biomass-to-biofuels supply chain

- Biofuel Conversion Technologies and Feedstock Pathways
- Biofuel Industry Capacity Growth and Learning Dynamics
- Biomass Feedstock Production, Agriculture, and Land Use
- Transportation Sector Fuel Demands
- Policy and Market Dynamics

Biofuel Conversion Pathway
Techno-Economic Analyses
Technology Dynamics, Logistics, Learning, and Costs

Static Inputs

Dynamic Scenario Inputs

Energy, Fuel, Crop, and Carbon Prices
US Crop Production/Demands/Yield
Multi-Sector Bioenergy Demands

Multi-sector model of the global energy system

- Energy Production, Demand, Prices, and Trade
- Agricultural Production, Demand, Prices, and Trade
- Commercial and Other Land Uses
- Carbon Emissions from Energy and Land Use
- Carbon Pricing

Variations*

- Carbon price
- Transportation electrification
- Ethanol blending constraints
- Arable land availability
- Value of the carbon in land

Parallel Results for the United States

- Bioenergy Production by Feedstock
- Bioenergy Crop Land Use
- Transportation Biofuel Demands
- Production by Conversion Pathways

*GCAM variations affect BSM results as GCAM scenario results are inputs for the BSM.

Results

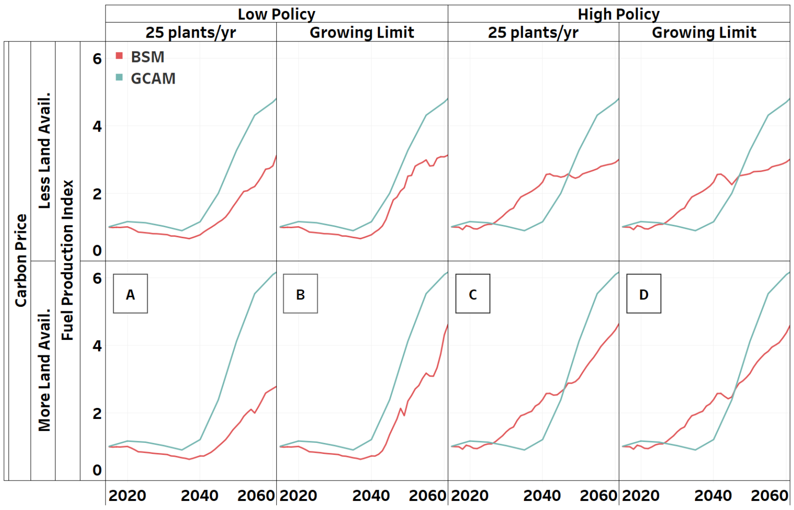


Figure 1. Biofuel production index in BSM and GCAM with a carbon price trajectory consistent with 2.6 W/m². Initial fuel production in 2015 (index = 1) begins at 1.54 EJ/year in both models. Note: Only the BSM results differ across the columns. Effects shown: Columns – Policy Level (Low; High), Annual Biorefinery Capacity Expansion Limit (25 plants/year; Growing Limit up to 105 plants/year); Rows: Carbon Price, Initial Arable Land Availability (More; Less)

- Land availability constrains biofuels production in both models (Figure 1, compare rows).
- When more land is available, capacity expansion does not increase biofuel production in BSM in the high policy case (Figure 1, cells C and D), as BSM limits the rate of land re-allocation.
- However, biofuels deployment is slower in the low policy case and the BSM land-reallocation rate effect is not dominant. Thus, biofuels capacity expansion results in higher biofuels production (Figure 1, cells A and B).

- Across both models, more initial arable land availability (Figure 2, blue wedge) increases land used for biofuel production (Figure 2, compare Rows 2,3) when a carbon price is present.
- In BSM, a lag between feedstock price changes and land reallocation enables representation of potential volatility in biomass land allocation (Figure 2, Cell A, oscillations in green wedge). Greater land availability reduces feedstock price and volatility (smaller oscillations in Figure 2, Cell B).

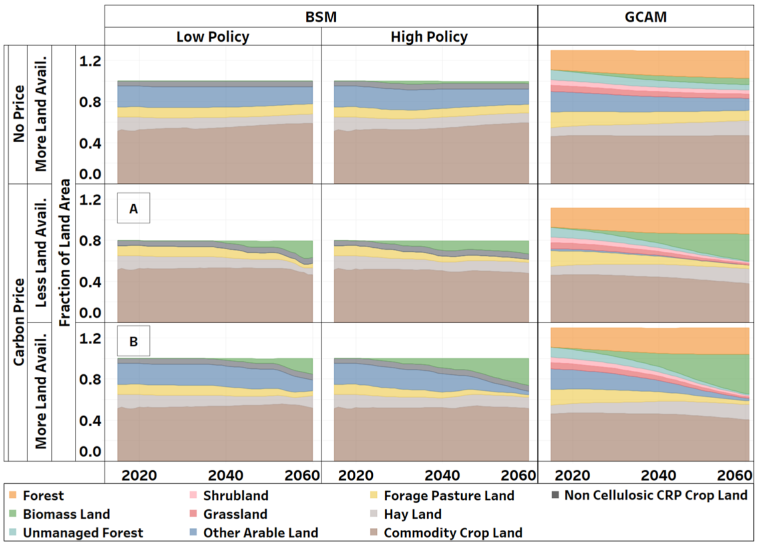


Figure 2. Land allocation fractions in BSM and GCAM. Fractions are calculated based on the higher BSM land availability, 1933.3 thousand sq.km., as the basis. Note: All land categories that change are included in the GCAM column; some might not be included in the BSM. Effects shown: Columns – Policy Level (BSM Only); Rows: Carbon Price, Initial Arable Land Availability

References

[1] "Global Change Analysis Model (GCAM)." Joint Global Change Research Institute (JGCRI). https://github.com/JGCRI/gcam-core.
[2] "Biomass Scenario Model." 2019. National Renewable Energy Laboratory. https://github.com/NREL/bsm-public.

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