2024 U.S. Forestry and Agriculture Greenhouse Gas Mitigation Report

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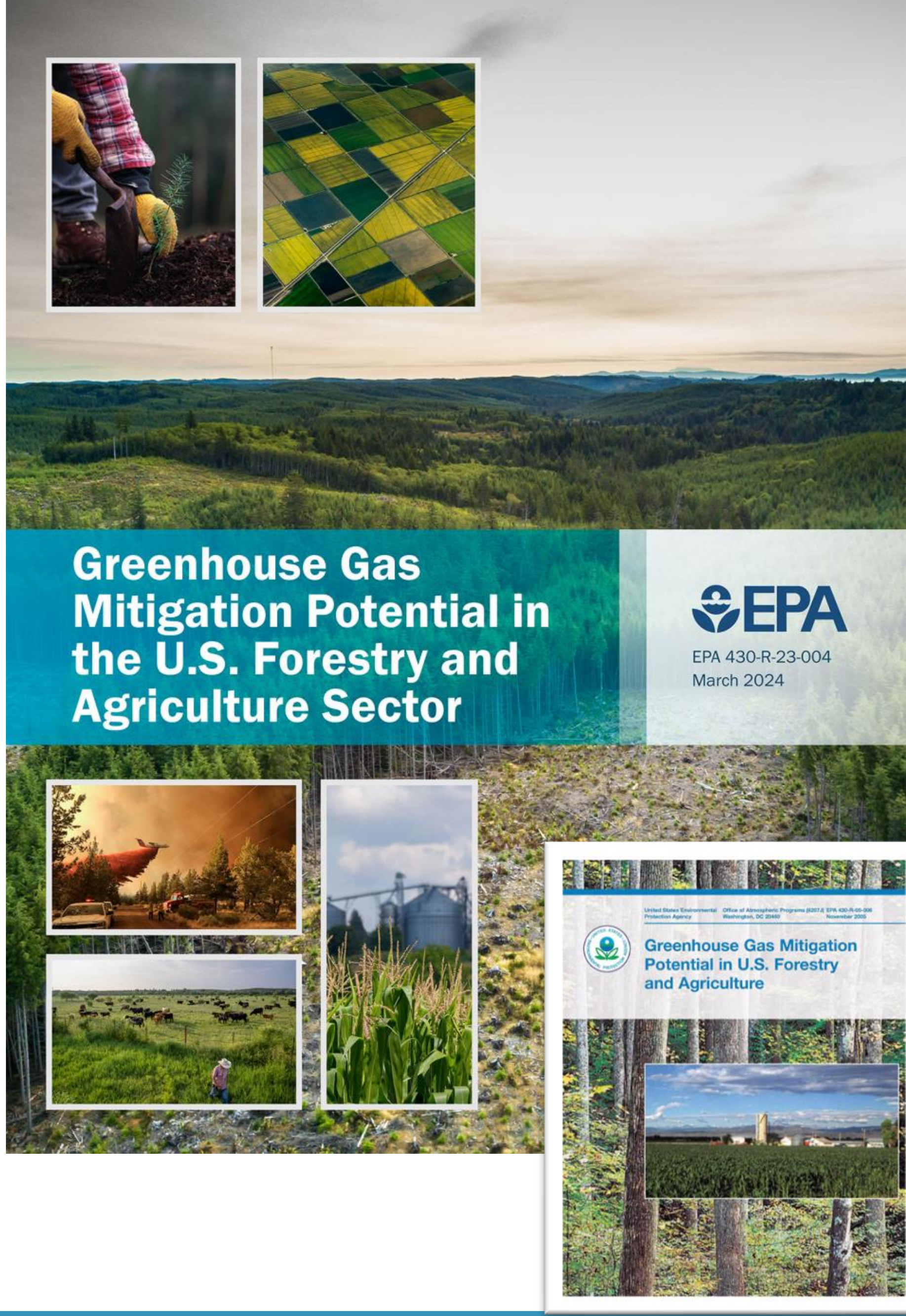
Purpose & Goals

*What is the **Greenhouse Gas Mitigation Potential in the U.S. Forestry and Agriculture Sector** report?*

- This EPA technical report provides **updated estimates of cost-effective future GHG mitigation potential** for specific forestry and agriculture abatement activities under specific future conditions, now to 2050.

- It is a **policy-agnostic evaluation** that uses **three well-known economic models** and a **range of GHG price paths** to estimate market competitive GHG mitigation potential across activities, time, and costs.

- It updates work in the 2005 EPA report *GHG Mitigation Potential in U.S. Forestry and Agriculture* and integrates **additional and updated modeling tools and new mitigation opportunities** to provide a **contemporary perspective** on GHG abatement options for the U.S. land use sector.

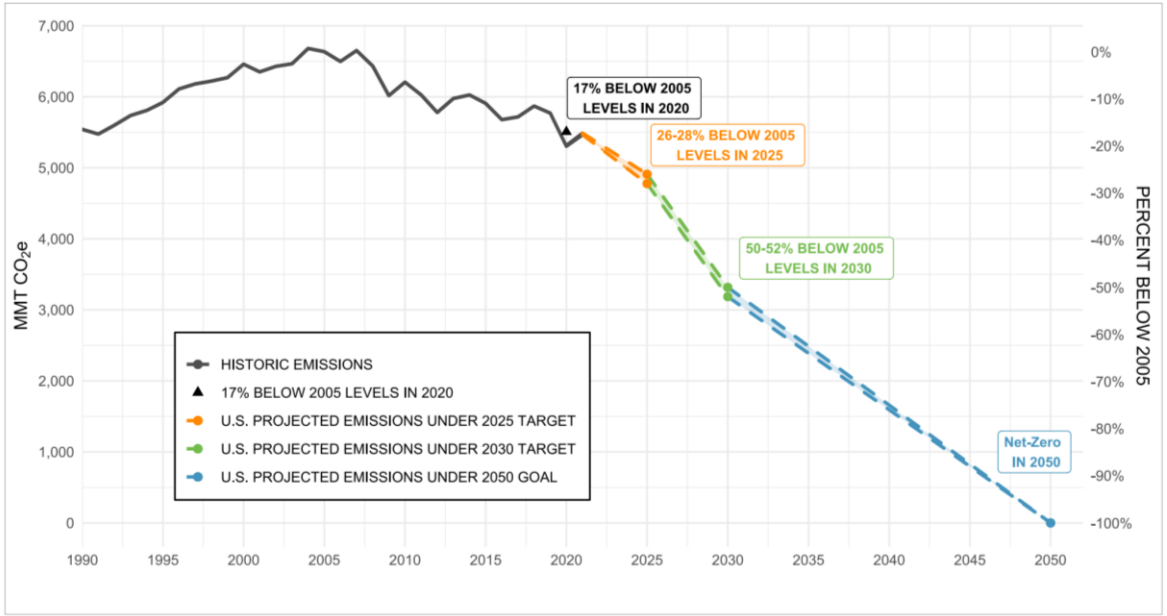


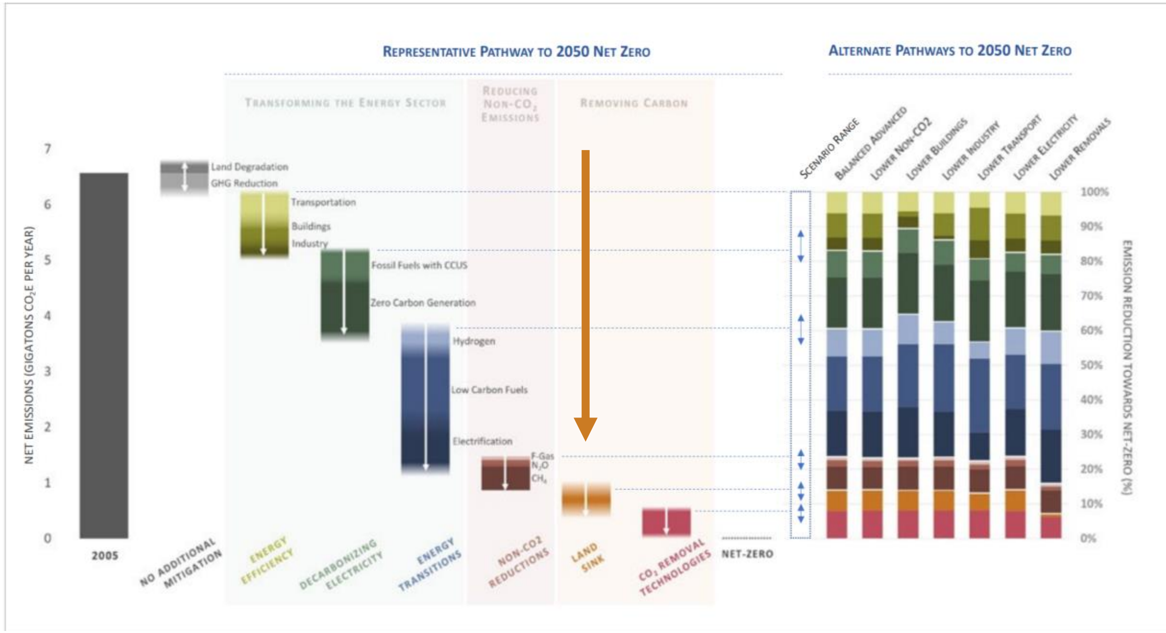
Purpose & Goals

Why are we doing it?

- **Land sector is recognized as playing a key role in national and subnational strategies aimed at reducing GHG emissions and increasing net CO_2 removals.**
    - Achieving our U.S. Long Term Strategy 2050 goals requires important contributions from land-based activities and other CO_2 removal activities.
    - 2021 Global Methane Pledge by the U.S. and the EU aims at reducing global methane emissions by 30% below 2020 levels by 2030 from different sectors including lands.

- **This report provides an updated and robust foundation to consider the technical feasibility and costs of meeting land-based mitigation targets**
    - Models include opportunity cost of land/resource tradeoffs, which is relatively unique: without this ability, studies may overestimate potential mitigation, which has implications for anticipated role of lands in meeting GHG targets.





Process

When?

- Process started in 2016
- Peer-review conducted by Eastern Research Group in 2023, included 4 forestry and/or agriculture experts
  - Ruben Lubowski, Alison Eagle, Gert-Jan Nabuurs, Hongli Feng
- Report release: early/mid March 2024

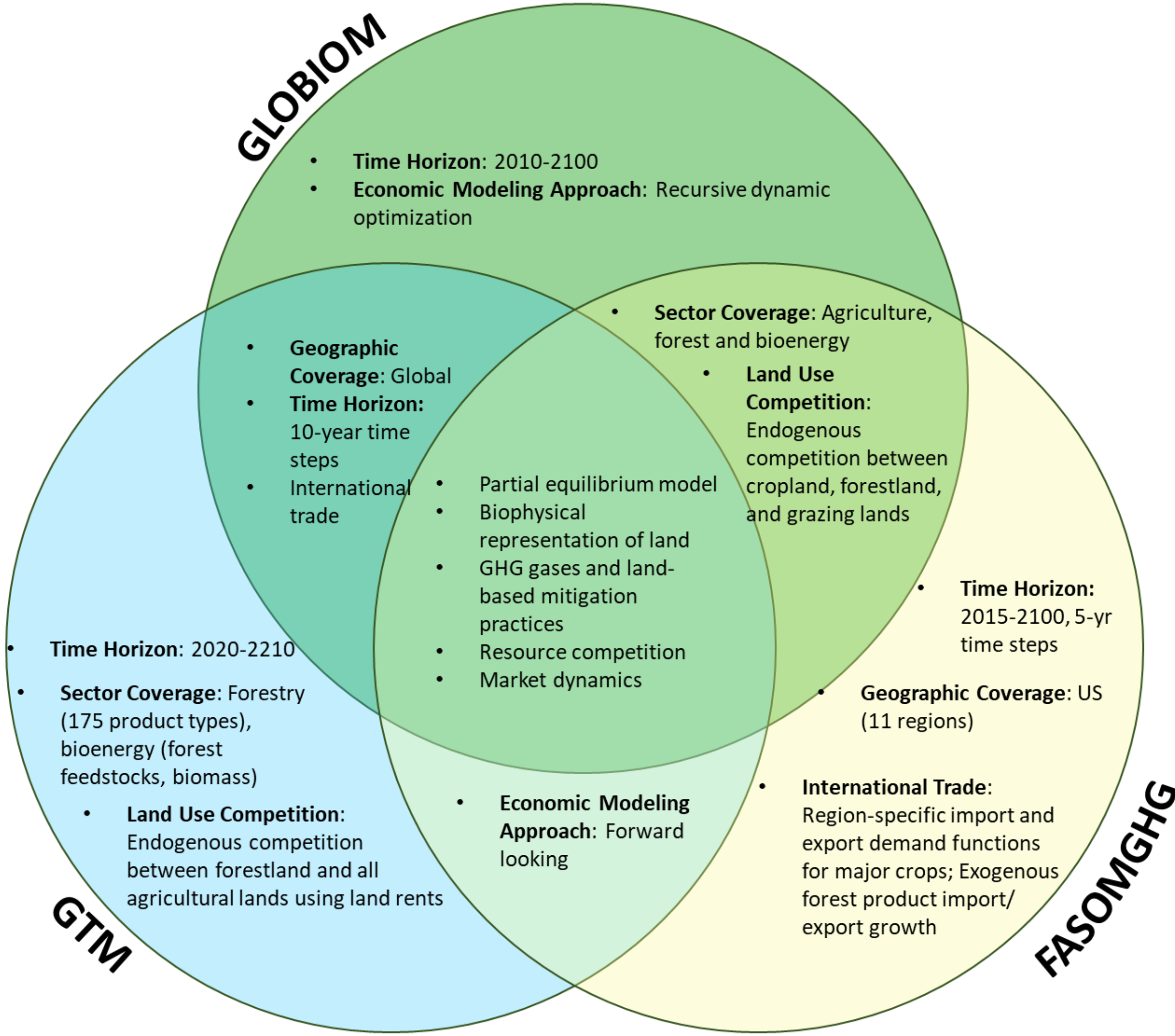
Who contributed to the report?

- EPA: Sara Ohrel, Jared Creason, Shaun Ragnauth, Allen Fawcett
- Academic/research partners:
  - Research Triangle Institute: Alice Favero, Chris Wade, Yongxia Cai
  - Justin Baker, NCSU; Brent Sohngen, OSU; Greg Latta, UI; Stephen Frank and Petr Havlik, IIASA
  - Other contributors: Kemen Austin, Bruce McCarl, Jason Jones

THANK YOU

Models

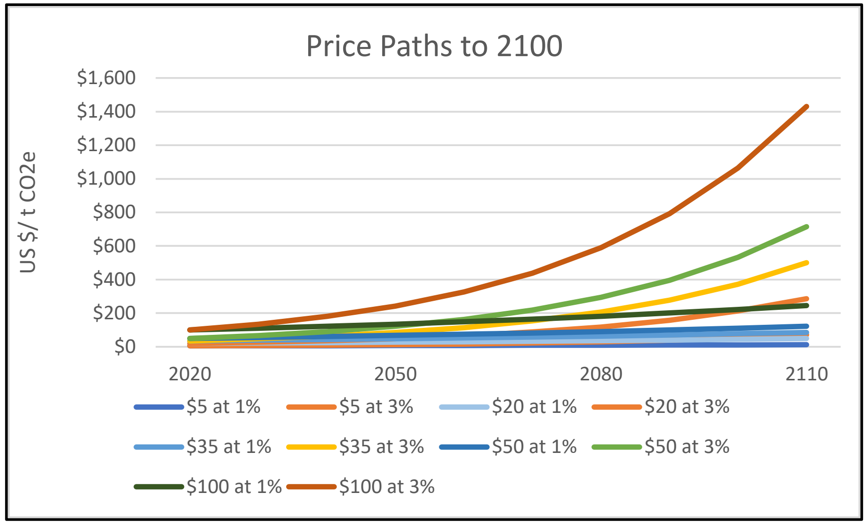
- **Three detailed economic-biophysical models** that simulate future potential GHG fluxes, land cover change, and commodity production in the forestry and agriculture sectors using detailed biophysical and economic land input data.
  - Forestry and Agriculture Sector Optimization Model with Greenhouse Gases (FASOMGHG)
  - Global Biosphere Management Model (GLOBIOM)
  - Global Timber Model (GTM)
- **Multi-model approach** allows for more transparent representation of uncertainties and robust understanding of directionality and magnitude of mitigation potential and costs than a single-model approach.



Primary models' attributes (similarities and differences)

Methods: Scenarios

Inputs like historic data on GHG emissions fluxes, land management practices, and other biophysical and market characteristics plus projected future socio-economic conditions produce baseline and GHG reduction projections.



GHG price paths included in each model, 2020-2100, $/tCO2e

11 Future Scenarios, focused on 2025-2050

- 1 Baseline Scenario
  - No recent policies (e.g., IRA) or additional climate change effects
- 10 GHG price scenarios
  - 5 starting CO2e prices ($5, $20, $35, $50, $100) in 2020
  - 2 annual growth rates (1% and 3%) so prices rise over time
- Mitigation is measured as the DELTA from the baseline
- Harmonization of basic socioeconomic drivers
  - Macroeconomic: AEO 2022, Shared Socioeconomic Pathway 2
  - Otherwise, generally preserve models' key unique characteristics

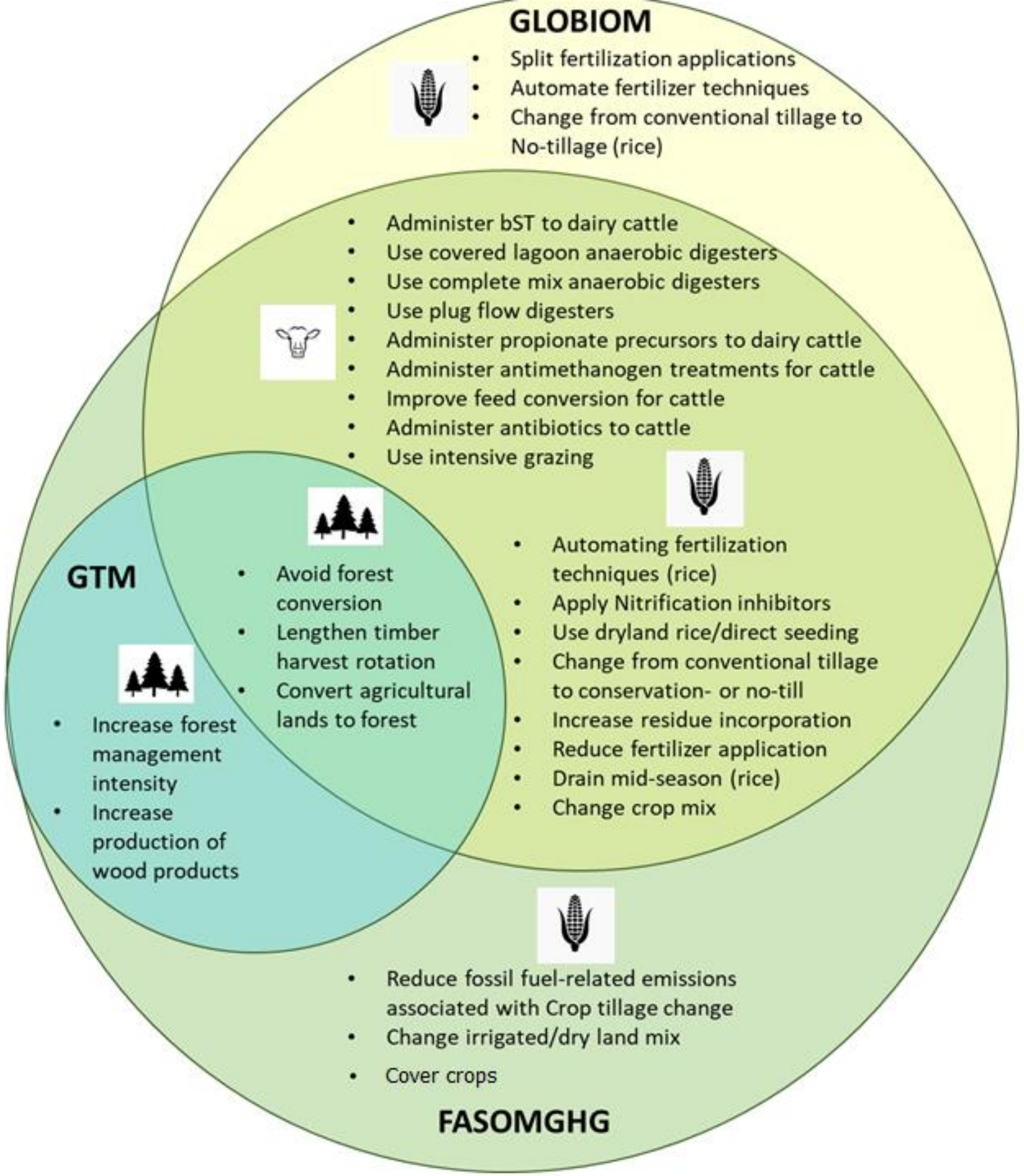
Each model selects the optimal use of land and management levels that maximizes the land sector net welfare.

- E.g., in a mitigation scenario, emitting GHGs = direct cost on land-based activities which drives landowners to less GHG-intensive practices (e.g. less fertilizer use) or different land uses (e.g. from cropland to forests).
- In the optimization process, **landowners behave as 'rational agents', with full information and no transaction costs.**

Mitigation Options

8 GHGs categories and 24 mitigation activities

- Includes established practices with robust historic national or otherwise comprehensive datasets including those on costs, GHG emissions and abatement potential estimates.
- Does not include:
  - Emerging technologies in pilot/small scale levels.
  - Biofuels/BECCS: not GHG mitigation measures directly applied in land sector to address land sector emissions, but in energy or transportation sectors to affect GHG emissions levels in those sectors
- Each model selects optimal mix of mitigation activities in response to GHG price.



Mitigation technologies and management strategies available in each model

Results

BASELINE & MITIGATION SCENARIOS

Key Findings

This technical report reenforces the fact that agriculture and forestry both play key roles in achieving U.S. GHG mitigation goals.

Baseline

- **U.S. AFOLU sector remains a net sink,** though the sink declines over time (90-120 $MtCO_2e$/yr in 2050).
    - Agriculture emissions projected to slightly increase
    - Net forest sequestration either remains stable or decreases

Mitigation Scenarios (10 scenarios = 30 runs)

- Mitigation potential similar across AFOLU projections
    - Across models, **32-364 $MtCO_2e$/yr reductions in 2050** at prices ranging from $7 to $243/$tCO_2e$.
    - In 2050 at $100/$tCO_2e$, ~256-348 $MtCO_2e$/yr.
- Results indicate that forestry activities offer the most mitigation.
- While agriculture remains a net emitter, **considerable reductions are available from croplands and livestock**.
- Low cost opportunities: E.g., With 10 year $20B cumulative investment = 780 $MtCO_2e$ potential total abatement, which equals a projected average cost per ton of abatement of $25/ton.

Baseline Emissions

1. U.S. land use sector projected to **remain a net carbon sink past** mid-century in the baselines
   - Net sequestration is around 90-120 $MtCO_2e$/yr in 2050 (FASOMGHG and GLOBIOM)
2. Emissions from agriculture stabilize/increase
   - Rising populations and GDP lead to increased demand for agricultural commodities, despite projected crop yield increases.
3. Net sequestration from forests stabilizes/decreases
   - As forests age and harvesting activities grow
   - In 2050, net flux = 405 $MtCO_2$yr in FASOMGHG, 431 in GLOBIOM, and 641 in GTM
   - Estimated net flux 688 MtCO2 in 2020 (EPA GHGI 2023)

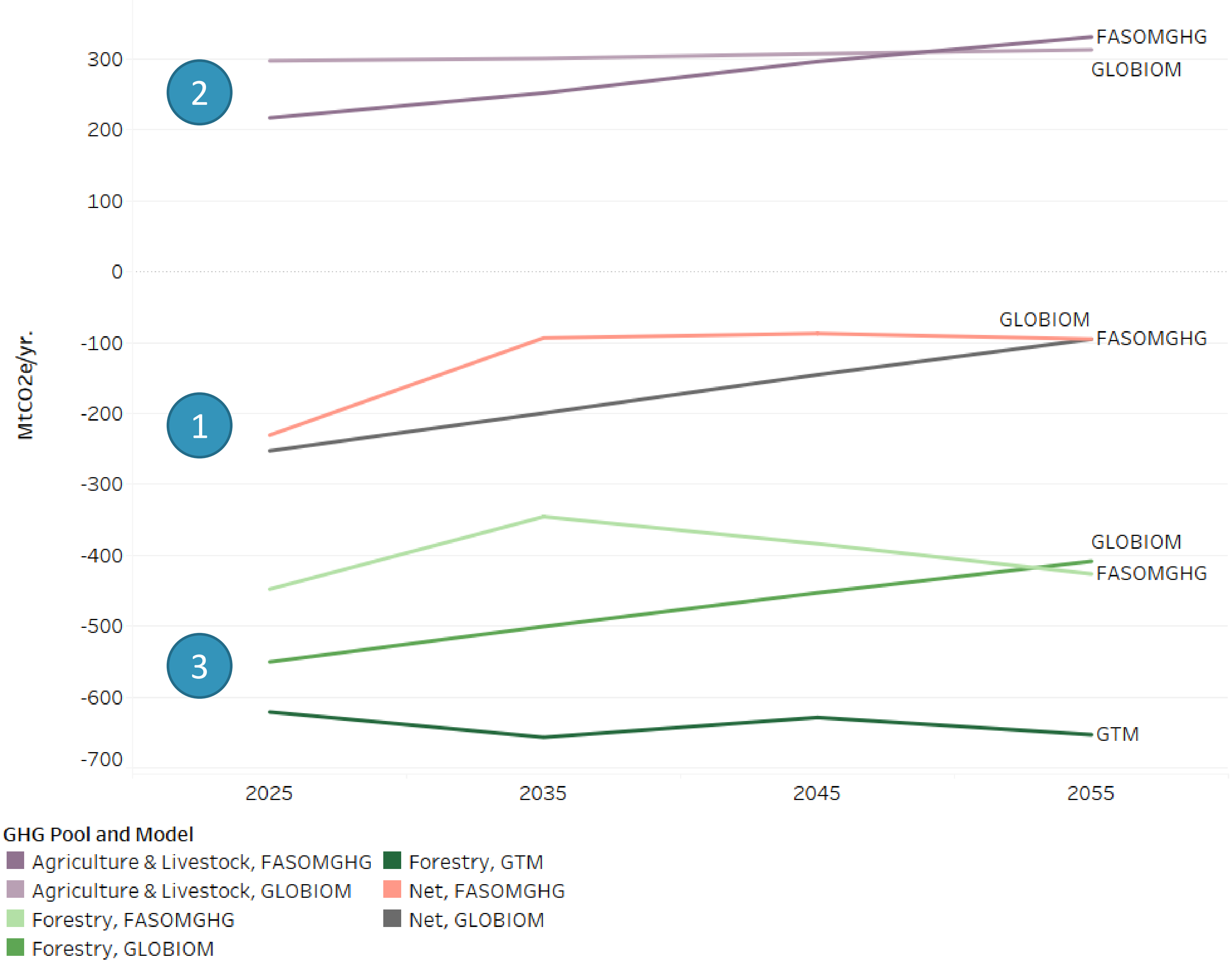
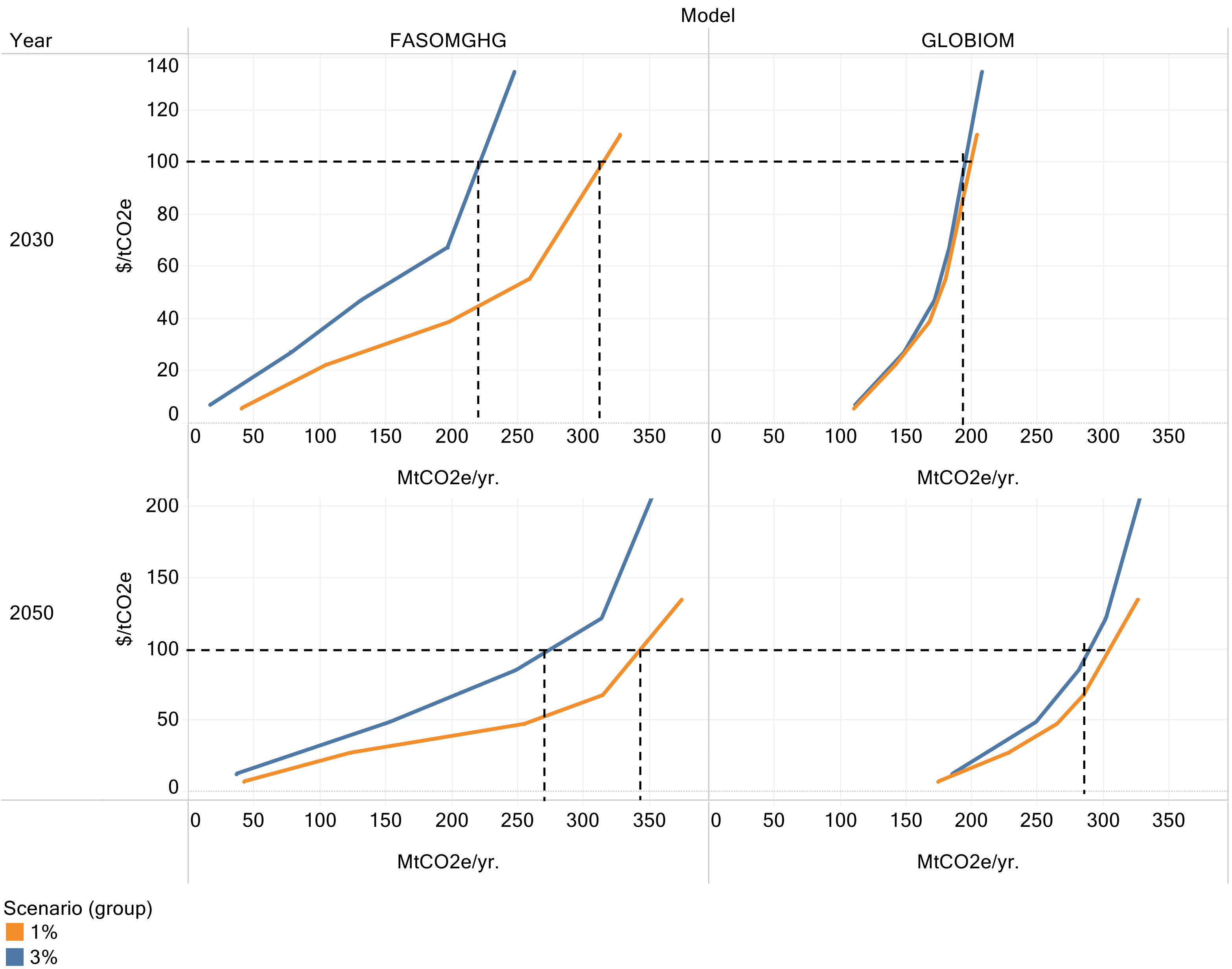


Figure: GHGs Emissions by GHG under Baseline Scenario, 2025-2050

Annual U.S. GHGs Emissions in MtCO2e by land sector under Baseline Scenario by Model, 2025-2050. Results are presented in terms of atmospheric accounting. Therefore, positive flux equates emissions; negative flux represents sequestration. Initial values in each model differs due to varying GHG pools included in each model, such as FASOMGHG including emissions from on-farm fuel consumption, which GLOBIOM does not. Additionally, GTM and GLOBIOM include representation of Alaska, while FASOMGHG does not. Forest CO2 values represented here are net estimates.

MACCs: AFOLU 2030 and 2050

- At a GHG price of 100 $/tCO$_2$eq, AFOLU can abate (across models and scenarios)
    - 195-310 MtCO$_2$eq in 2030
    - 256-348 MtCO$_2$eq in 2050
- GLOBIOM shows high potential for abatement at low prices.
    - E.g., at low price like $10, seeing >100 MtCO$_2$eq in GLOBIOM in 2050.
    - Steeper MACC so as prices increase, see less abatement potential (relative to FASOMGHG)



AFOLU Marginal Abatement Cost Curves in 2030 and 2050

Marginal Abatement Cost Curves (MACCs) for AFOLU in 2030 and 2050 by models (FASOMGHG and GLOBIOM) and growth rate scenarios (1% and 3%). MACCs are built using the abatement under each GHG price scenario starting at $5/tCO$_2$e. A total of 5 observations per year are used to build each MACC. MACCs show the level of abatement in MtCO2e (x-axis) associated with a specific monetary value of GHG emissions in $/tCO$_2$e (y-axis) for a specific reference year (2030 and 2050). GTM is not included in the figure because it does not explicitly model agriculture.

MACCs: by Sector, 2050

- Forestry is projected to have the largest potential across models and scenarios
  - 2050: ~124-454 MtCO2e (F) and 284-430 MtCO_2e (GL)
  - Forest sector capacity to reach of at least 1 GtCO2e net sequestration in 2050 in half GTM scenarios
  - Why so much potential in forestry?

    - GHG incentives for reduction activities leads to LU management decisions that maximize net GHG and related $ benefits for the land sector.
  - As trees sequester and store more carbon over time, forestry activities = highest level of cost-effective mitigation potential due to sequestration potential/$.
- While agriculture remains a net emitter, considerable cost-effective mitigation reductions in croplands and livestock
  - Up to 16% reductions from croplands, 18% from livestock activities by 2050, without significant changes in production.
  - Available at GHG $ as low as 8$/tCO2e in 2030, emphasizing the key role in achieving interim GHG reduction targets.
- Livestock has slightly greater mitigation potential than cropland in FASOMGHG and GLOBIOM
  - More low-cost opportunities

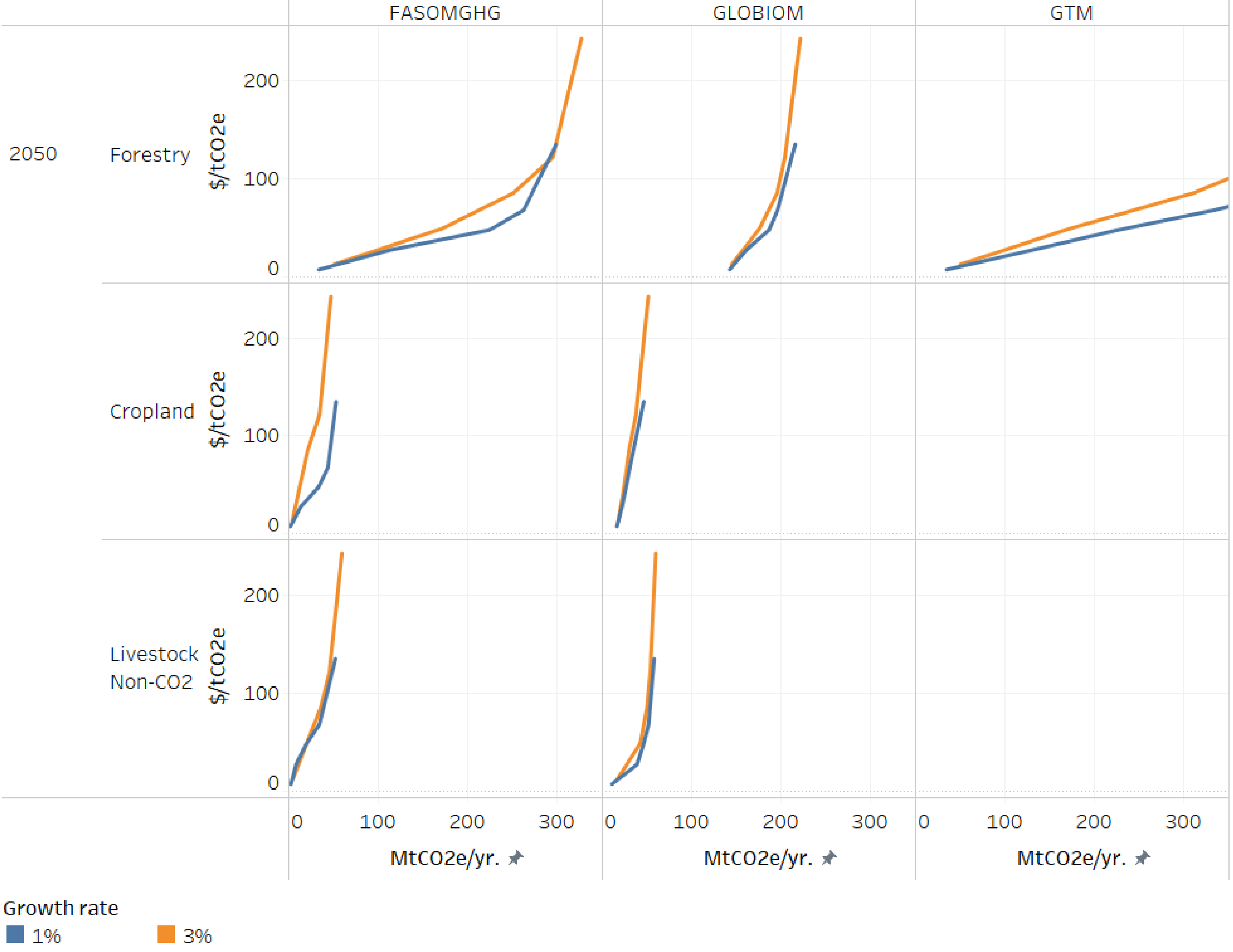
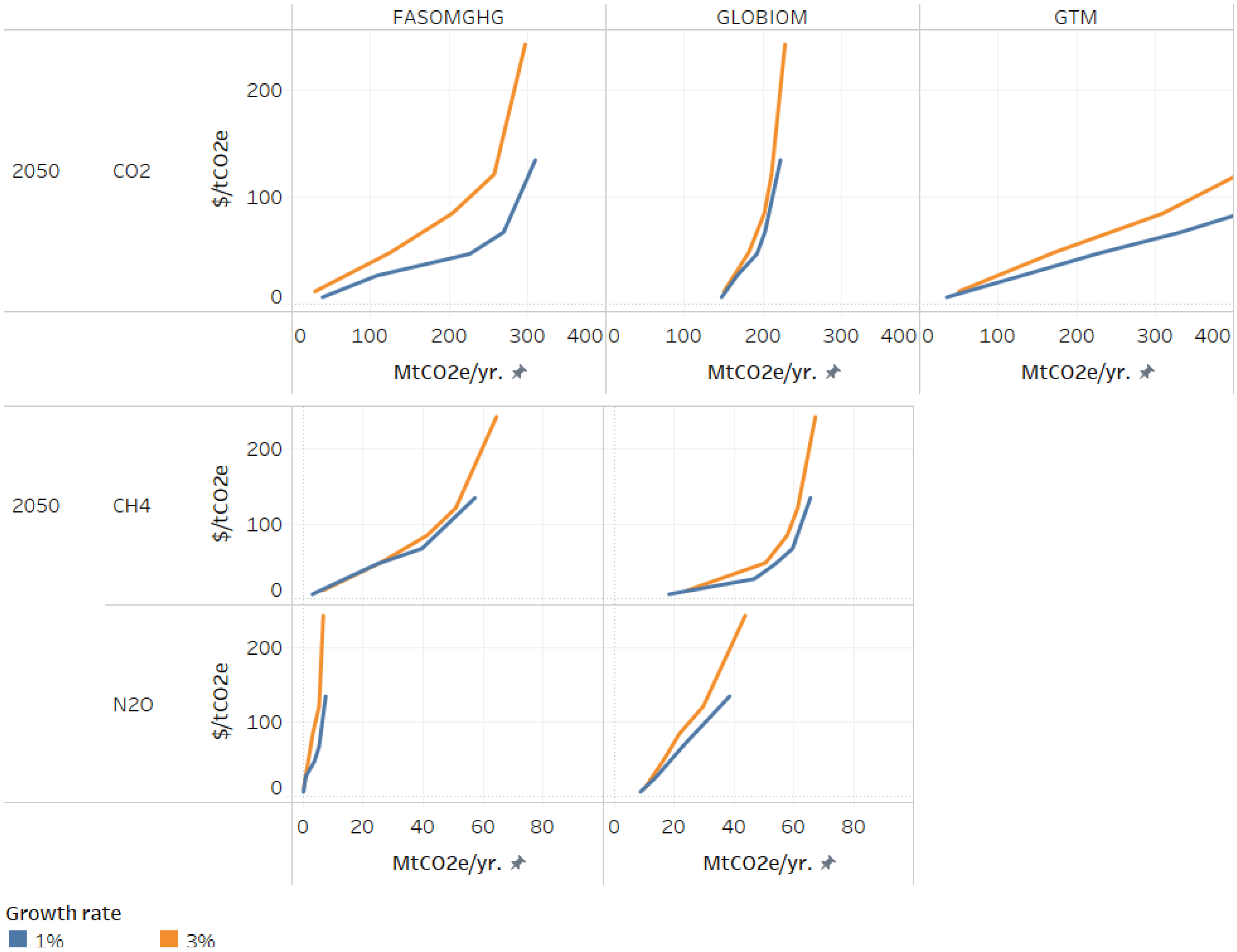


Figure: Marginal Abatement Cost Curves by Sector in 2030 and 2050

Sector-based Marginal Abatement Cost Curves (MACCs) in 2030 and 2050 by models and growth rate scenarios (1% and 3%). MACCs are built using the abatement under each GHG price scenario starting at $5/tCO2e. A total of 5 observations per year are used to build each MACC. MACCs show the level of abatement in MtCO2e (x-axis) associated with a specific monetary value of GHG emissions in $/tCO2e (y-axis) for a specific reference year (2030 and 2050). GTM models only the forestry sector and does not explicitly model agriculture Note: x-axis is limited to allow for comparison of cropland and livestock MACCs. GTM projects a maximum of 720 MtCO2/yr from forestry

MACCs: by GHG, 2050

- CO_2:
  - Potential *increases significantly* over time due to forest growth dynamics
  - GLOBIOM offers less largely due to recursive dynamic approach
- CH_4 and N_2O
  - While *mitigation potential may be smaller* for non-CO_2 gases than CO_2, the MACCs show that there are *cost-effective opportunities* available for both CH_4 and N_2O and they play an important role in achieving mitigation reductions.



GHG-based Marginal Abatement Cost Curves in 2030 and 2050

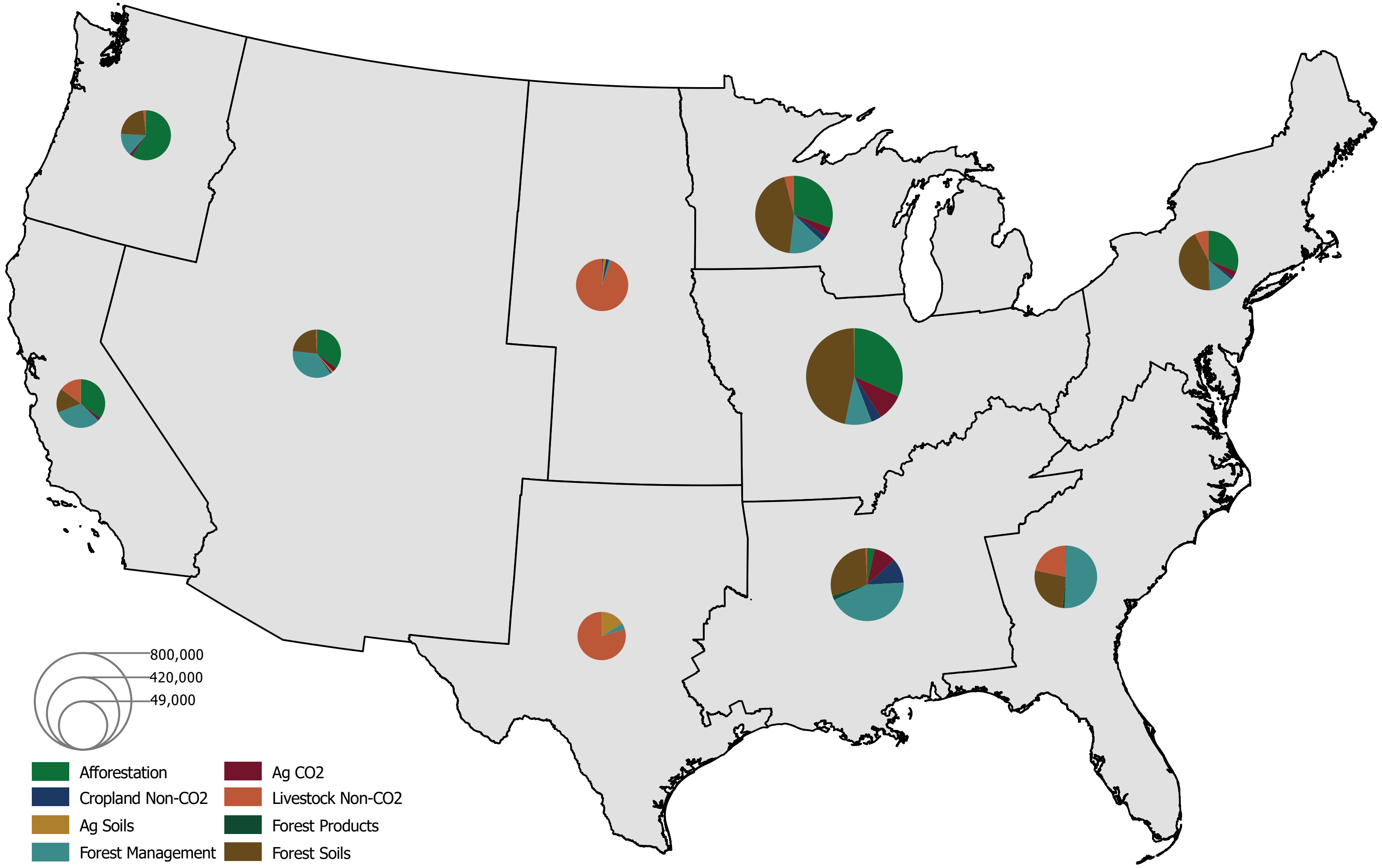
Greenhouse gas-based MACCs in 2030 and 2050 by models and growth rate scenarios (1% and 3%). MACCs are built using the abatement under each GHG price scenario starting at $5/tCO2e. A total of 5 observations per year are used to build each MACC. MACCs show the level of abatement in MtCO2e (x-axis) associated with a specific monetary value of GHG emissions in $/tCO2e (y-axis) for a specific reference year (2030 and 2050). GTM models only CO2 emissions from forests not explicitly model agriculture

Note: x-axis is limited to allow for comparison of N2O and CH4 MACCs. GTM projects a maximum of 720 MtCO2/yr from forestry

Regional Results FASOMGHG

Cumulative mitigation by region by activity and GHG type

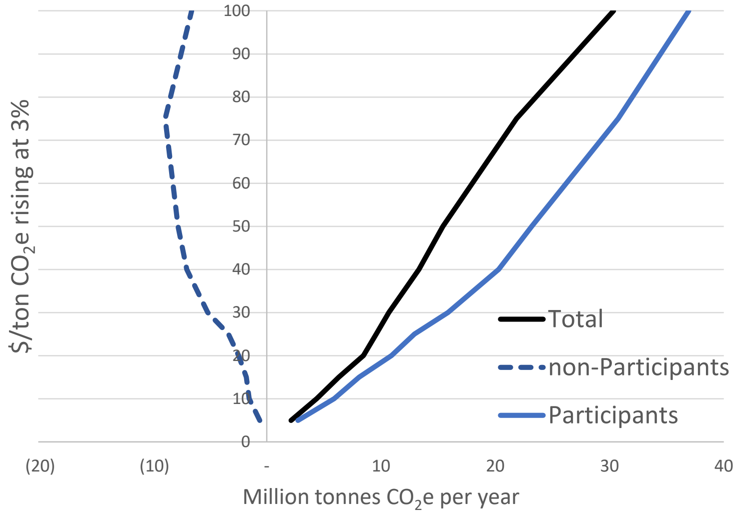
- example: under $50 at 3% scenario, 2025-2050

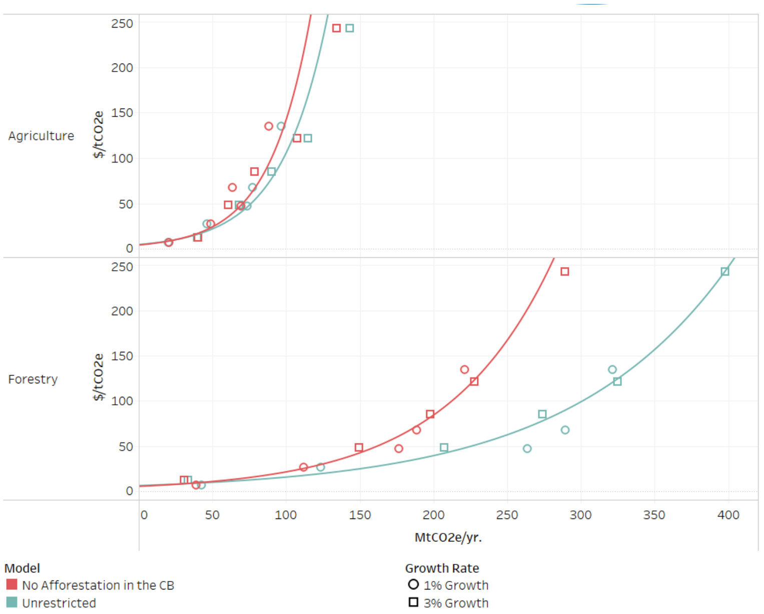


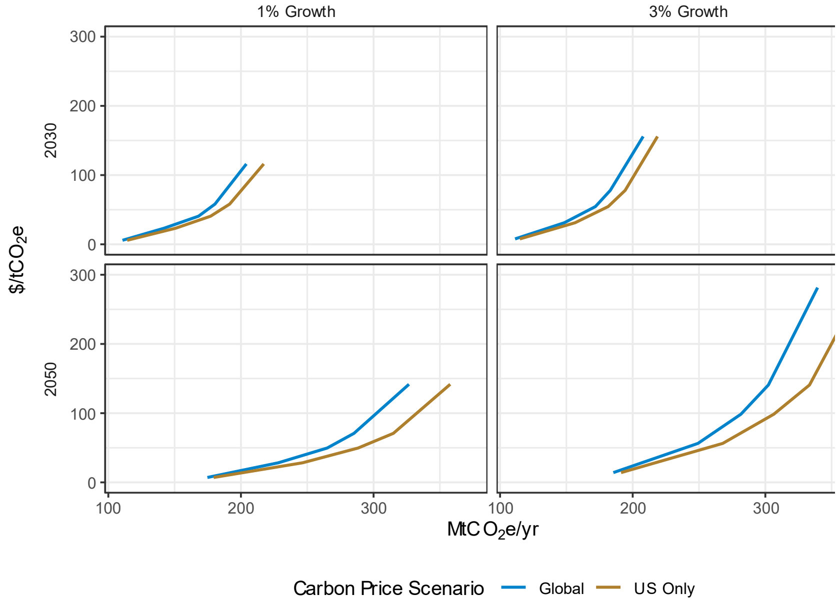
Distribution of Cumulative Mitigation by Region and GHG type under the $50 at 3% scenario, 2025-2050.
Notes: Size of pie represents share of national mitigation

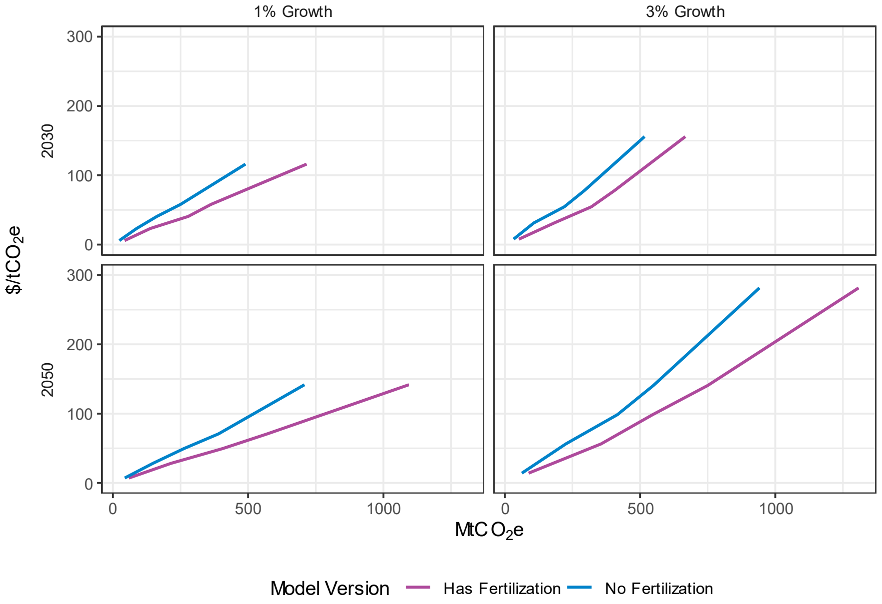
Case studies

- Key variables tested in case studies/sensitivities
  - Opt-in forest program design (FASOMGHG)
  - Limiting forestry expansion in key agricultural regions (FASOMGHG)
  - Global vs national carbon price incentives (GLOBIOM)
  - CO_2 fertilization (GTM)
  - Accounting price and land constraints (GTM)









Contributions to the field

- New estimates and analysis
  - Generalized results from broad range of tools and scenarios give sense of potential directionality and magnitude
  - Analysis includes resource competition not represented in recent high-profile studies
    - Accounts for economic tradeoffs between mitigation
  - Practitioners can get insights on e.g.,
    - Possible implications of applying different GHG reduction strategies or research designs to help achieve different goals.
    - Can serve as a foundation against which potential GHG reductions from recent/new strategies can be generally estimated.
    - Incorporation of voluntary market structure, ability to produce updated leakage results

- This technical report reenforces the fact that agriculture and forestry both play key roles in achieving U.S. GHG mitigation goals.
  - Findings a complement to/support for broader USG climate goals
- Addressing climate change is an all-sectors effort and this report specifically finds that lands-based activities have important low-cost mitigation opportunities available and can materially contribute to deep decarbonization goals.

Thank you

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