Representing forestry and forest management in land models

Session: Technical challenges for adding people to models and coupling

Jennifer Holm; Lawrence Berkeley National Laboratory

Wednesday, 9/14/2022

1st Land Surface Modeling Summit

E3SM Energy Exascale Earth System Model

NGEE–TROPICS NEXT-GENERATION ECOSYSTEM EXPERIMENTS

EARTH & ENVIRONMENTAL SCIENCES

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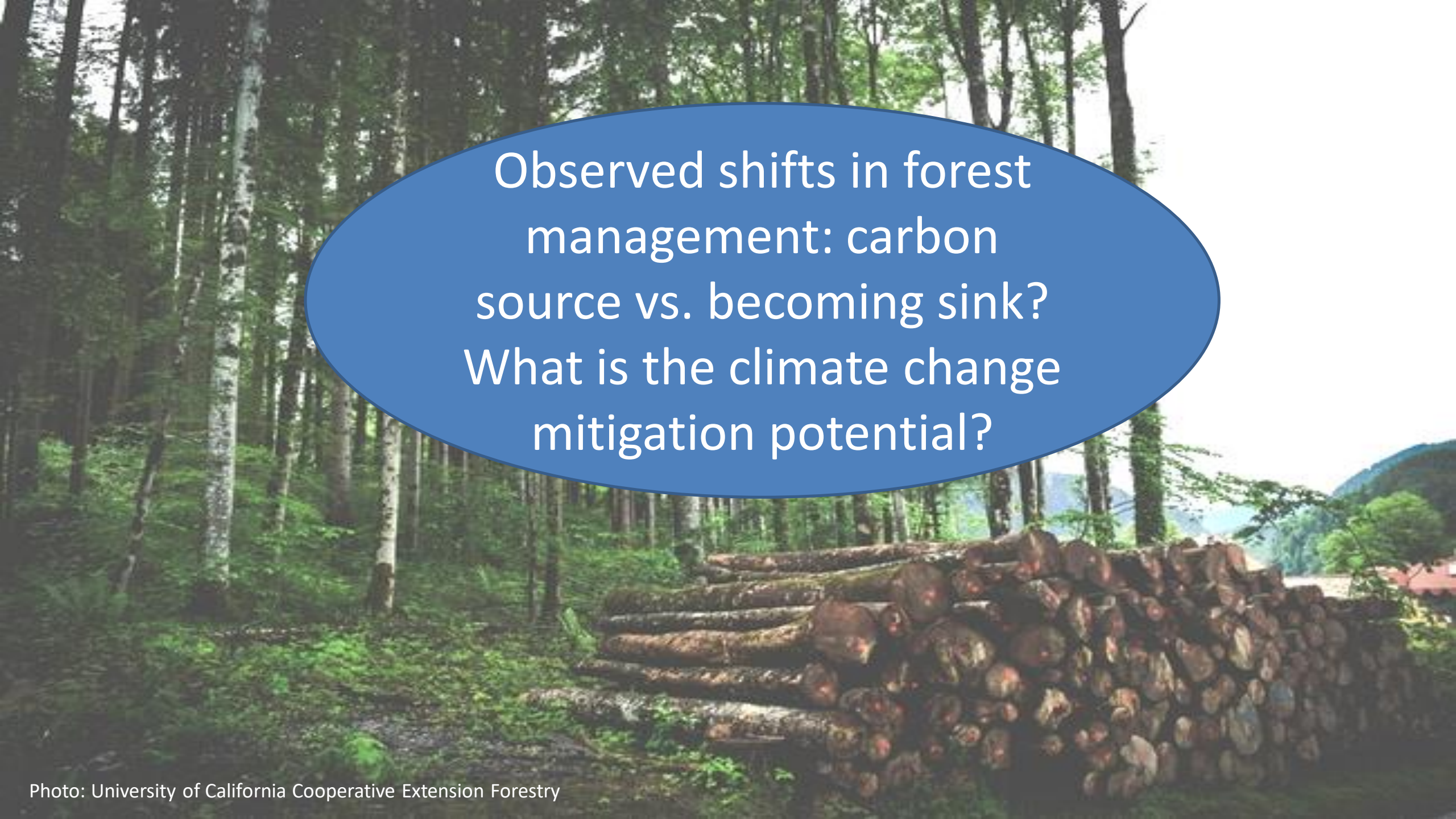
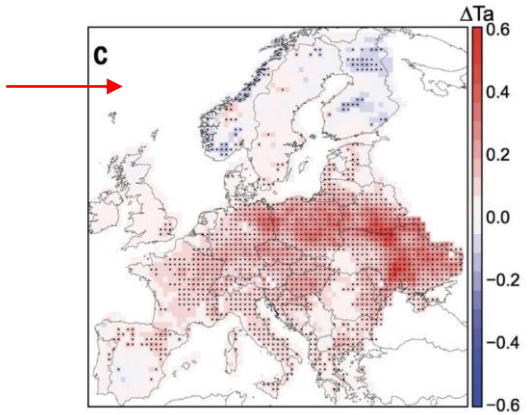


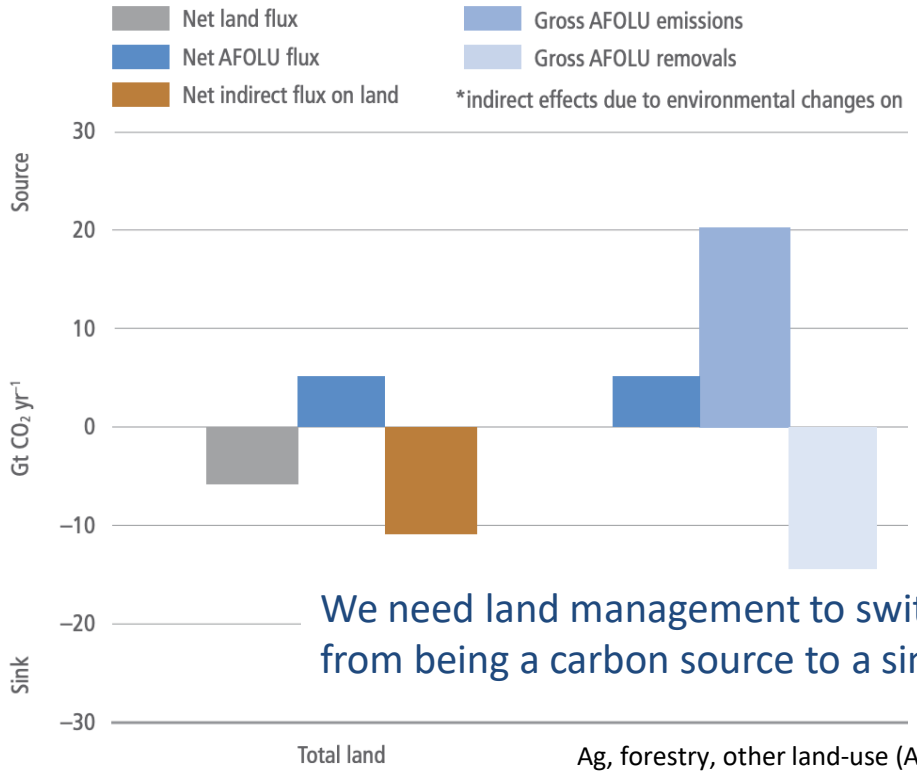
Photo: University of California Cooperative Extension Forestry

Observed Shifts in Forest Management – Carbon sink vs. source?!

- Forest management in Europe over 250 years has been a carbon source (3.1 PgC), and switch from broadleaf to conifers leading to albedo induced warming (Naudts et al. 2016).
- Land management has just as high impact as LUC on surface temperature (Luyssaert et al. 2014)
- Wild-west of carbon offsets, nature-based climate solutions, afforestation, Trillion Trees as a “silver bullet, cure-all fix”.

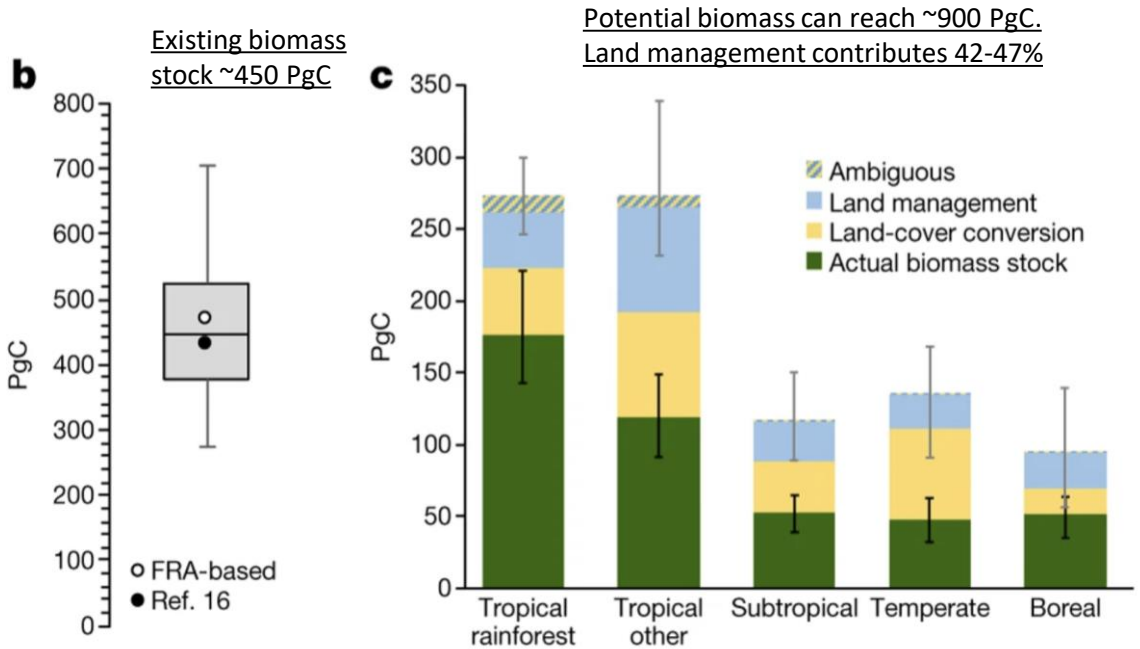


Total temp change due to species conversion since 1750



We need land management to switch from being a carbon source to a sink!

Shukla et al. 2019 IPCC Technical Summary



Erb et al. 2018

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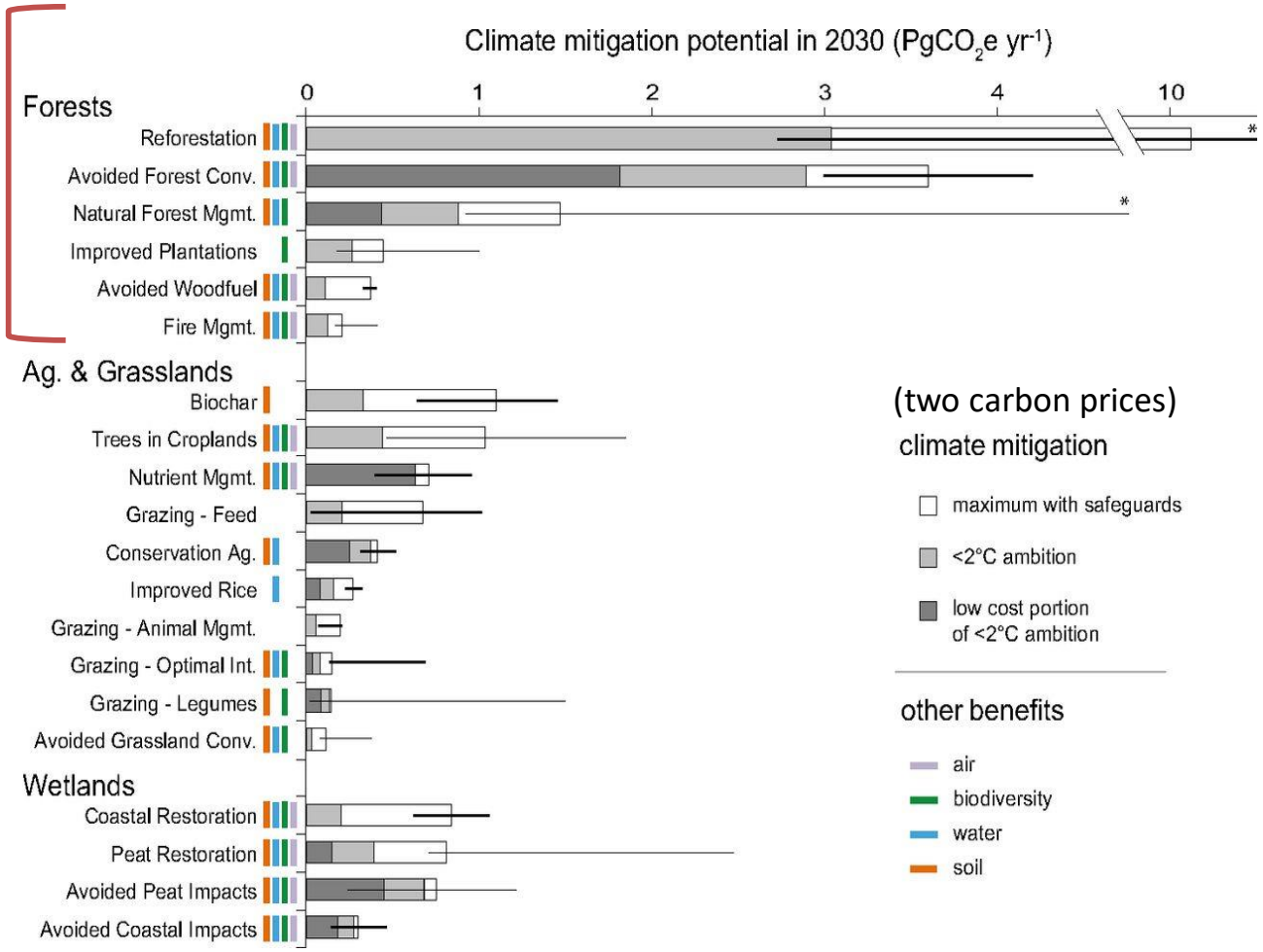
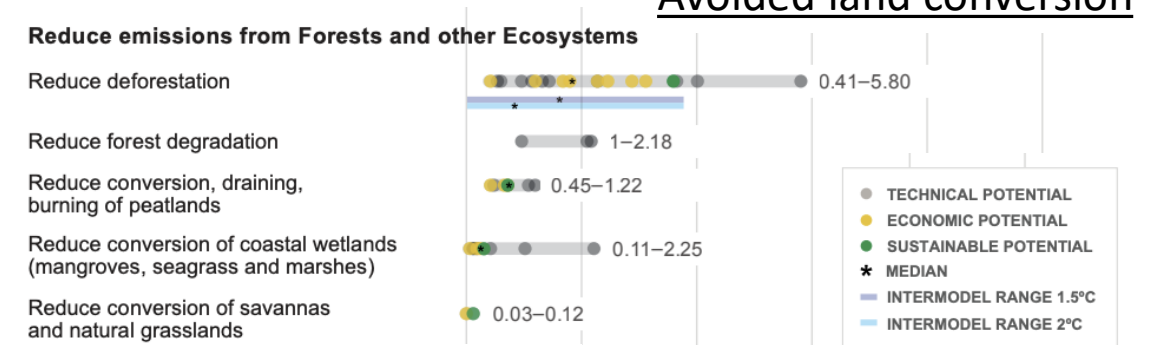
Estimates of Land-based mitigation ***potential***

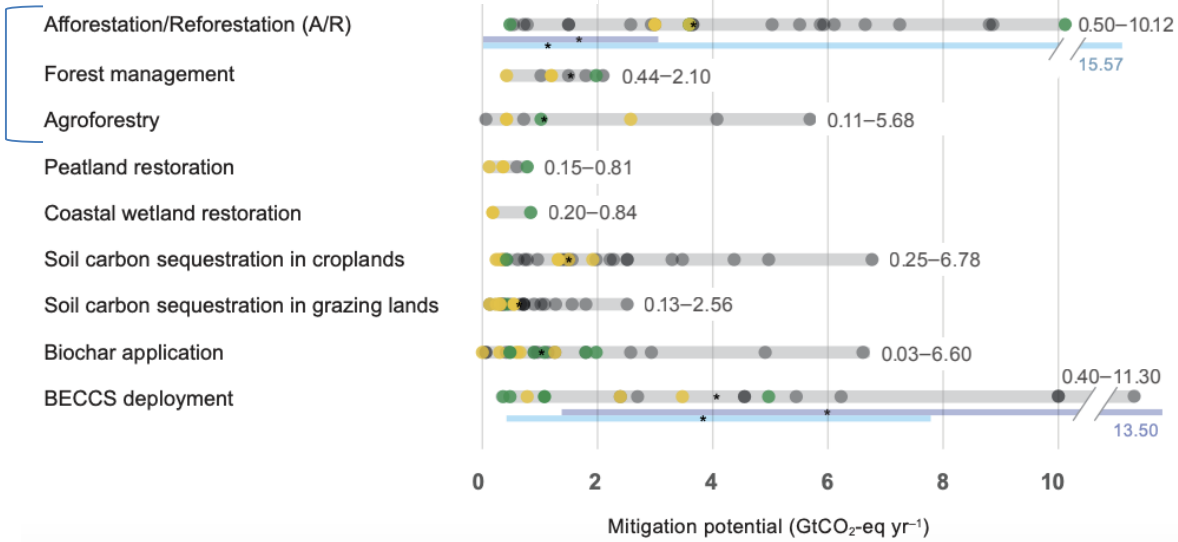


Griscom et al. 2017. PNAS - "Natural climate solutions can provide 37% of cost-effective CO_2 mitigation needed through 2030"

Avoided land conversion



Restoration/Sequestration



Shukla et al. 2019 IPCC

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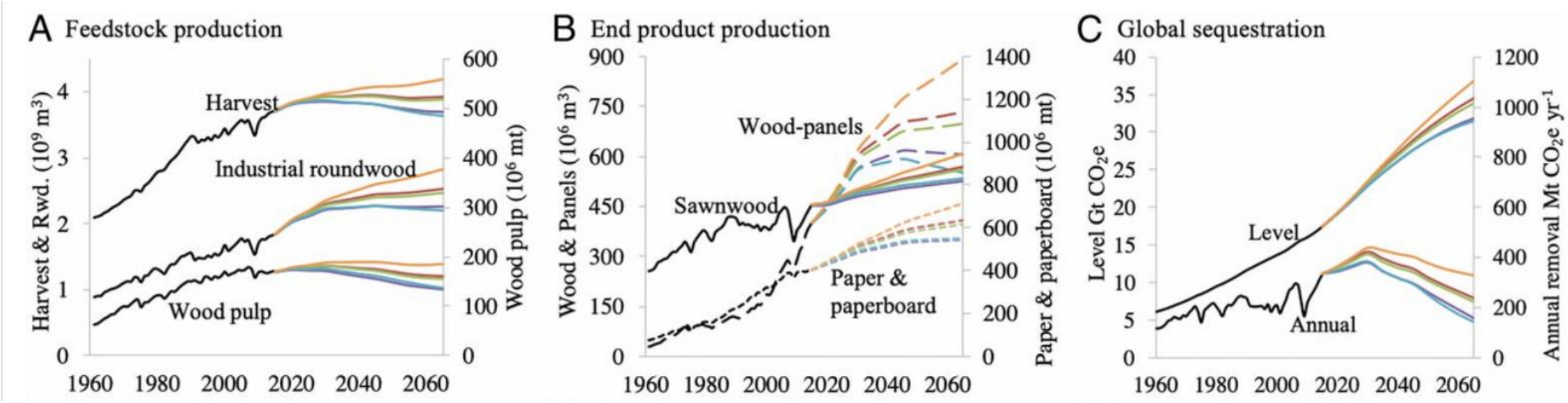
Observed Shifts in Forest Management – Harvested Wood Products

- Global harvests have risen from: 2.1 to 3.78 billion m^3 (1961 – 2015).
- Kyoto Protocol - adding HWPs as a mandatory pool to be reported within land use, land use change, and forestry (LULUCF) activities.
  - And now part of Nationally Determined Contributions under the Paris Agreement.
- Harvested wood products (HWPs) = pool was a net sink of 335 Mt of CO_2 equivalent (CO_2e)·y^{-1} in 2015
- BUT, what is the best method to account for carbon in HWPs (production vs. end use)?



Johnson and Radeloff, 2019, PNAS

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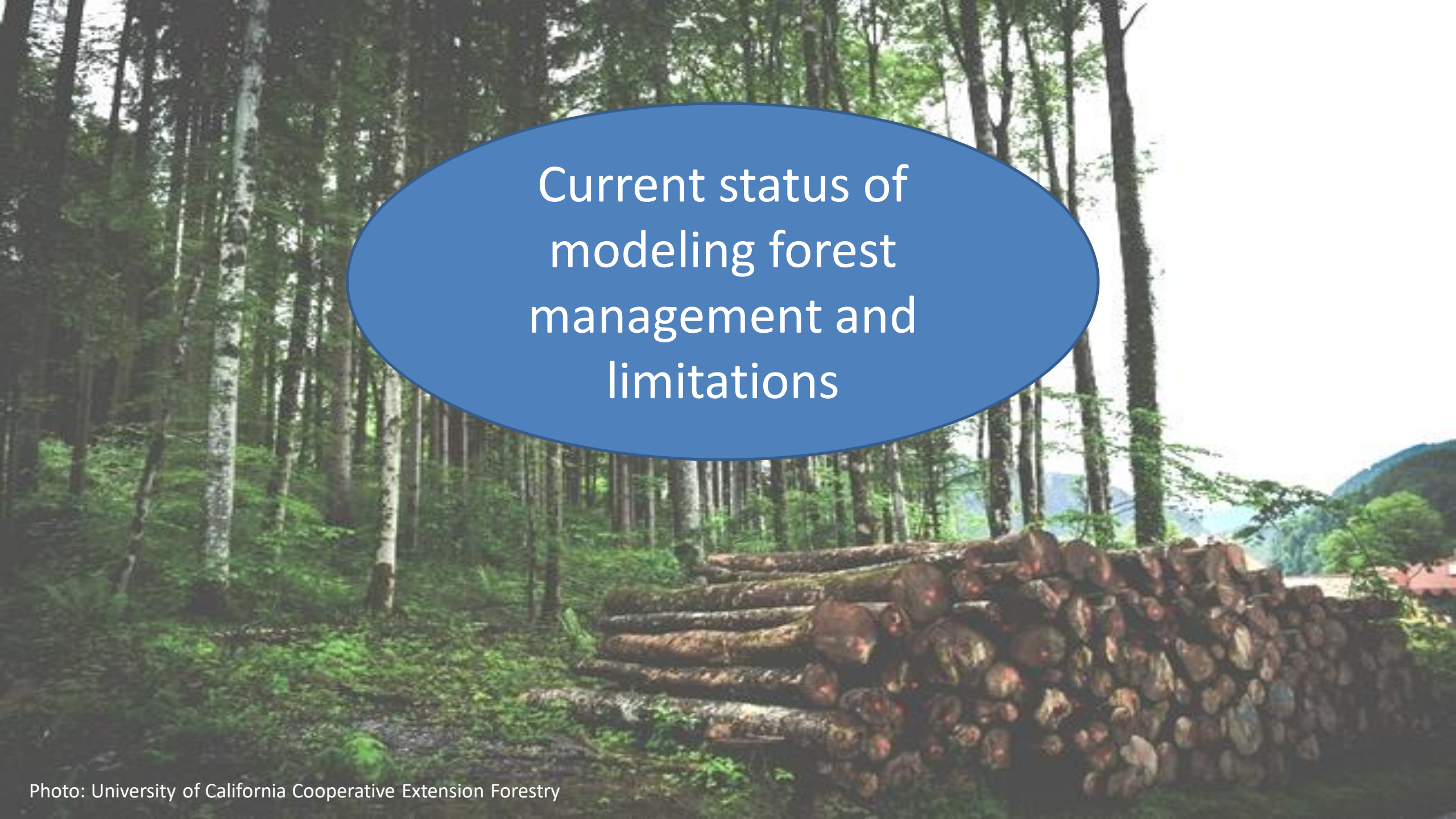

Photo: University of California Cooperative Extension Forestry

History of land/forest management in LSMs

RESEARCH REVIEW | Open Access

Models meet data: Challenges and opportunities in implementing land management in Earth system models

Julia Pongratz, Han Dolman, Axel Don, Karl-Heinz Erb, Richard Fuchs, Martin Herold, Chris Jones, Tobias Kuemmerle, Sebastiaan Luyssaert, Patrick Meyfroidt, Kim Naudts

First published: 13 December 2017 | https://doi.org/10.1111/gcb.13988 | Citations: 60

"Individual modeling studies confirm that land management practices such as irrigation, ……. or forestry practices can notably alter biogeophysical properties and biogeochemical cycles in large regions of the world."

Tree age and forest structure is needed for when to apply harvesting,

but also to capture both biogeophysical effects (surface temperature, albedo, cooling) and biogeochemical effects (GPP, biomass, litterfall C:N).

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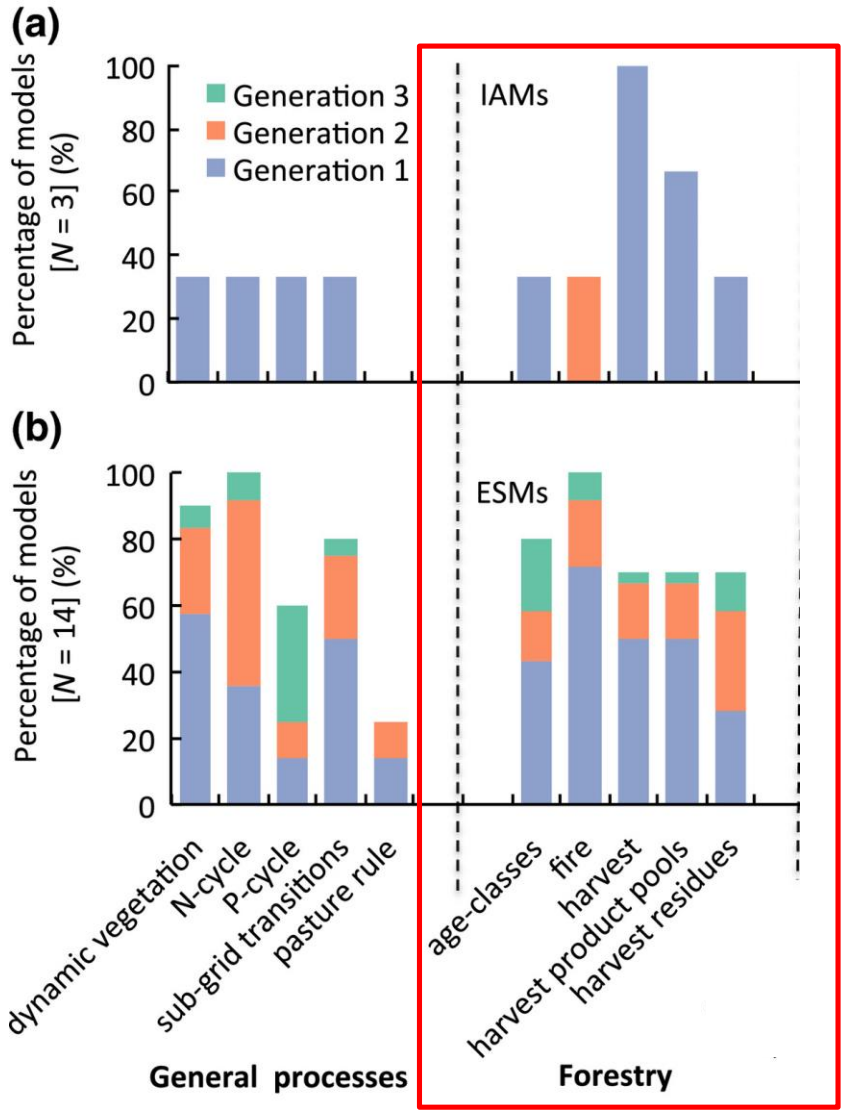
Status of forest management in land models



- 20% of ESMs do not include wood harvest and corresponding product pools.
- Disagreement on if fires occur on managed land or not.
- Lack of **explicit interaction of natural and anthropogenic land-cover modifications (e.g., pasture occurs on natural grasslands).**
- Need to have tree age or size class for wood harvest.

Pongratz et al. GCB, 2018

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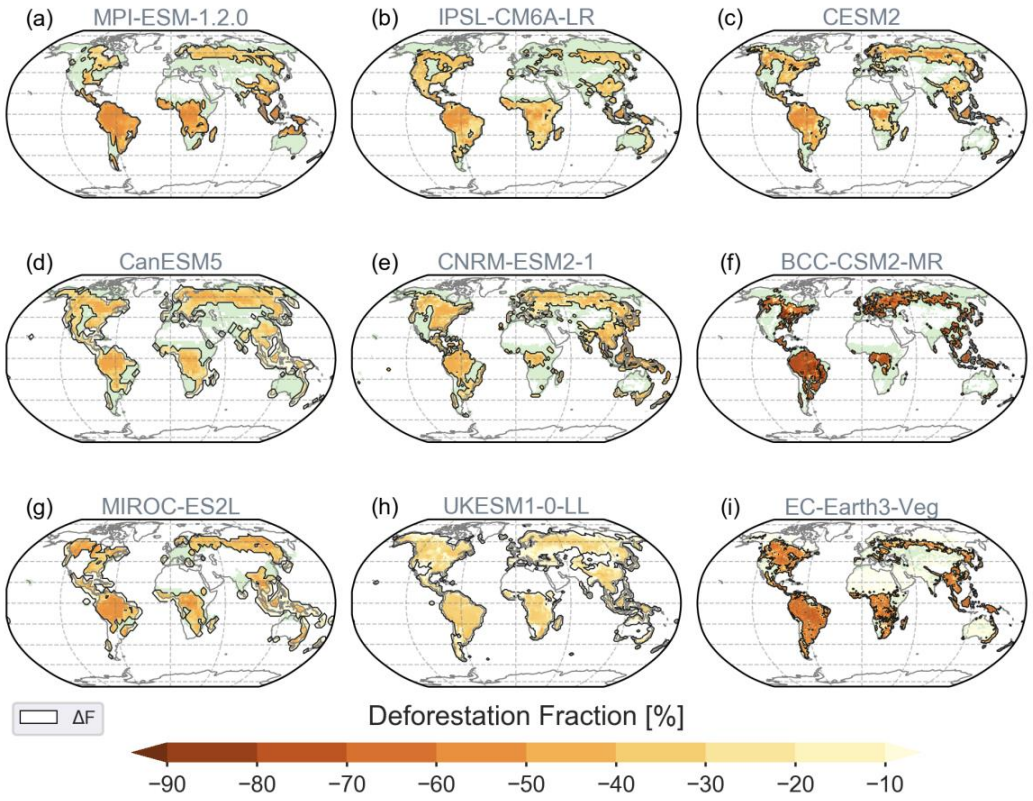
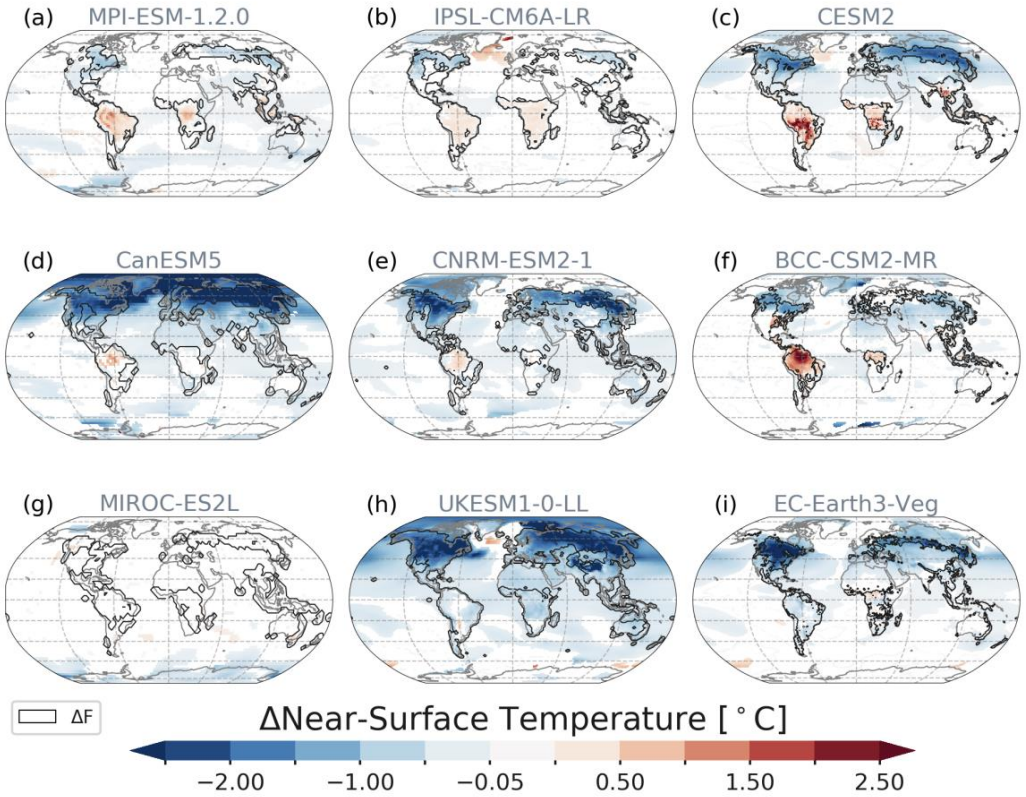
Large Range in biogeophysical and biogeochemical effects

"deforest-glob" experiment: 20 M/km2 of (idealized) deforestation **by fraction of initial forest**



Change in surface temperature varies across models



Not shown here, but also large differences in GPP predictions and many other outputs!

Biases in ET with deforestation = Cai et al. 2019, *JAMES,* Wang et al. 2021 ERL

Boysen et al., 2020. Biogeosciences

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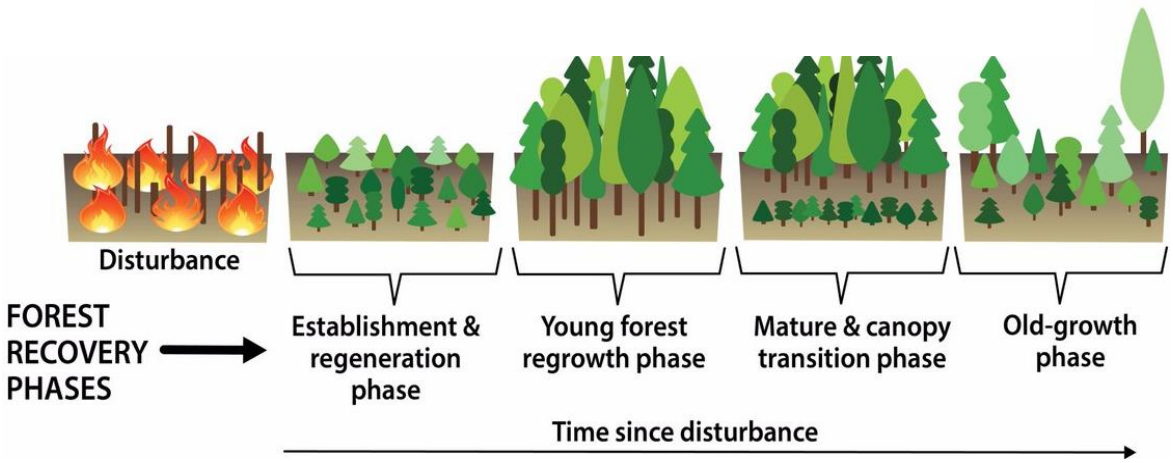
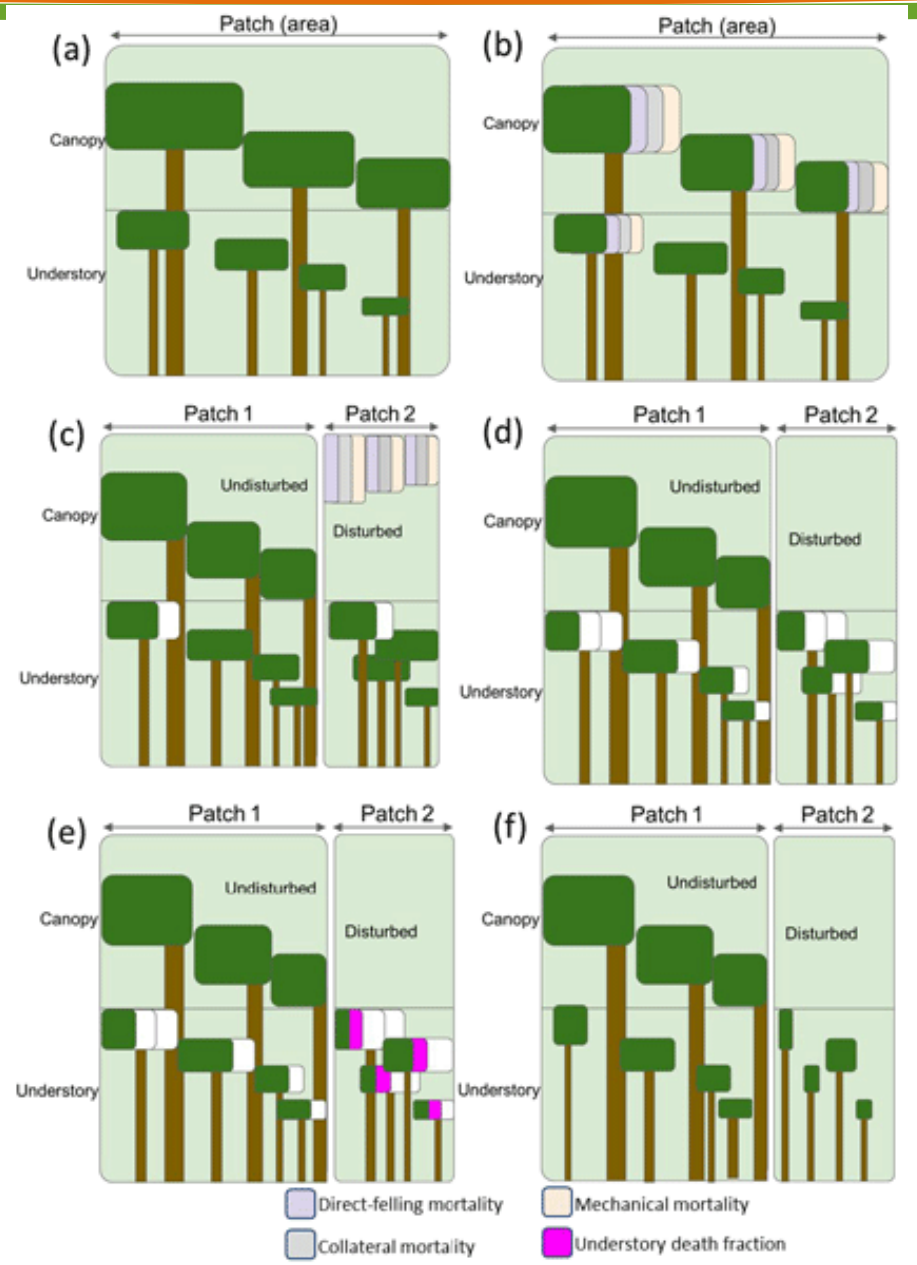
Current wood harvesting, selective logging in FATES

FATES = Functionally Assembled Terrestrial Ecosystem Simulator
Vegetation Demography Model (VDM) coupled to LSMs (CLM and ELM)
Time since disturbance patches, PFT cohorts
Dynamic competition, species co-existence and exclusion
Plant distribution emerges from trait filtering



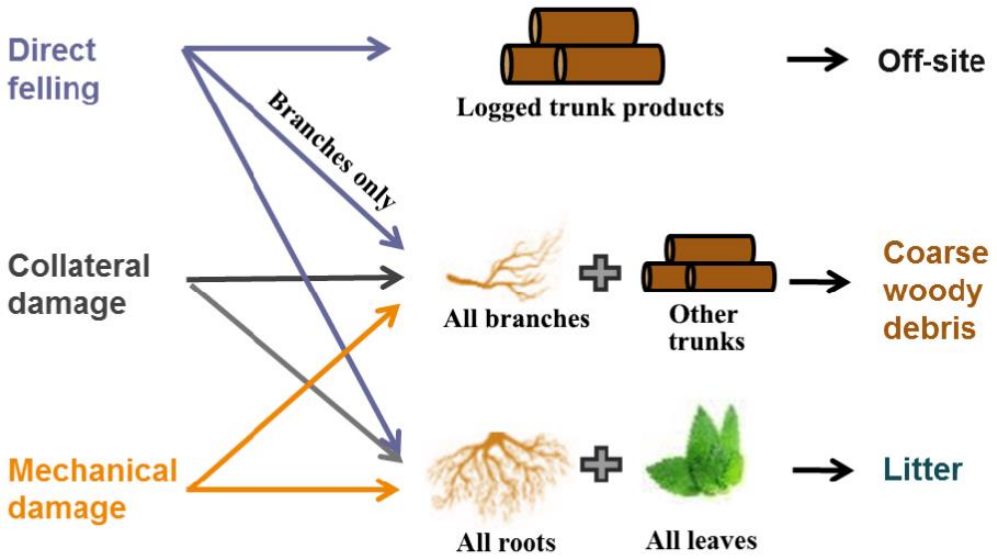


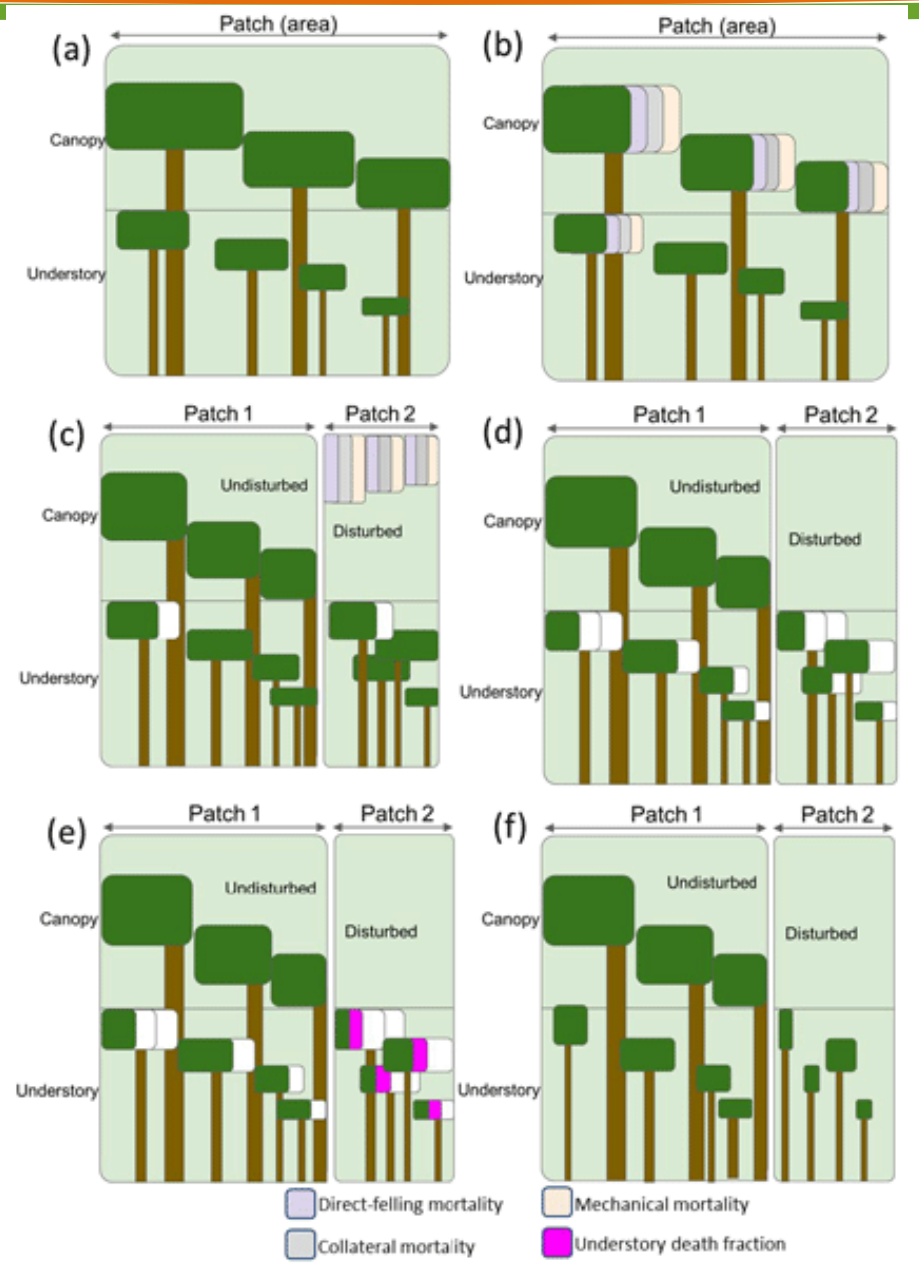
Huang et al., 2020 Biogeosciences

Current wood harvesting, selective logging in FATES

Selective Logging module allows for:

- Min. and max. DBH logging is applied
- Collateral damage
- Mechanical mortality
- Understory mortality fraction





Huang et al., 2020 Biogeosciences

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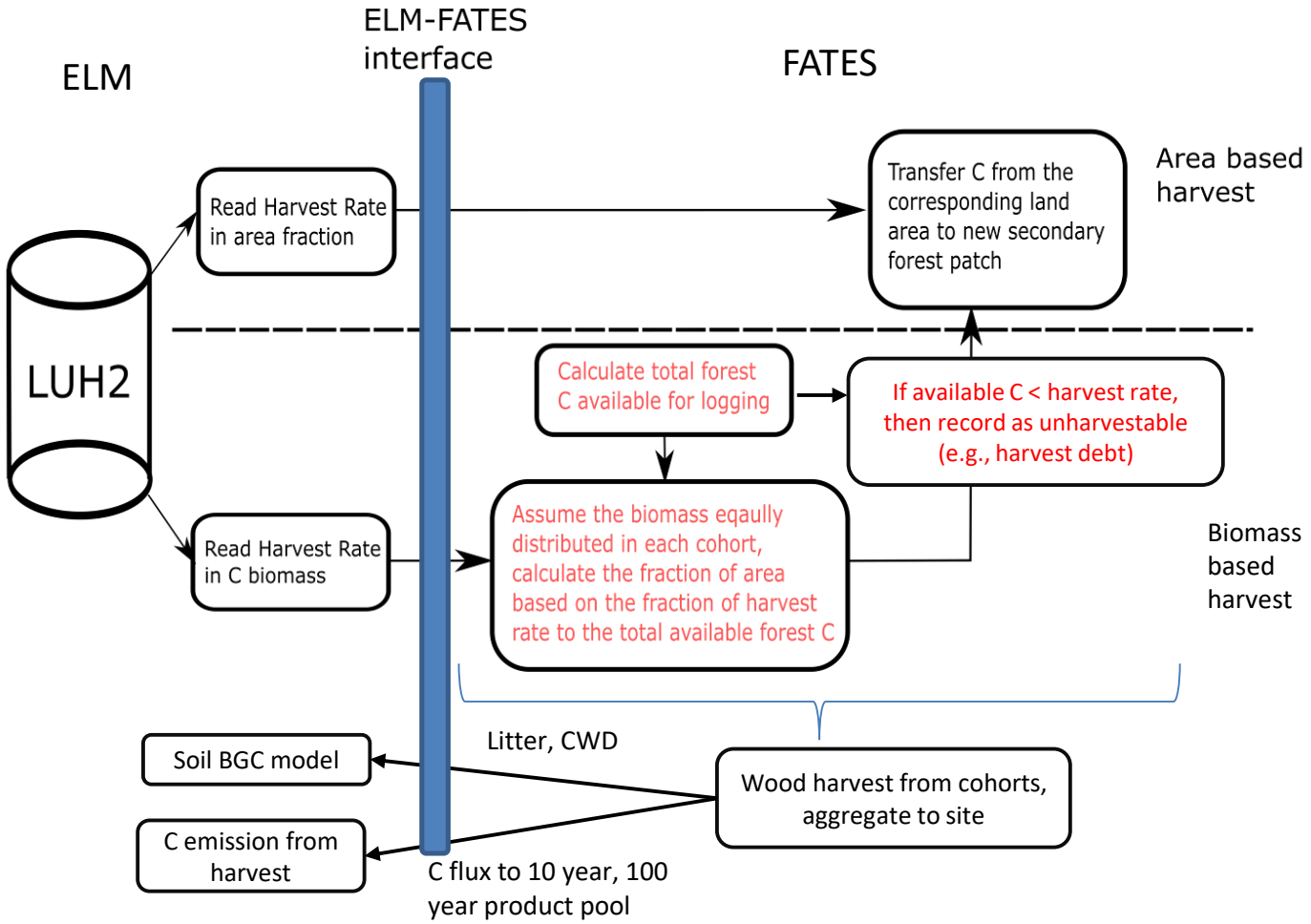
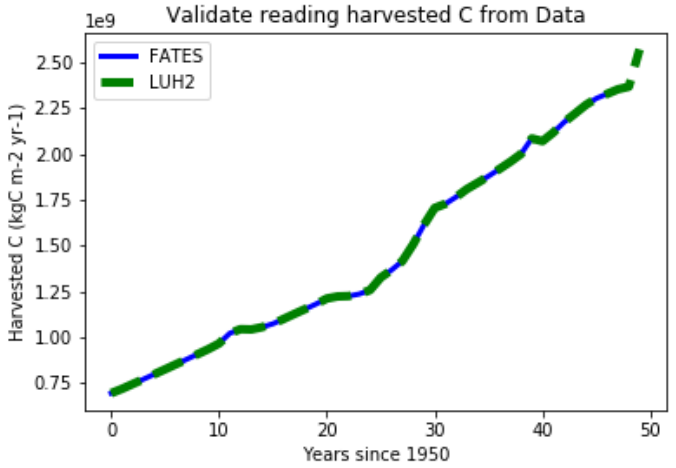
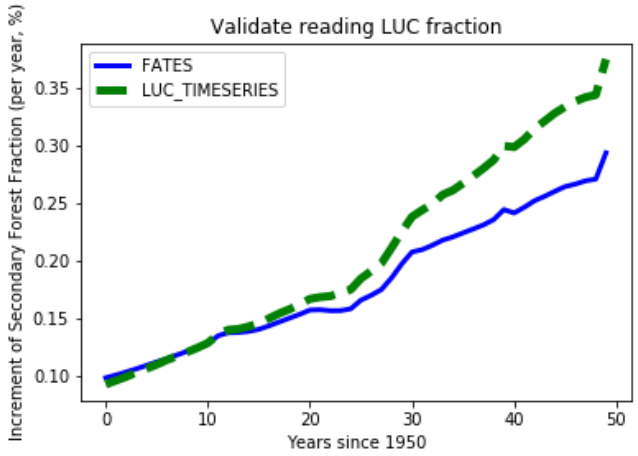
Current wood harvesting, LULCC in ELM-FATES (Shijie Shu)



Model validation check at Brazil site:



Consistency check between LUH2 harvested carbon and FATES harvested C



FATES secondary forest fraction is less than the harvested area fraction by LUH2, likely due to higher biomass in model compared to data by LUH2

Figures from: Shijie Shu (LBNL) and Alan Di Vittorio

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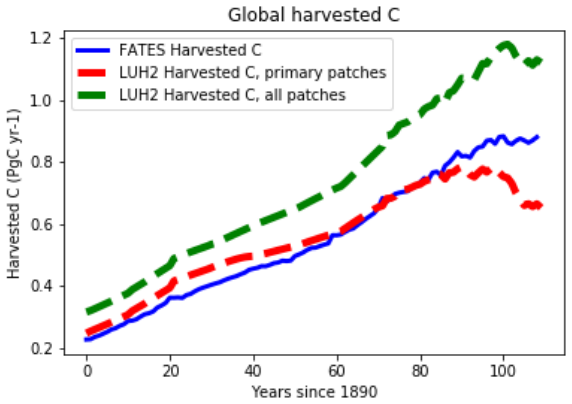
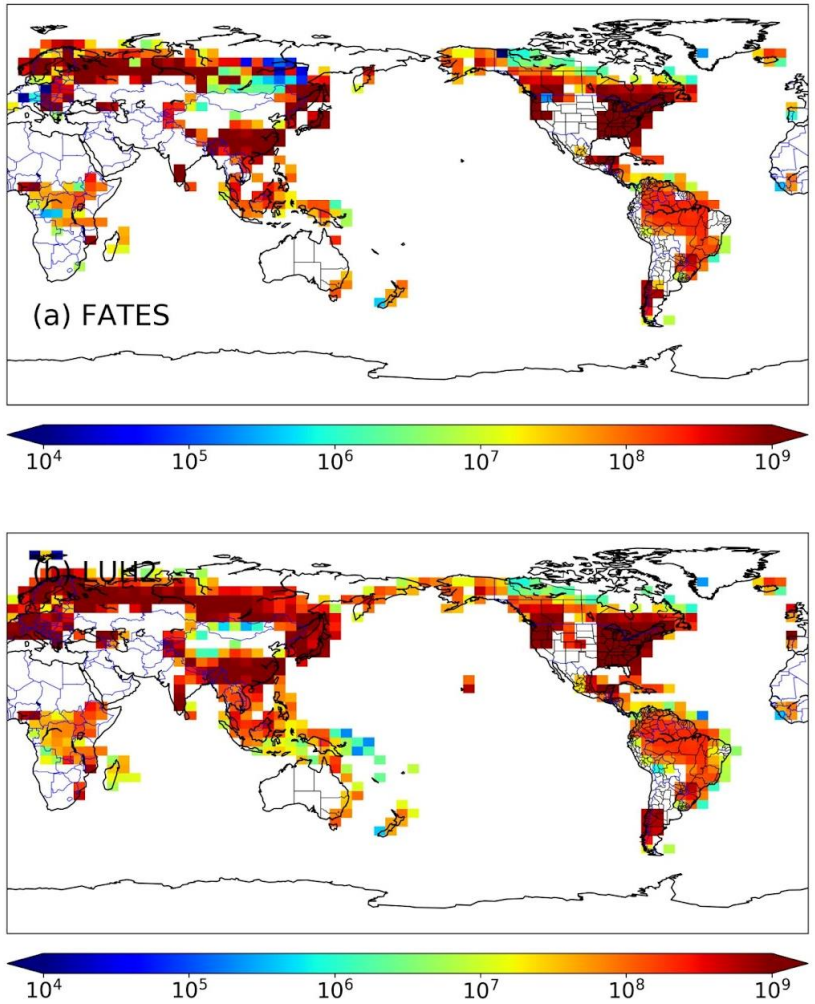
Current wood harvesting, LULCC in ELM-FATES



Primary forest harvested C (2009, in kgC)



Secondary forest area
(2009, fraction of grid area)

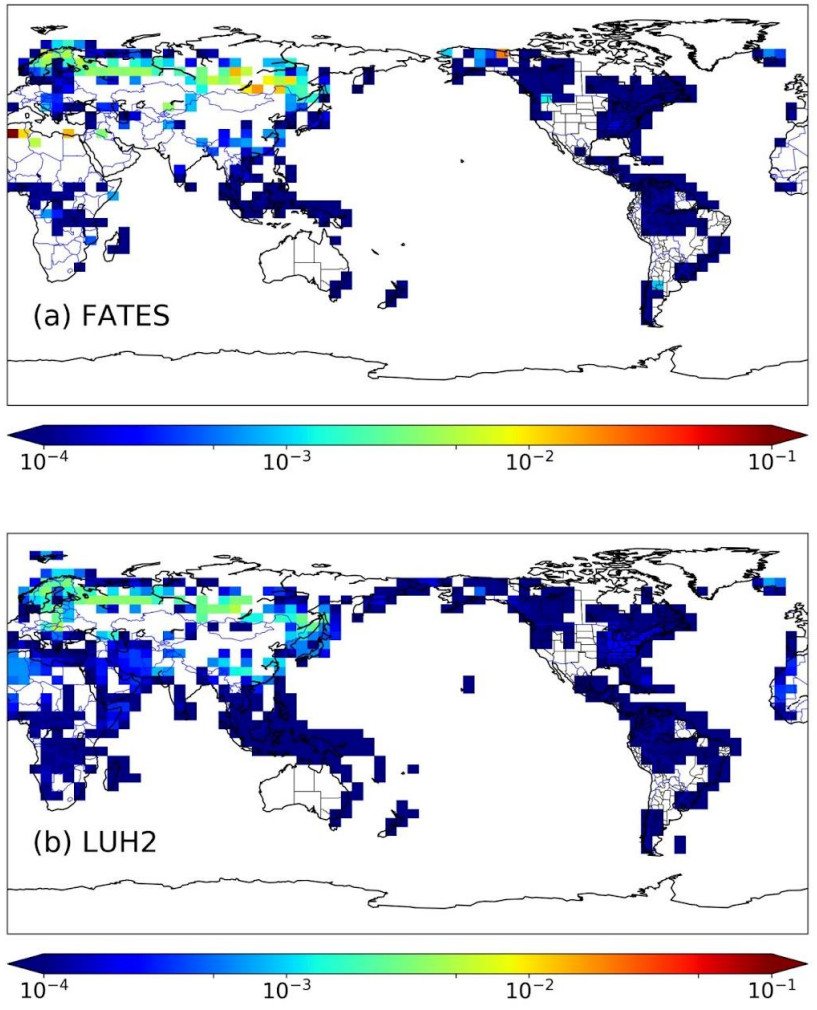
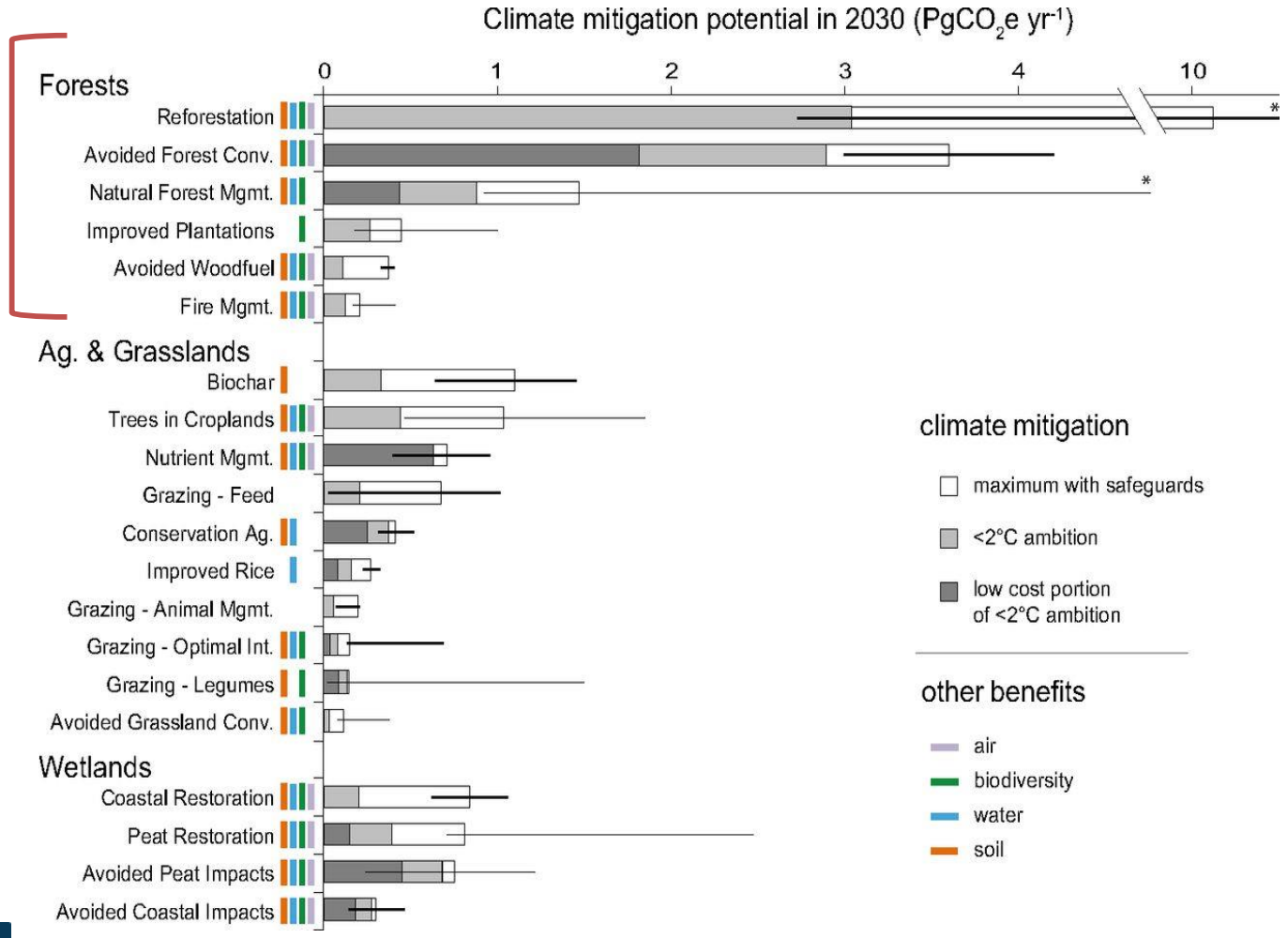
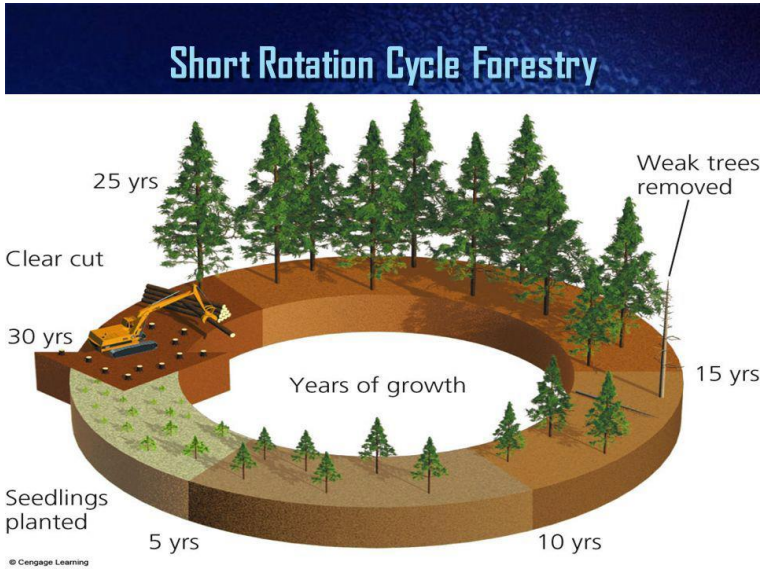


Photo: University of California Cooperative Extension Forestry

Regrowth!! Need to have demography

Need to have regrowth, successional dynamics after a clearing, or land use.



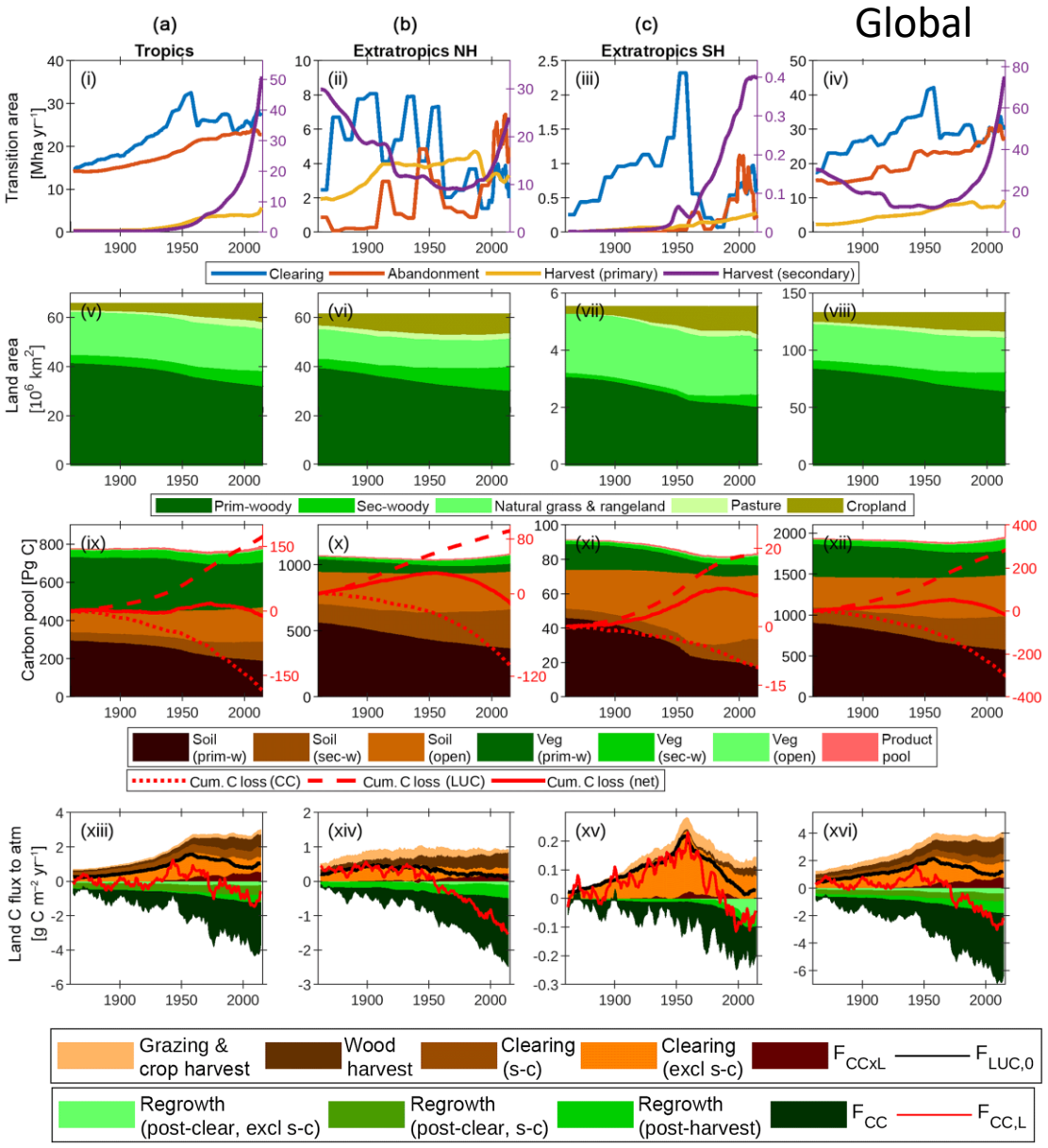


Improving forest management in LSMs – **Secondary Forest Sink**

- Accounting for forest age, or successional status.
- Representing secondary forests and degraded forests.

Haverd et al. 2018 - "*Traditional* LSMs are also unable to simulate realistic dynamics resulting from the accumulation of carbon in forests following harvest and agricultural abandonment –

the so-called secondary forest sink – that is an important contributor to the extant global terrestrial carbon sink (Shevliakova et al., 2009) **second only to CO_2 fertilization."**



CABLE-POP example:
(single PFT canopies)

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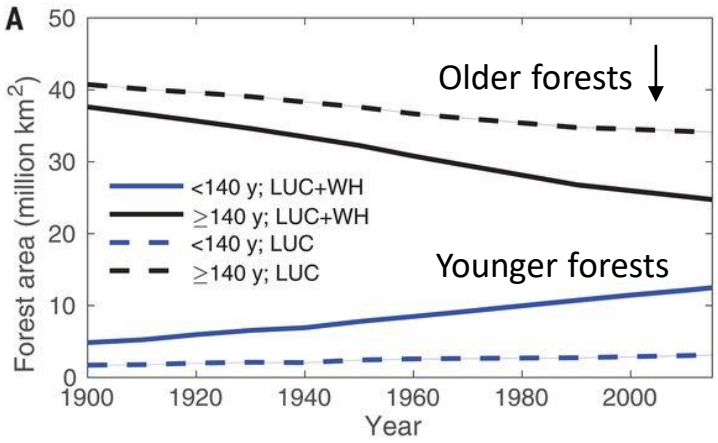
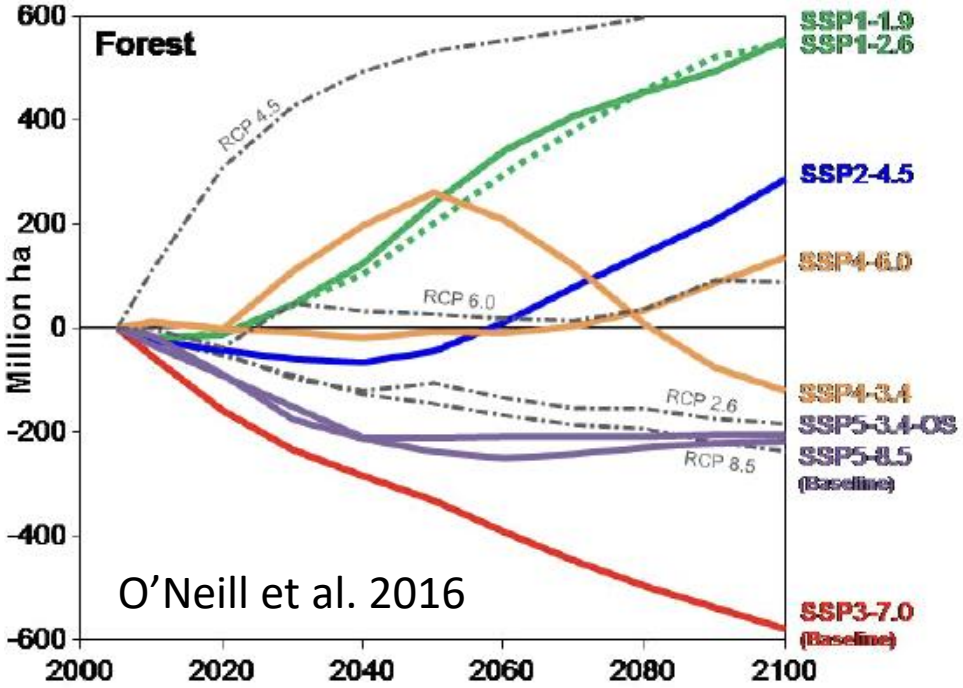
Improving forest management in LSMs – **Demography and novel shifts**

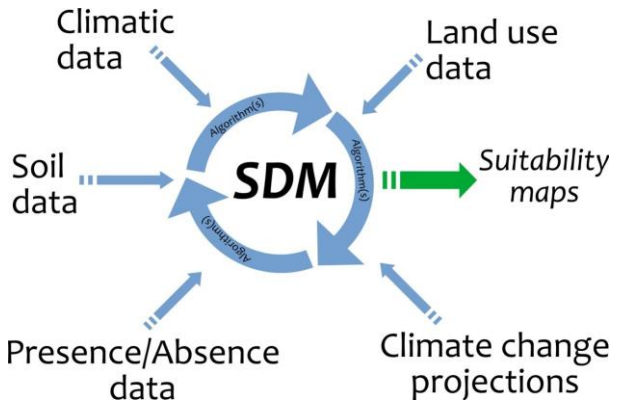
- Need VDMs, i.e., disturbances, competition for light, mechanistic mortality, etc. in forestry management modules.
  - Forest management = young forests have sparse tree canopies, more light to forest floor, higher surface area (more reflective), higher albedo.
- **Solutions** in removing bioclimatic envelopes, and emergent biogeography (yet, a challenging endeavor).



McDowell et al. 2020. Science



O'Neill et al. 2016



Pecchi et al. 2019

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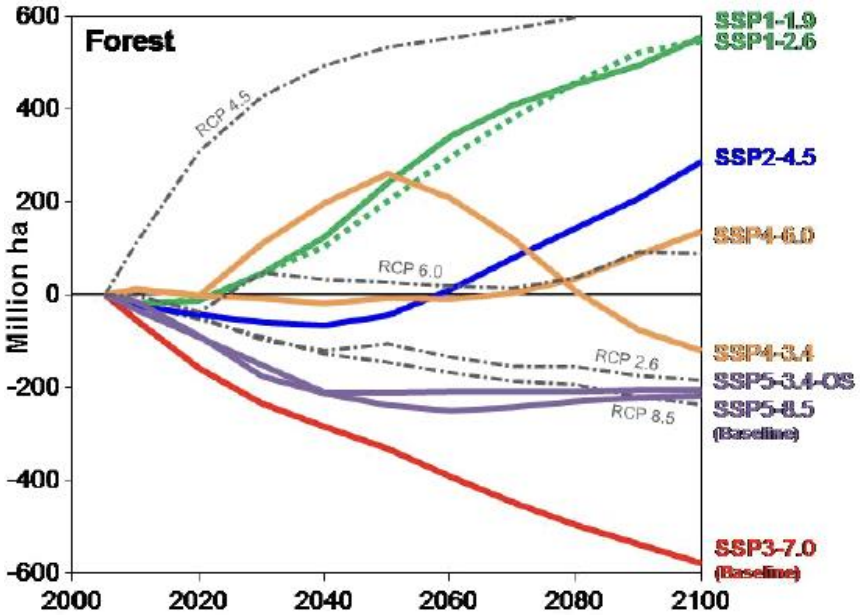
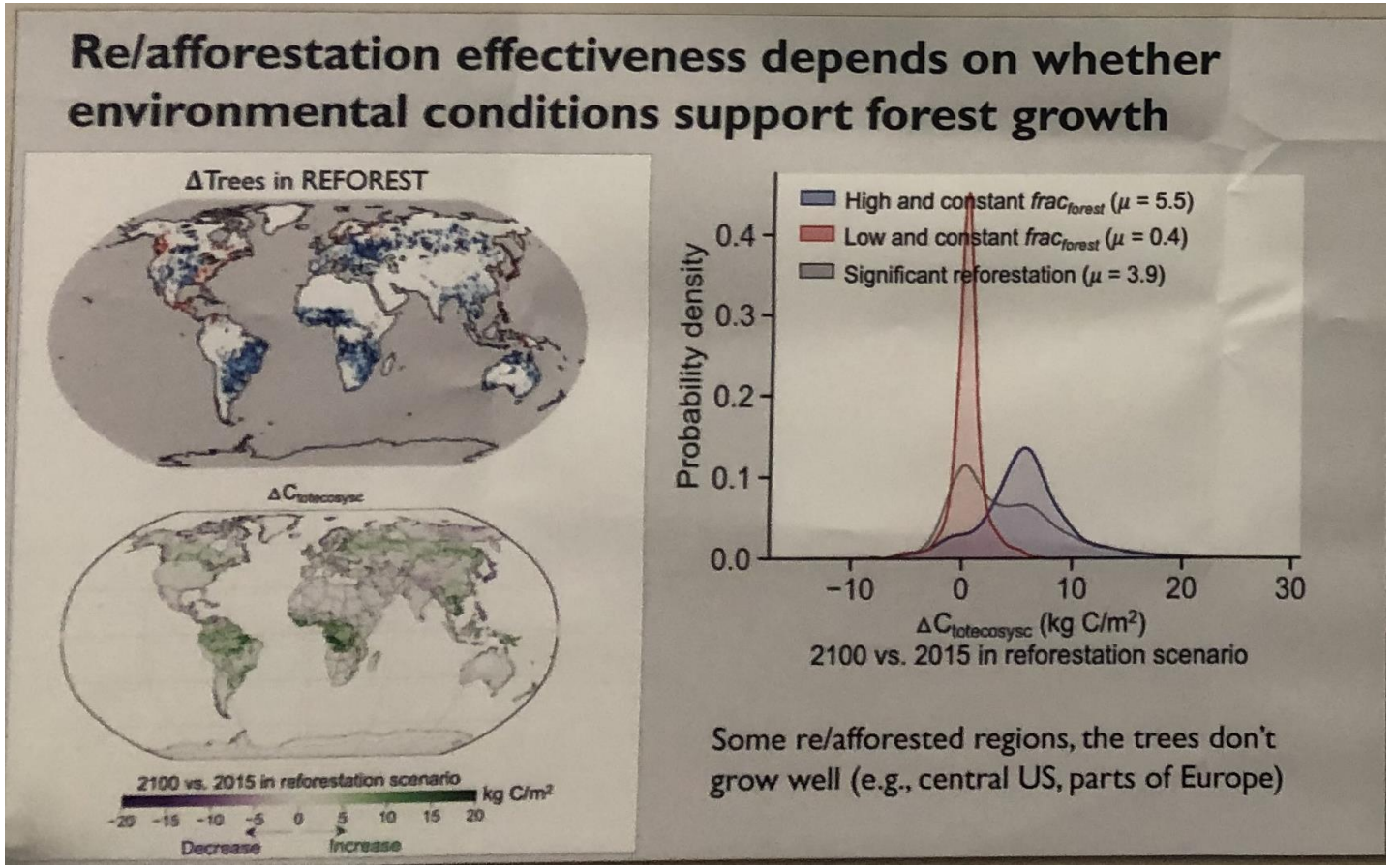
Improving forest management in LSMs – **Reforestation**

Bioenergy based (SSP2) vs. Re/afforestation based (SSP1) sceanrio

- Dave Lawrence, Yanyan Cheng; Under Review; Poster 24



O'Neill et al. 2016



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Improving forest management in LSMs – **Soil Tiling**

Blyth et al., 2021

LSM Process:	Pre 2000	Recent Advances	Future Direction
Vegetation competition and the agriculture affect the land-cover.	Dynamic vegetation model informs tile fractions. Agriculture fraction fixed.	More tiles used to describe age-classes.	Age classes inform forestry and land-use tiles. Agriculture tiles dynamic with land-use and climate. Better description of heterogeneity to interpret land-use decisions.

Long- Term Goal: Multiscale heterogeneity

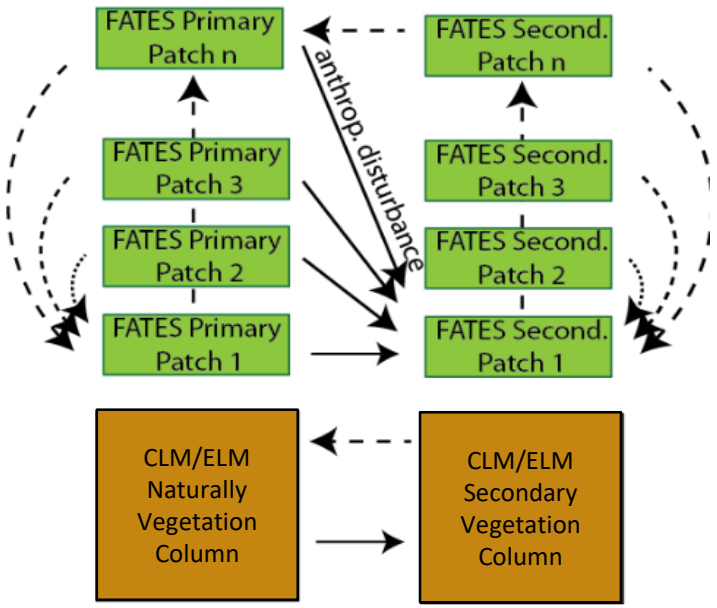

Figure: Charlie Koven

- Vegetation heterogeneity linked **across soil tiling.**
- Multiple soil columns existing on the same gridcell.
- Important for developments like:
  - Irrigated forests
  - Fertilized plantation forests and water quality
  - Different CNP cycling of disturbed, secondary forests and soils.

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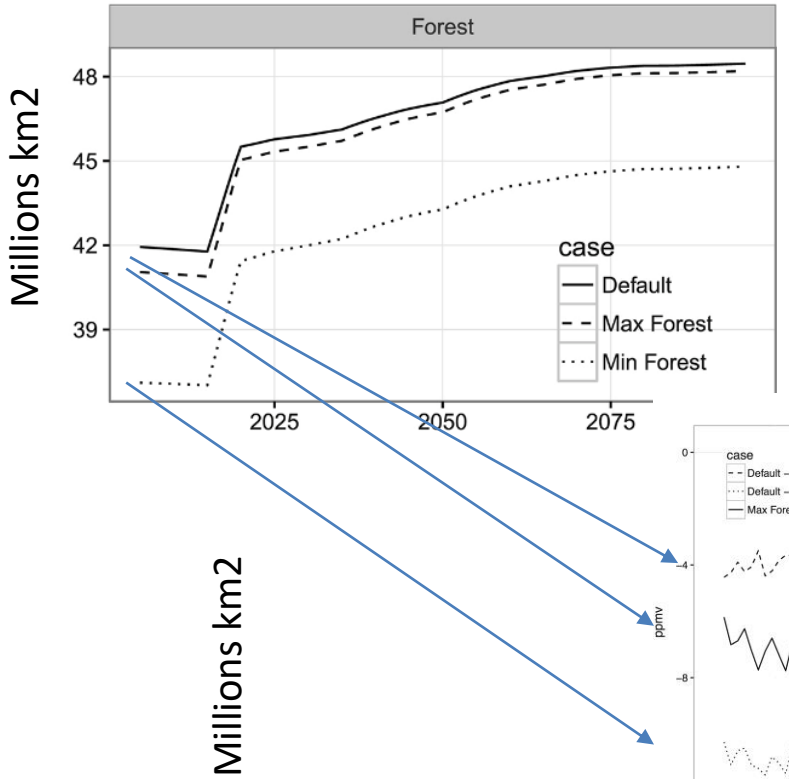
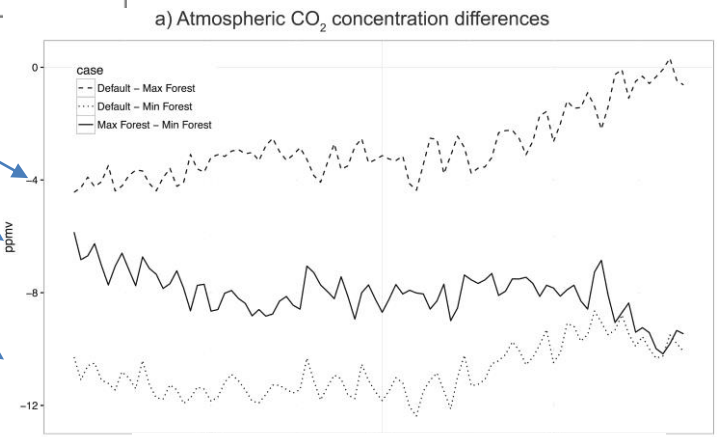
Improving forest management in LSMs – **Data Translation**

- Propagating errors from forest harvesting data interpretation into model (i.e. mapping of gridded LUC data into annual plant function types)
- **Initial forest cover distribution** substantially affects global carbon and local temperature projections in the integrated Earth system model.

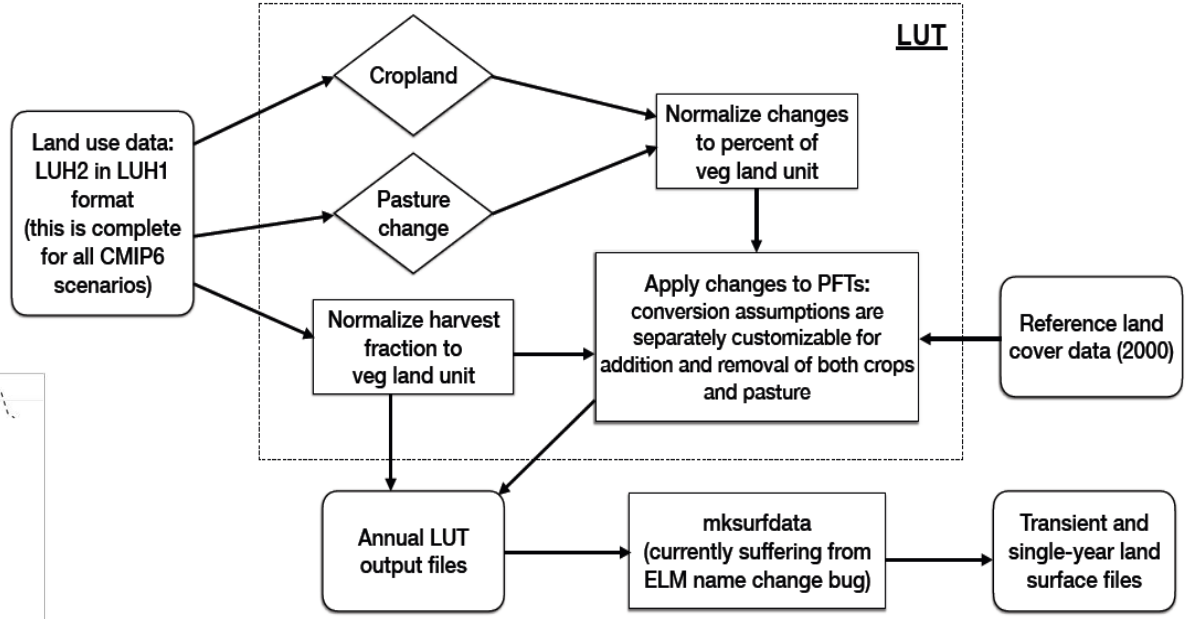


Fully coupled IAM and ESM, prognostic CO_2, and BGC



2025 2050 2075

New ELM land surface files from updated land use translator (LUT)



Di Vittorio et al., 2018, 2020

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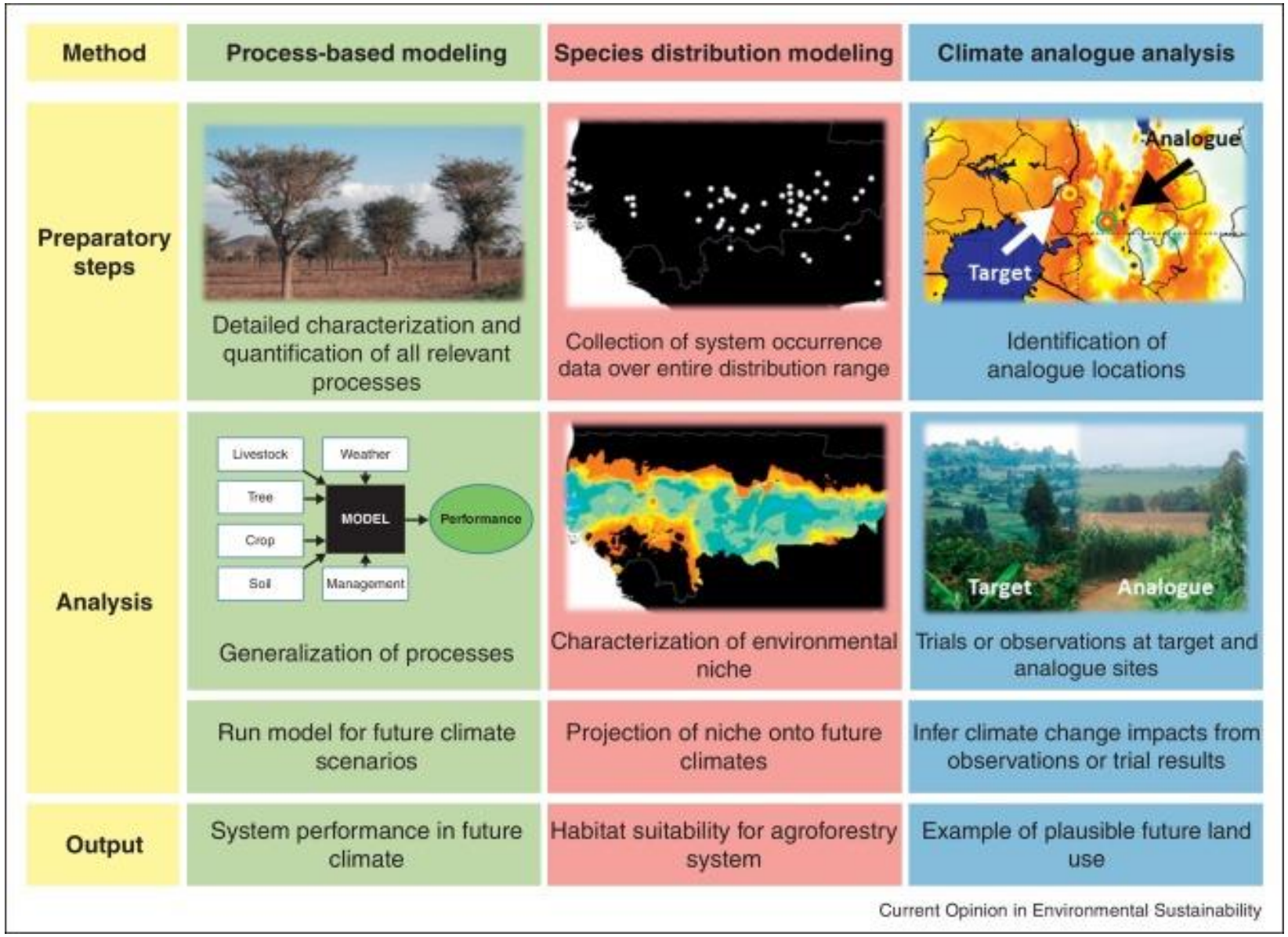
Improving forest management in LSMs – **Agroforestry**

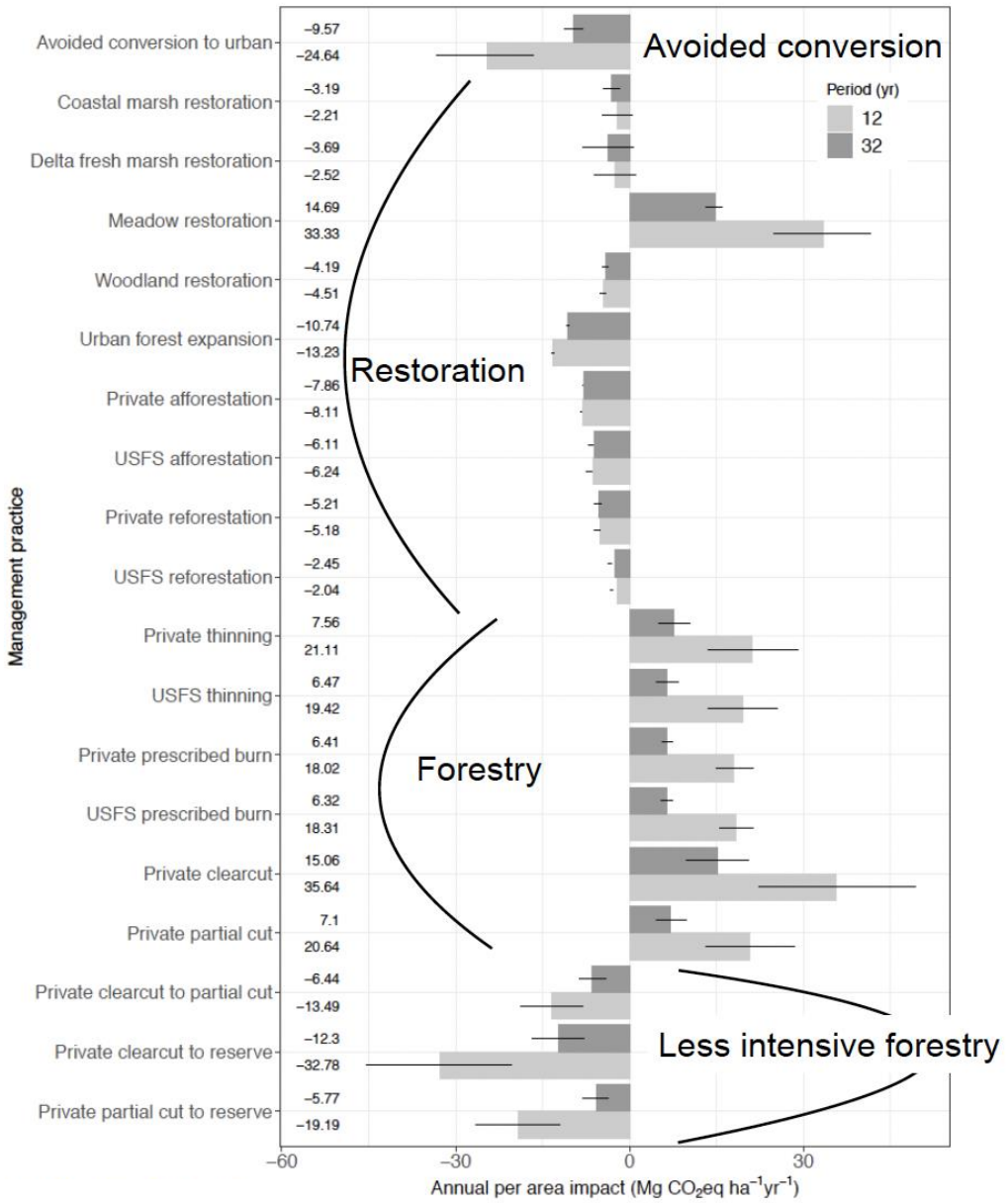
Need to include agroforestry (!) to help mitigate climate change and nature contribute to people.



Luedeling et al. 2014

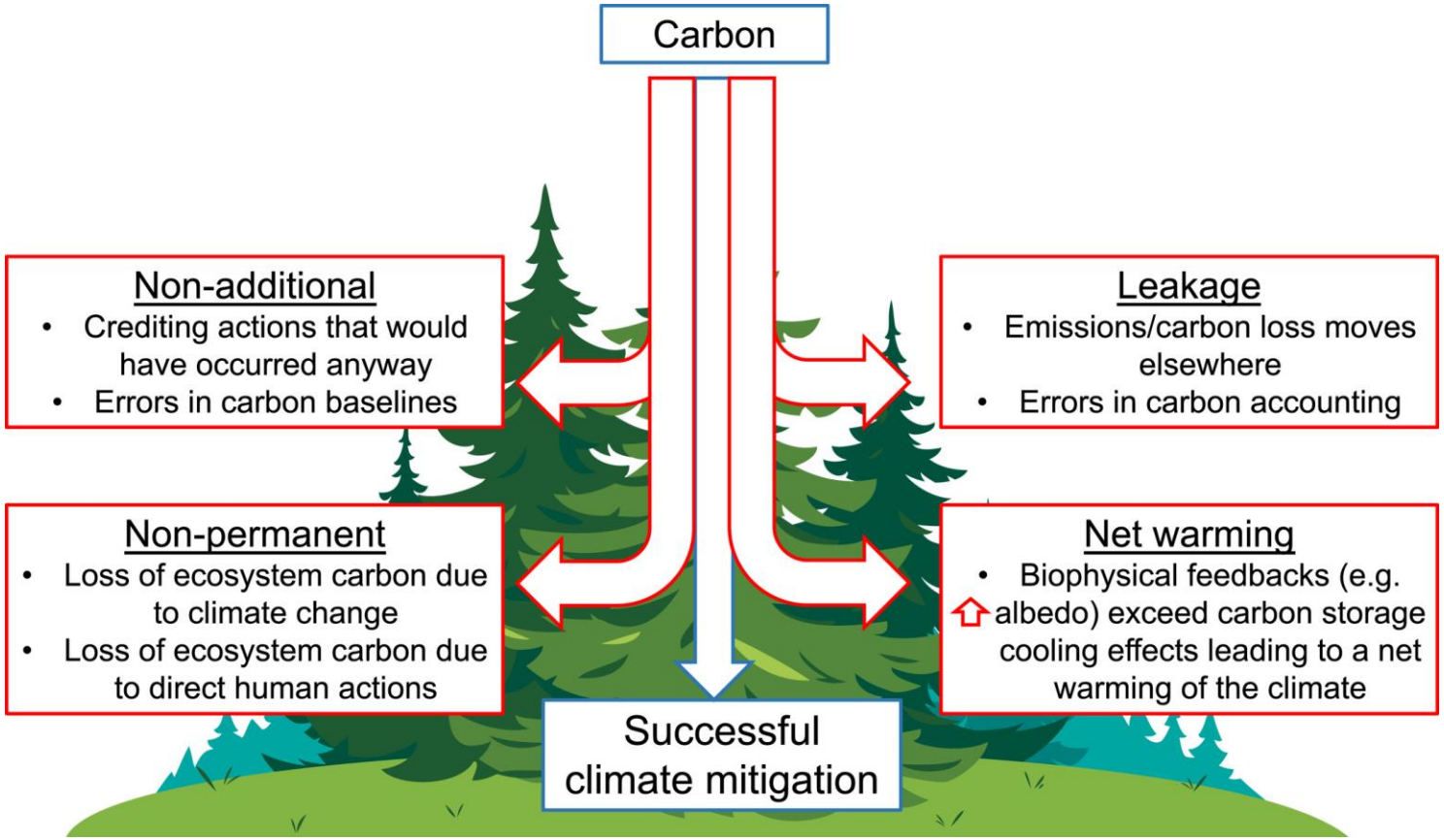
Challenges for Forestry Modeling

- Forest management not just logging anymore, need to be thinking about reforestation, and restoration in models.
  - GHGs and CO_2 equivalent impacts of woodland restoration, urban forests expansion, private afforestation.
- Carbon lifecycle of wood products
  - Role in carbon credits? Leakage, permanence issues?



Forests as Nature-Based Climate Solutions

- Forests may help climate mitigation ***if*** they can store carbon for centuries.
- Climate-driven disturbances may greatly undermine these aims.
- Multi-disciplinary and open research is urgently needed to inform policy.



Positive climate feedbacks

Anderegg 2021 AGU Advances

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How to improve benchmarking land management?

- Paired FLUXNET sites over forest/grassland, FAOSTAT, NASA products?
- Update model-data benchmarking packages (like ILAMB) to include metrics for forest management?

- Other land use datasets? (See Chini et al. 2021)
  - LUH2-GCB, HILDA+
  - Land use transition rules from LUH-HYDE 3.2 data?
  - “Bookkeeping” models
  - Other data sources for wood harvest?
  - Updating management to include things like restoration, prescribed burns, tiling


Thanks!