GLOBAL CARBON BUDGET

Dynamic Global Vegetation Models

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The GCP is a Global Research Project of futureearth Research. Innovation. Sustainability and a Research Partner of WCRP World Climate Research Programme

Dynamic Global Vegetation Models (DGVMs)

Process-based models that simulate leaf to global and minute to century scale land dynamics. Enable mechanistic understanding.

~20 models in GCB

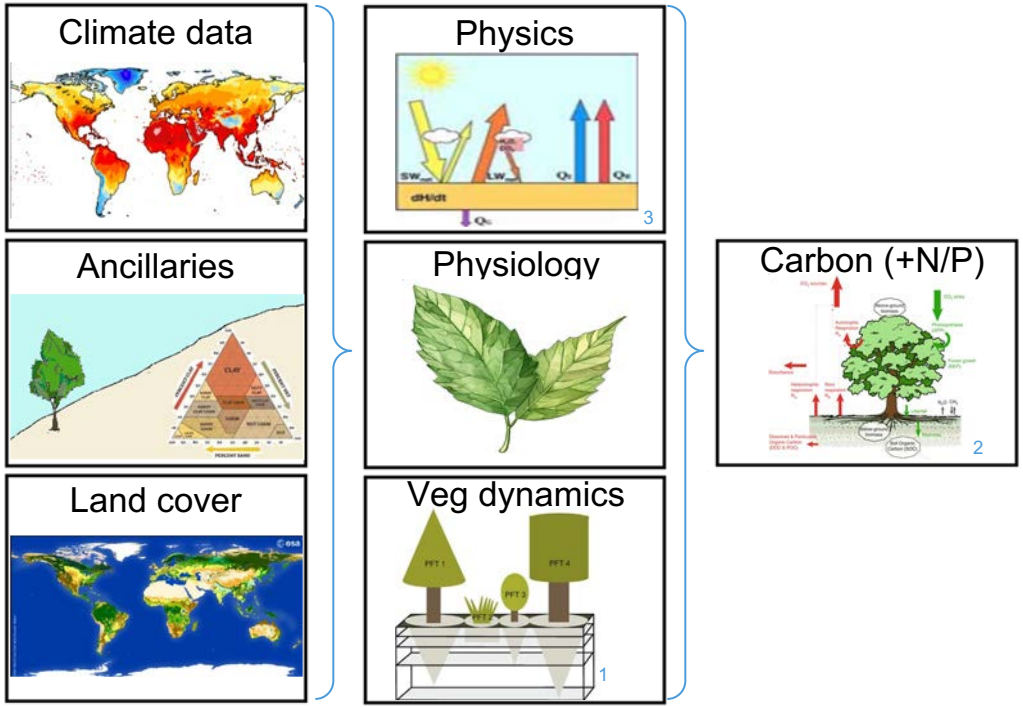
Varying levels of complexity:

- Fire
- Nutrient cycles
- Land management
- Permafrost
- Demography

CRU site obs + JRA diurnal cycle

Soils, elevation, etc

HYDE / LUH2 / prognostic



1) Schulze; 2) Makul; 3) Lodh

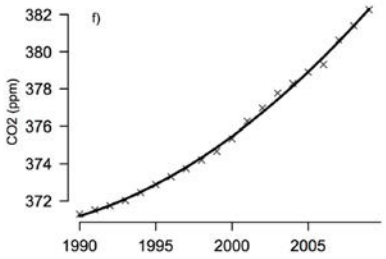
Start at equilibrium in 1700 -> human attribution.

Separate direct human fluxes and *indirect* fluxes.

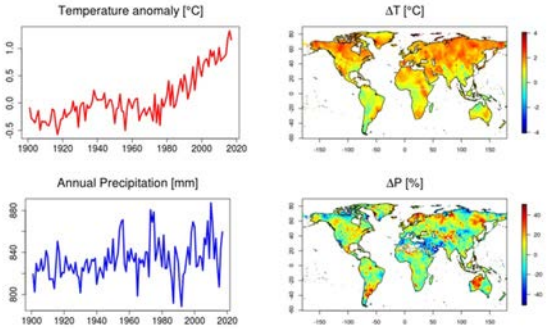
Input drivers of DGVMs

Factorial simulations enable the attribution of drivers to changes in the carbon cycle

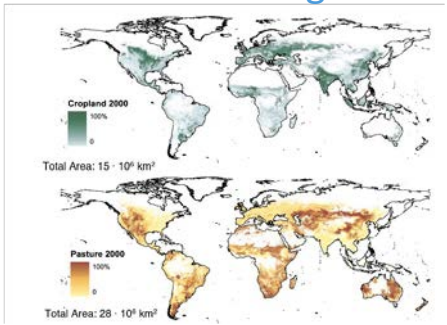
Atmospheric CO2



Surface climate



Land-use change

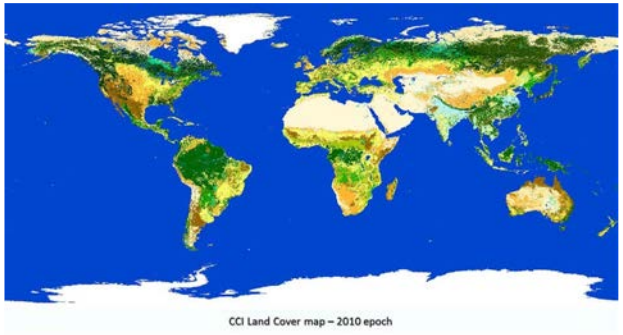


- ***Indirect*** carbon sink (also named ***natural*** / ***SLAND*** / ***S2*** sink) - used in GCB.
- ***Net*** carbon sink (***S3*** sink) - **not** directly used in GCB.

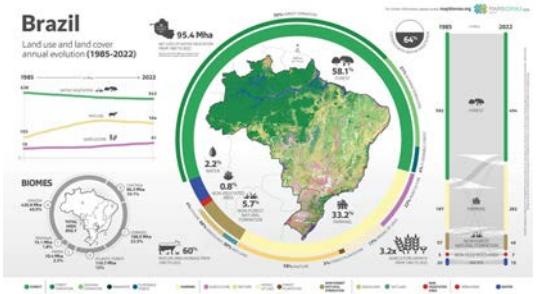
In theory, DGVMs can capture the carbon cycle impacts of all major changes to the system.

How EO is used to constrain ELUC

ESA CCI Land Cover is used to spatially allocate country level FAO data



- Forest, cropland, and pasture spatially constrained with EO.
- Crop & Pasture country totals from FAO

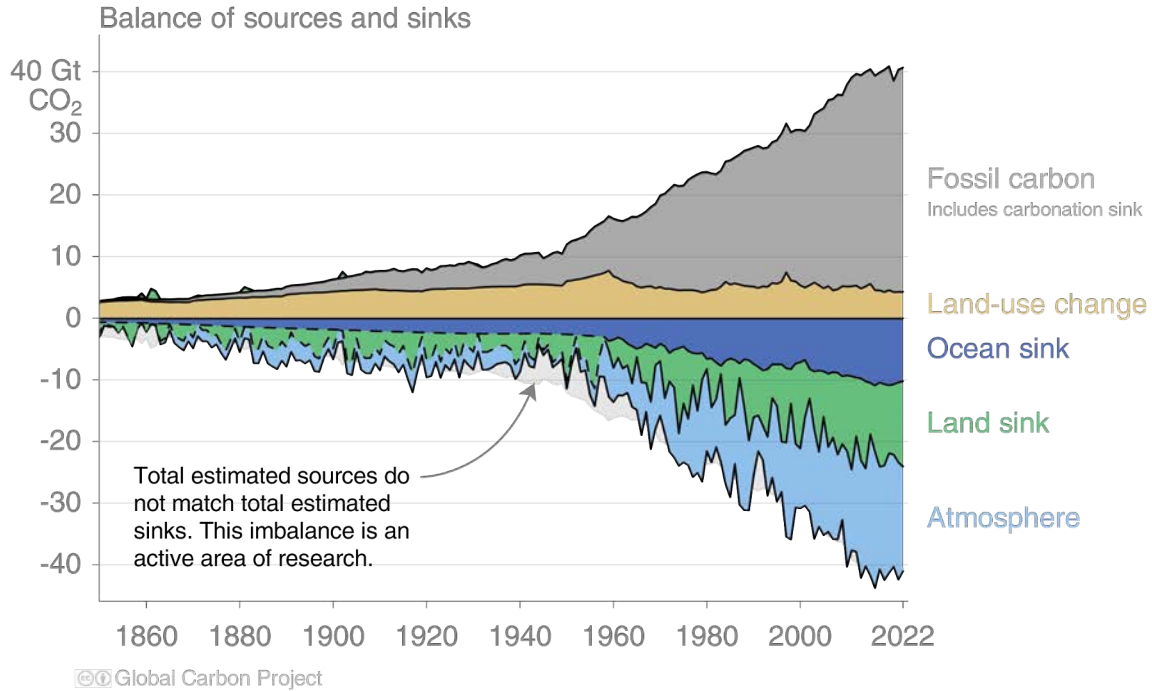


- For Brazil & Indonesia (45% of global emissions) - we now use Mapbiomas (Landsat)

Corrected ELUC trends in Brazil (decrease after 2004 peak), and reduced ELUC by 0.2 GtC/yr in Indonesia compared to FAO/HYDE.

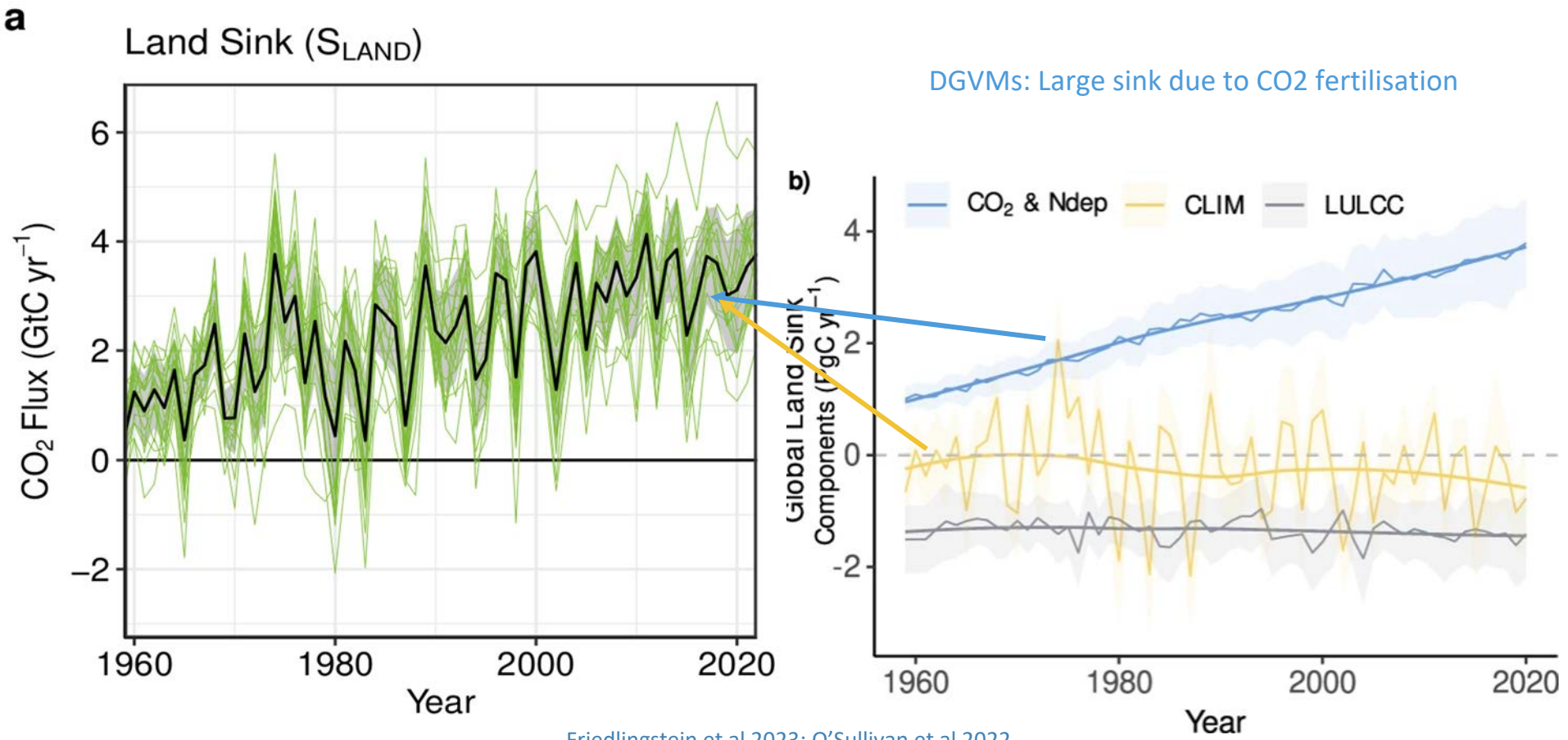
Global carbon budget

Carbon emissions are partitioned among the atmosphere and carbon sinks on land and in the ocean
The "imbalance" between total emissions and total sinks is an active area of research



Source: Friedlingstein et al 2023; Global Carbon Project 2023

Global Land Carbon Fluxes

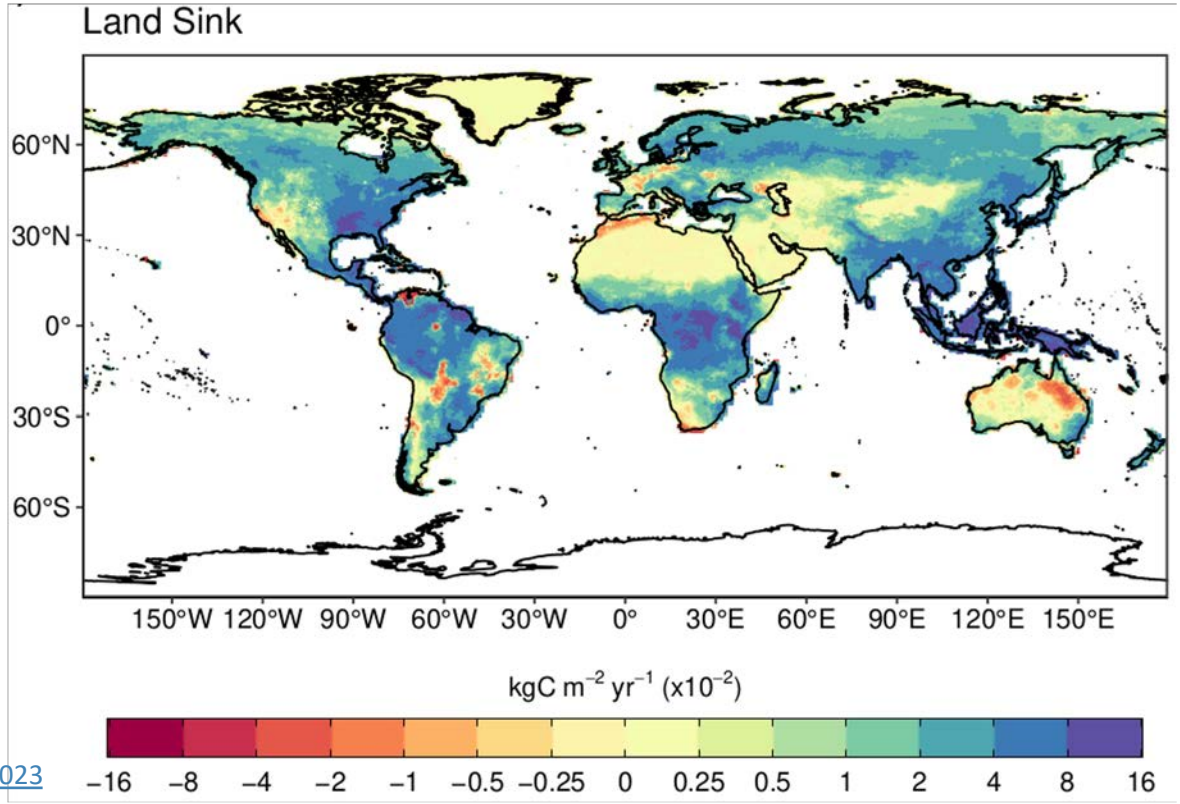


DGVMs: Large sink due to CO2 fertilisation

Friedlingstein et al 2023; O'Sullivan et al 2022

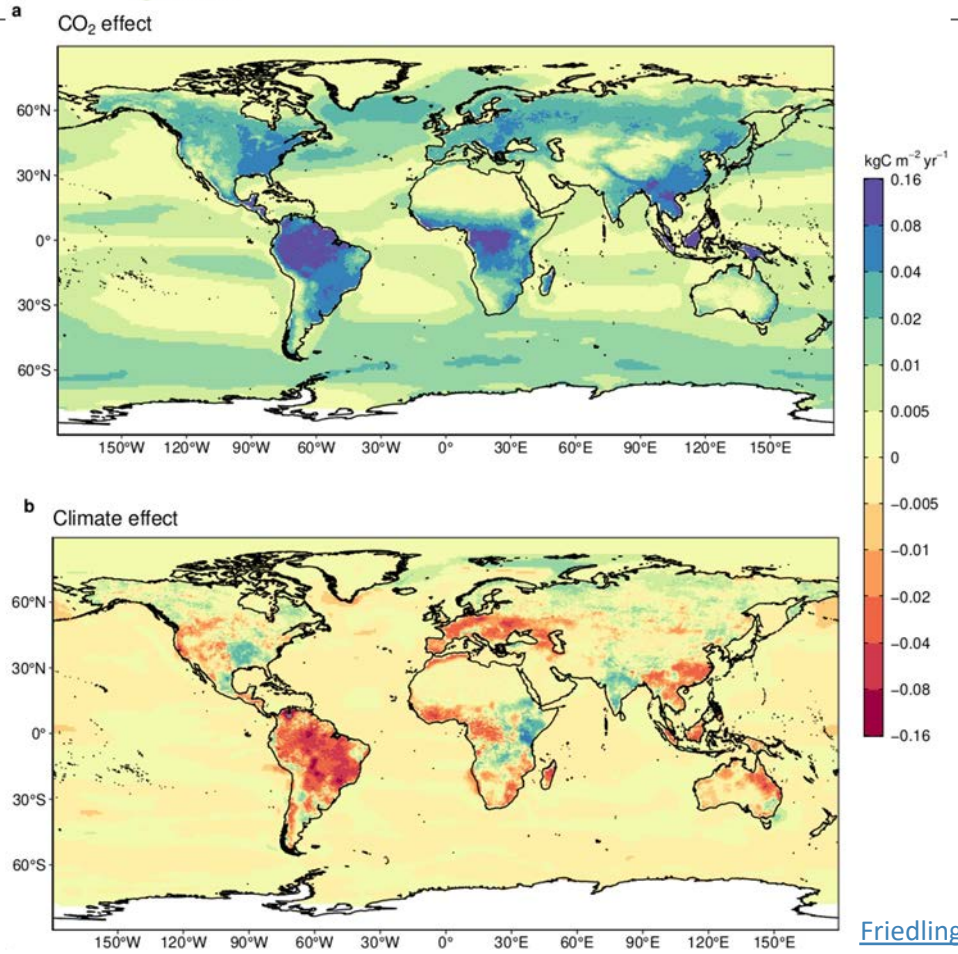
‘Natural’ / ‘indirect’ land carbon sink

SLAND (CO2 + NDep & Climate - “indirect” effect)



Friedlingstein et al 2023

Process attribution



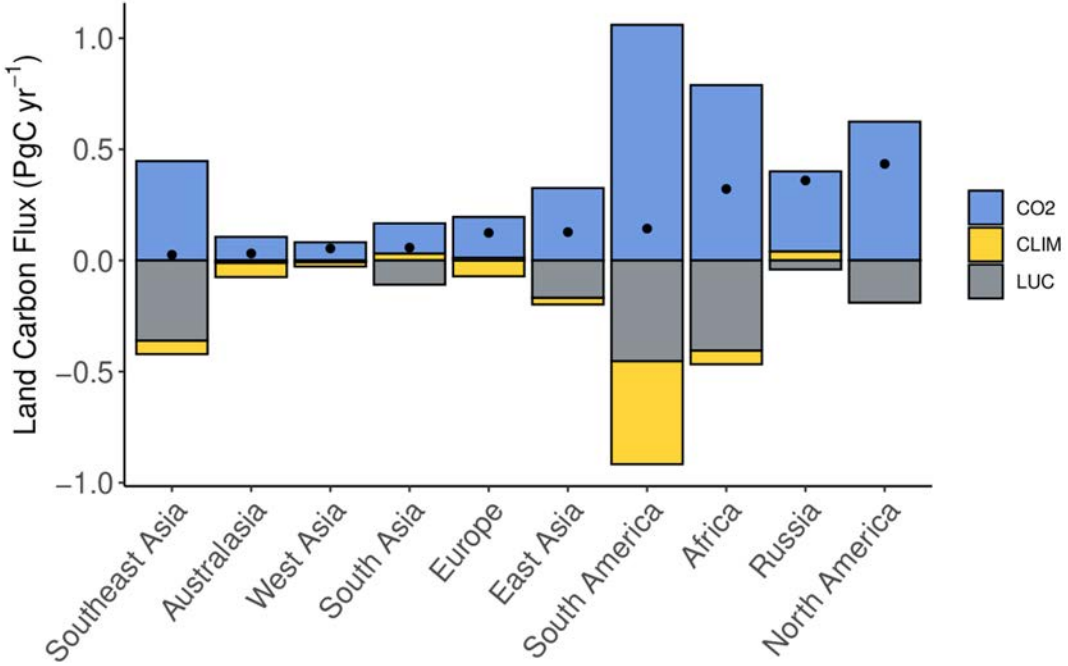
Substantial response of global forests to rising atmospheric CO2 concentrations

Globally during the 2013–2022 decade, climate change reduced the land sink by ~20%

Friedlingstein et al 2023

Regional carbon budgets

2013-2022 mean regional fluxes. Mean of DGVMs.



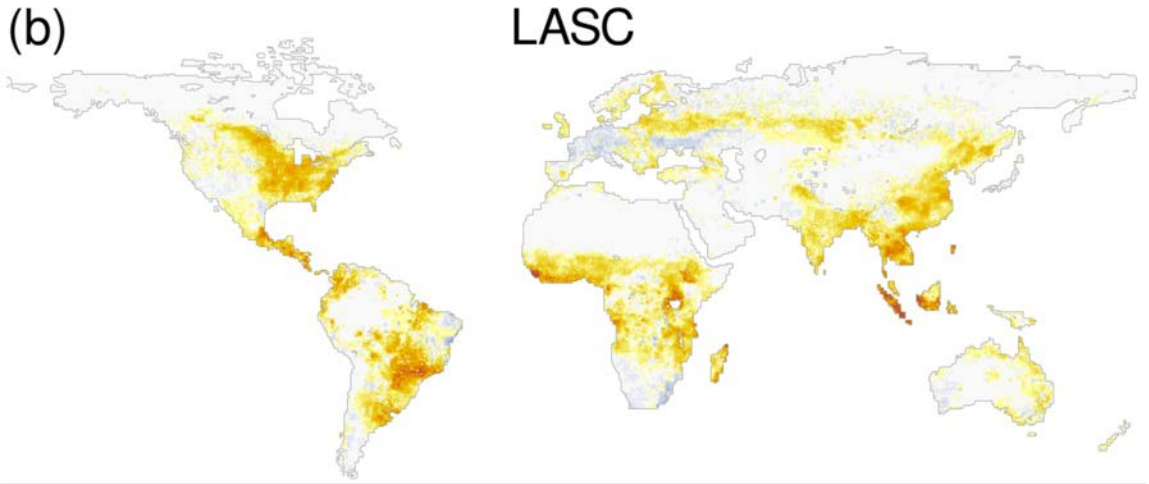
Largest gross fluxes in tropical lands - but mostly cancel out

Northern lands substantial net C sinks - DGVMs indicate this is CO2 driven, not LUC

Loss of additional sink capacity (LASC)

Simulations use 1700 land cover -> too high forest area.

LASC -> **Carbon uptake by trees that no longer exist.**



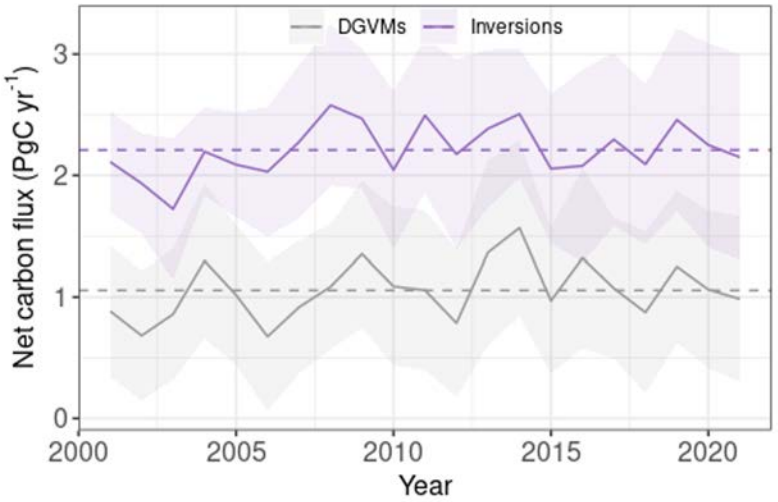
LASC = ~0.7 GtC/yr
SLAND = 3.3 GtC/yr
ELUC = 1.7 GtC/yr

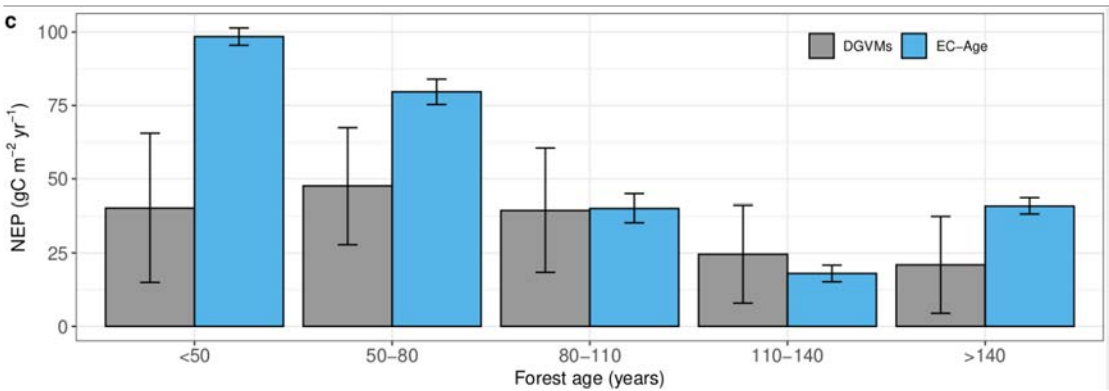
Likely too high! -> Don't use DGVM ELUC

Obermeier et al. 2021

DGVMs missing forest regrowth sink?

DGVMs underestimate *northern* carbon sink compared with top-down atmospheric inversions



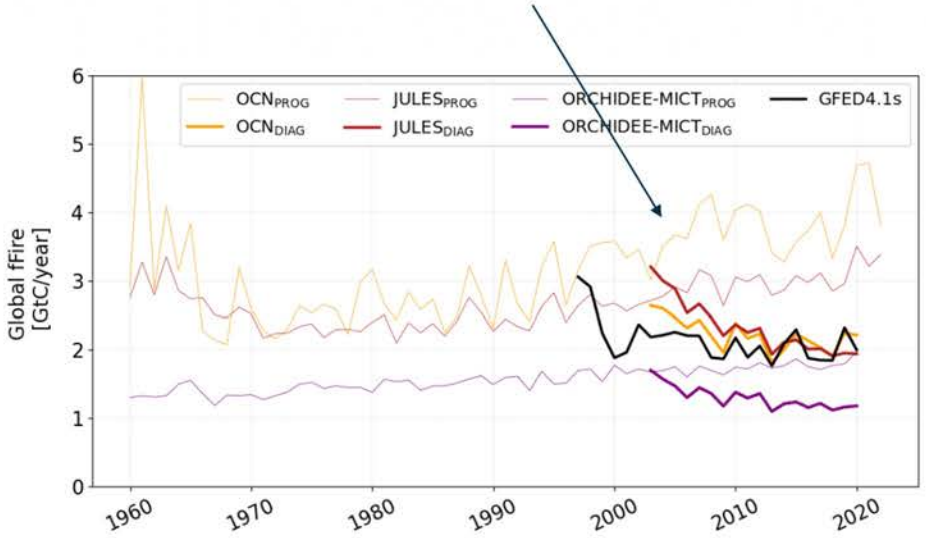


DGVMs underestimate carbon uptake of young forests compared to flux tower observations

O'Sullivan et al. 2024

Improving fire emissions from DGVMs with EO

Many DGVMs simulate burned area and their trends quite poorly.



Source: Ana Bastos (pers. comm.)

Improved agreement in fire emissions in magnitude, spatial distribution, IAV and trends, but also other variables, e.g. biomass

We prescribe burned area from Fire CCI in DGVM simulations to assess the impact on C budgets & other variables

fire cci

Conclusions

- DGVMs are the only tool to estimate SLAND (“indirect” carbon fluxes).
  - Submodels of ESMs -> key tools for TCRE and remaining C budget
- Results are robust at global scale (budget is closed)
- Uncertainties increase as we focus on regional/country scale -> active research in improving DGVMs
- EO can transform our modelling capabilities (novel forcing data, model benchmarks, parameterisations, resolution) -> better support NGHGIs

More processes = Higher ELUC flux

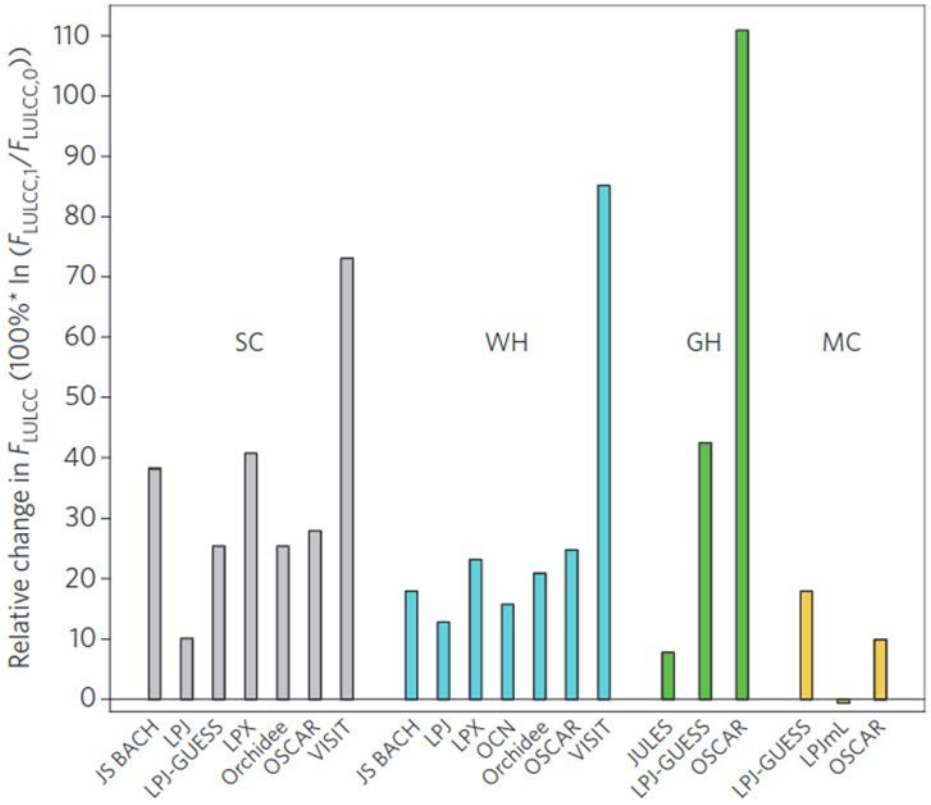


Figure 2 | Response ratio of cumulative $F_{LULCC,1}$ and $F_{LULCC,0}$. See Supplementary Table 1 and Methods for individual processes and models.

Arneth et al. 2017