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Reconciling land use CO_2 fluxes: Efforts done so far (2)

Gidden, M.J., **Gasser, T.**, Grassi, G. et al. Aligning climate scenarios to emissions inventories shifts global benchmarks. *Nature* 624, 102–108 (2023). https://doi.org/10.1038/s41586-023-06724-y

The study:

Article

Aligning climate scenarios to emissions inventories shifts global benchmarks

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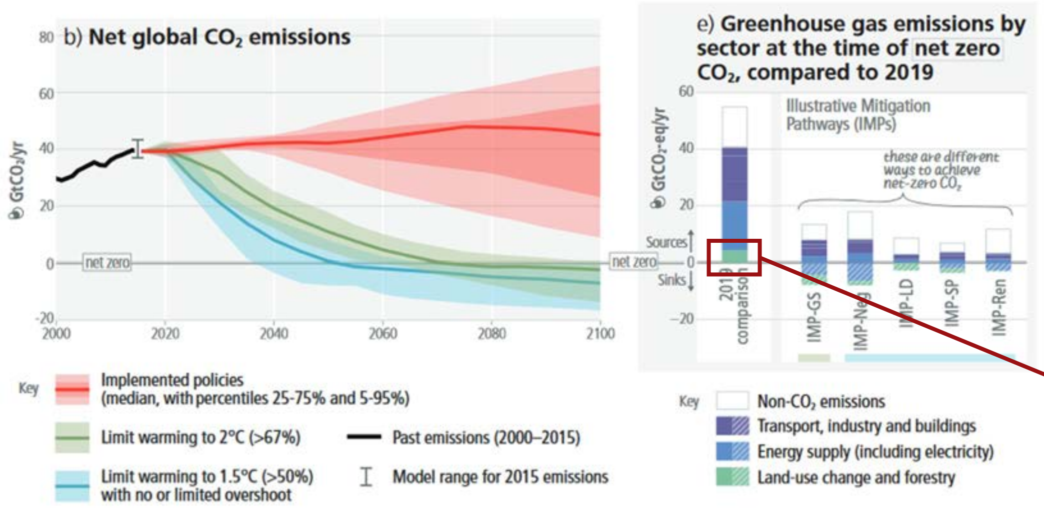
Motivation: IPCC benchmarks from WG3

- IPCC WG3 scenario database provides high-level mitigation benchmarks for policy advice

- Excerpts from SYR SPM:

Figure SPM.5: Global emissions pathways consistent with implemented policies and mitigation strategies.

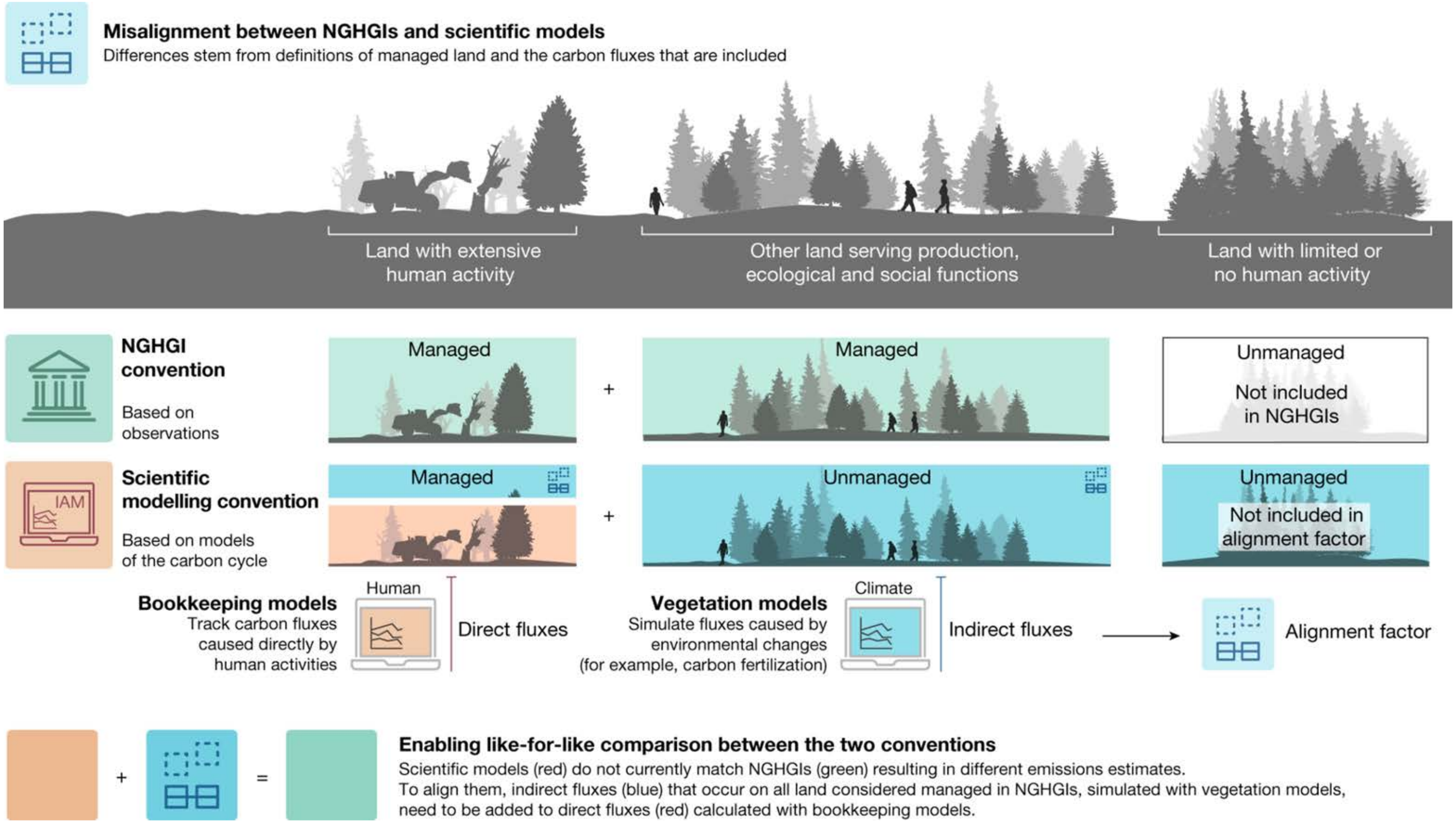


Land emissions reported under model convention

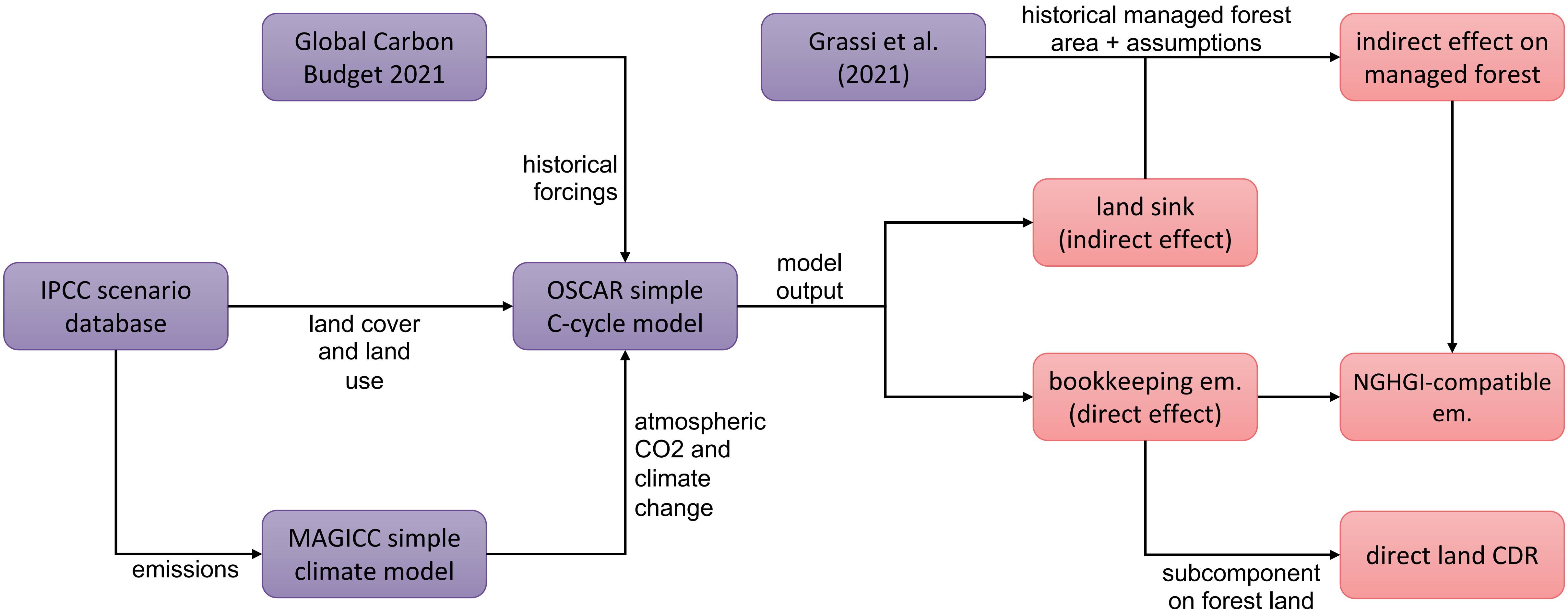
Table SPM.1: Greenhouse gas and CO_2 emission reductions from 2019, median and 5-95 percentiles.

		Reductions from 2019 emission levels (%)			
		2030	2035	2040	2050
Limit warming to1.5°C (>50%) with no or limited overshoot	GHG	43 [34-60]	60 [49-77]	69 [58-90]	84 [73-98]
	CO_2	48 [36-69]	65 [50-96]	80 [61-109]	99 [79-119]
Limit warming to 2°C (>67%)	GHG	21 [1-42]	35 [22-55]	46 [34-63]	64 [53-77]
	CO_2	22 [1-44]	37 [21-59]	51 [36-70]	73 [55-90]

- Goal: Reassess IPCC benchmarks under the NGHGI reporting convention


Misalignment between NGHGIs and scientific models
Differences stem from definitions of managed land and the carbon fluxes that are included
Land with extensive human activity
Other land serving production, ecological and social functions
Land with limited or no human activity
NGHGI convention
Based on observations
Managed
+
Managed
Unmanaged
Not included in NGHGIs
Scientific modelling convention
Based on models of the carbon cycle
IAM
Managed
+
Unmanaged
Unmanaged
Not included in alignment factor
Bookkeeping models
Track carbon fluxes caused directly by human activities
Human
Direct fluxes
Vegetation models
Simulate fluxes caused by environmental changes (for example, carbon fertilization)
Climate
Indirect fluxes
Alignment factor
+
=
Enabling like-for-like comparison between the two conventions
Scientific models (red) do not currently match NGHGIs (green) resulting in different emissions estimates.
To align them, indirect fluxes (blue) that occur on all land considered managed in NGHGIs, simulated with vegetation models, need to be added to direct fluxes (red) calculated with bookkeeping models.

Approach: reanalysis with OSCAR



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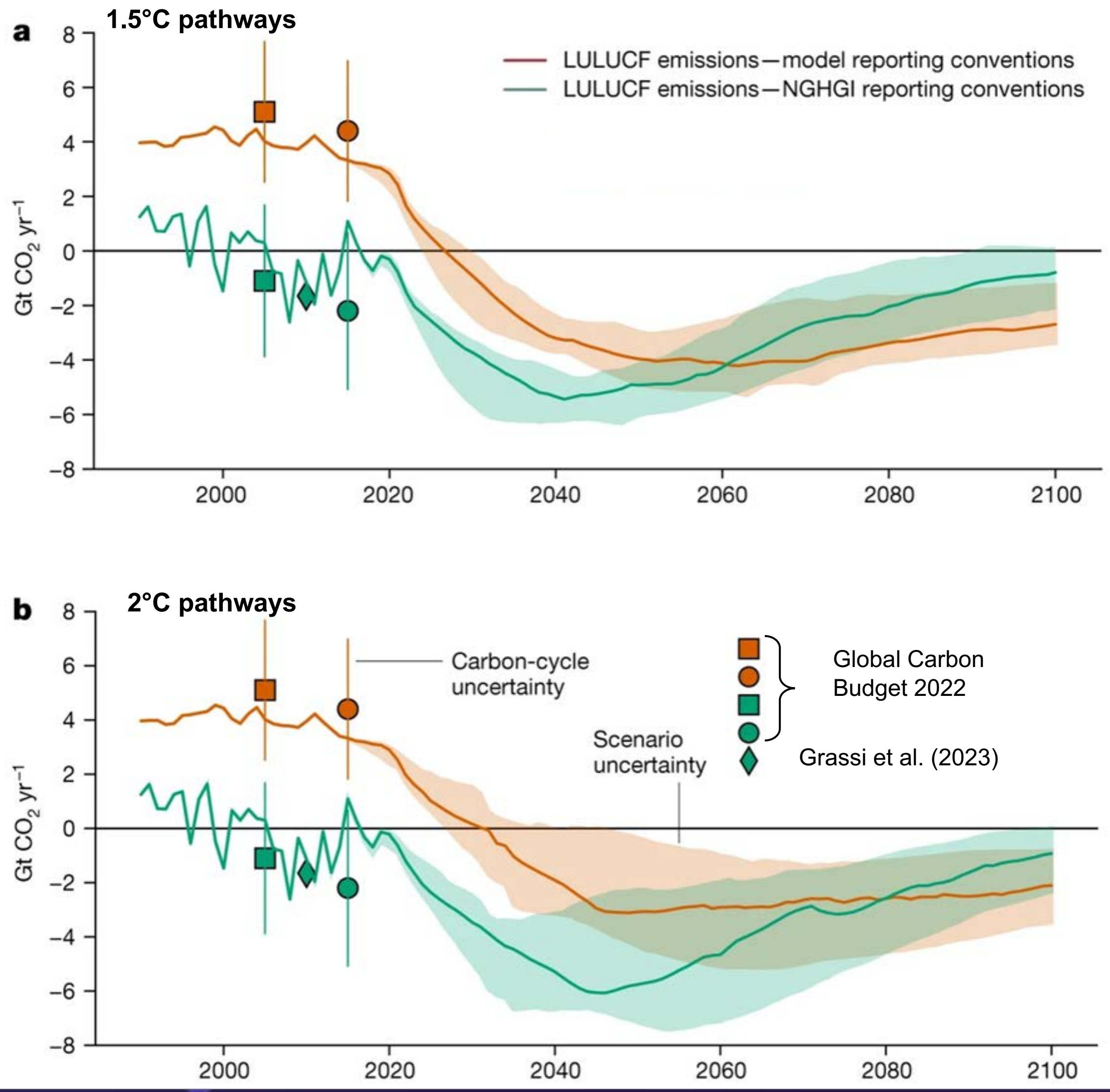
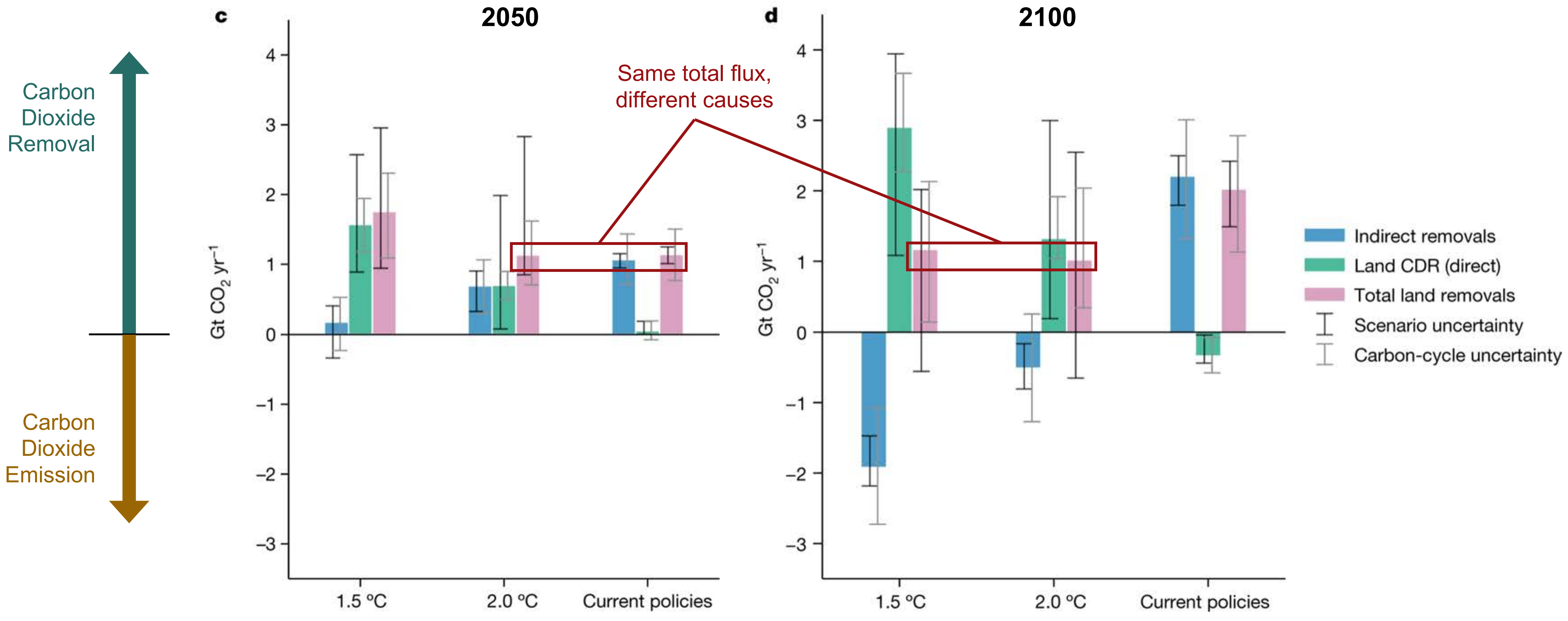
Results: shift of global benchmarks



combined with fossil emissions

Benchmark	Change in 1.5°C Pathways	Change in 2°C Pathways
(Earlier) year of Net-Zero CO2	1 to 5 years	-1 to 7 years
Emissions reductions by 2030	+3.4 to +5.9 %	+2.5 to +5 %
Cumulative CO2 until Net-Zero	−54 to −95 GtCO2 (−15 to −18 %)	−93 to −167 GtCO2 (−15 to −18 %)

Results: potential masking of efforts



Methods: the OSCAR model

A simple Earth system model, designed to emulate complex models, with a **specific focus on biogeochemical cycles**

One of the three bookkeeping models used for the Global Carbon Budget

Parameters (carbon densities) calibrated on complex vegetation models used for the Global Carbon Budget

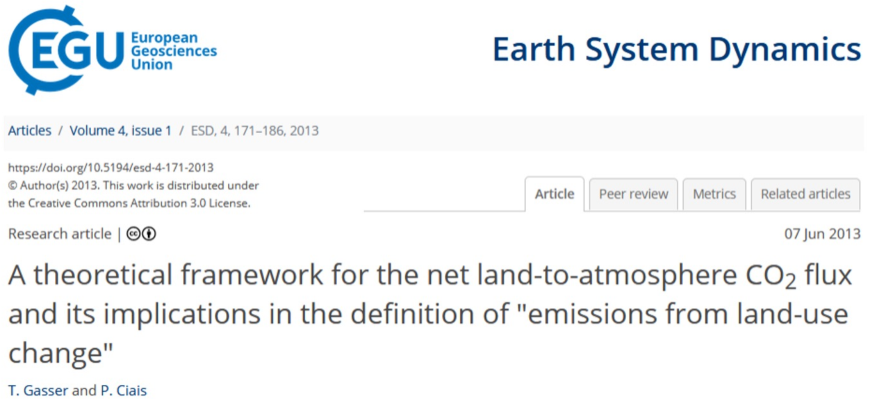
Follows a **theoretical framework to separate direct and indirect effects** (Gasser and Ciais, 2013; https://doi.org/10.5194/esd-4-171-2013)

Keeps track of disturbed and undisturbed ecosystems separately:

- Emissions from land use change (direct effect) defined as **the difference between disturbed and hypothetically recovered ecosystems** (Ⓐ − Ⓑ)
- Natural land carbon sink (indirect effect) includes the hypothetically recovered ecosystems

Coupling between the direct and indirect effects:

- Emissions affected by changing carbon densities (indirect □ direct)
- Land sink affected by land cover change (direct □ indirect)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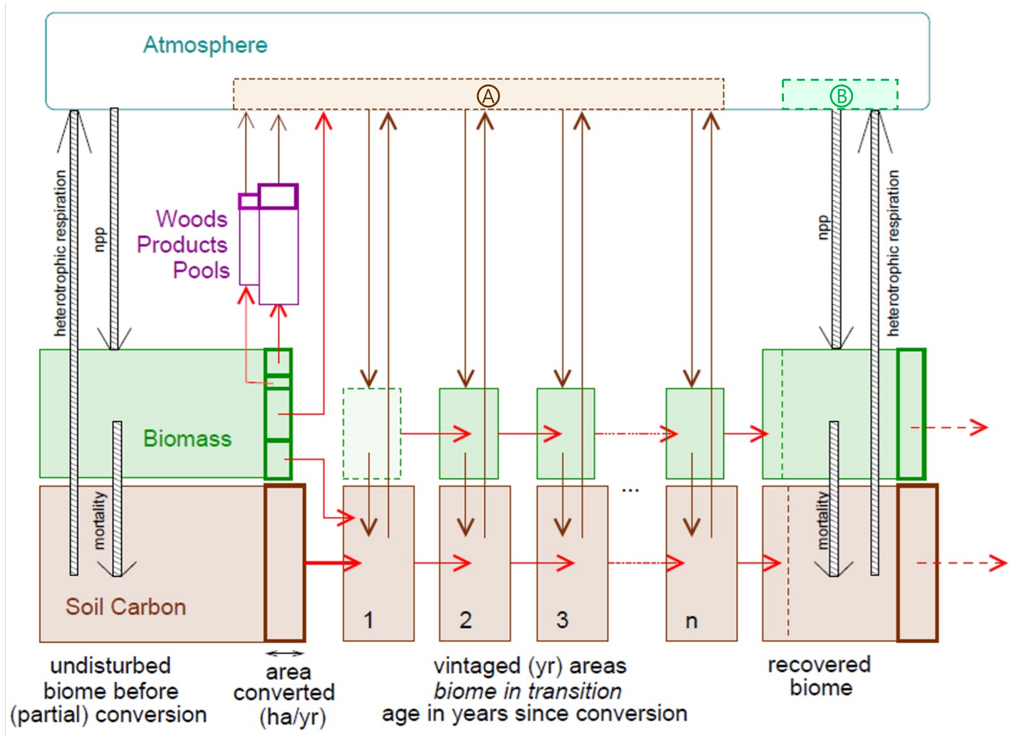
A theoretical framework for the net land-to-atmosphere CO_2 flux and its implications in the definition of "emissions from land-use change"

T. Gasser and P. Ciais



Methods: assumptions and limitations

Many assumptions because of limited data in the scenario database:

- **Some scenarios did not provide basic land cover information**:
  - minimum required was Forest, Pasture, Cropland
  - ~900 scenarios left out of ~1200
  - still representative of the database in terms of climate outcome
- Worked at **very coarse resolution** with 5 IPCC regions
  - instead of national level for the Global Carbon Budget
  - 10 regions was an option but would retain ~400 scenarios
- **Database provided land cover and not land cover *change***:
  - created a transition matrix using simple proportionality rules
  - added a constant amount of reciprocal transitions to match historical gross transitions (as only net could be deduced)
- Used **other variables as proxies** for other model drivers:
  - ‘Forestry Production|Roundwood’ for wood harvest
  - ‘Primary Energy|Biomass|Traditional’ for shifting cultivation
  - assumed constant if not provided

Additional modeling assumptions with room for improvement:

- Global assumption regarding future managed forest area
- Simple **pattern scaling to get regional climate** in OSCAR
- **High CO2-fertilization in OSCAR** (because it is constrained to close the C budget over the historical period)

Recommendations

First, climate targets can be formulated explicitly for areas of critical mitigation action, including gross CO_2 emission reductions without LULUCF, net land-based removals, engineered carbon removals and non-CO_2 GHG emission reductions, allowing for parties to define their expected contributions and to measure progress in each domain separately.

Second, parties can clarify the nature of their deforestation pledges, because direct and indirect carbon fluxes vary greatly in different forest types.

Third, scientific and practitioner communities can convene discussions on how to enhance monitoring, reporting and verification of LULUCF fluxes to better align estimates from both groups.

Fourth, IAM teams can provide their individual assumptions and estimates for direct LULUCF emissions and removals, including the indirect flux component consistent with the NGHGIs and their assumptions about the land-use contribution of NDCs and long-term strategies.

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Thank you.

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