Aligning climate scenarios to emissions inventories shifts global benchmarks

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1. Scientific Models and National Inventories Account for LULUCF Emissions Differently

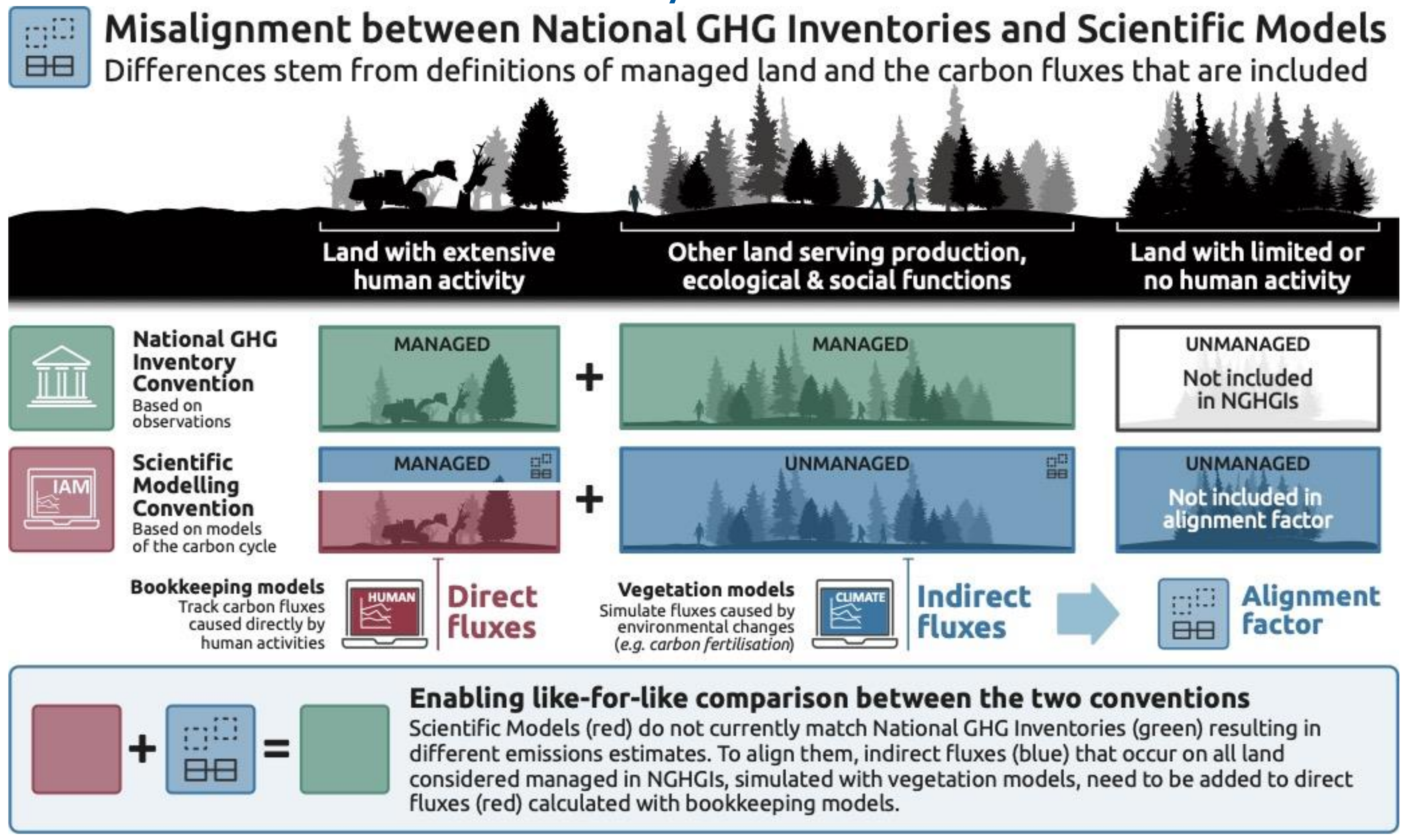

Fig. 1. A schematic displaying the difference in accounting conventions between NGHGIs (green) and scientific models (bookkeeping models in red and vegetation models in blue). Models like IAMs are based on 'bookkeeping' approaches and consider direct fluxes due to land use (e.g. wood harvest) and land-cover changes. Additional indirect fluxes due to evolving environmental conditions can be estimated by processed-based vegetation models. NGHGIs consider a wider managed land area and are generally based on physical observations, thus include both direct and indirect fluxes. In this study, we estimate the 'alignment factor' to translate between both conventions (the indirect flux considered in NGHGIs but not in models, blue).

2. Aligning Pathways to Inventories Change Dynamics and Can Result in Positive LULUCF Emissions by 2100

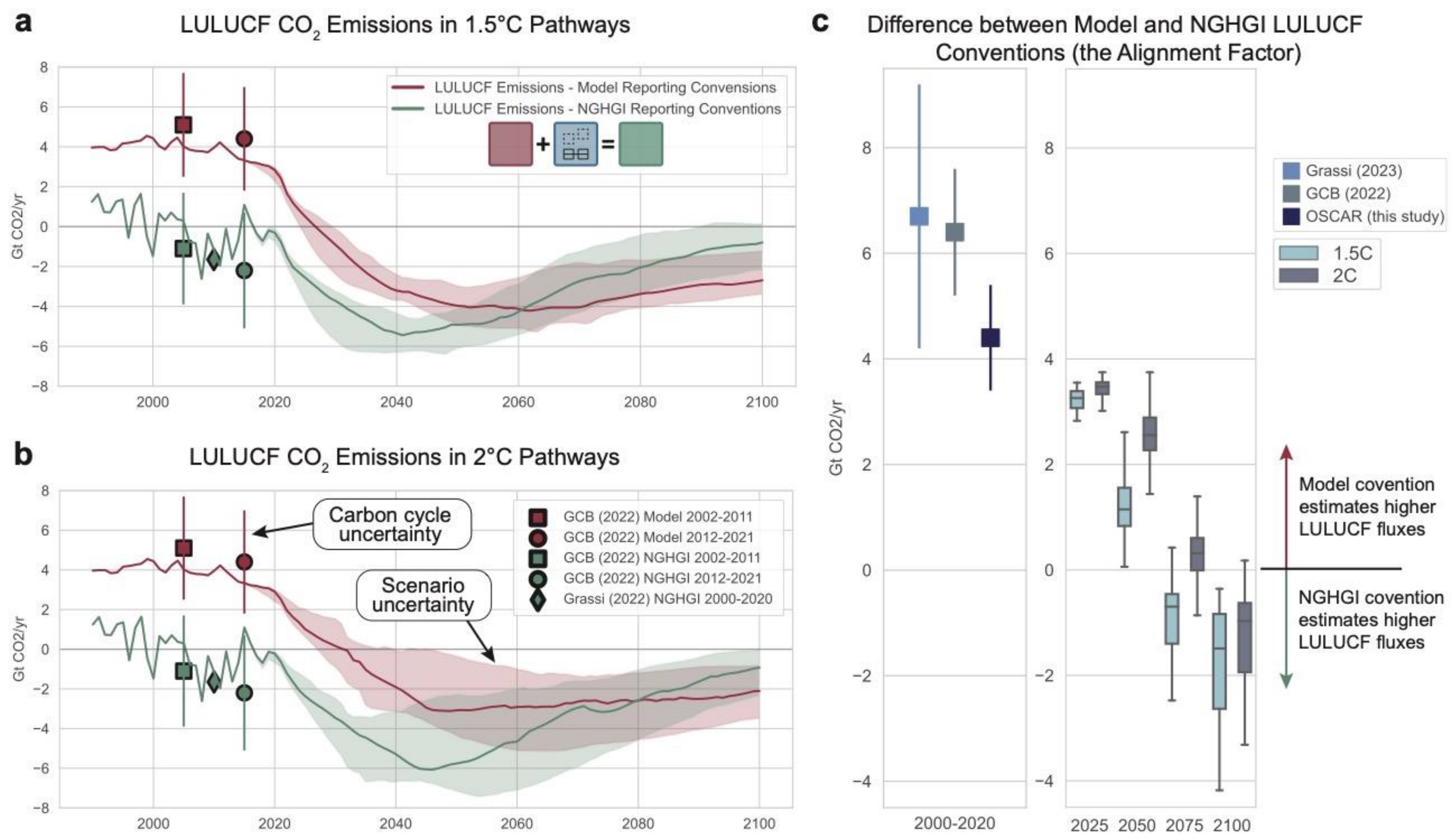

Fig. 2. Land use emissions pathways before and after alignment to match NGHGIs for 1.5°C and 2°C pathways are shown (**a, b**). Historical estimates[2,3] are displayed with carbon cycle uncertainty (1-σ), and the median of scenario pathways are shown with the scenario interquartile range in shaded plumes. Pathways consistent with model-based convention is shown in red, while the NGHGI convention is shown in green. Comparing the two conventions results in a difference between reanalyzed and NGHGI-adjusted pathways, i.e., an alignment factor, (**c**) which evolves as a function of the strength of land-based climate mitigation.

3. Aligned Pathways Result in More Ambitious Global Benchmarks when using Inventory Accounting

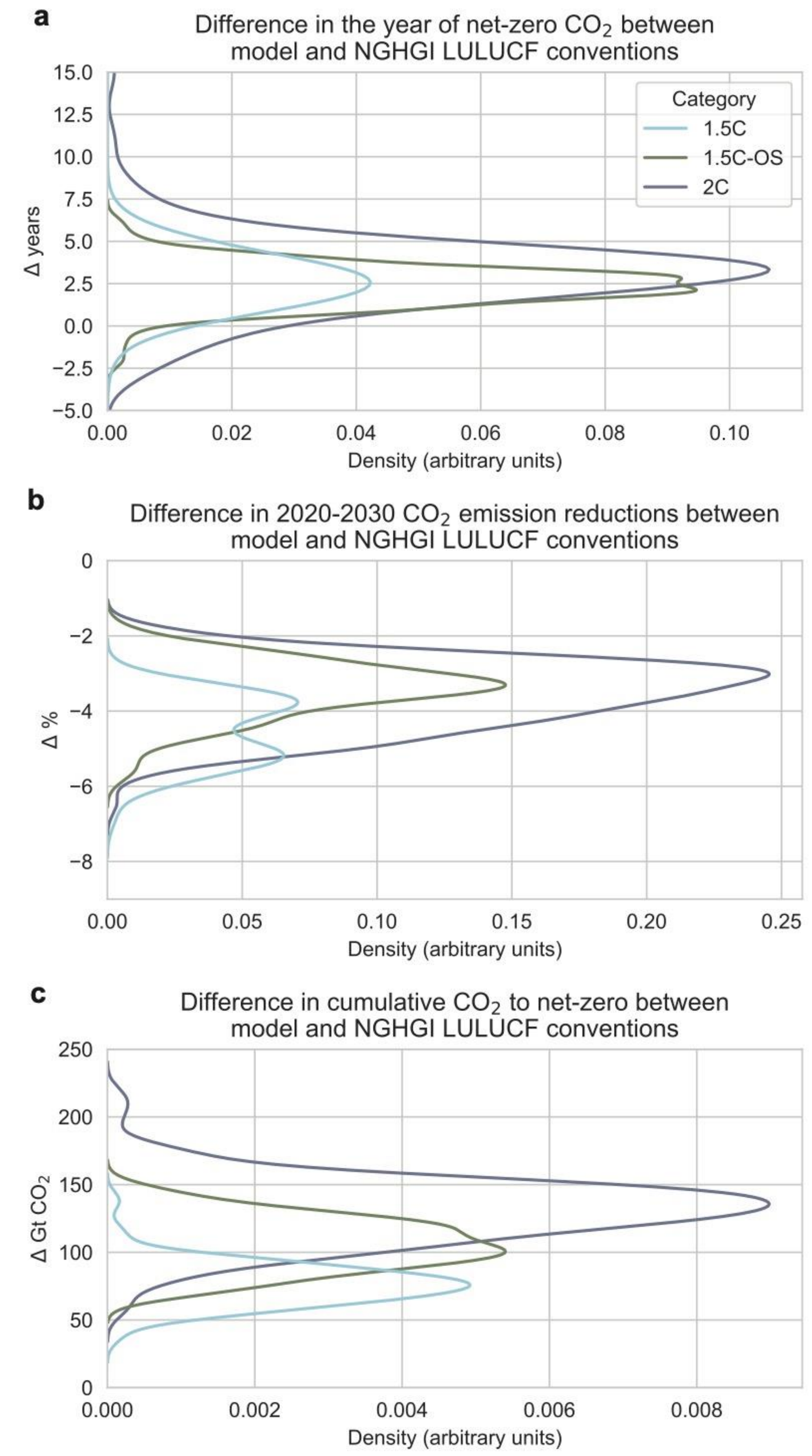

Fig 3. Scenario-wise distributions of the estimated change in the net-zero CO_2 year (**a**), 2020-2030 CO_2 emission reductions (**b**), and cumulative emissions until net-zero CO_2 (**c**) between the reanalyzed model-based and NGHGI LULUCF accounting conventions are shown for 1.5°C (blue, IPCC category C1), 1.5°C-OS (green, IPCC category C2), and 2°C (purple, IPCC category C3) scenarios. A positive value indicates that the benchmark comes later (for net-zero years) or is higher (for cumulative emissions) in the model-based framework compared to the NGHGI-based framework whereas a negative value indicates the benchmark is higher in the NGHGI-based framework (for emission reductions). Across all benchmarks, NGHGI-based accounting tends to result in more stringent outcomes (earlier net-zero years, higher emission reductions, and lower cumulative emissions to net-zero CO_2 emission).

4. National and Global Effort Affects Achievement of Targets

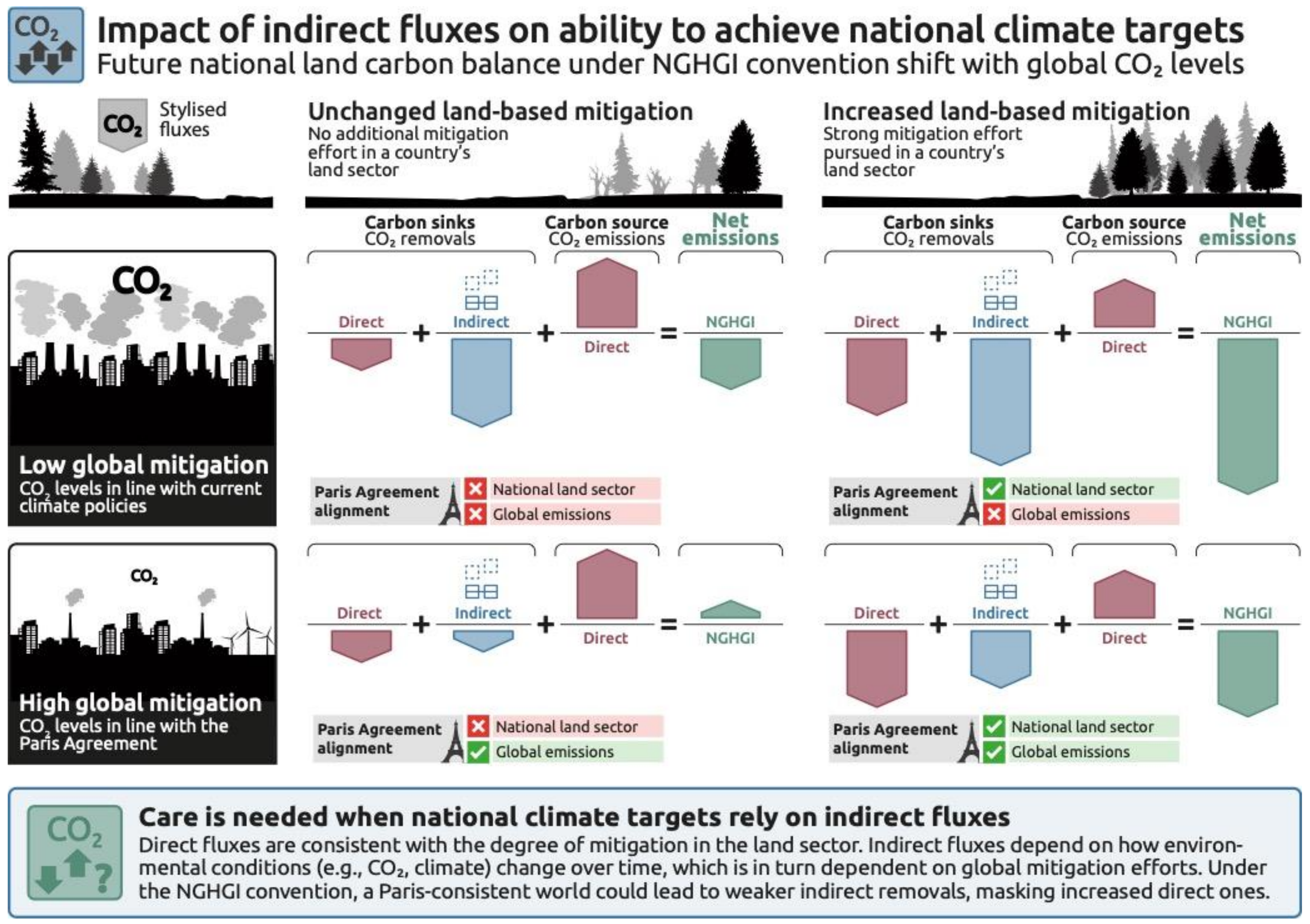

Fig 4. In a future with strong mitigation action in line with the goals of the Paris Agreement (bottom row), stabilizing or even decreasing atmospheric CO_2 will result in a weakening of the indirect sink (blue arrows), whereas a future with weak mitigation action will see increased indirect sink (as long as CO_2 fertilization dominates over climate feedbacks, top row). The direct component of LULUCF fluxes (red arrows) is entirely due to land-use management decisions (columns). Future estimates of net LULUCF emissions (green arrows) will differ between conventions dependent on how much overall mitigation occurs and how much land-based mitigation occurs, which can have unexpected consequences.

5. Inventory Methods for CDR Measurement Pose Challenges

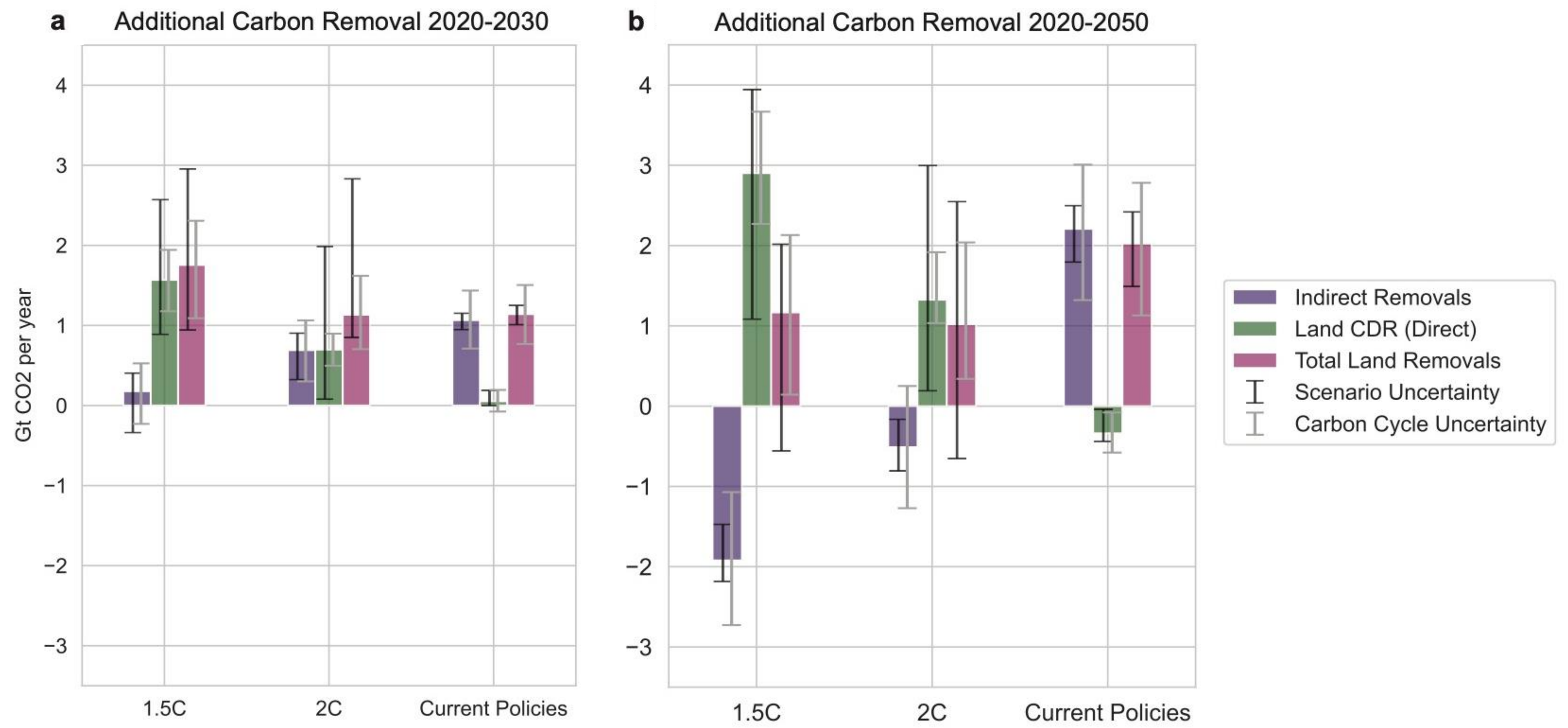

Fig 5. The direct component of land-based removal flux, which constitutes land-based CDR, and the indirect component of the removal flux evolve differently across pathways. In the near-term, until 2030, 1.5°C pathways see a strong enhancement of additional removals (pink bar) whereas 2°C pathways see a similar addition of total removals as current-policy pathways (**a**). By mid-century, additional removals in current-policy pathways out-pace both 1.5 and 2°C pathways, owing to the continued enhancement of indirect removals compared to an overall weakening of this flux in mitigation pathways (**b**). Scenario uncertainty in (**a, b**) is estimated by the interquartile range of scenario-based estimates, whereas the carbon cycle uncertainty is estimated by the interquartile range of the median ensemble of climate runs.

Conclusions

- Key global mitigation benchmarks become harder to achieve when calculated using NGHGI conventions, requiring both earlier net-zero CO_2 timing by up to 5 years and lower cumulative emissions.
- Weakening natural carbon removal processes such as carbon fertilization can mask anthropogenic land-based removal efforts, with the result that land-based carbon fluxes in NGHGIs may ultimately become sources of emissions by 2100.
- Our results are critically important to the Global Stocktake, suggesting that nations will need to increase the collective ambition of their climate targets to remain consistent with global temperature goals.

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