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Verifying emission inventories using global models

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Introduction. LULUCF emission estimates in National GHG Inventories (NGHGIs) follow the IPCC reporting guidelines. Even in Annex I countries using detailed National Forest Inventories (NFIs), updates to data and methods can lead to significant revisions, reflecting the large uncertainty in LULUCF estimates. Consequently, there is interest to use partially or fully independent data and methods to verify and improve NGHGIs. Likewise, the NGHGIs can also help improve other data and methods. Key methods used to compare with NGHGIs include bookkeeping models (BMs), Dynamic Global Vegetation Models (DGVMs), Inversion Models (IMs), and Earth Observations (EO).

Global Models. A challenge is that different methods cover different effects and land uses (Fig 1). An advantage of DGVMs is that they cover all effects (direct, indirect, natural) and land uses, but they have a poor representation of management compared to NGHGIs. DGVMs are process based and capture natural variability, making comparisons with NGHGIs more difficult. DGVMs run a variety of simulations, which is relevant for comparisons with NGHGIs:

- S0: control with pre-industrial atmospheric CO_2 and land cover,
- S1: historical changes in atmospheric CO_2 and nitrogen deposition,
- S2: S1 and climate,
- S3: S2 and changing land use and wood harvest

Grassi et al[1] (2023) have used DGVMs to map between BMs and NGHGIs and show good aggregate agreement[2], but the goal was to map between BMs (used in IPCC Assessment Reports) and NGHGIs. For this purpose, the S2 simulation was used to add indirect effects on managed land to the BMs.

If the goal is to verify NGHGIs then the S3 simulation can be used directly.

Conceptually, Grassi et al (2023) mapped NGHGI ~ BM + αS2, where α is the managed forest share. Since BM ~ S3-S2 (ignoring the Loss of Additional Sink Capacity[3]), then the NGHGI ~ (S3-S2) + αS2. If nearly all land is defined as managed (e.g., USA, EU27, China), then α =1 and NGHGI ~ S3, without the need for a mask to exclude unmanaged forests. The challenges arise when α <1, and careful disaggregation of land uses and management is needed.

Comparisons. For countries with near 100% managed land, S3 can be compared directly with NGHGIs. The agreement with the EU27 (Fig 2) is good (noting interannual variability and the variability across DGVMs), but China (Fig 3) has a larger sink in its NGHGI potentially since re/afforestation is underestimated in the input data for the DGVMs[2] (LUH2). For countries with less than 100% managed land, or to compare different areas of management requires disaggregation of S3 (re/afforestation, deforestation, harvest, HWPs). Within each DGVM, based on the internal land-use data, it should be possible to construct estimates of re/afforestation, deforestation, wood harvest, HWPs, other management, and unmanaged as a function of time, with comparable estimates provided by BMs (direct effects only) and NGHGIs. This would allow a direct comparison of NGHGIs and DGVMs using the S3 simulations and avoid the complex mapping of BMs via DGVMs using the S2 simulations.

Discussion. An advantage of DGVMs (S3) is that they measure the same effects as NGHGIs and can be compared with observations (e.g., NFIs). DGVMs can also theoretically separate direct, indirect, and natural effects, and it is expected that the importance of direct and indirect effects will vary by type of management (Fig 4). If this is the case, then disaggregating managed land (particularly forest remaining forest) into management types may offer a pathway to bring more consistency across the science and inventory communities (Fig 5) using clear definitions of each type of management. We recommend that BMs, DGVMs, and NGHGIs all routinely report emissions allocated to different management uses and areas. This would require NGHGIs to disaggregate 'forest remaining forest' and DGVMs to devise methods to allocate emissions to different types of management through time[4].

References. [1]Grassi et al 2023, *Earth System Science Data*, [2]Schwingshackl et al 2023, *One Earth*, [3]Obermeier et al 2021, *Earth System Dynamics*, [4]Pongratz et al 2014, *Earth System Dynamics*.

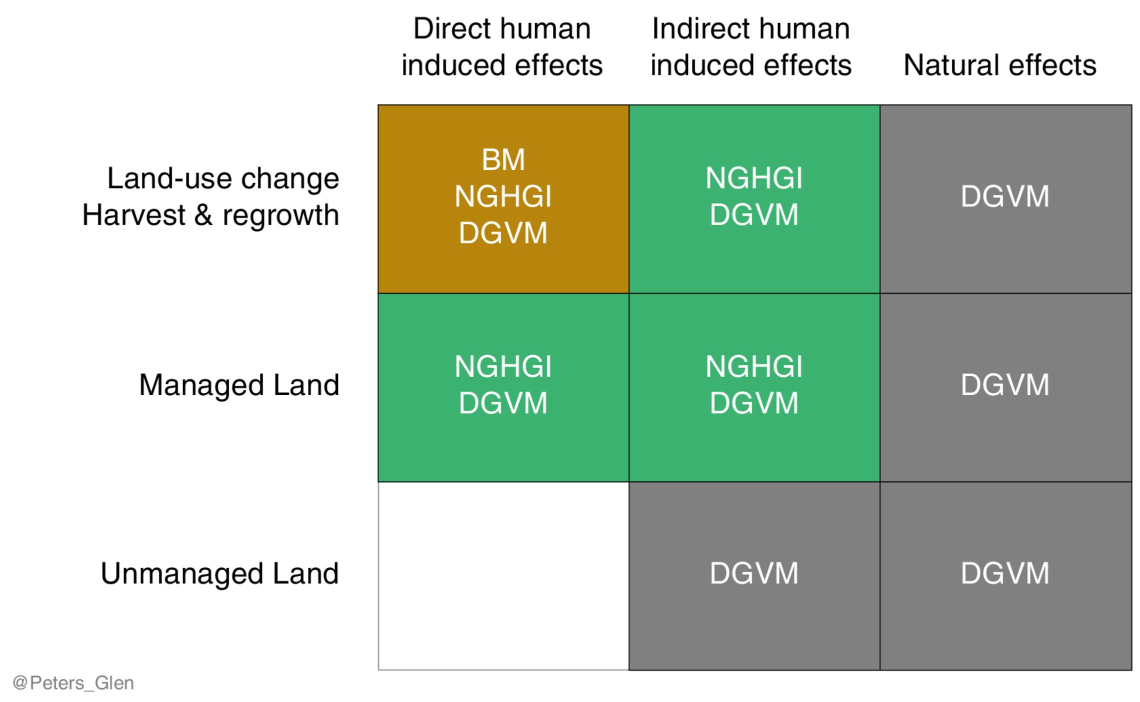

Figure 1 (Schematic)

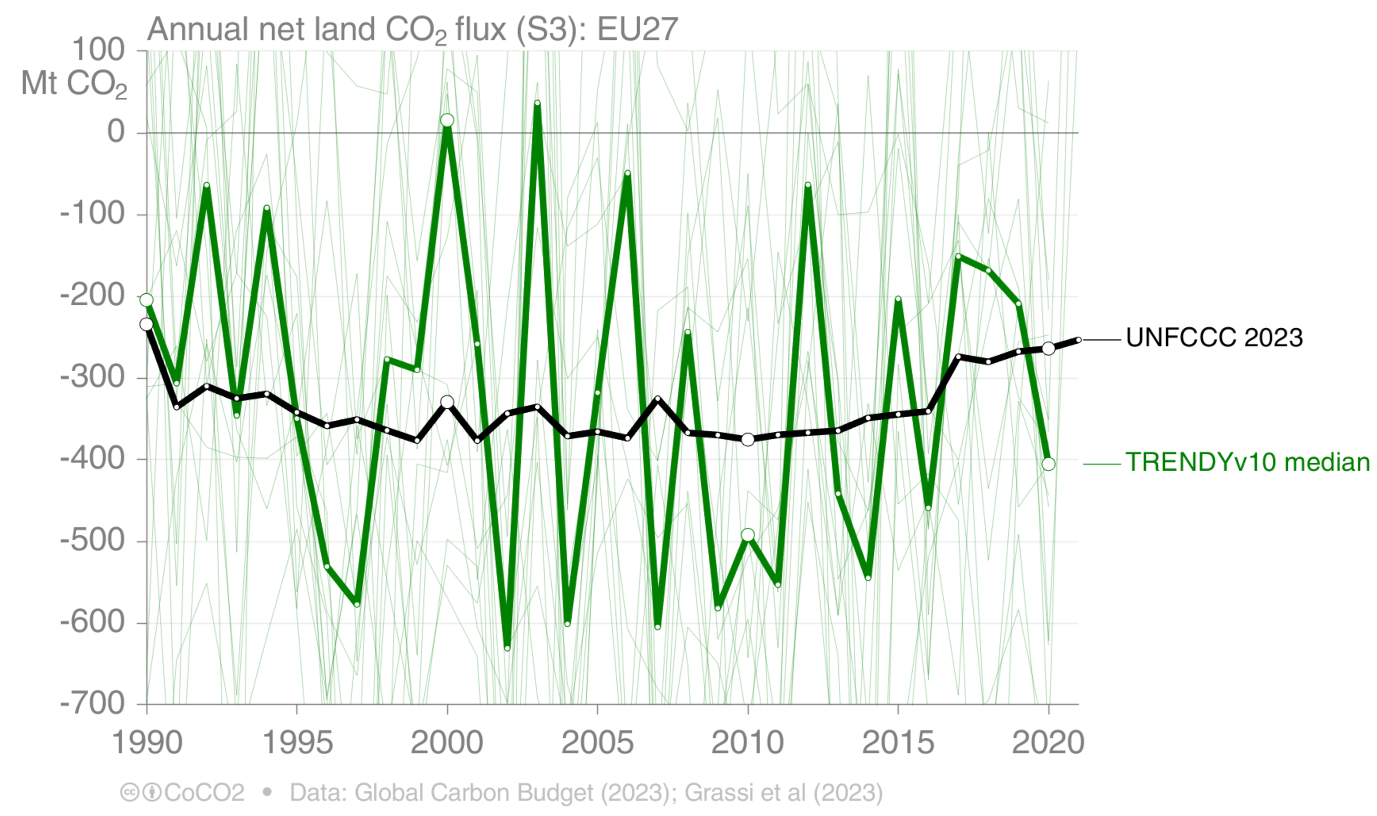

Figure 2

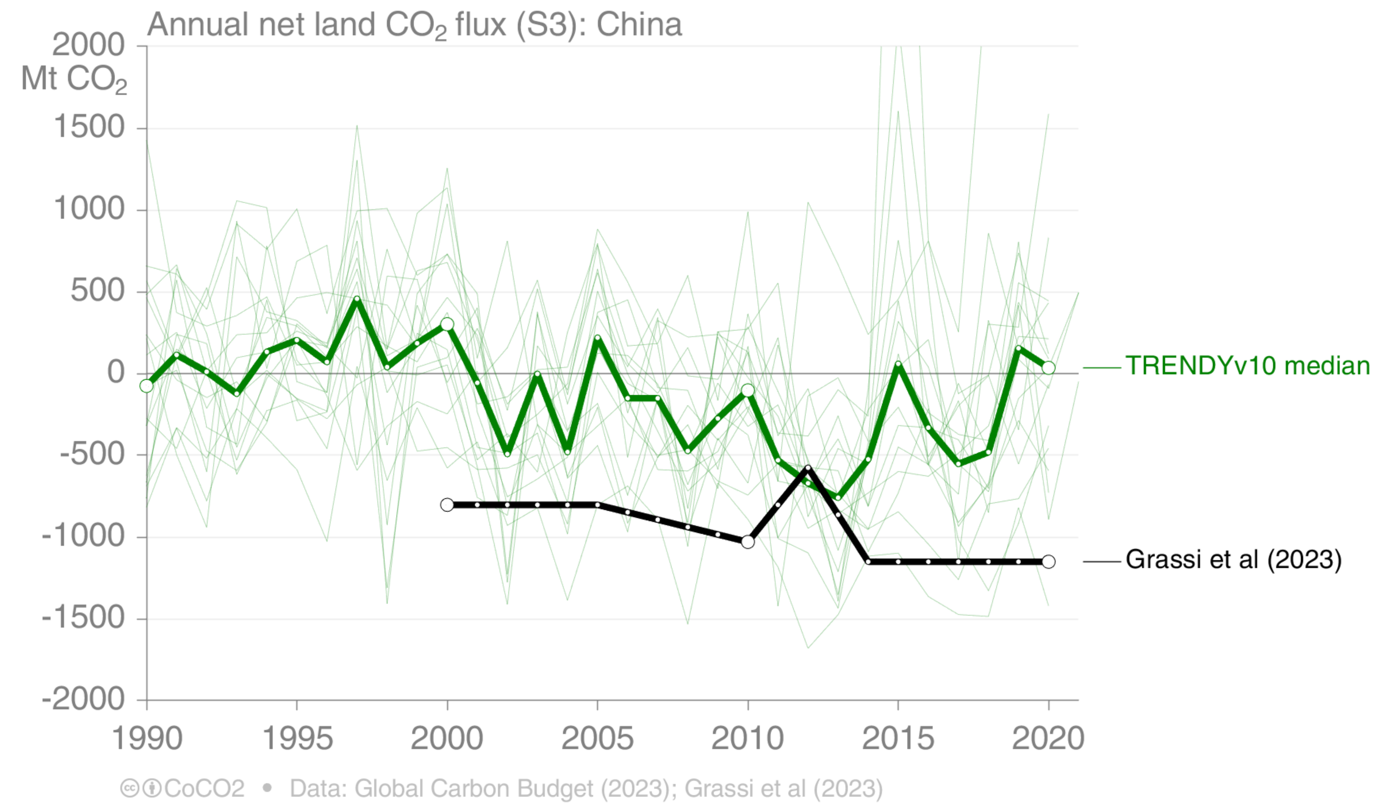

Figure 3

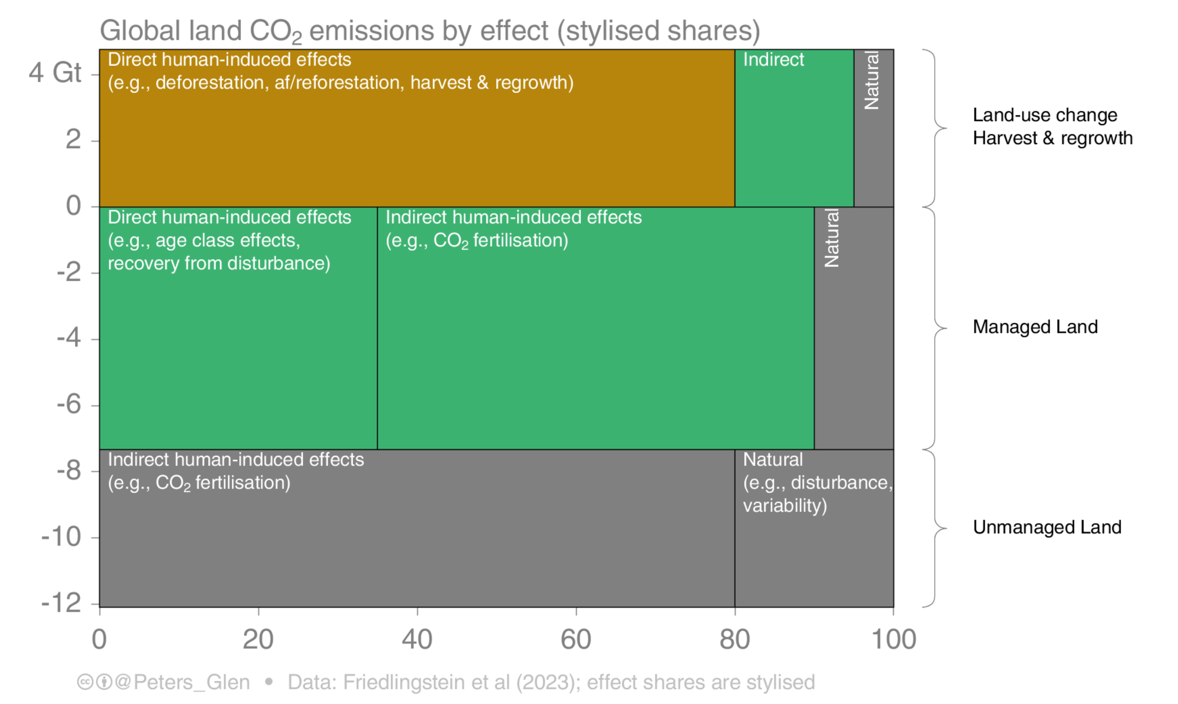

Figure 4 (Stylised)

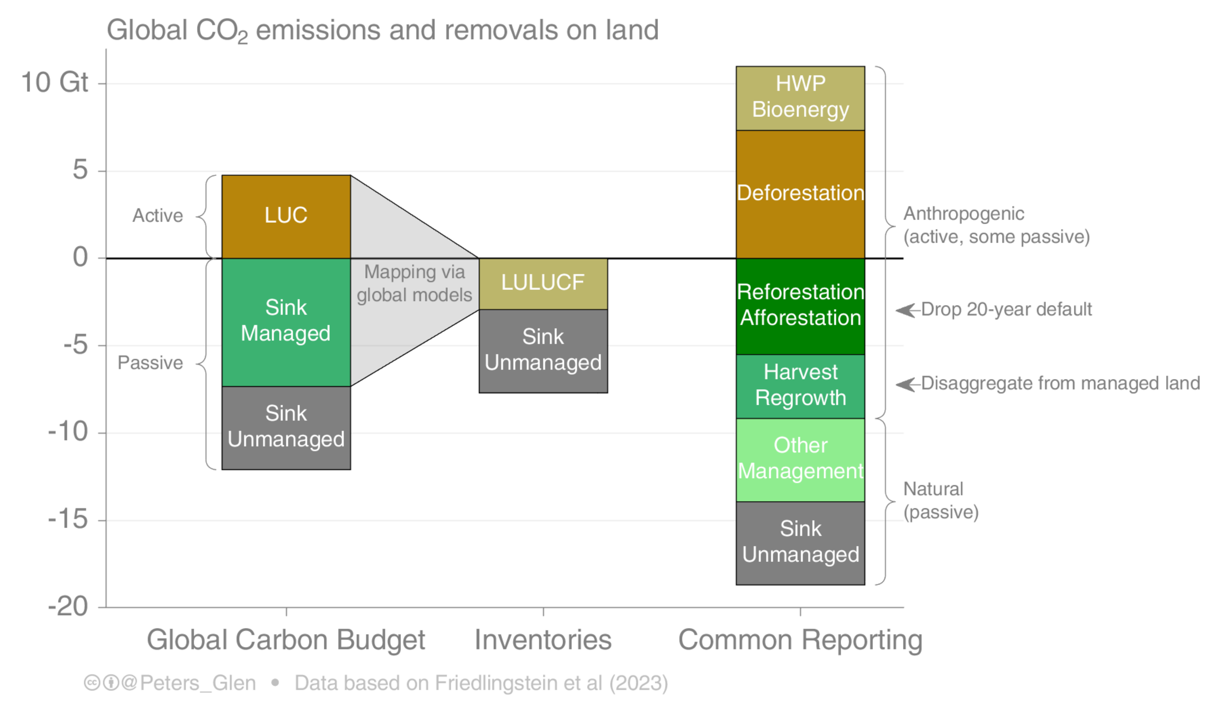

Figure 5 (Stylised)

Active: exogenous input into carbon cycle model

Passive: Response of the carbon cycle (e.g., CO_2 fertilisation)