Land & Carbon Lab

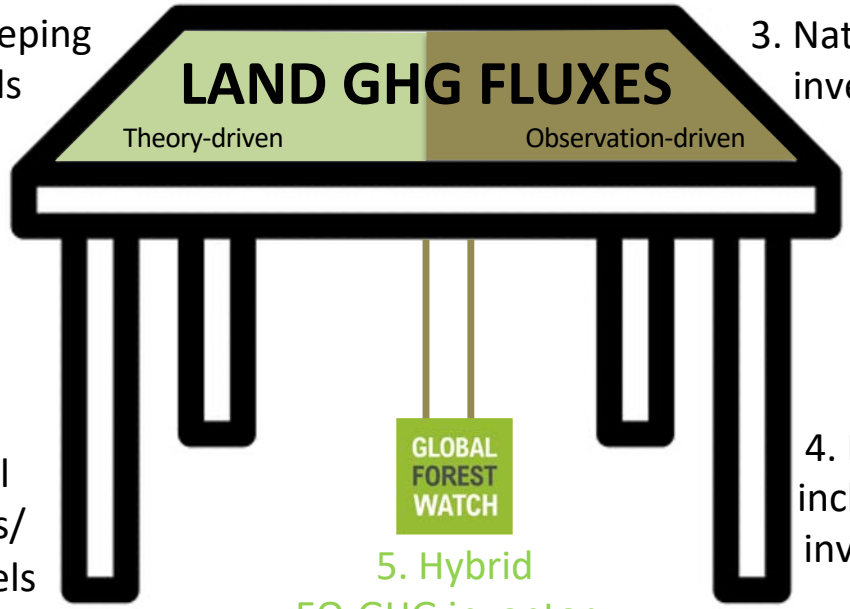
GLOBAL FOREST WATCH

Revised geospatial monitoring of 21st century forest carbon fluxes by Global Forest Watch

WORLD RESOURCES INSTITUTE

Nancy Harris, David Gibbs, Melissa Rose
(+Giacomo Grassi, Joana Melo, Simone Rossi)

A NEW GEOSPATIAL CARBON MODELING APPROACH



1. Bookkeeping models

2. Dynamic Global Vegetation Models/ Earth System Models

3. National GHG inventories

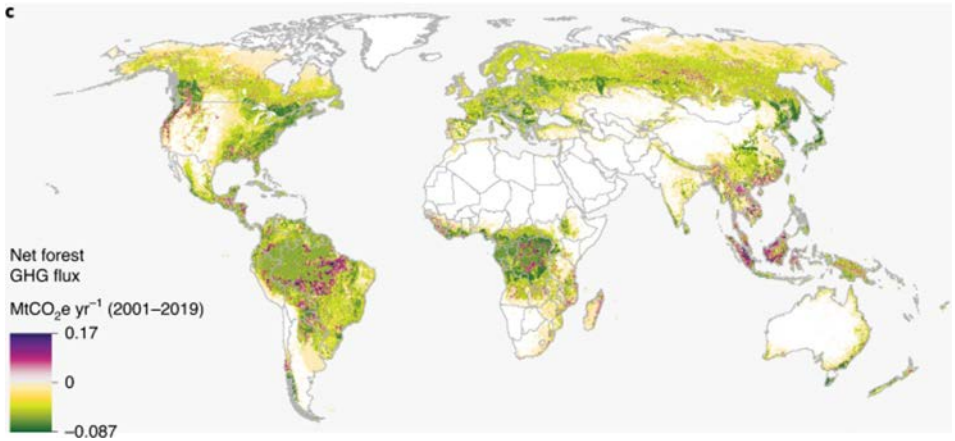
4. Earth Observation, including atmospheric inversion models and stock-changes

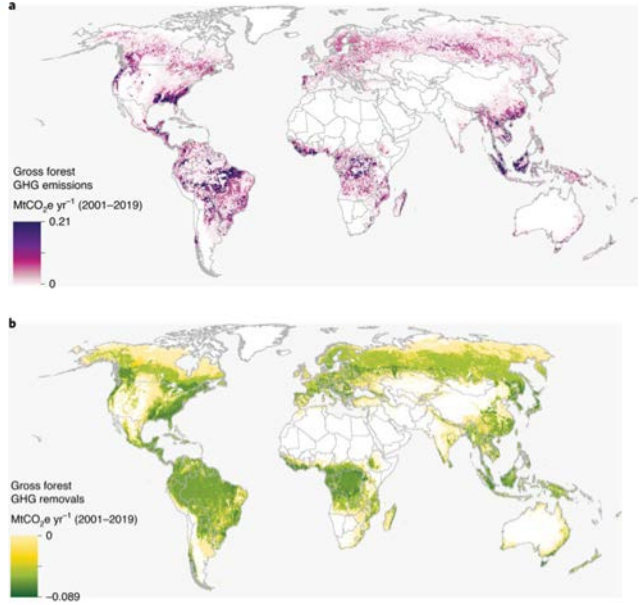
5. Hybrid EO-GHG inventory geospatial approach

GFW FOREST CARBON FLUX MODEL

Global maps of twenty-first century forest carbon fluxes

Nancy L. Harris[1], David A. Gibbs[1], Alessandro Baccini[2,10], Richard A. Birdsey[2], Sytze de Bruin[3], Mary Farina[2,11], Lola Fatoyinbo[4], Matthew C. Hansen[5], Martin Herold[3], Richard A. Houghton[2], Peter V. Potapov[5], Daniela Requena Suarez[3], Rosa M. Roman-Cuesta[6], Sassan S. Saatchi[7,8], Christy M. Slay[9], Svetlana A. Turubanova[5] and Alexandra Tyukavina[5]





Harris et al. 2021

DATA SOURCES

Model Component	Source
Forest Extent 2000	
Tree cover extent	Hansen et al. 2013
Mangrove Forest Extent	Giri et al. 2011
Tropical Humid Primary Forest Extent	Turubanova et al. 2018
Intact Forest Landscapes	Potapov et al. 2017
Plantations / Tree Crops	**Richter et al. 2024 (Spatial Database of Planted Trees v2.0)*
Peatland Extent	Miettinen et al. 2016 (Indonesia + Malaysia) **Crezee et al. 2022 (Congo Basin)* **Hastie et al. 2022 (Amazonian Peru)* Gumbrict et al. 2017 (<40 degrees North) **Xu et al. 2018 (≥40 degrees North)*
Oil Palm Extent 2000 (areas excluded from model)	Austin et al. 2017 (Indonesia) Gaveau et al. 2014 (Borneo) Miettinen et al. 2016 (Sumatra, Borneo) Gunarso et al. 204 (peninsular Malaysia)
Carbon Density 2000	
Aboveground live woody biomass density	Harris et al. 2021 (non-mangrove) Simard et al. 2008 (mangrove)
Belowground biomass density ratio	**Huang et al. 2021 (root:shoot ratio for non-mangrove forests)*
Soil organic carbon density	Hengl et al. 2017 (non-mangrove) Sanderman et al. 2018 (mangrove)
Ecological zone (for deadwood & litter)	FAO 2012
Elevation (for deadwood & litter)	Farr et al. 2007
Mean annual precipitation (for deadwood & litter)	Fick and Hijmans 2017 (WORLDCLIM)

* Updated inputs are denoted with an * and *italics*

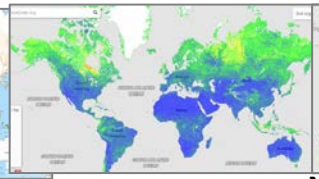
DATA SOURCES

Model Component	Source
Activity Data	
Tree cover loss	**Hansen et al. 2013 (2001-2023)*
Tree cover gain	**Potapov et al. 2022 (2000-2020)*
Burned Areas	**Tyukavina et al. 2022 (2001-2023)*
Emission Factors	
Drivers of Forest Loss	**Curtis et al. 2018 (2001-2023)*
Climate Zone	FAO 2012
Fire combustion and emission factors	IPCC 2019 Refinement, Table 2.5 and 2.6
Removal Factors	
US Forest Type	Ruefenacht et al. 2008
US Stand Age	Pan et al. 2011
US Removal Factors (by region x type x age class)	USDA FIA
Europe Forest Type	Brus et al. 2011
Europe Removal Factors (by forest type)	IPCC 2019 Refinement Table 4.11 FAO Planted Forest Thematic Study Portugal's NGHGI
Plantation Removal Factors	**Richter et al. 2024*
Mangrove Removal Factors	IPCC 2013 Wetlands Supplement, Tables 4.4 and 4.5
Agroforestry Removal Factors	IPCC 2019 Refinement Tables 5.1 and 5.3
Natural Regrowth Removal Factors (<20 years)	Cook-Patton et al. 2020
Primary Forest Removal Factors	IPCC 2019 Refinement Table 4.9
Secondary Forest Removal Factors (>20 years)	**IPCC Refinement Table 4.9*
Harvested Wood Products	
Production, import and export of sawnwood, wood-based panels and paper & paperboard	**FAOSTAT (2001-2021)*

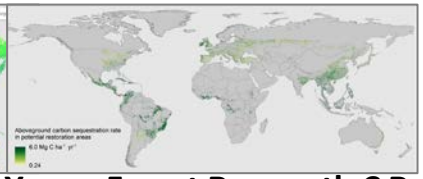
* Updated inputs are denoted with an * and *italics*

MAPPING FOREST EMISSIONS AND REMOVALS

Tree Biomass/Carbon

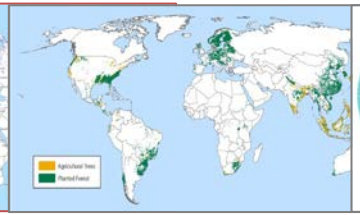


Soil Carbon

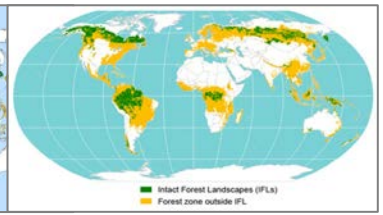


Young Forest Regrowth C Rates and IPCC Default Rates

Peatlands

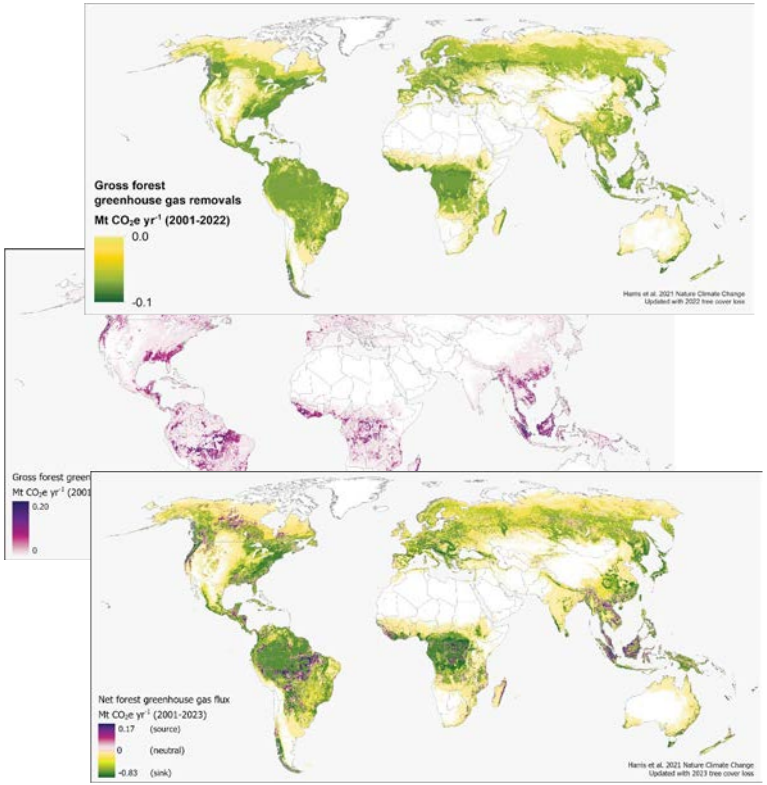


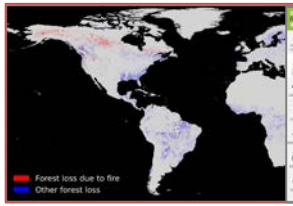
Plantations



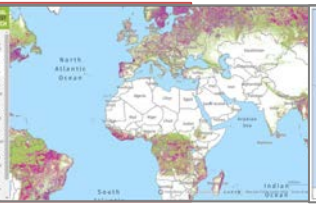
Intact Forests

IPCC rules

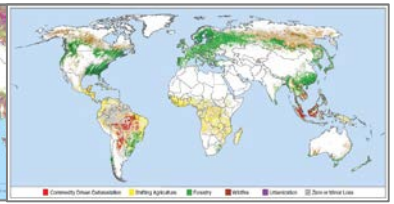




Tree cover loss from fires



Tree Cover, Loss and Gain



Drivers of Forest Loss

And many more…

Harris et al. 2021; https://www.wri.org/insights/forests-absorb-twice-much-carbon-they-emit-each-year

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GFW CARBON FLUX MODEL UPDATES

Annual updates through 2023

Tree cover loss

Drivers of tree cover loss

Tree cover loss due to fires

Revised activity data

Tree cover gain through 2020

Higher resolution burned area data

Larger peatland extent

Larger planted tree extent

Revised emission/removal factors

Root:shoot ratio map for belowground biomass

Planted tree removal factors

Global Warming Potentials

IPCC Tier 1 defaults for temperate forests

HIGH UNCERTAINTY IN TEMPERATE REMOVAL FACTORS

Domain	Ecological Zone[4]	Continent	Status/ Condition	Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]	Uncertainty	Uncertainty type	References
Temperate	Oceanic	New Zealand	Primary	0.37	±0.85	95%CI	33
			Secondary >20 years	2.12	±0.82	95%CI	33
			Secondary ≤20 years	3.12	0.83	SE	34
		Europe	All	2.3	-	-	35
		North and South America	Secondary >20 years	9.1	20.2	SD	36
			Secondary ≤20 years	6.3	7.4	SD	36
	Continental	North and South America	Secondary >20 years	3.6	15.0	SD	36
			Secondary ≤20 years	3.3	5.2	SD	36
	Mountain	North and South America	Secondary >20 years	4.4	100.7	SD	36
			Secondary ≤20 years	3.1	3.6	SD	36

Table 4.9, IPCC 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories (uncorrected)

CORRECTION = LOWER RATES + UNCERTAINTY

TABLE 4.9 (UPDATED) (CONTINUED)
ABOVE-GROUND NET BIOMASS GROWTH IN NATURAL FORESTS[1,2,3,4] (TONNES D.M. HA^{-1} YR^{-1})

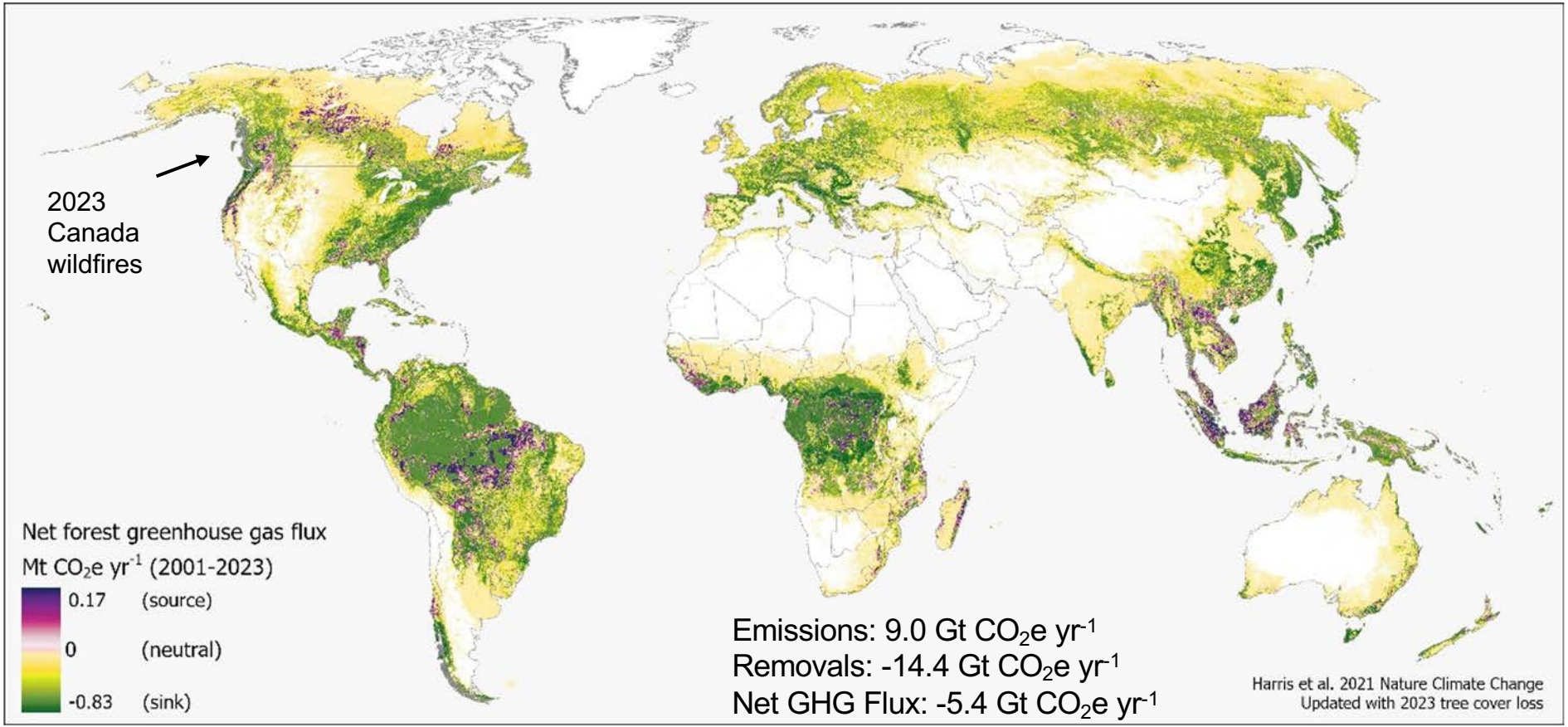
Domain	Ecological Zone[4]	Continent	Status/ Condition	Aboveground biomass growth [tonnes d.m. ha^{-1} yr^{-1}]	Uncertainty	Uncertainty type	References
			Primary	0.37	±0.85	95%CI	33
		New Zealand	Secondary >20 years	2.12	±0.82	95%CI	33
			Secondary ≤20 years	3.12	0.83	SE	34
	Oceanic	Europe	All	2.3	-	-	35
		North and South America	Secondary >20 years	4.94	0.25	SD	36
Temperate			Secondary ≤20 years	3.5	0.87	SD	36
	Continental	North and South America	Secondary >20 years	1.97	0.01	SD	36
			Secondary ≤20 years	1.96	0.04	SD	36
	Mountain	North and South America	Secondary >20 years	2.09	0.02	SD	36
			Secondary ≤20 years	1.38	0.07	SD	36

Table 4.9, IPCC 2019 Refinement to the 2006 Guidelines for National Greenhouse Gas Inventories (Corrigenda 4)

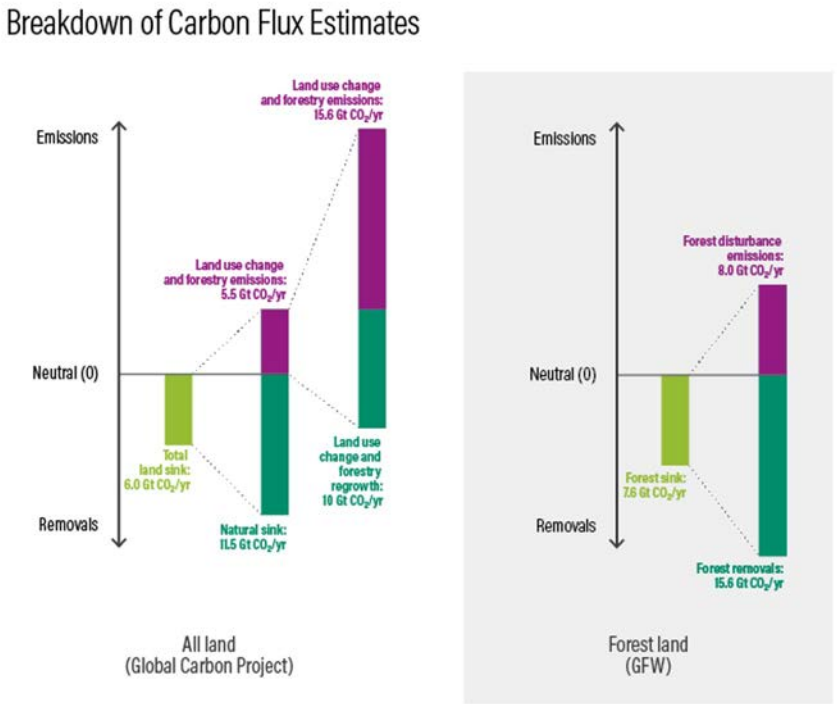
REDUCED OVERALL MODEL UNCERTAINTY

Forest GHG Fluxes Gt CO_2e yr^{-1}

Climate Domain	Gross Emissions		Gross Removals		Net GHG Flux	
	Original *(2001-2019)*	Revised *(2001-2023)*	Original *(2001-2019)*	Revised *(2001-2023)*	Original *(2001-2019)*	Revised *(2001-2023)*
Boreal	0.88±0.42	1.4±0.75	-2.5±0.96	-2.5±0.95	-1.6±1.1	-1.1±1.2
Temperate	0.87±0.60	0.93±0.62	-4.4±**48**	-3.1±**0.55**	-3.6±**48**	-2.2±**0.83**
Subtropical	1.0±0.59	1.0±0.93	-1.6±0.56	-1.7±0.56	-0.65±0.81	-0.70±0.80
Tropical	5.3±2.4	5.7±2.4	-7.0±7.6	-7.1±7.6	-1.7±8.0	-1.4±7.9
Global	8.1±2.5	9.0±2.7	-16±**49**	-14.4±**7.7**	-7.6±**49**	-5.4±**8.1**


2023
Canada
wildfires
Net forest greenhouse gas flux
Mt CO_2e yr^{-1} (2001-2023)
0.17 (source)
0 (neutral)
-0.83 (sink)
Emissions: 9.0 Gt CO_2e yr^{-1}
Removals: -14.4 Gt CO_2e yr^{-1}
Net GHG Flux: -5.4 Gt CO_2e yr^{-1}
Harris et al. 2021 Nature Climate Change
Updated with 2023 tree cover loss

COMPARISON TO GLOBAL CARBON BUDGET



Source: Harris et al. (2021), Global Carbon Project.

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Comparison through 2019

https://www.globalforestwatch.org/blog/data-and-tools/forest-carbon-flux-data-explained/

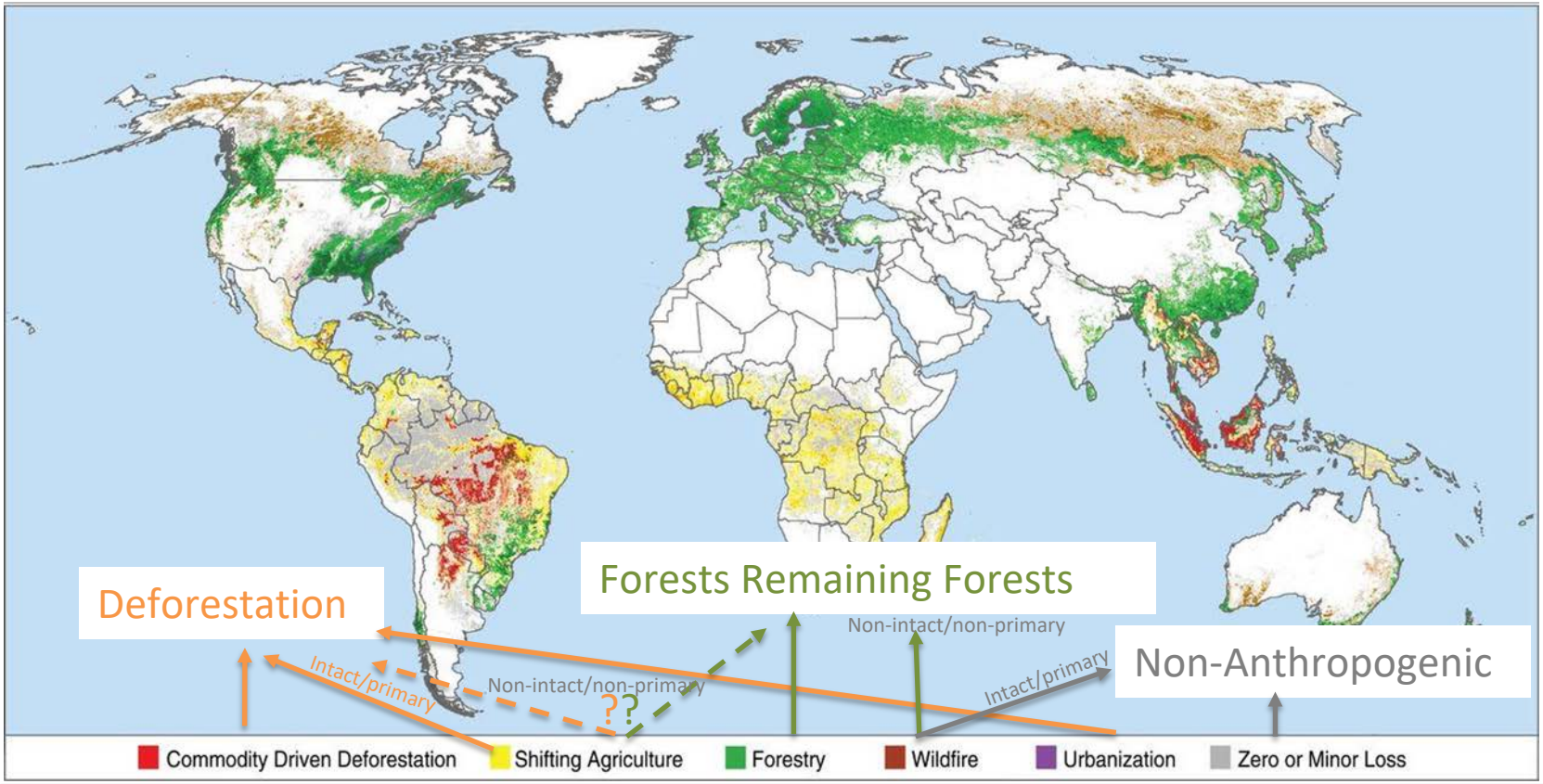
UPDATED COMPARISON TO GLOBAL CARBON BUDGET

Global Carbon Budget, 2001-2022 (Gt CO_2 yr^{-1})

Global Carbon Project		**Global Forest Watch**	
Sources			
Fossil fuel emissions and industrial processes	33.0	Fossil fuel emissions and industrial processes	33
Land-use change (net, anthropogenic)	4.9	Forests (gross, all observed disturbances)	8.6
Total Sources	**38.0**		**41.6**
Sinks			
Atmospheric Growth	17.2	Atmospheric Growth	17.2
Ocean Sink	9.5	Ocean Sink	9.5
Land Sink (net, non-anthropogenic)	11.4	Forests (gross, all forests)	14.5
Cement Carbonization	0.6	Cement Carbonization	0.6
		Harvested Wood Products	0.20
Total Sinks	**38.6**		**41.9**
Land (net, all land)	**-6.4**	**Forests (net, all forests)**	**-6.1**
Budget Imbalance	-0.7	Budget Imbalance	-0.3

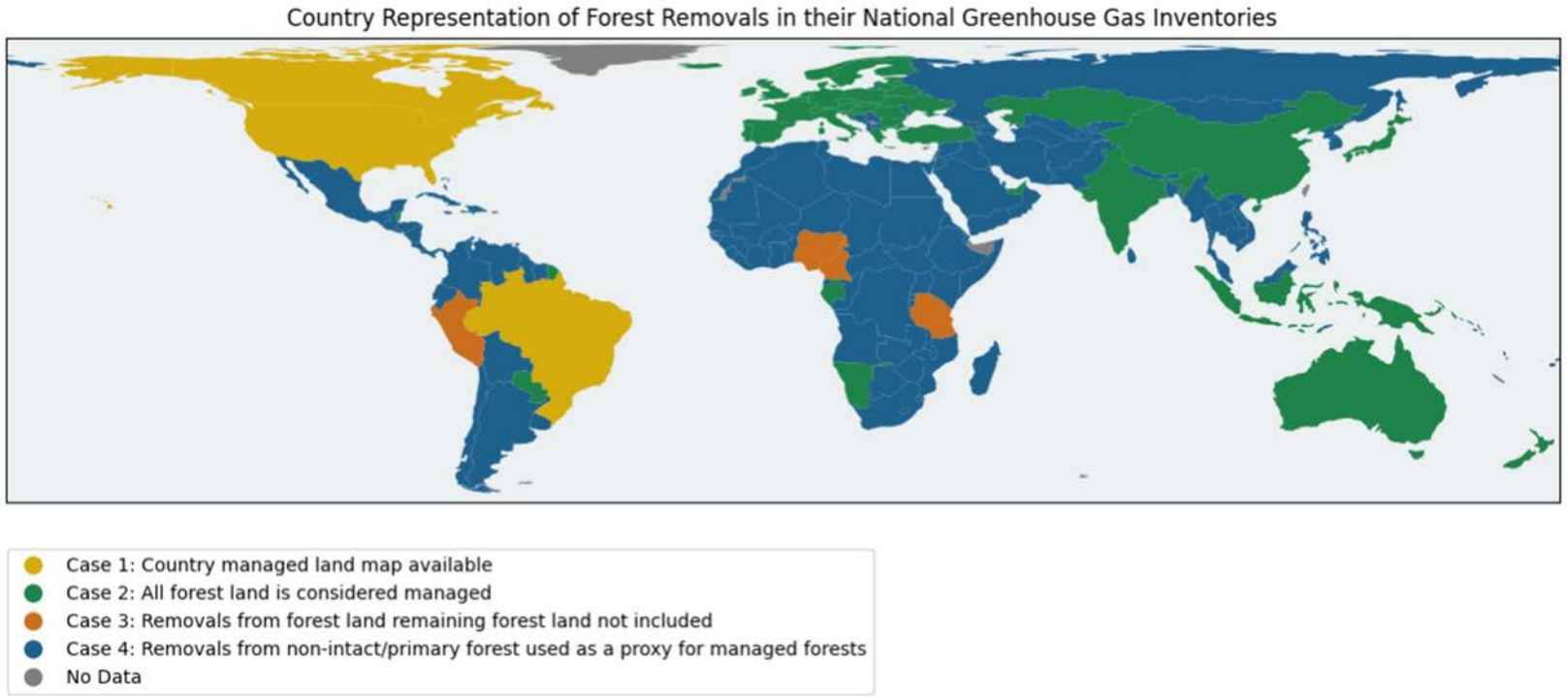
Gibbs et al. (in prep)

COMPARISON TO NATIONAL GHG INVENTORIES



Curtis et al. 2018

COMPARISON TO NATIONAL GHG INVENTORIES



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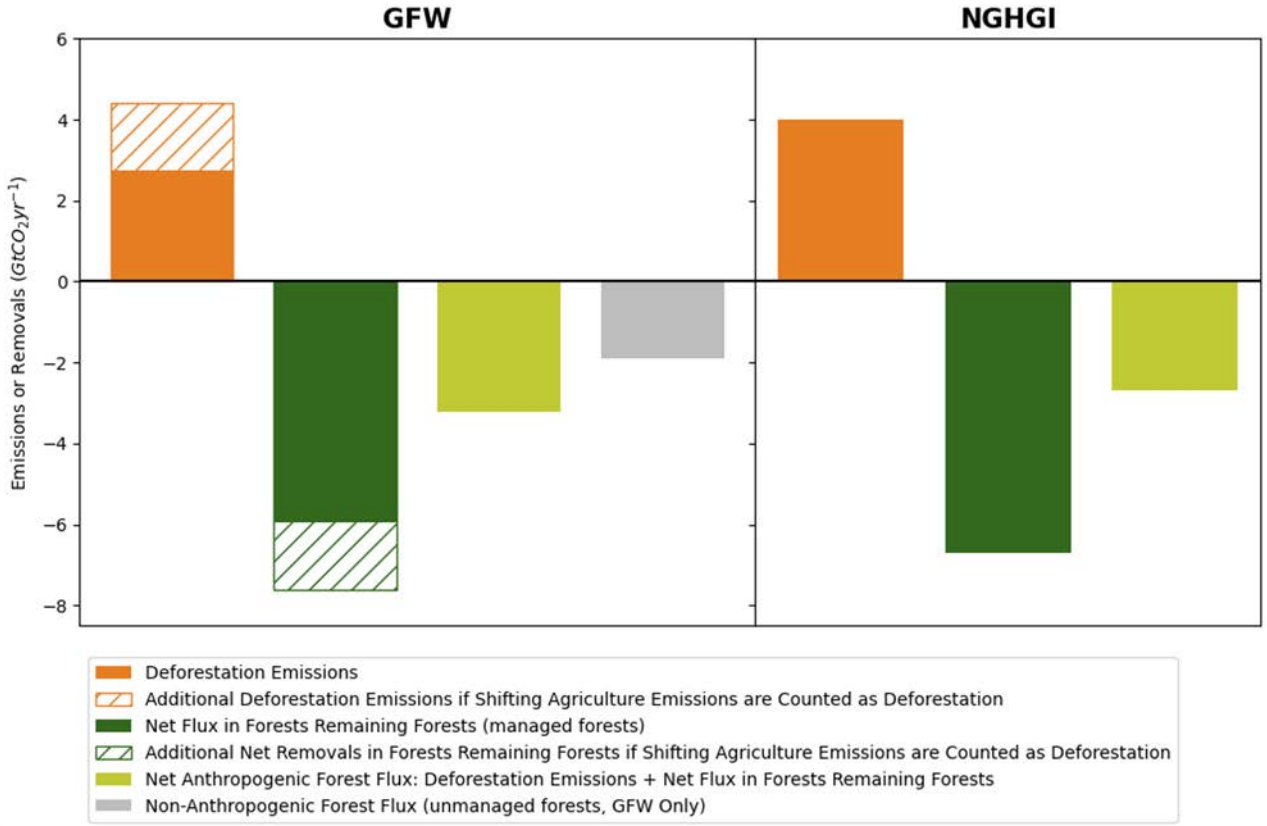
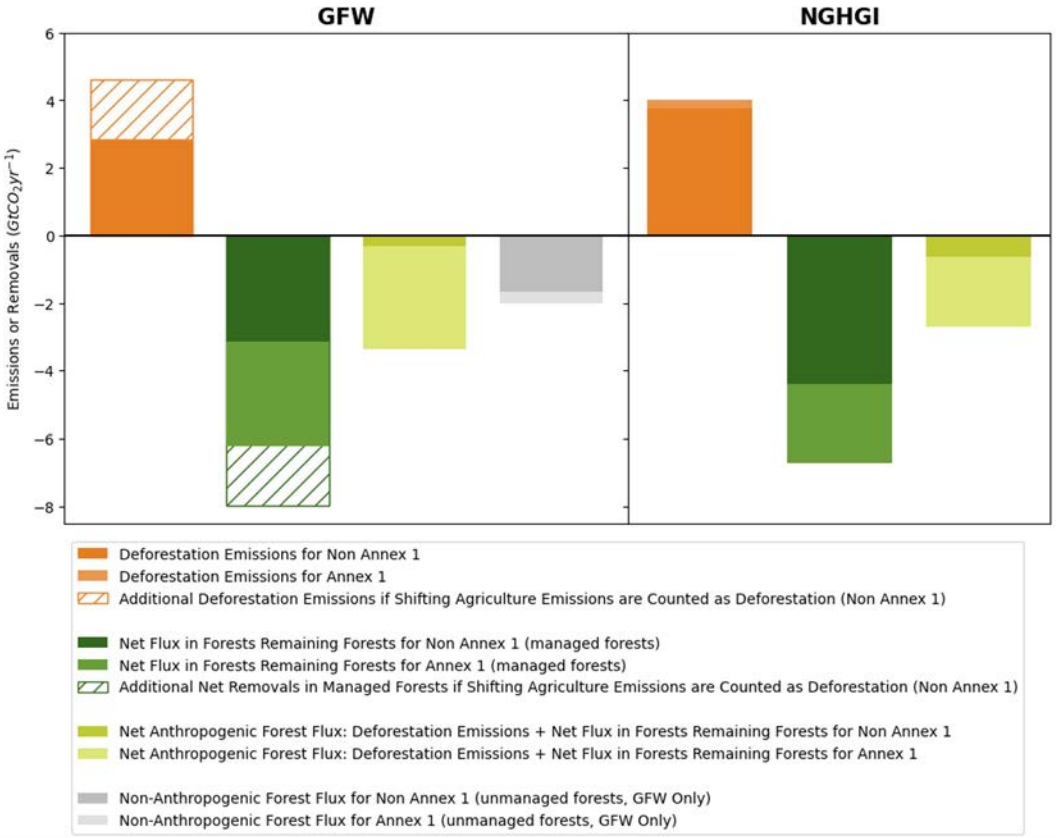
COMPARISON TO NATIONAL GHG INVENTORIES



Data are preliminary (Gibbs et al. in preparation)

COMPARISON TO NATIONAL GHG INVENTORIES



Data are preliminary (Gibbs et al. in preparation)

CONCLUSIONS AND NEXT STEPS

- There is high and continually growing demand for GHG monitoring across the world's lands
- A consistent global approach to mapping emissions and removals separately highlights land's full GHG contribution across different geographies
- Flexible, operational framework enables numerous possibilities for aggregation (or disaggregation) of results for areas of interest, comparability with other data sources, and more
- Future data improvements should further reduce uncertainties:
  - Higher spatial and temporal resolution of **forest carbon removals** (Liang et al. in prep)
  - **Annual** tree cover extent, loss *and* gain (Potapov et al. in prep)
  - Improved **mangrove** activity data (Bunting et al. in prep)
  - Higher resolution and more detailed **drivers of forest disturbance** map (Sims et al. in prep)
  - Improved **soil carbon stock change** map (Hengl et al. in prep)
  - Improved **organic soil drainage emissions** map (Glen et al. in prep)
  - Expansion of framework **from forests to all AFOLU**

Thank you

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www.globalforestwatch.org