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RECCAP2-Climate Space

esa

Global Land Carbon Budget & Attribution To Regional Drivers

Project Lead: Philippe Ciais
Presenter: Stephen Sitch

LSCE · INRAE · CITEPA · Estellus · KAYRROS · cmcc · Brockmann Consult GmbH

Technical University of Munich · Universität Leipzig · University of Copenhagen · Université Libre de Bruxelles · Universidad de Alcalá · Stockholm University · University of Exeter

History of RECCAP2

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Global CO_2 budget
Global CH_4 budget
Global N_2O budget

Climate Space

'Cross ECVs
Six regional case studies
high resolution estimates
Top down / Bottom up
CO2 & CH4
New regional EO products Pre-operational system
Hands on work with inventory agencies

RECCAP-3
2025-
Global Stock Stake 2028

RECCAP-2
2019-Ongoing

CCI-phase 2
'Attribution
National scale
CO2 & CH4
2 global datasets'

CCI-phase 1
'Top-down / bottom up
Stock change/ fluxes

Pre-CCI Project ECV
'Fluxes mean and variability
CO_2 only'

RECCAP-1
< 2019

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Key scientific achievements : 15 Nature family papers
A few more in the pipeline …

nature geoscience

Article

https://doi.org/10.1038/s41561-023-01274-4

Global increase in biomass carbon stock dominated by growth of northern young forests over past decade

PNAS

RESEARCH ARTICLE | ENVIRONMENTAL SCIENCES

Climatic and biotic factors influencing regional declines and recovery of tropical forest biomass from the 2015/16 El Niño

Hui Yang, Philippe Ciais, Jean-Pierre Wigneron, Jérôme Chave, Oliver Cartus, Xiuzhi Chen, Lei Fan, Julia K. Green, Yuanyuan Huang, Emilie Joetzjer, Heather Kay, David Makowski, Fabienne Maignan, Maurizio Santoro, Shengli Tao, Liyang Liu and Yitong Yao

communications
earth & environment

ARTICLE

OPEN

Synthesis of the land carbon fluxes of the Amazon region between 2010 and 2020

Thais M. Rosan, Stephen Sitch, Michael O'Sullivan, Luana S. Basso, Chris Wilson, Camila Silva, Emanuel Gloor, Dominic Fawcett, Viola Heinrich, Jefferson G. Souza, Francisco Gilney Silva Bezerra, Celso von Randow, Lina M. Mercado, Luciana Gatti, Andy Wiltshire, Pierre Friedlingstein, Julia Pongratz, Clemens Schwingshackl, Mathew Williams, Luke Smallman, Jürgen Knauer, Vivek Arora, Daniel Kennedy, Hanqin Tian, Wenping Yuan, Atul K. Jain, Stefanie Falk, Benjamin Poulter, Almut Arneth, Qing Sun, Sönke Zaehle, Anthony P. Walker, Etsushi Kato, Xu Yue, Ana Bastos, Philippe Ciais, Jean-Pierre Wigneron, Clement Albergel & Luiz E. O. C. Aragão

nature geoscience

Article

Siberian carbon sink reduced by forest disturbances

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Check for updates

Lei Fan, Jean-Pierre Wigneron, Philippe Ciais, Jerome Chave, Martin Brandt, Stephen Sitch, Chao Yue, Ana Bastos, Xin Li, Yuanwei Qin, Wenping Yuan, Dmitry Schepaschenko, Liudmila Mukhortova, Xiaojun Li, Xiangzhuo Liu, Mengjia Wang, Frédéric Frappart, Xiangming Xiao, Jingming Chen, Mingguo Ma, Jianguang Wen, Xiuzhi Chen, Hui Yang, Dave van Wees & Rasmus Fensholt

ARTICLE

OPEN

Large carbon sink potential of secondary forests in the Brazilian Amazon to mitigate climate change

Viola H. A. Heinrich, Ricardo Dalagnol, Henrique L. G. Cassol, Thais M. Rosan, Catherine Torres de Almeida, Celso H. L. Silva Junior, Wesley A. Campanharo, Joanna I. House, Stephen Sitch, Tristram C. Hales, Marcos Adami, Liana O. Anderson & Luiz E. O. C. Aragão

nature sustainability

ANALYSIS

OPEN

Doubling of annual forest carbon loss over the tropics during the early twenty-first century

Key contribution to GCP RECCAP-2 protocols and synthesis
Inversions for the 2023 global stock-stake : Deng et al. , Byrne et al. 2022
New datasets : L-VOD processing, inundated areas
New methodologies : loss and recovery C budgeting models
Exchange with IPCC task force on national GHG inventories (workshops in 2023 and 2024)

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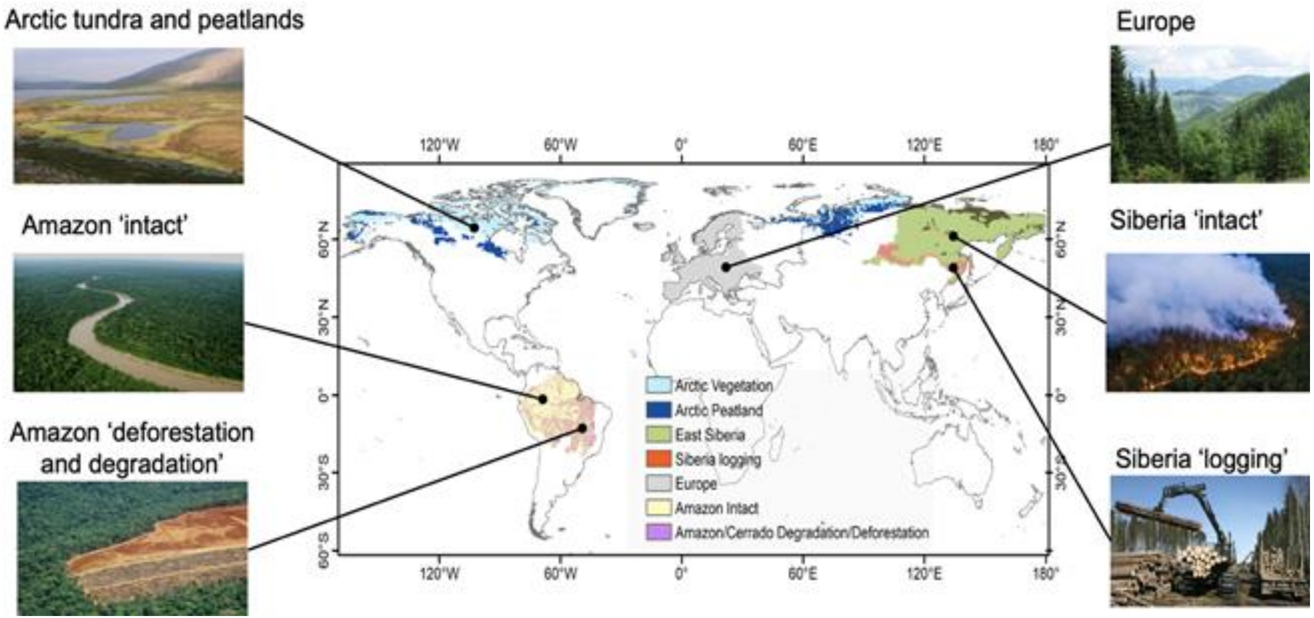
GHG 'hotspots'

- Assessment of GHG gross and net fluxes for six case study regions
- Top down + bottom-up estimates using EO will be compared and reconciled with inventories.
- These regional case studies are completed by the collection and analysis of global ECVs aiming to reduce the uncertainty on the global biomass carbon change and methane budgets
- **This project integrates across CCI ECVs**

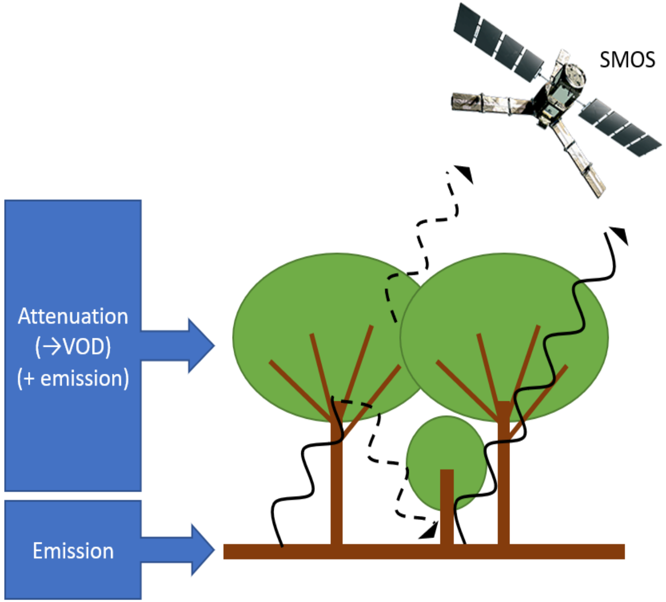


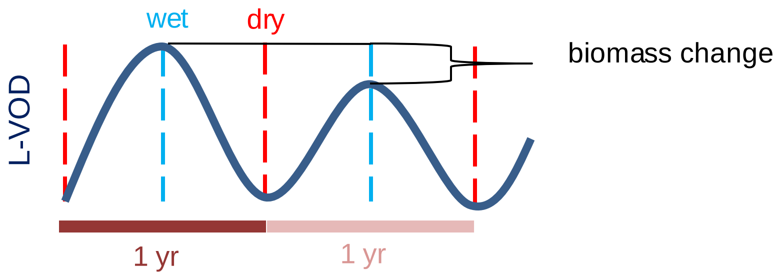
Case study regions - Amazon

Case study region		Importance for the land C budget	Approach used in this project	Existing ECV input data	New ECV datasets produced in the project
1	Amazon 'deforestation and degradation' University of Exeter	Brazil is currently the largest contributor of land-use emissions, representing 17%-29% of the global total (Rosan et al., 2021), as a result of large-scale deforestation in the Amazon. F Forest degradation through fire and selective logging is underreported (Silva Junior et al., 2021) but associated emissions can exceed those from deforestation (Aragao et al., 2018, Fawcett et al., 2023).	Expand the application of the fire carbon book-keeping model developed in CCI RECCAP2-A to the whole of the Amazon Develop a new wood density product across the basin, by mapping a ubiquitous tree species characteristic of forest disturbance combining deep-learning and remote -sensing. Aid disturbance and biomass mapping.	FireCCISFD CCI Biomass	Extension of the FireCCISFD time series and product for southern Amazonia over the domain from the HRLC project. (UAH)
2	Amazon 'intact forest' INRAE	Globally, Amazon forest accounts for about 40% (140 GtC) of the C stocks of forests and 25% (93 GtC) of AGB (Pan et al., 2011). Intact Amazon forests have been exposed to severe drought and mortality during the previous years (El Niño) Exposure to wind blowdown events disturbances in central and north Eastern Amazon intact forests	Top-down approach based on L-VOD for estimating the net annual C balance of AGB at 25 km Disaggregation attempt of L-VOD derived forest C losses and gains at 100 m from a statistical downscaling model Attribution of C loss to fires and other natural disturbances (wind blowdowns) & attribution of C gain to climate, vegetation and soil parameters	FireCCISFD CCI Biomass CCI Land temperature CCI Soil moisture	L-VOD derived AGB changes over 2010-2021 for southern Amazonia, including corrections of moisture content, roughness and albedo (INRAE) Map of attribution of C losses and gains to natural disturbances, vegetation and soil parameters over 2010-2021 (INRAE) **High resolution annual maps of forest height & AGB in Option B** **Full GHG budget of inland waters in Option C**

L-band Vegetation Optical Depth (L-VOD)

- SMOS measurements of L-band microwave emissions can be used to derive VOD which is not fully attenuated even by high biomass
- How much is attenuated depends on the amount of vegetation but also on its water content
- However, **low resolution (~25 km) means it aggregates many processes (but from 2011 onwards)**

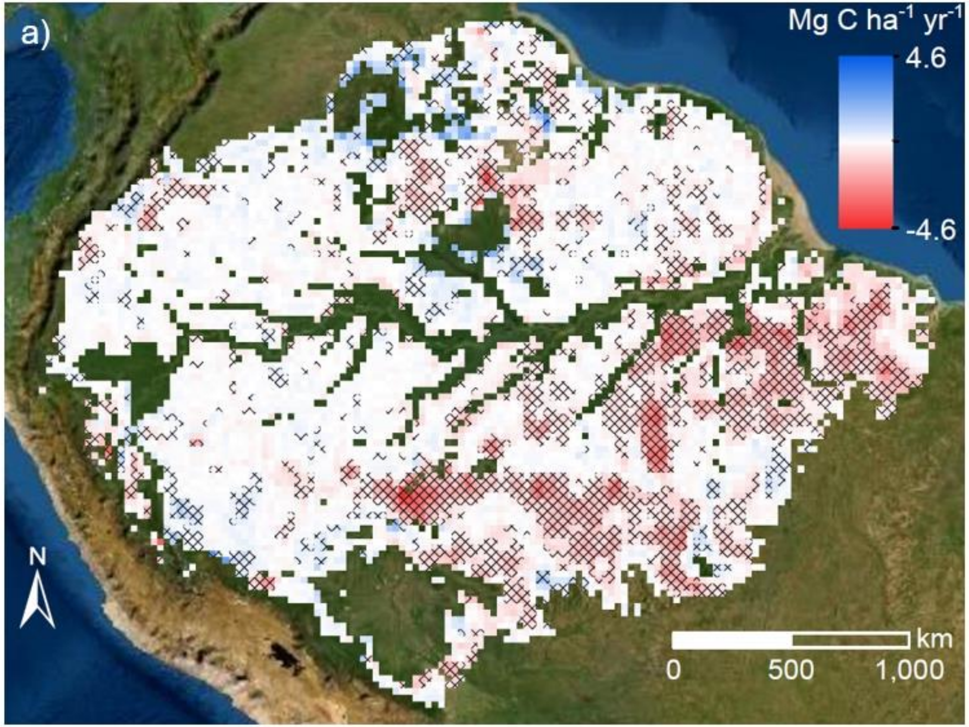




Fawcett et al., GCB, 2022

Trends in Amazon AGC using L-VOD

2011-2019

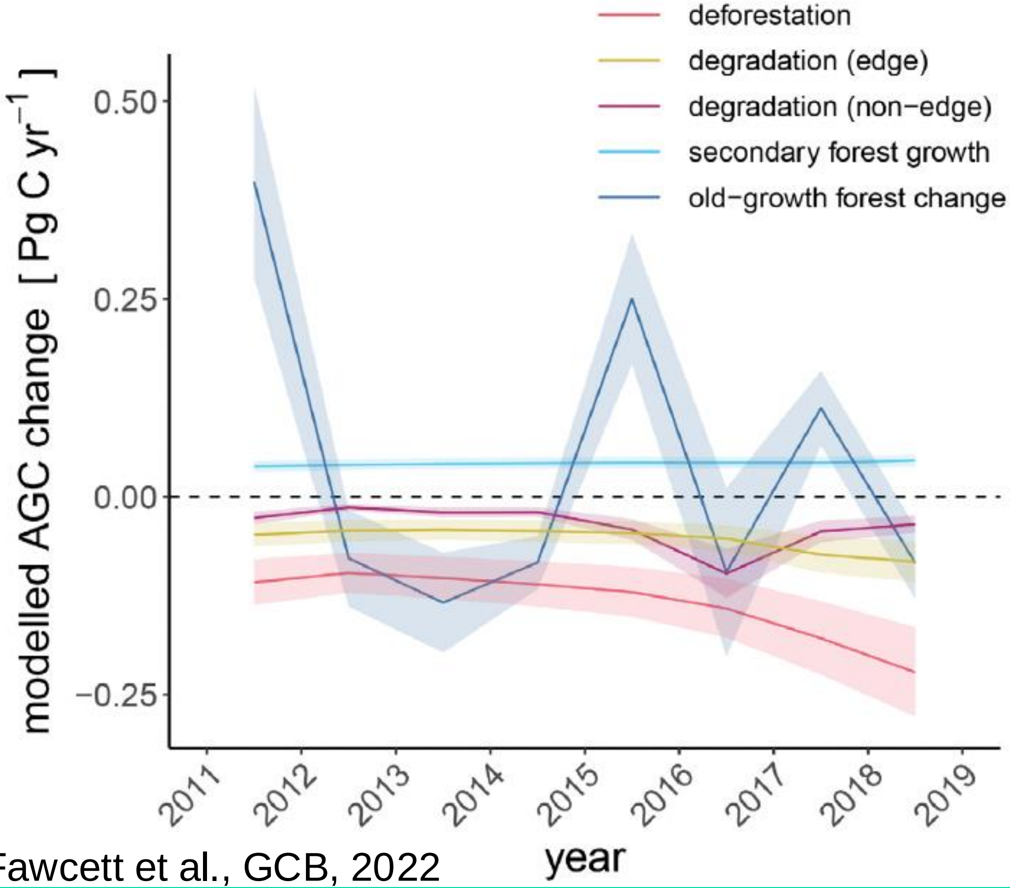


- Negative trends associated with deforestation regions
- Areas of significant loss are ~5 times greater than those of gain
- Recovery observed in regions in South-West, impacted by drought in preceding years

Fawcett et al., GCB, 2022

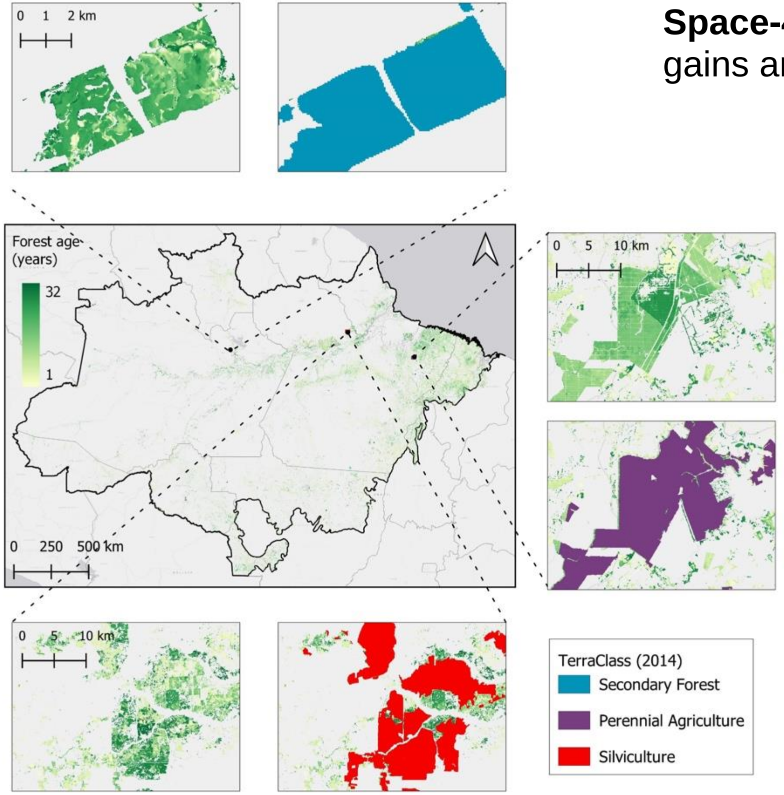
Declining Amazon biomass due to deforestation and subsequent degradation losses exceeding gains

- Increase of deforestation and associated degradation losses since 2012 greatly outweigh secondary forest gains.
- Degradation accounted for 40% of gross losses.
- Old-growth forests show a net loss of AGC between 2012 and 2019.



Fawcett et al., GCB, 2022

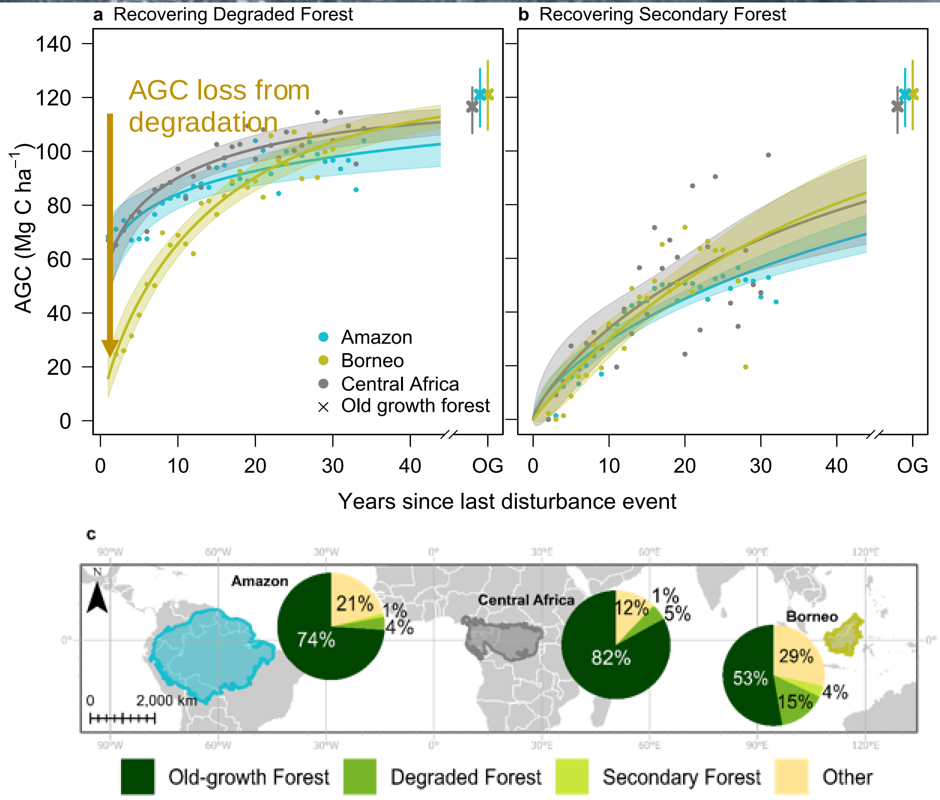
New estimates of Secondary forest regrowth using **high-resolution** satellite data

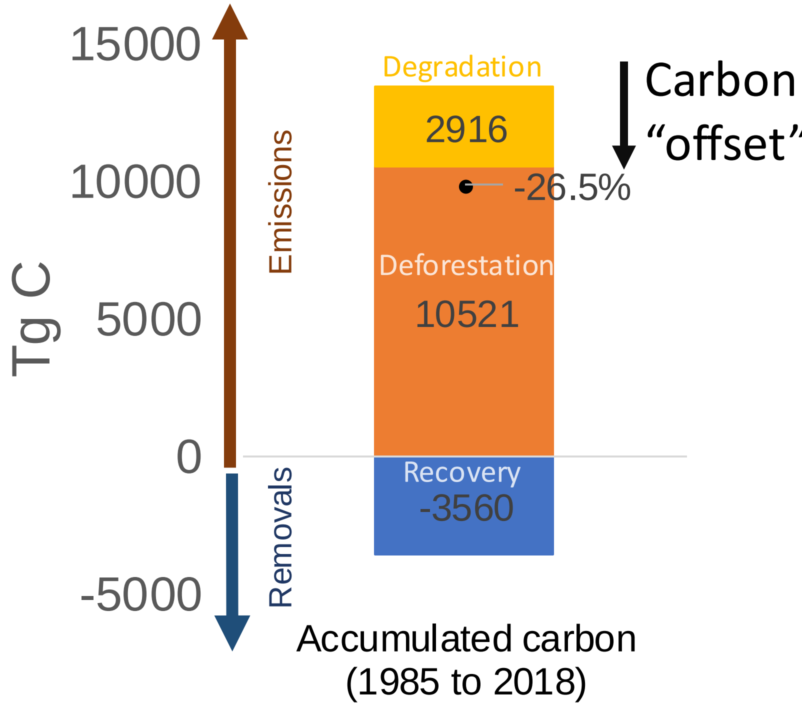


Space-4-Time. Secondary Forest age map + AGC map = map of gains and losses due to Secondary forest growth and deforestation

Heinrich et al., Nat Comms 2021

One quarter of humid tropical forest emissions offset during recovery

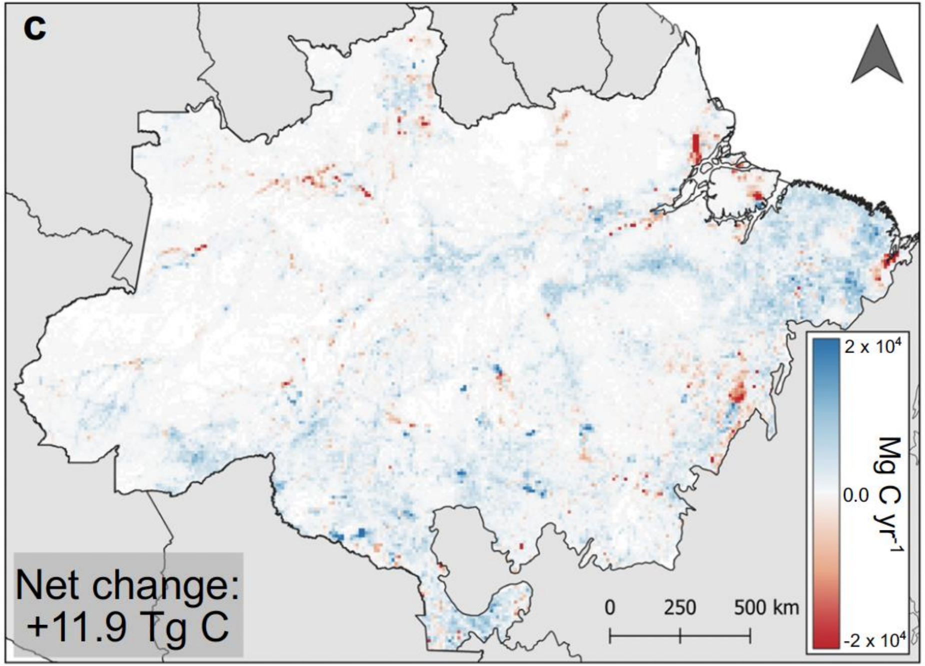




Heinrich et al., Nature 2023

Large carbon sink potential of secondary forests in Amazonia to mitigate climate change

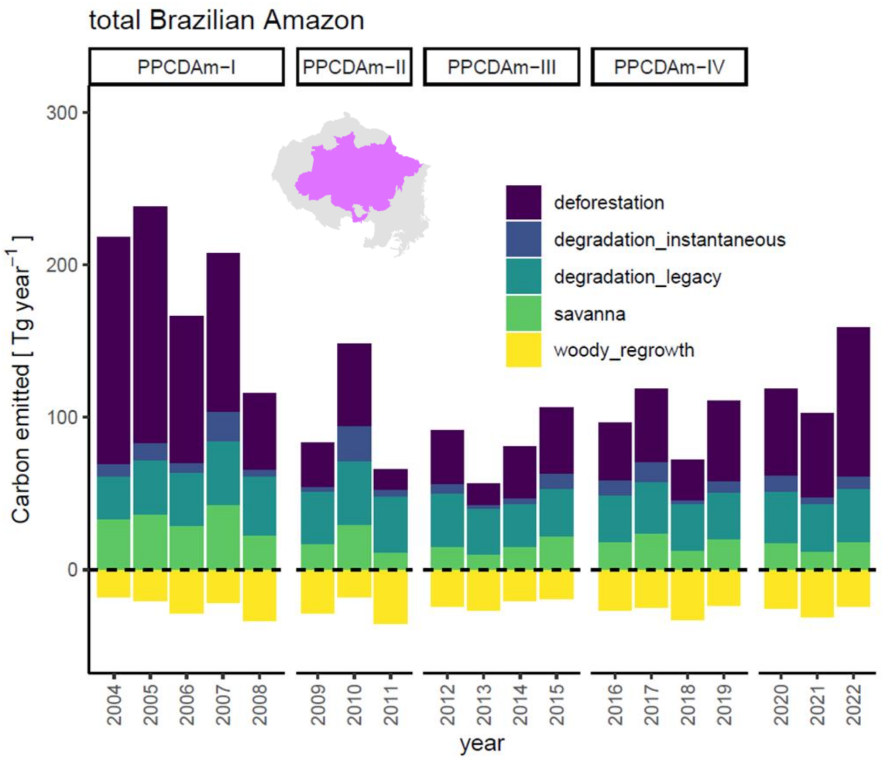
net change in SF carbon stock 2016- 2017



- ➢ Maintaining 2017 SF area potential to accumulate ~19 TgC yr^{-1} until 2030
- ➢ ~5.5% Brazil's 2030 net emissions reduction target

Heinrich et al., Nat. Comms. 2021

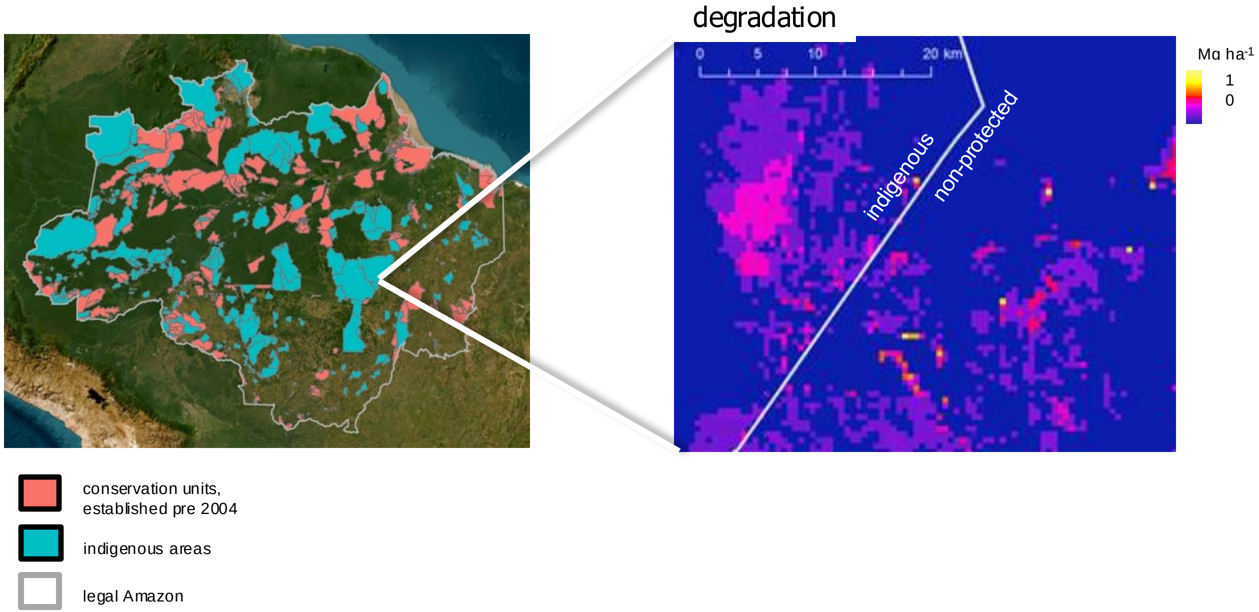
EO-based Fire Emissions: Brazilian Amazon, 2004-2022



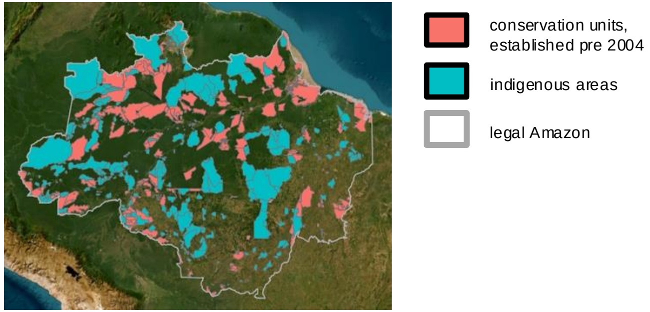
- High emissions related to high deforestation rates in early 2000s
- Changes to the forest code result in upturn of deforestation emissions since 2012
- While instantaneous degradation emissions are comparatively small (9.5% of total instantaneous emissions), legacy fluxes account for 30.3% of gross emissions on average

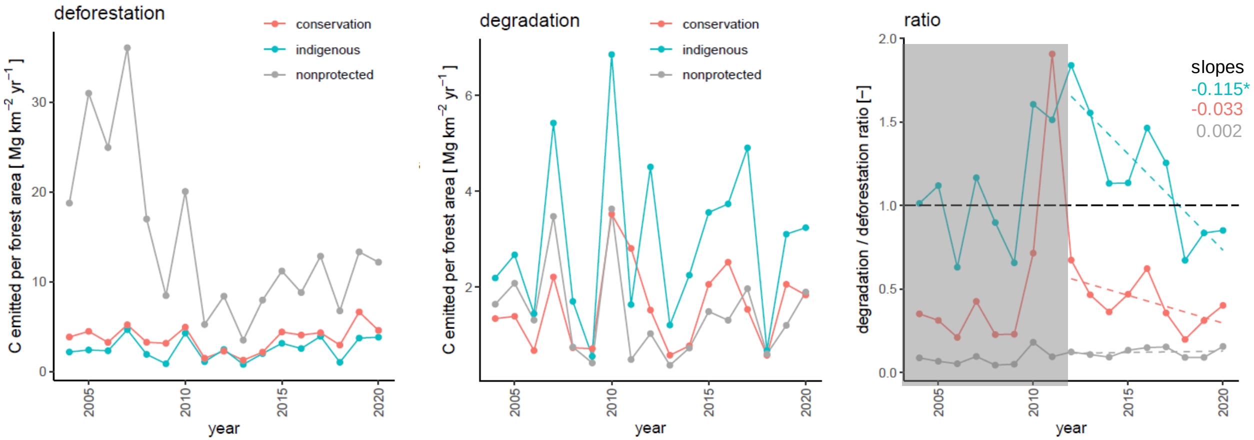
Fawcett et al., in prep

Protected vs non-protected Areas



Trends in Deforestation and Degradation





Fawcett et al., in prep

Case study regions - Siberia

Case study region		Importance for the land C budget	Approach used in this project	Existing ECV input data	New ECV datasets produced in the project
3	East Siberia 'harvested southern forests' Technical University of Munich TUM	Southern Siberia, in particular near the border with China, has experienced a large increase in harvest, causing forest loss, combined with natural disturbances Fast warming and drying trends at the southern edge of Siberian boreal forests pose a threat to the stability of regionally widespread trees species such as Larch	New disturbance maps from Landsat attributed to harvest vs. other disturbances and new Planet-based cover, height, AGB map Empirical model of forest C loss from disturbances from remote rensing Bookkeeping model of loss and gain with RS AGB and in-situ data woody debris and soil carbon	FireCCISFD CCI Biomass CCI permafrost CCI Land temperature CCI Soil moisture	Tree cover and tree height map from Planet data at 3 m for the year 2020 (UCPH) AGB map at 30 m resolution based on Planet tree cover and tree height (UCPH) Map of attribution of C losses and gains to natural disturbances, vegetation and soil parameters over 40 years (LSCE) **Extension to all Siberia in Option A**
4	East Siberia 'intact forest' LSCE LABORATOIRE DES SCIENCES DU CLIMAT & DE L'ENVIRONNEMENT	1270000 km2 of boreal forests with 8 PgC in biomass and 61 PgC of C in soils, including 44 PgC in permafrost There is a recent large increase of fires and drought over Siberia causing carbon losses, which are unknown in magnitude and spatial patterns. Currently, the region is a carbon sink that may turn into a carbon source	Empirical model of forest C loss from disturbances from remote rensing Attribution of C loss to fires and other natural disturbances with RS data Bookkeeping model of loss and gain with RS AGB and in-situ data woody debris and soil carbon, for different disturbance agents	FireCCISFD CCI Biomass CCI permafrost CCI Land temperature CCI Soil moisture	New burned area datasets Fire disturbance maps from Landsat 1984 to present 30 m annual (UAH) Tree cover and tree height map from Planet data at 3 m for the year 2020 + AGB map at 30 m resolution based on Planet tree cover and tree height (UCPH) Map of attribution of C losses and gains to natural disturbances, vegetation and soil parameters over 40 years (LSCE)

nature geoscience

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Siberian carbon sink reduced by forest disturbances

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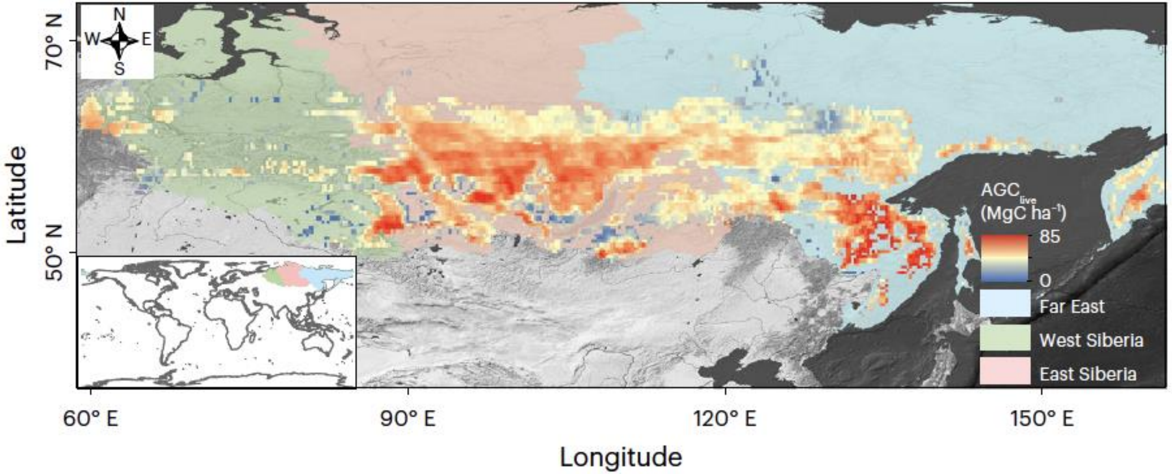
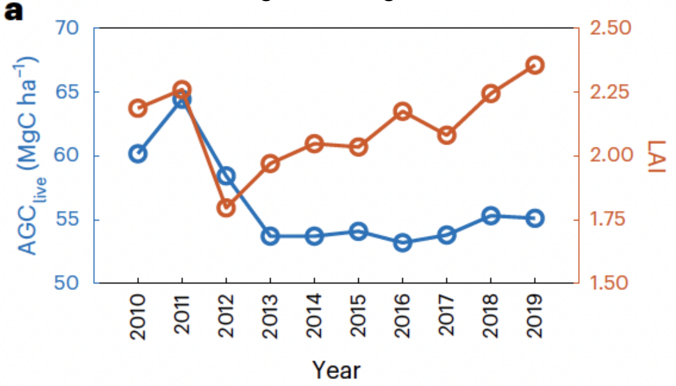
Check for updates

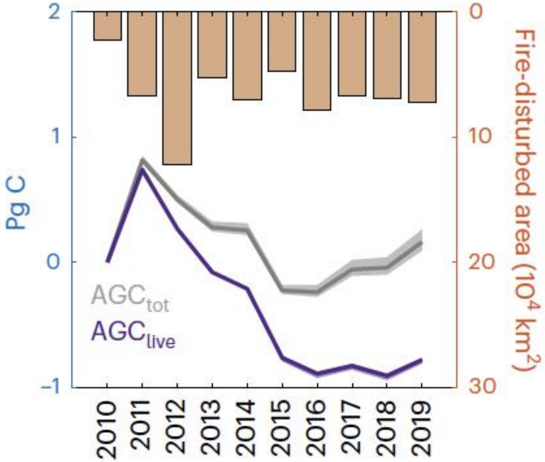
Lei Fan[1], Jean-Pierre Wigneron[2,3], Philippe Ciais[4], Jérome Chave[5], Martin Brandt[6], Stephen Sitch[7], Chao Yue[8], Ana Bastos[9], Xin Li[10], Yuanwei Qin[11], Wenping Yuan[12], Dmitry Schepaschenko[13,14,15], Liudmila Mukhortova[14], Xiaojun Li[2,3], Xiangzhuo Liu[2,3], Mengjia Wang[2], Frédéric Frappart[2,3], Xiangming Xiao[11], Jingming Chen[16], Mingguo Ma[1], Jianguang Wen[17], Xiuzhi Chen[12], Hui Yang[9], Dave van Wees[18] & Rasmus Fensholt[6]



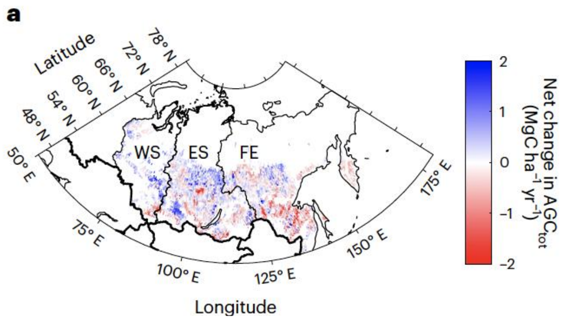
Single 25km gridcell



Region



Fan et al., Nat Geo, 2022

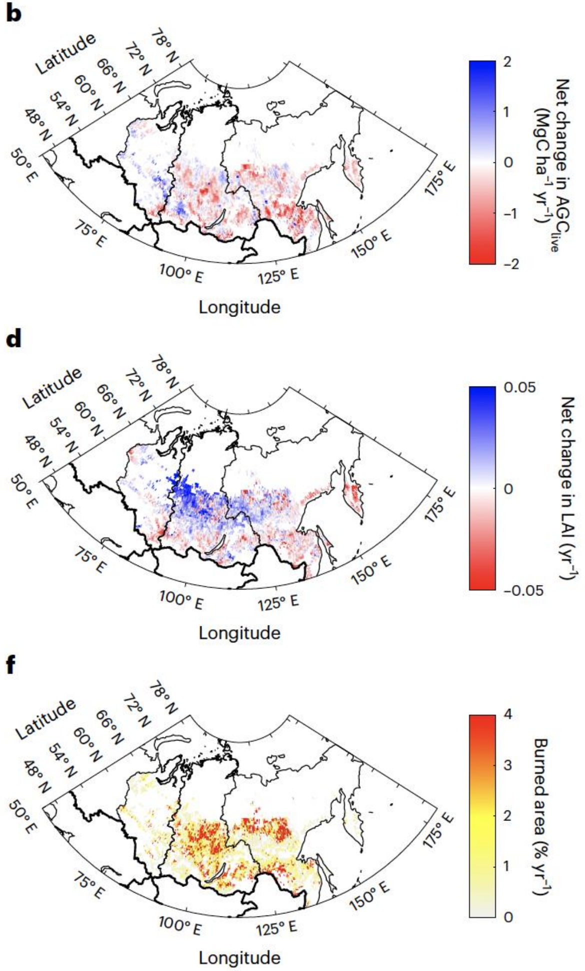


Substantial losses of live above-ground carbon are attributed to fire and drought

- widespread fires in northern Siberia in 2012, extreme drought in eastern Siberia in 2015.

Live AGC losses contrast with ‘greening’ trends seen in leaf area index

- faster post-disturbance recovery of leaf area than live above-ground carbon.

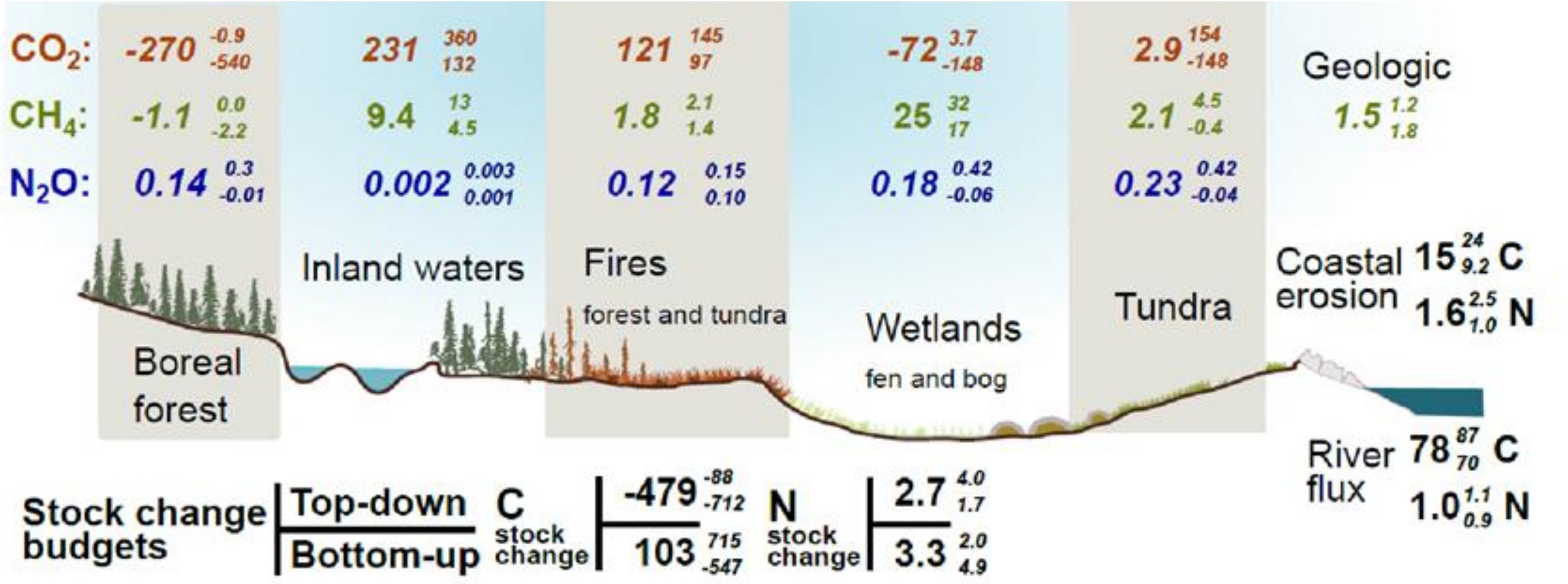


Fan et al., Nat Geo, 2022

Case study regions - Europe and Northern Peatlands

Case study region		Importance for the land C budget	Approach used in this project	Existing ECV input data	New ECV datasets produced in the project
5	Europe UNIVERSITAT LEIPZIG	Rather intensively managed forests (ca. 75% of forests are even-aged and available for wood supply) Many trees outside forest recently revealed Alarming decline of forest carbon sinks though to be a combination of increased harvest, severe droughts, bark beetles, and slow-down in growth Declining anthropogenic CH4 emissions but risk of increased natural emissions from warming Trends and variability in lake CH4 emissions, including decomposition into natural flux and anthropogenic flux	Coarse resolution L-VOD for estimating biomass annual change since 2010 Direct estimation of biomass annual change from regional high-resolution biomass maps since 2018 Attribution of C loss and gains to fires and other natural and human disturbances with the new regional biomass maps & bookkeeping model Attribution of C gain to climate, vegetation and soil parameters Improved representation of lake surface areas and temporal dynamics. Attribution of changes to anthropogenic factors	CCI Biomass CCI Fire burned area CCI Land temperature CCI Soil moisture CCI Land Cover CCI Lake ECVs	Forest annual disturbance map from Landsat 1984-present 30 m (TUM) Fire fuel parameters 1 km resol. (UAH) Tree cover / height map from PlanetScope data at 3 m for years 2018-present / update each year ; AGB maps 30 m (UCPH) Map of attribution of C losses and gains to natural disturbances, vegetation and soil parameters over 40 years (LSCE) Map of lake CH4 emissions at 30 m resolution and changes over 40 years (ULB)
6	Arctic peatlands (and lakes) Stockholm University	Arctic permafrost peatlands cover 1.7 ± 0.5 M km2 and store 185 ± 66 Pg organic carbon in the peat. Have been strong C sinks, and sinks of net GHG forcing, for >12,000 years. Large C losses and CH4 fluxes projected from permafrost thaw and fires. Shift to net warming projected to offset the full peatland C sink. Trends and variability in peatland, inland waters and lakes CH4 emissions, including decomposition into natural flux and anthropogenic flux	Combine field data with RS and machine learning to create high-resolution petland maps that are presently lacking. Peatland mapping coordinate with high-resolution lake and pond inventories to remove risk of double counting fluxes. Assessment of peatland fires from new maps and emerging RS time series of fire occurrence at high resolution. Data-driven book-keeping model of GHG fluxes from 2000 to 2024 plus projections in the future. Improved representation of lake surface areas and their temporal dynamics. Contribution of peatland C compared to autochthonous C as sources of lake CH4 emissions.	CCI Land Cover CCI Biomass CCI Fire burned area CCI Land temperature CCI Soil moisture CCI Permafrost CCI lake ECVs	High-resolution pan-Arctic wetland map downscaled from regional and/or global maps. Observation-driven modelling of peatland permafrost extent over 40 years. Maps of modelled GHG balance from permafrost peatlands over 20 years Maps of modelled CH4 emissions from peatland lakes

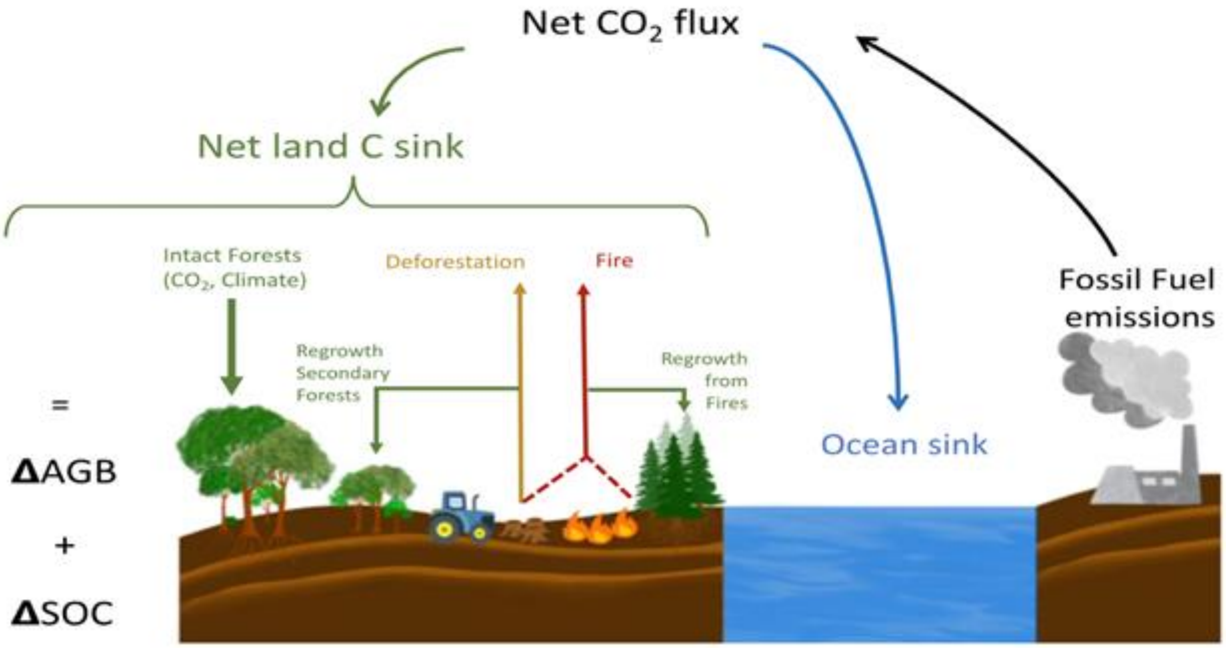
Building on a recent RECCAP2 GHG budget for the full permafrost region



Hugelius et al., in press, GBC

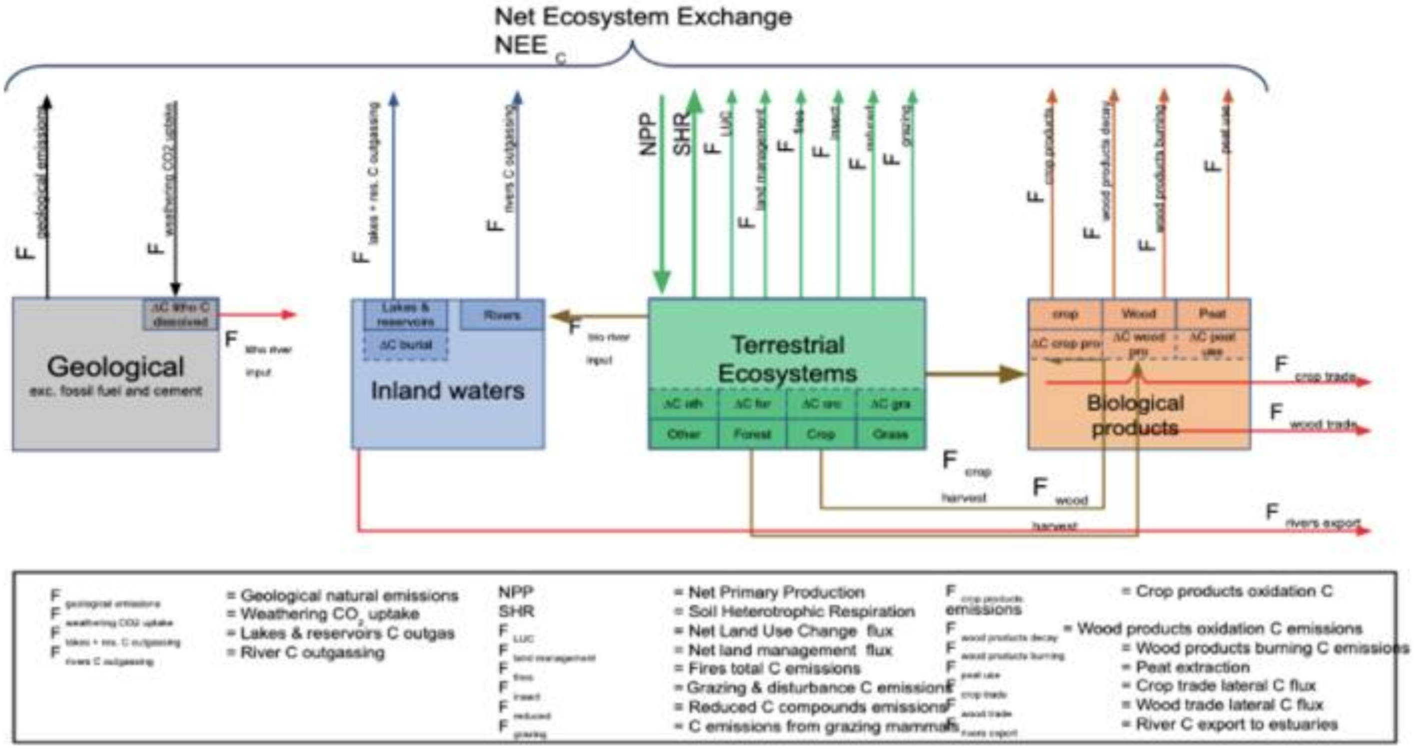
Units Tg C / N yr^{-1}

System design - Attribution of regional carbon budget into fluxes and C stock change components



GCP RECCAP2 protocol (Ciais et al. 2020)

System design - Attribution of regional carbon budget to fluxes and stock change components



GCP RECCAP2 protocol (Ciais et al. 2020)

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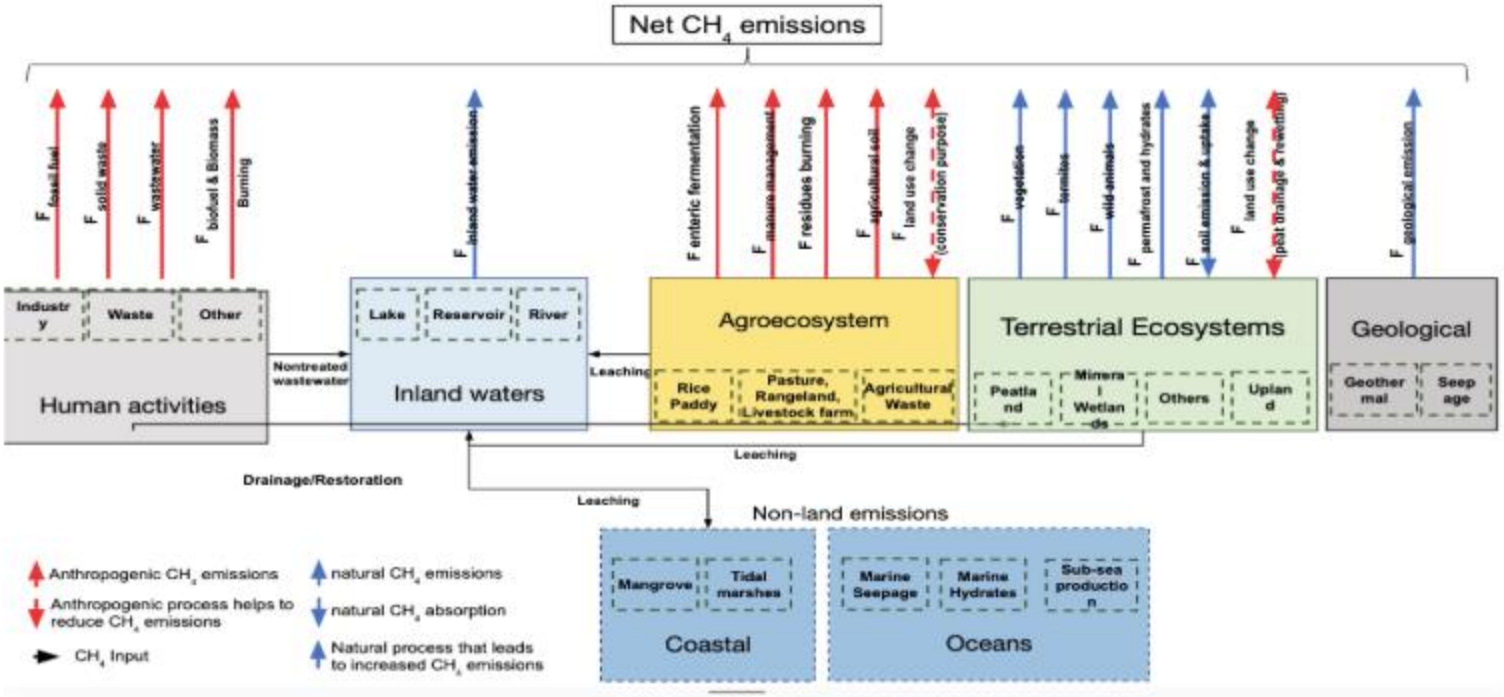
System design - Attribution of regional CH_4 budget to anthropogenic and natural fluxes



Periodical comparison and evaluation of EO based GHG budgets against UNFCCC national Greenhouse Gas inventories

Integration and synthesis

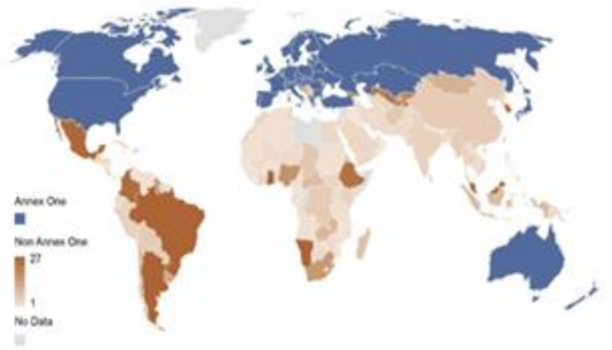


Fig 8. Number of years covered by NGHGIc reports (National communications +Biennial Update Reports) in each country (as of March 6 , 2023)

Deng et al. 2022, 2024 part of CCI RECCAP2

- **Partnership with CITEPA, CMCC. Collaboration with UKDES and INPE**
- **Make system boundaries & definitions as close as possible between EO data and IPCC Guidelines used for NGHGIs**
- **Data cube for data homogenization and visualisation (Brockmann)**
- **Scientific publication to track progress of national mitigation efforts (LSCE)**
- **National Agency engagement and contribution to the Global Stocktake (U Leipzig)**

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Summary

- ✓ CLIMATE SPACE RECCAP2 project aims **to harness satellite based ECV to reduce the uncertainty on the emissions and sinks of CO_2, and CH_4 over key land regions, and attributing them to anthropogenic and global change drivers**.

- ✓ Integrate bottom-up and top-down methods and compare results with inventories for **case study land regions that are of key importance for global budgets** and where uncertainties on current CO_2 and CH_4 fluxes remain very large : Europe, Siberia, Amazon and Arctic.

- ✓ In addition to high resolution gridded fluxes over regional case studies, RECCAP2 will keep a focus on how these advances can contribute to improve the **global land carbon budget**