Satellite-based carbon removal estimates in regrowing forest: Examples from the tropics with potential for European applications

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EO for Monitoring, Reporting and Verification of Carbon Removals

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Secondary, Planted & Plantation forest

Credit: V Heinrich, 2019

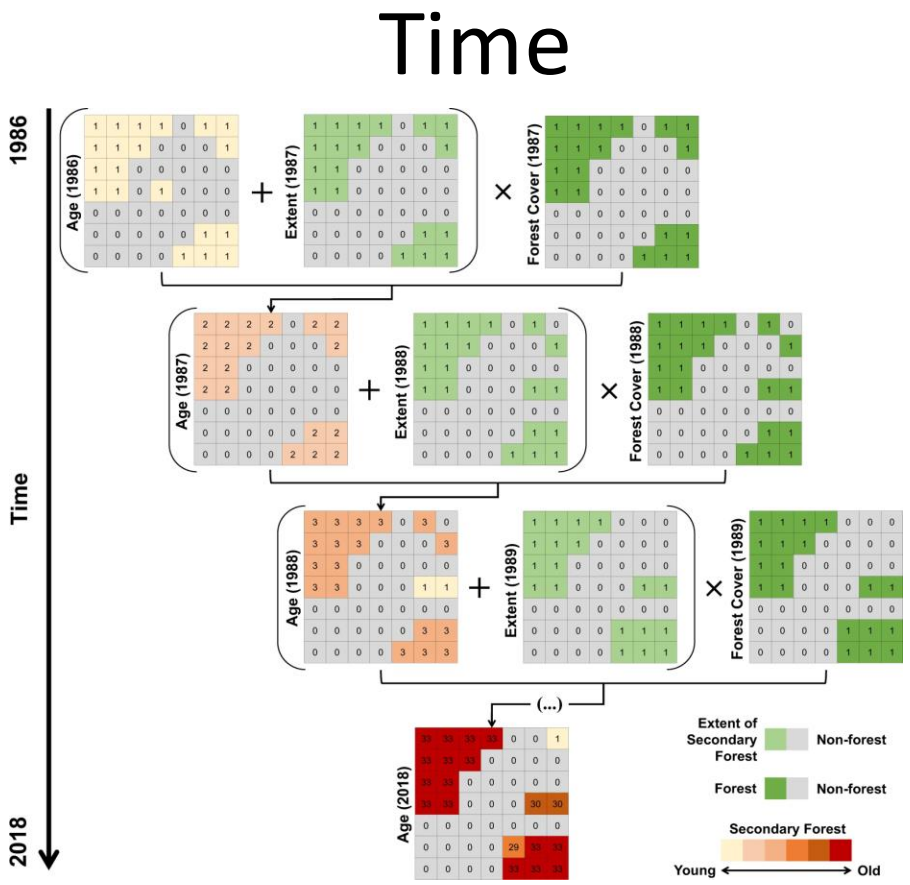
- Secondary forest form largely through natural regeneration after human disturbance.
- They can establish through planting/seeding (Planted forest).

Credit: WSL, 2023

- Plantation forest ≠ Planted forest.
- Plantation forests may be a *type* of planted forest.
- All relate to the reemergence of forest cover after a period of absence.
- Similar EO approaches may therefore be applied.

Credit: IECF, 2025

The role of Satellite data: mapping regrowth



Silva Junior et al. 2020

Sensor	Start time	Resolution	Open Access
Landsat collection	1970s	30m	✅
MODIS Terra	1999	250m	✅
Sentinel-2	2015	10m	✅
PlanetScope Doves	2019	3 – 5 m	❌
CHIME 2029 30m	2029	30m	✅
Sentinel-2 Next Gen	2033	5 – 10m	✅

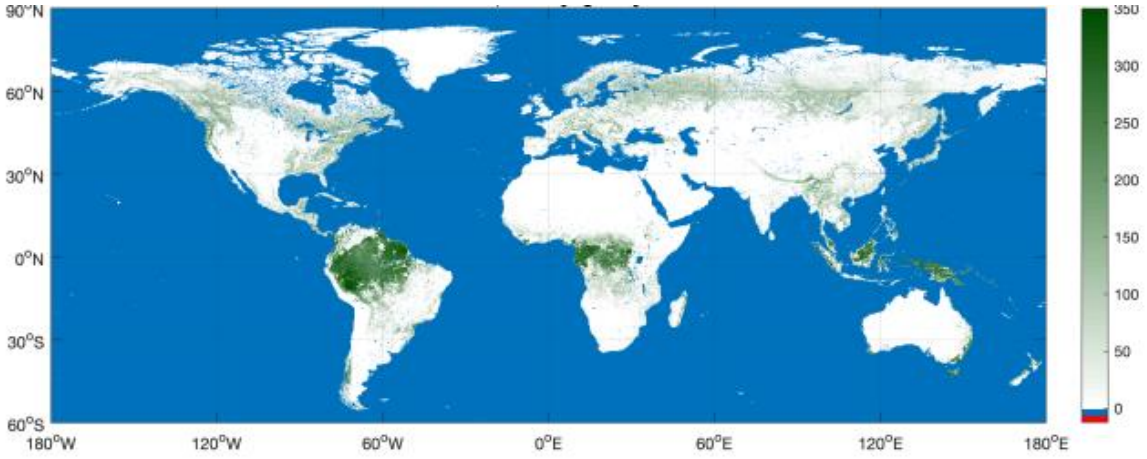
(+ others …)

The role of Satellite data: carbon accumulation

Products	Start time	Resolution	Open Access
ESA CCI biomass	2007, 2010, 2015 - 2022	100m	✅
Ctrees	Annual since 2000s	100m	❌
ESA Biomass	2020, 2021	20m	✅
GEDI	2018	25m footprint	✅
ESA BIOMASS Mission	2026	200m	✅

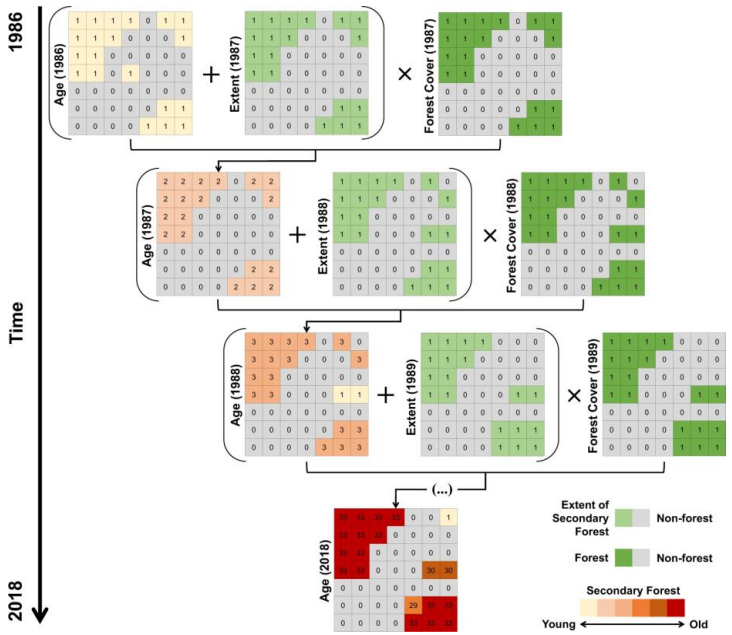
Space

Map of Aboveground Carbon, 2017, ESA-CCI



The role of Satellite data: carbon accumulation

Time



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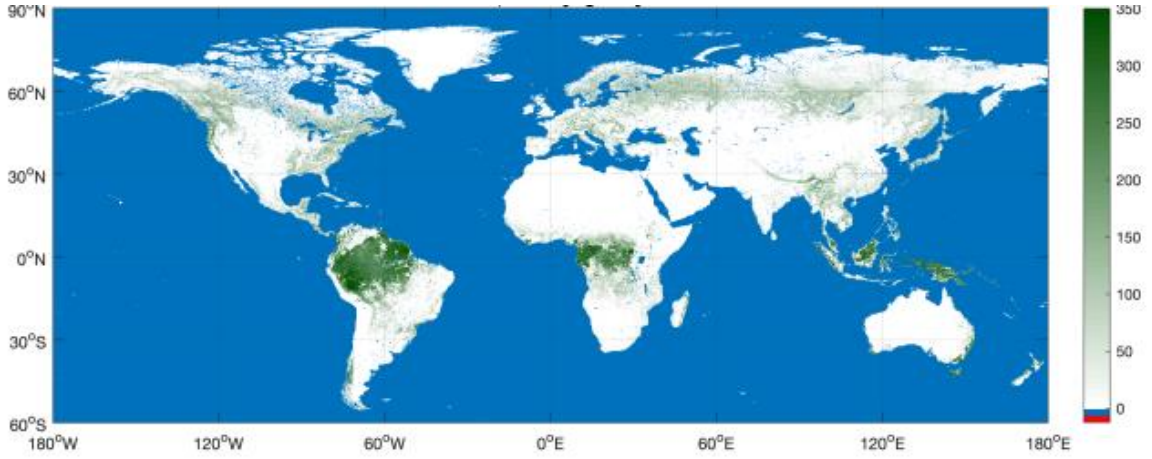
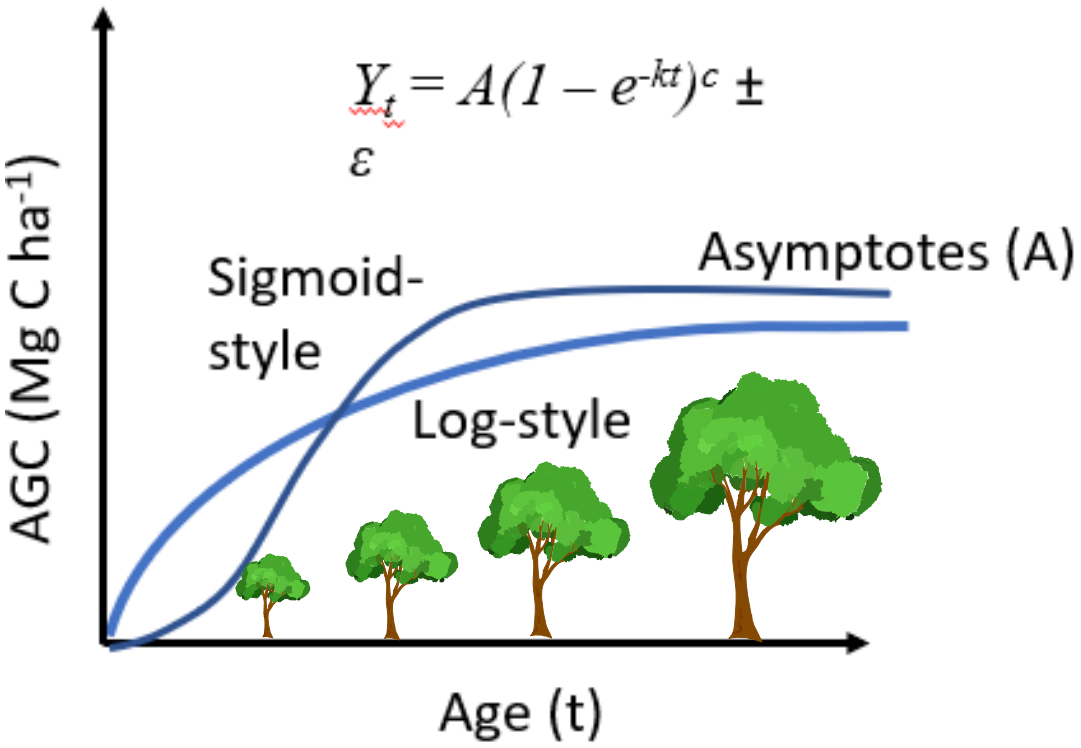


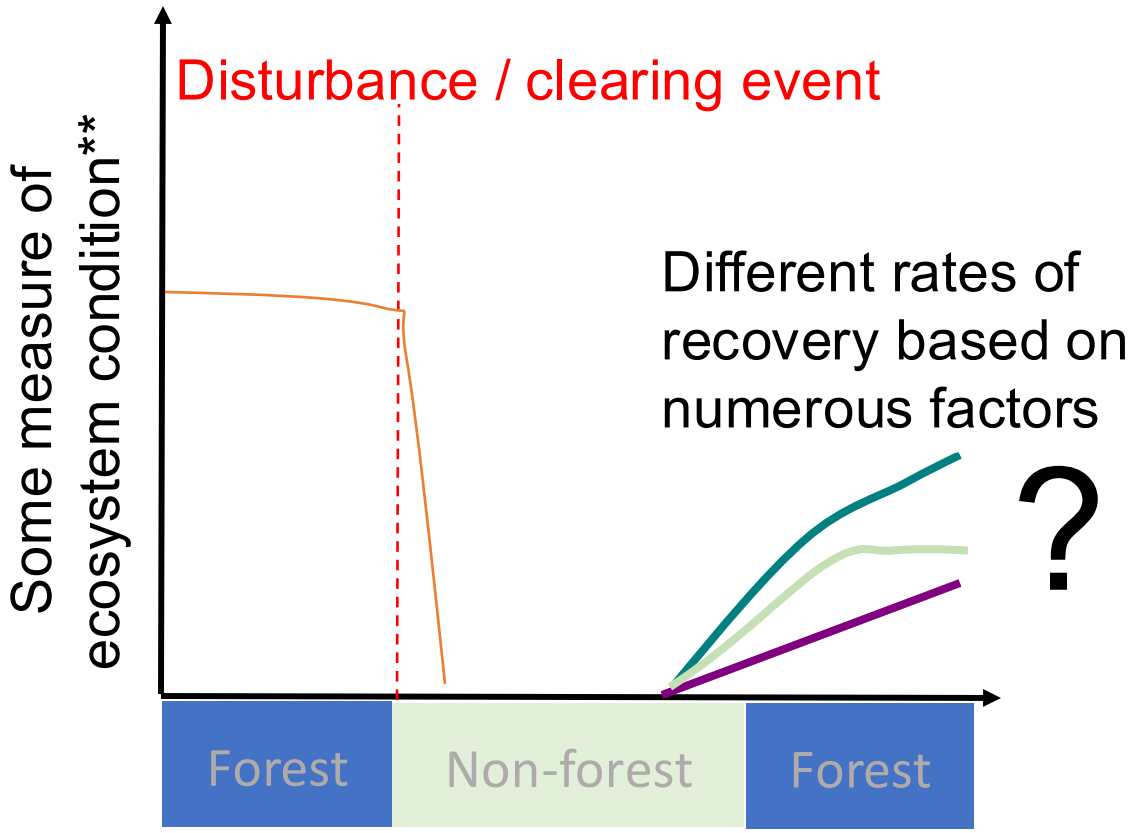
Space for time substitution

The role of Satellite data: carbon accumulation



Space for time substitution

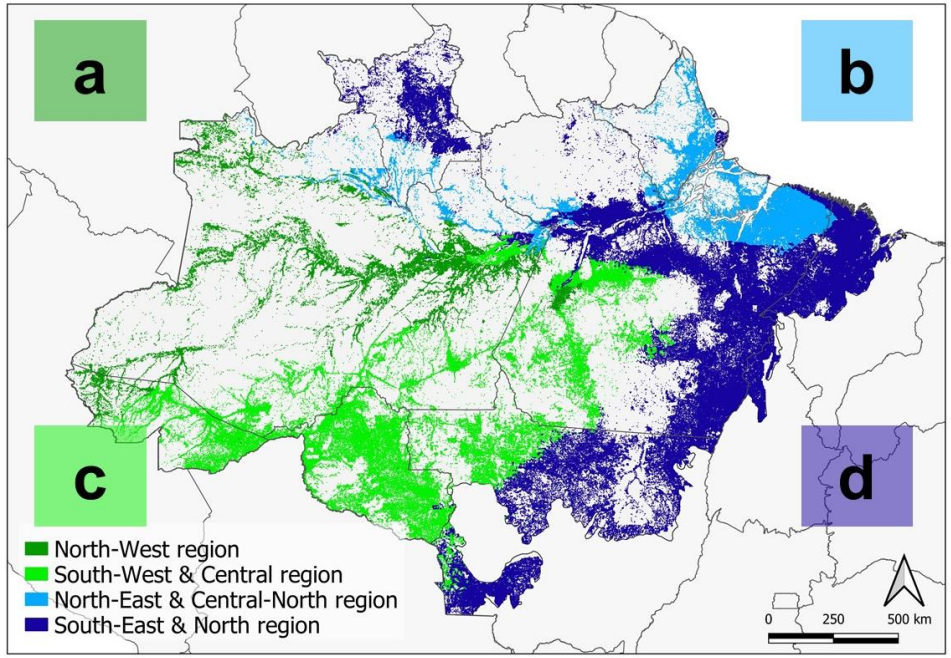
Regrowth after forest loss



**e.g. Carbon storage, Structure, Species composition Biodiversity, Perceived human value, Biophysical processes

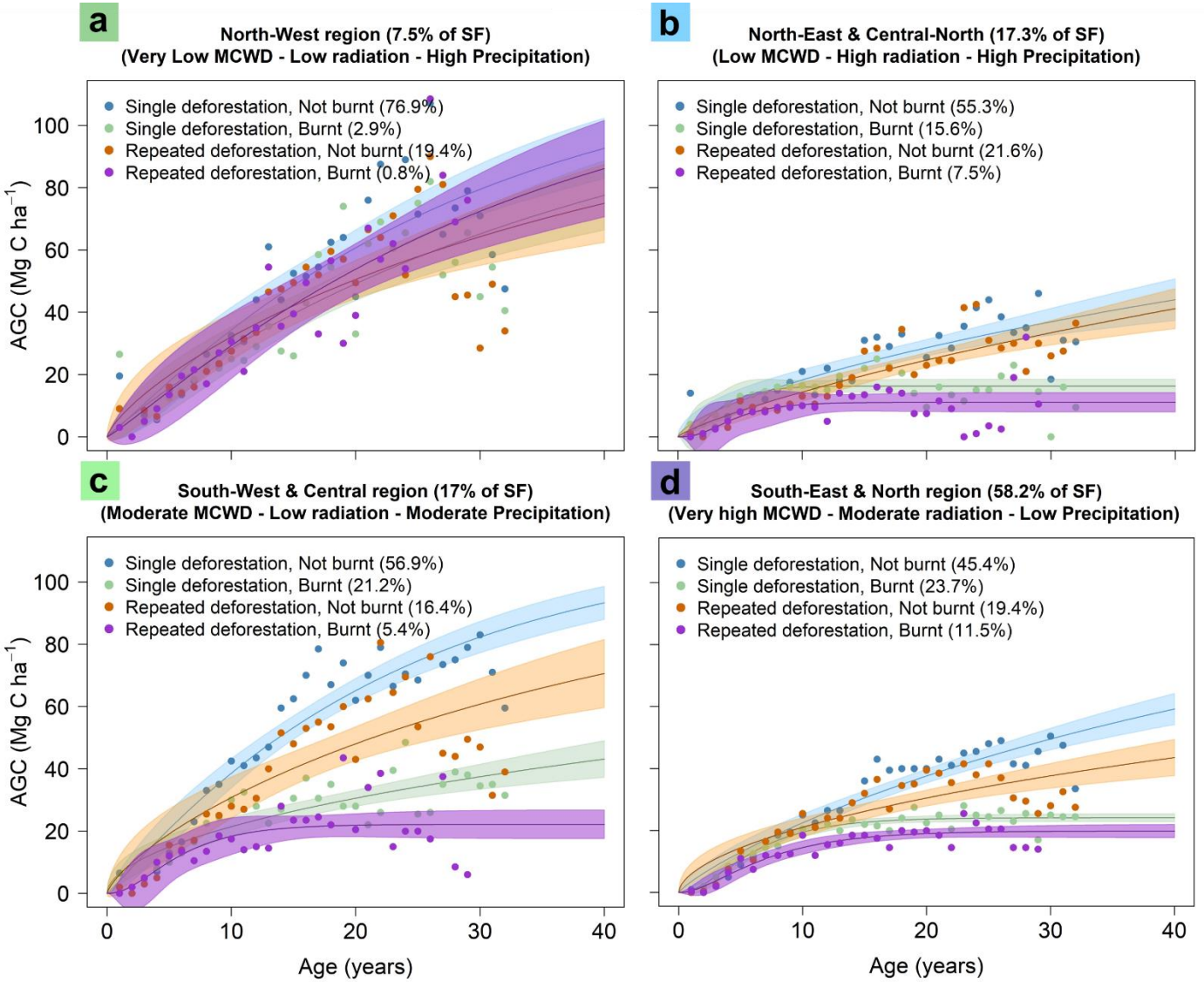
Examples from the tropics

Regional regrowth rates for the Brazilian Amazon



Heinrich et al., 2021, *Nat Comms*

[Rainforest Biome Map]



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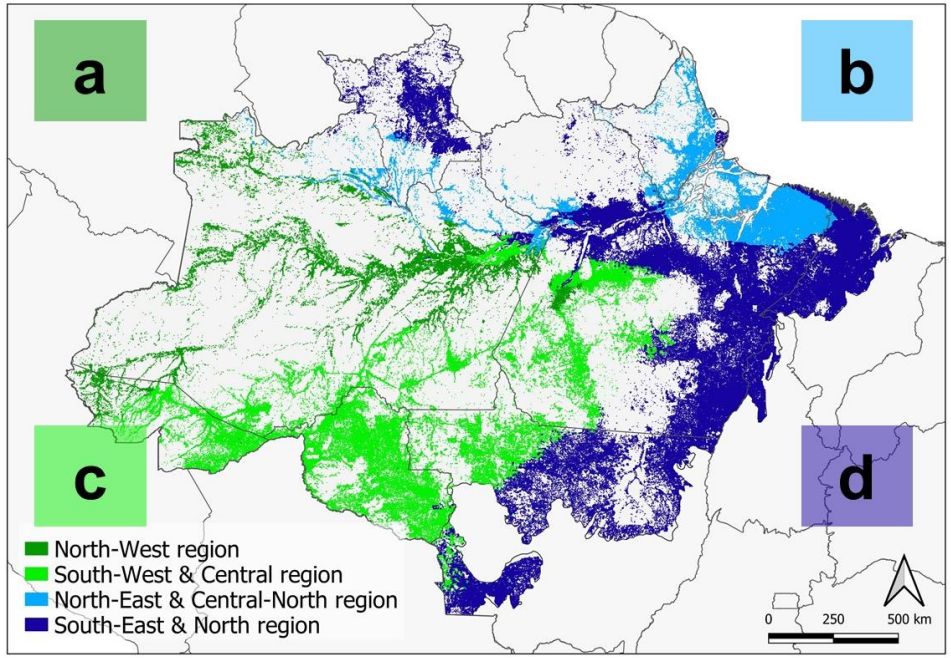

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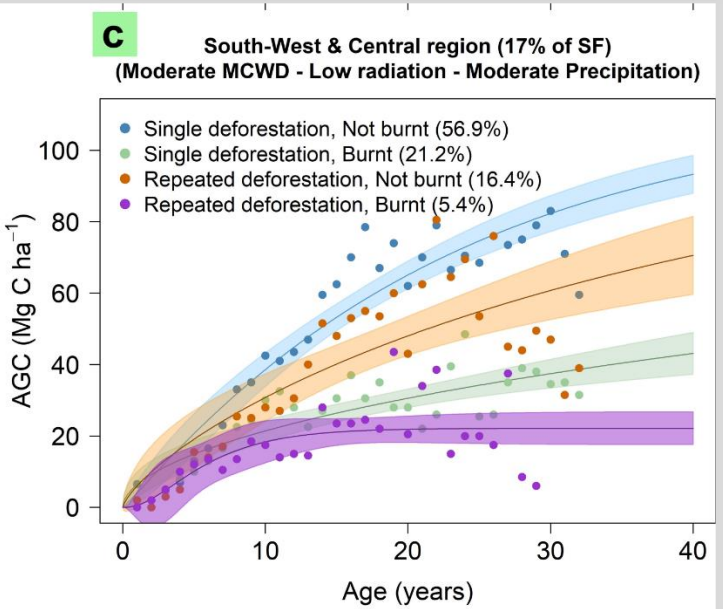
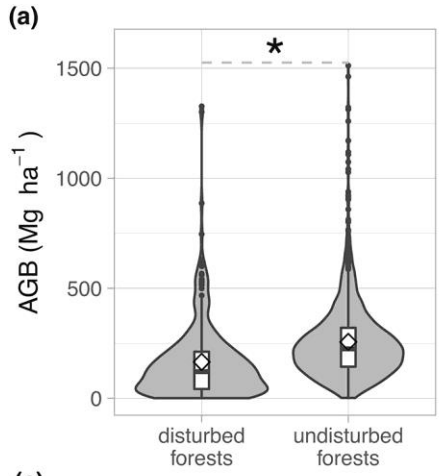
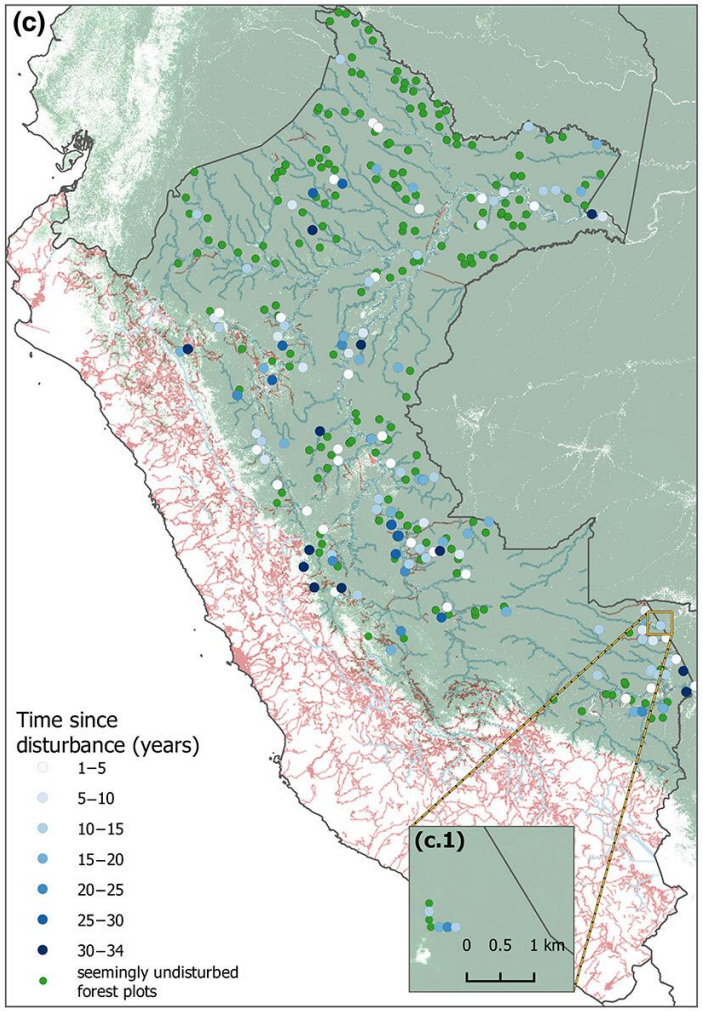
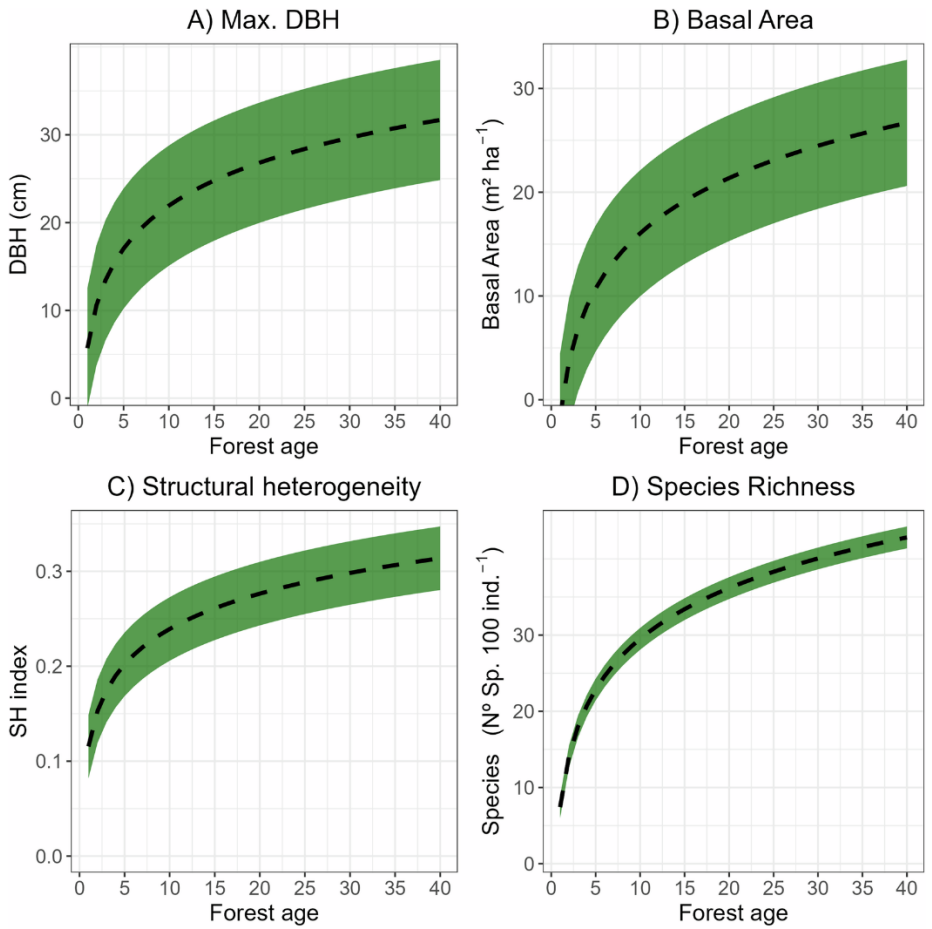


Integrating field data with satellite data





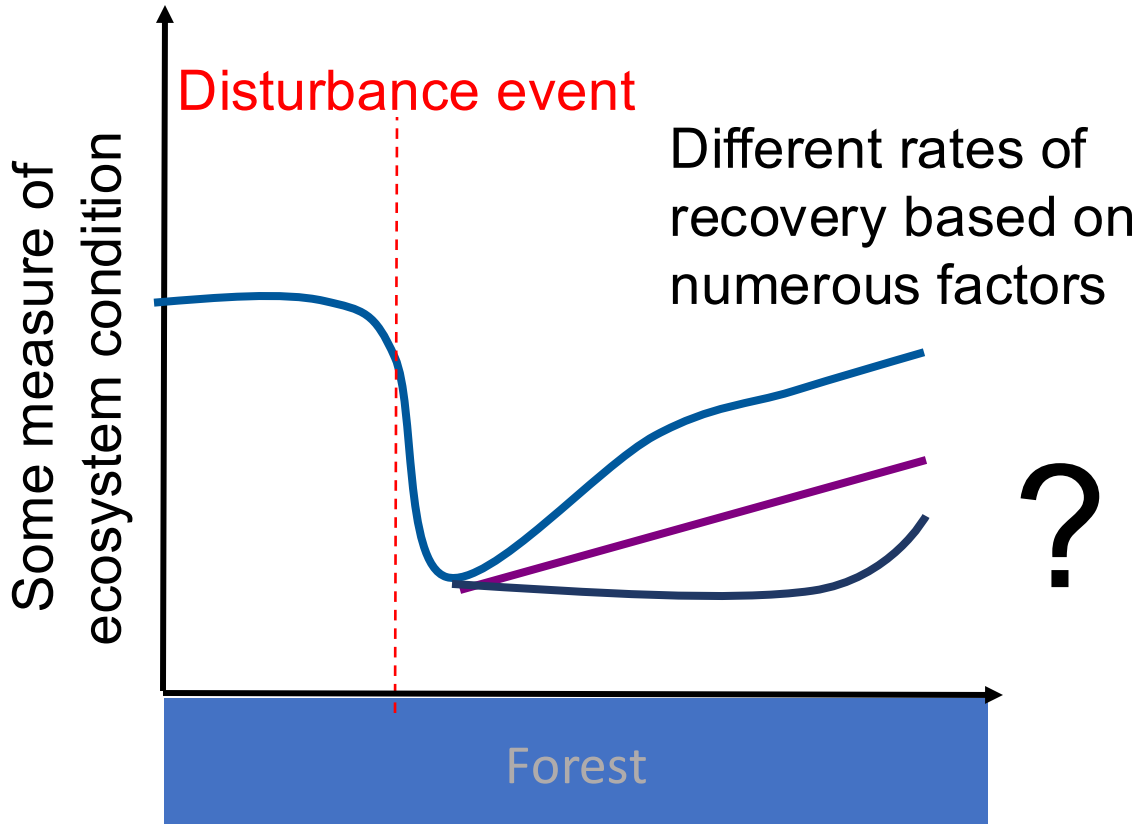


Requena Suarez et al., 2023, *Global Change Biology*

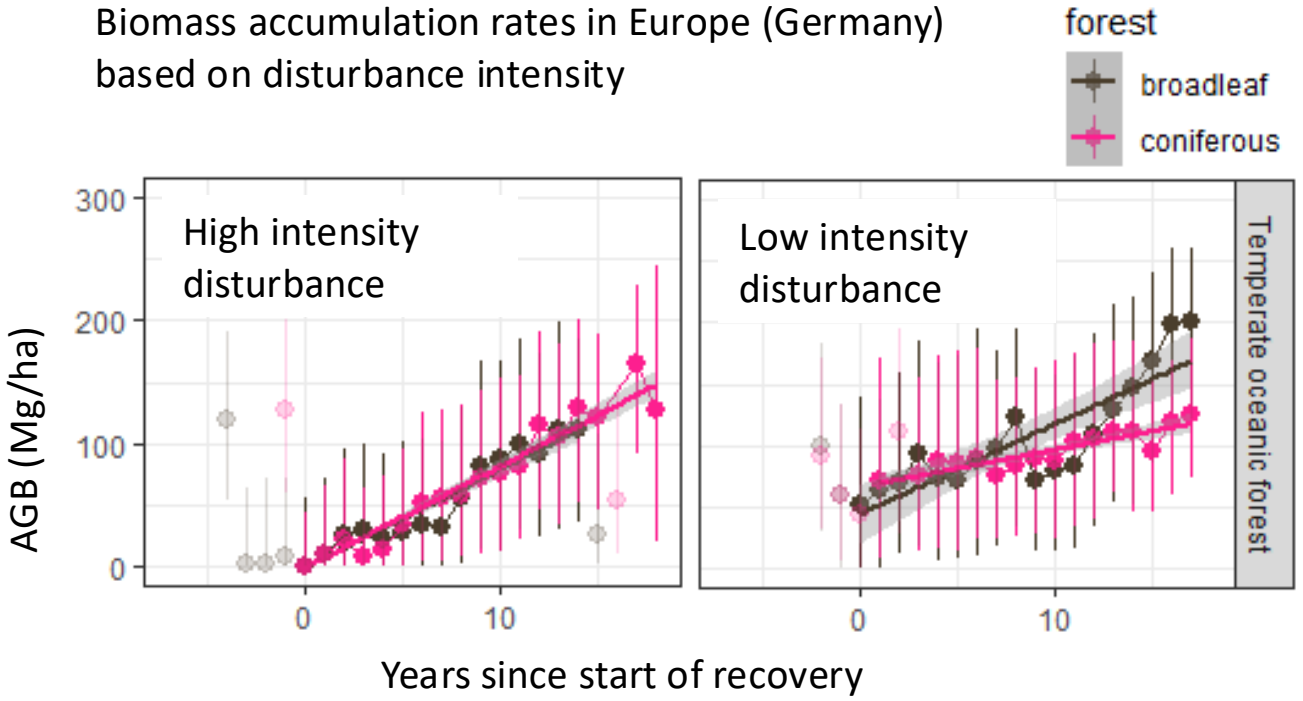
Giles et al., 2025, *Communications earth & environment*

Examples from the Northern Hemisphere

Recovery from Degradation

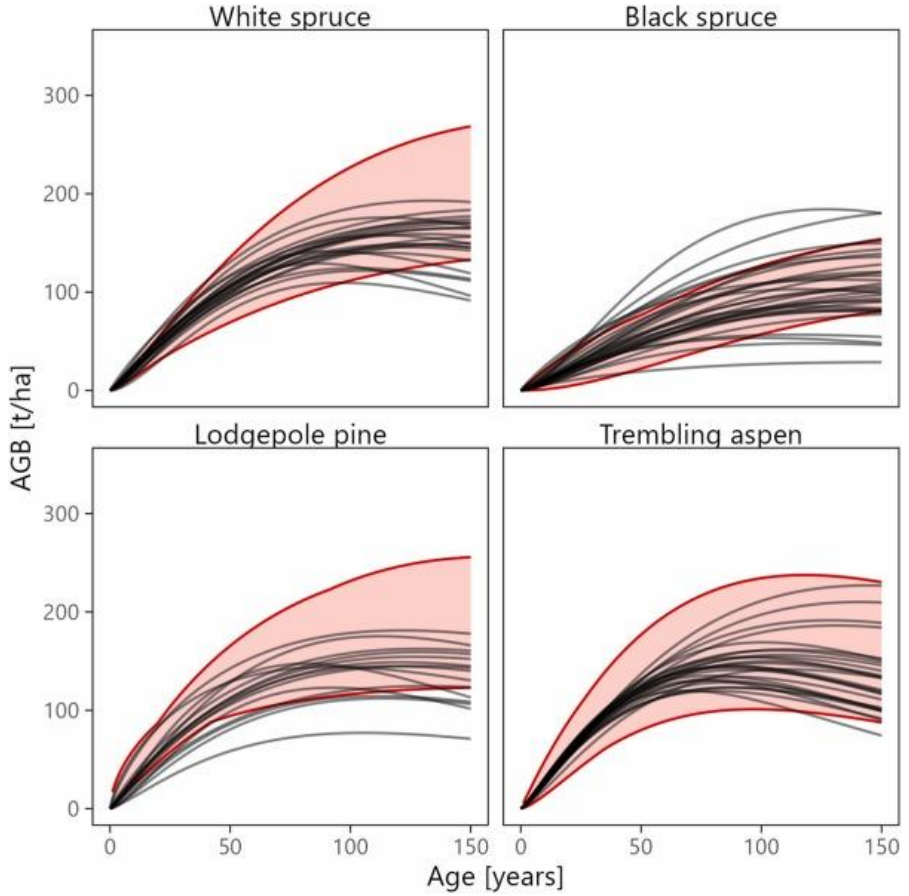


Biomass accumulation rates in Europe (Germany) based on disturbance intensity



Heinrich et al. unpublished

Examples from Canada



Tompalski et al. Forest Ecology and Management, 2024

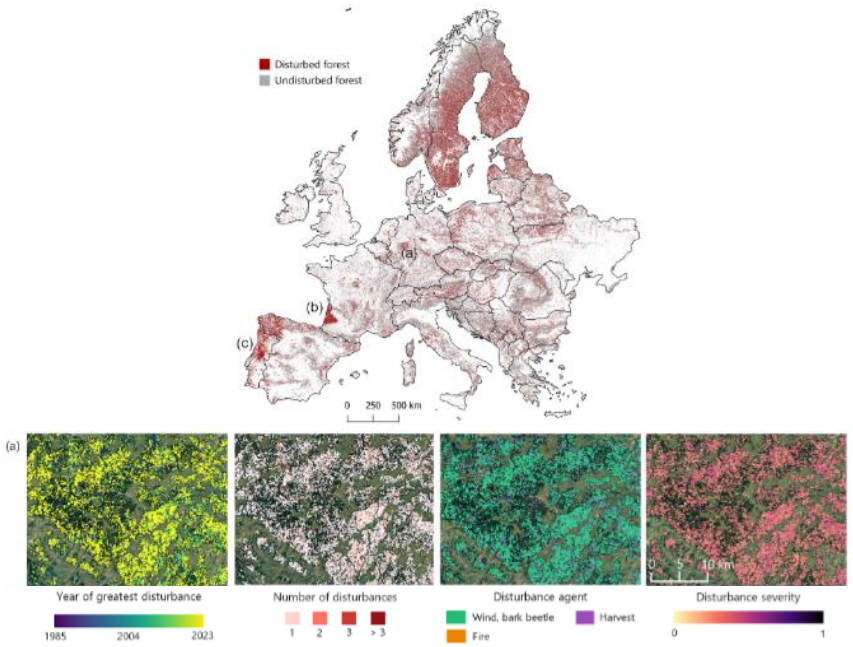
Potential indicators of forest degradation (and therefore recovery?)

- Biodiversity & Composition
- Productivity
- Carbon
- Water values
- Soil Values
- Indirect human pressures
- Integration indicators
- Context indicators

Venier et al. Measuring and responding to forest degradation in Canada: an operational framework, Environmental Reviews, 2025

Data available across Europe

The European Forest Disturbance Atlas:
a forest disturbance monitoring system using the Landsat archive (1985 – 2023)



Viana-Soto & Senf, 2025
Landsat: 30m
1985 – 2023

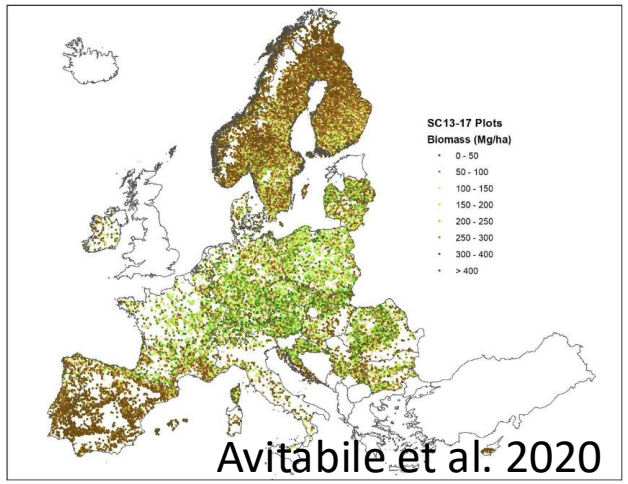
Coming soon to Europe!

Wageningen University & Research (2025)
Sentinel-1: 10m
2015 onwards

As we can detect disturbance, we can also detect regrowth

Cal/Val across Europe

NFI sites
(where available)

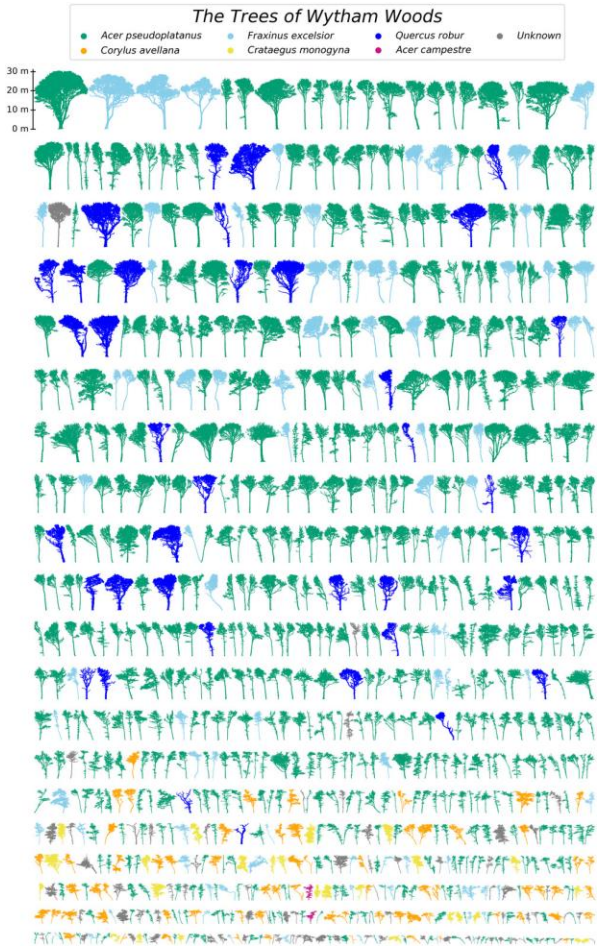


Avitabile et al. 2020

CEOS AGB Product Validation Good Practice Protocol

CEOS
Committee on Earth Observation Satellites

Terrestrial LiDAR Scanning



Calders et al. 2022

Open Geospatial Carbon Registry
(an OA carbon account tool)

Start date	End date
1 June 2025	31 May 2029

Integrated Carbon Observation System (ICOS) sites


https://www.icos-cp.eu/station-map

Satellite-based carbon removal estimates in regrowing forest…

- Studies have shown the success of using satellite-based data to generate information on forest regrowth:
  - To monitor extent & age
  - Their structural/biodiversity recovery
- Generating baselines & indicators of forest change can rely on multiple sources.
  - Satellite data are one such approach.
- Not a panacea: can integrate field data with information from satellite data.
  - E.g. information satellite cannot provide us with: belowground carbon, DBH, structural heterogeneity, diversity
- Scientific community needs to consider how to publish data/methods to make them useful beyond research and academia

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esa

NGC NextGenCarbon