Next Generation of Remote Sensing Data:
Contributions to global carbon cycle

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Observation of Terrestrial Carbon Fluxes

New observations from spacecrafts in orbit and upcoming mission allow an estimation of gross carbon fluxes, photosynthesis, biomass burning, evapotranspiration and live biomass, to create virtual eddy covariance sites in the sky.

- What is the primary productivity of the globe and how is it controlled? (OCO2/3, TROPOMI)
- How much carbon does the biosphere store and how could it change? (GEDI, NISAR, BIOMASS)
- How does direct human exploitation of the biosphere affect productivity and carbon storage? (Sentinel, Landsat, FLEX)
- What is the biological diversity of the world and how does it affect the function and stability of ecosystems? (HISUI, SBG)
New Observations of Carbon Stocks and Dynamics

“Bowman et al. 2017: CMS-Flux, courtesy Eastham (MIT)”

History or Evolution of SIF Measurement
Koehler et al (TROPOMI)

GEDI Data 2019-2020

2023
Biomass
NISAR

2018
GEDI

Biomass

2018
ICESat-2

NISAR

BIOMASS

GEDI Data 2019-2020

Biomass

2018
ICESat-2

NISAR

BIOMASS
aboveground live biomass carbon stocks & changes

Pan et al. 2011

- Forest Inventory data are not systematic and synchronous globally
- Forest definition and carbon reporting varies at national scales (trees outside forest definition are ignored)
- Emissions are not calculated systematically everywhere
- Removals do not include dynamics of land use change (secondary forests in tropics)
Carbon Emissions and Removals from Deforestation, Degradation, Regeneration

\[ \Delta C = \sum \Delta A \cdot B \cdot E_{\text{def}} + \sum A \cdot \Delta B \cdot E_{\text{deg}} + \sum A \cdot \Delta B \cdot R_{\text{reg}} \]

where A is the area of forest type, with biomass B, emission efficiency factor E, and removal efficiency R
Live Aboveground Biomass Must be Mapped

Systematic Error in estimating emissions from forest disturbance

Optimum spatial scale for mapping biomass < 1-ha

Yu et al., in Review
Existing 1-ha biomass maps have large uncertainty
Making Bottom-up Estimates Spatial

IPCC Guidelines

1. Difference between carbon stocks gives emission/removal

2. Emission/removal from sum losses and gains

(a) Stock change method

(b) Gain loss method

Combine data sources in inventory framework

RS Based Observations and Spatial Data

Harris et al., 2021

Net forest greenhouse gas flux
Mt CO\textsubscript{2}e yr\textsuperscript{-1} (2001-2019)

-0.087 (sink)
0 (neutral)
0.17 (source)

30 m resolution

Harris et al. 2021 Nature Climate Change
Forest Inventory from Space

ICESAT-GLAS Height
Where are gains and losses?

Trend from 2000 to 2019

\[ \Delta C_{LUC} + \Delta C_{ENV} \]

Xu et al., in Review
Live Biomass stock Changes Dominates Carbon Fluxes

Net Atmosphere Increase ($S_{Air}$)
4.6 [3.3, 6.3] PgCyrr$^{-1}$
(2001-2019)

Fossil Fuel Emission ($E_{Fuel}$)
8.7 [6.9, 10.0]

Live Biomass Emissions

$S_{gross}$ Gross Land Sink
-6.3 [-8.4, -4.0]

-4.9 (-5.5) [-9.1, -2.5]

Net Ocean Sink $S_{Ocean}$
2.4 [1.8, 2.7]

$\delta_{im} = S_{\delta} - E_{\delta}$
-1.4 (-0.8) (-3.8, 3.7)
Budget Imbalance
**AMAZON RIVER BASIN**

Sink
Net flux: -0.10
Emissions: 1.1
Removals: -1.2

**CONGO RIVER BASIN**

Sink
Net flux: -0.61
Emissions: 0.53
Removals: -1.1

**SOUTHEAST ASIA**

Source
Includes soil
Net flux: 0.49
Emissions: 1.6
Removals: -1.1

**Stock-Change (Xu et al., 2021)**

Neutral to Sink
Net flux: -0.03 (-0.38)
Emissions: 1.54
Removals: -1.57 (-1.95)

Sink
Net flux: -0.09 (-0.43)
Emissions: 0.9
Removals: -1.0 (-1.43)

Source to Sink
Net flux: 0.1 (-0.29)
Emissions: 1.33
Removals: -1.23 (-1.62)
Summary

**Uncertainty:** Uncertainty in live biomass stocks and changes remains a problem that can be resolved with NG observations.

**Live biomass fluxes:** Live Biomass stock changes explains more than 70-80% of global terrestrial sinks and sources & other pools remain important.

**Regional Importance:** Tropical forests dominate the sinks and sources of carbon in magnitude but remain a net neutral flux to small sink in this century.

**IAV of Atmospheric CO₂ growth:** Tropical forest carbon stock changes from post-disturbance recovery control IAV of atmospheric CO₂.