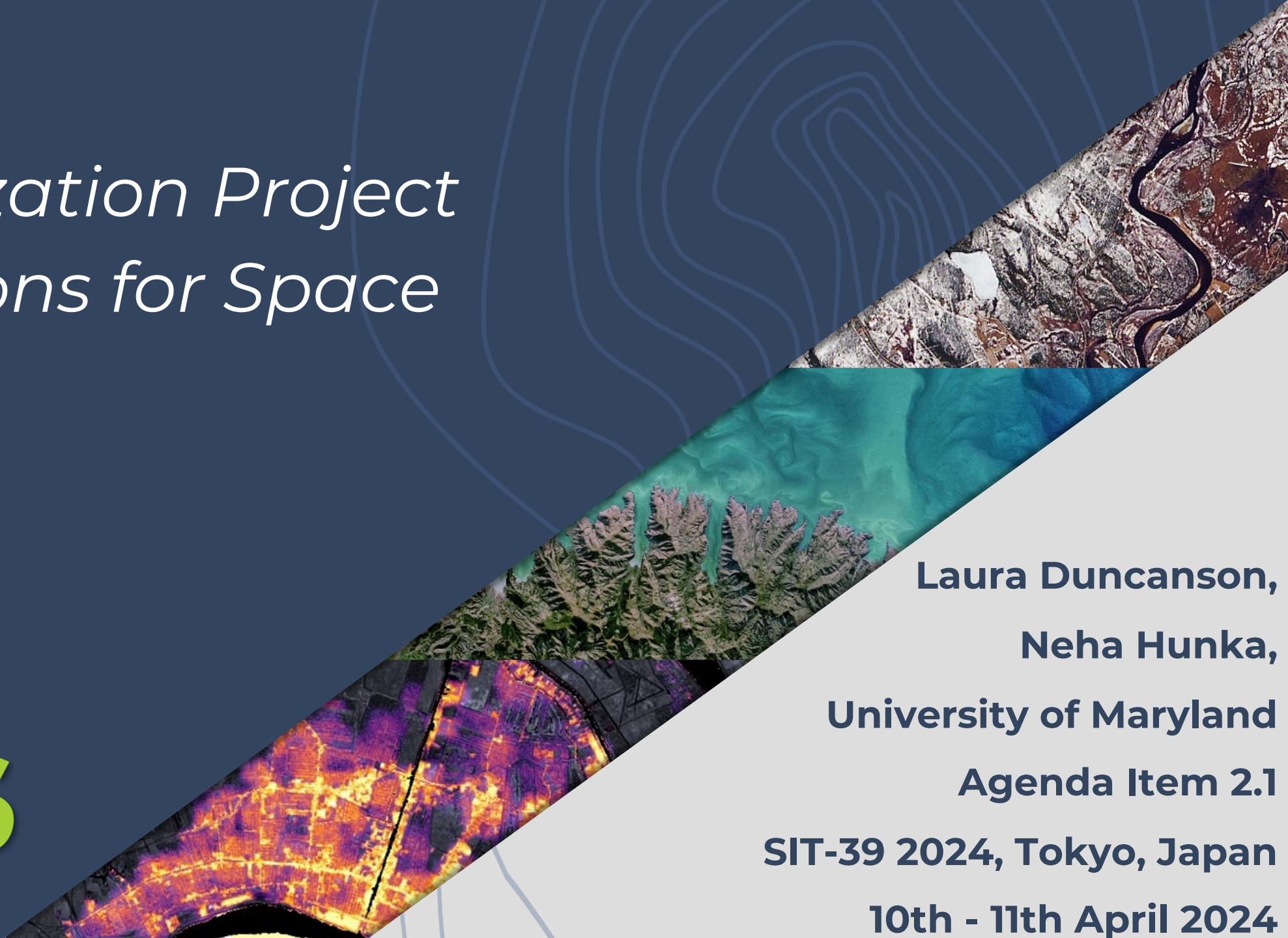
Biomass Harmonization Project and Lessons for Space Agencies



Laura Duncanson,

Neha Hunka,

University of Maryland

Agenda Item 2.1

SIT-39 2024, Tokyo, Japan

10th - 11th April 2024

CEOS

Committee on
Earth Observation Satellites

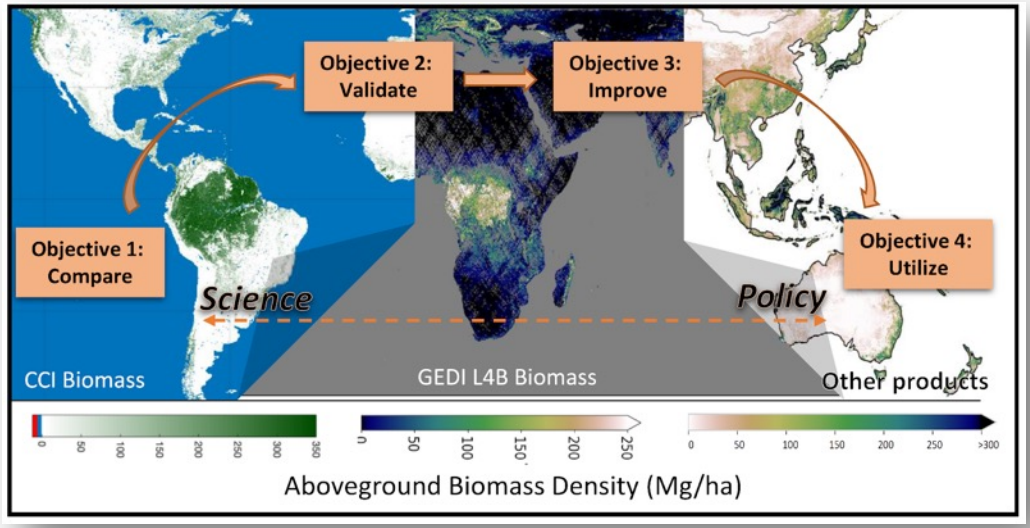
Biomass Harmonization

- Coordinated effort between CEOS agencies and users/producers of aboveground-biomass (AGB) maps. Effort part of LSI AFOLU in collaboration with WGCV LPV.

- Purpose is to communicate a clear and consistent message on forest AGB products, especially as the number of public datasets grow

- Increasingly important as new biomass mission launches are approaching (e.g. NASA/ISRO's NISAR, ESA's BIOMASS, JAXA ALOS-4 and MOLI, others…)

- Toward inclusion of EO biomass products in national reporting frameworks (currently missing!)



Committee on Earth Observation Satellites

Working Group on Calibration and Validation
Land Product Validation Subgroup

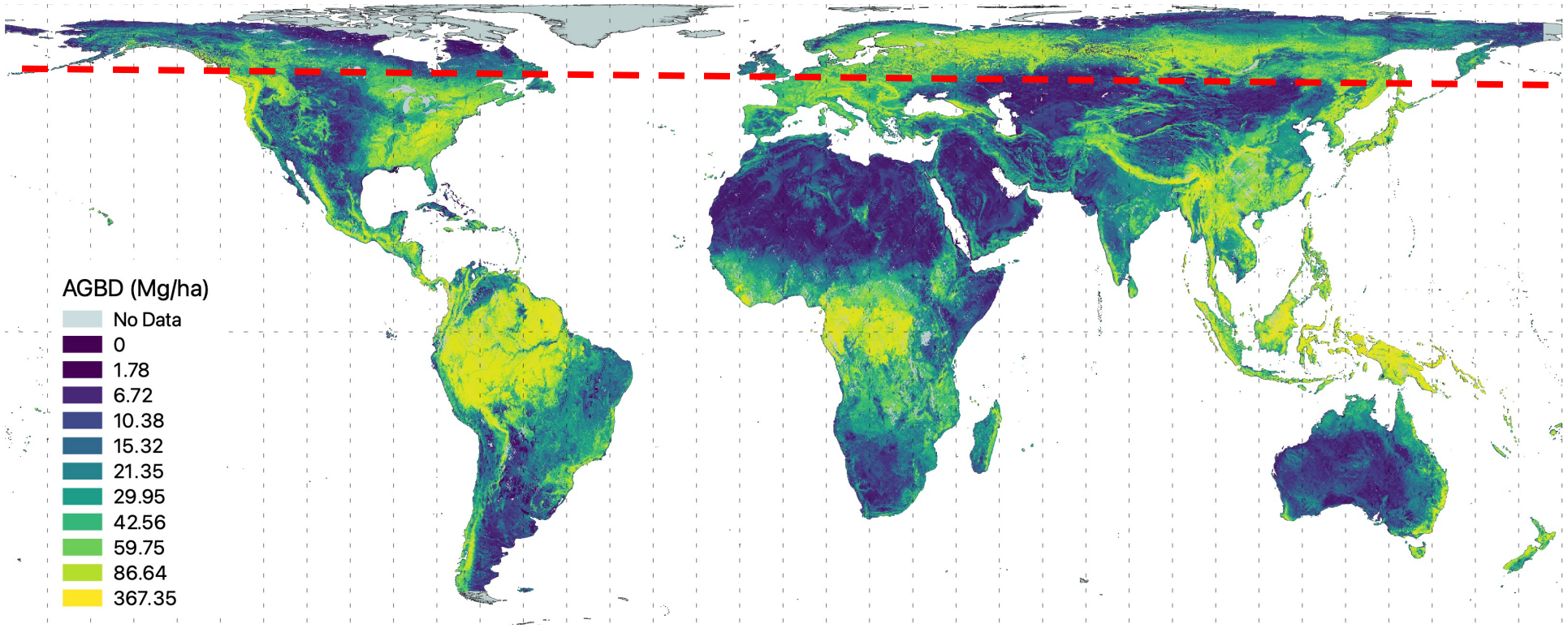
Global Aboveground Biomass Product Validation
Best Practice Protocol

Version 1.0 – 2020

Editors: Laura Duncanson, Mat Disney, John Armston, David Minor, Jaime Nickeson

Supports uptake of CEOS biomass protocol (endorsed in Spring 2021) which recommended consistent and transparent cal/val of biomass products across agencies

Current Biomass Products - NASA



ICESat-2 Boreal: 94 Pg

GEDI: 506 Pg

Global NASA Lidar AGB Estimate: ~600 Pg for 2020

Equivalent to ~ 1,100 billion tons of CO_2 – about 30 years of global emissions

Duncanson et al., in prep

biomass cci

esa

- Version 4 with global maps from 2010, 2017, 2018, 2019 and 2020 in cooperation with JAXA

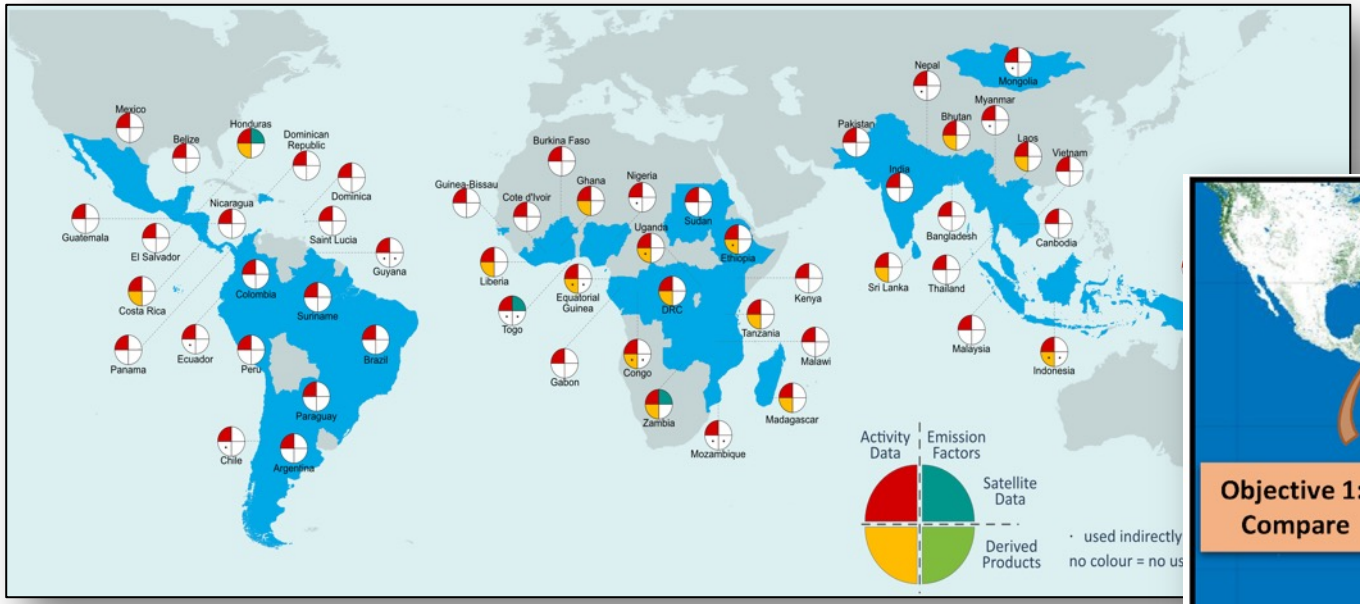
- Released at GFOI Plenary May 2023

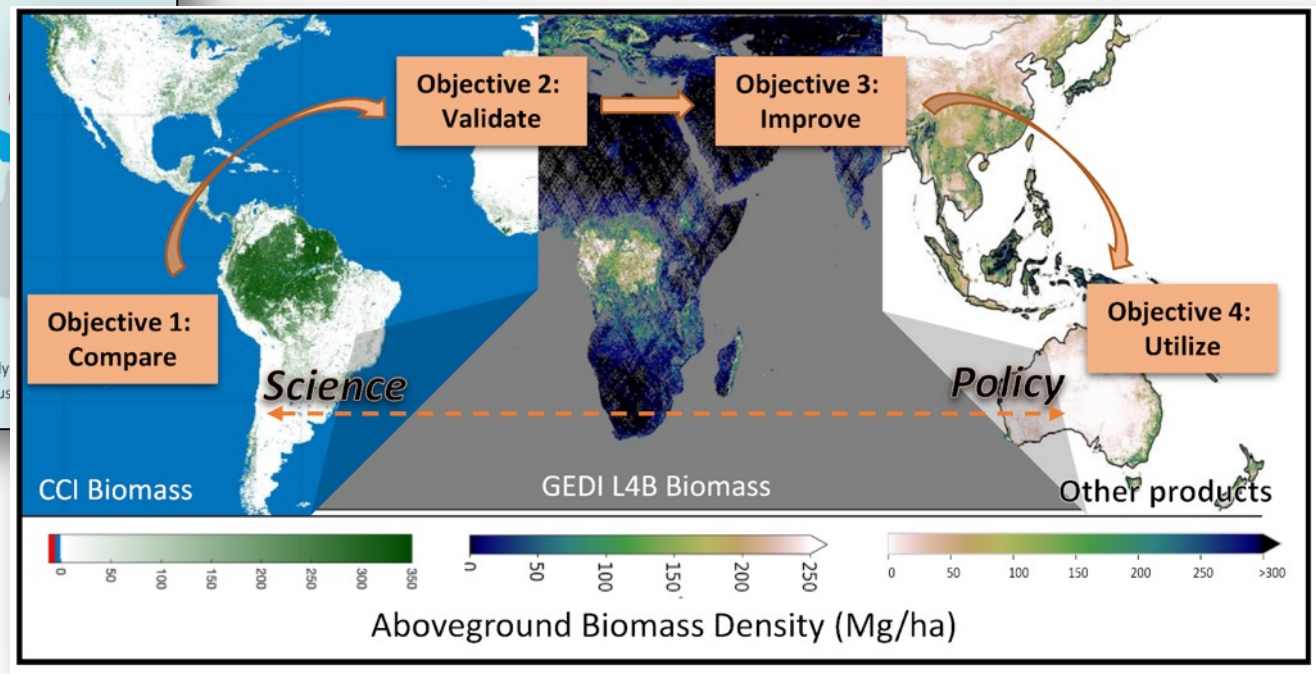
- Consistency: a decade of change
- Synergy of lidar and SAR data

➔https://climate.esa.int/en/odp/#/project/biomass

Space-based biomass estimates are not ***yet*** being used in UNFCCC reporting

Space-based activity data (typically from Landsat / Sentinel-2) are being frequently used in reporting.





Satellite-based global maps are rarely used in forest reference levels submitted to the UNFCCC

Joana Melo[4,1], Timothy Baker[1], Dirk Nemitz[2], Shaun Quegan[3] and Guy Ziv[1]

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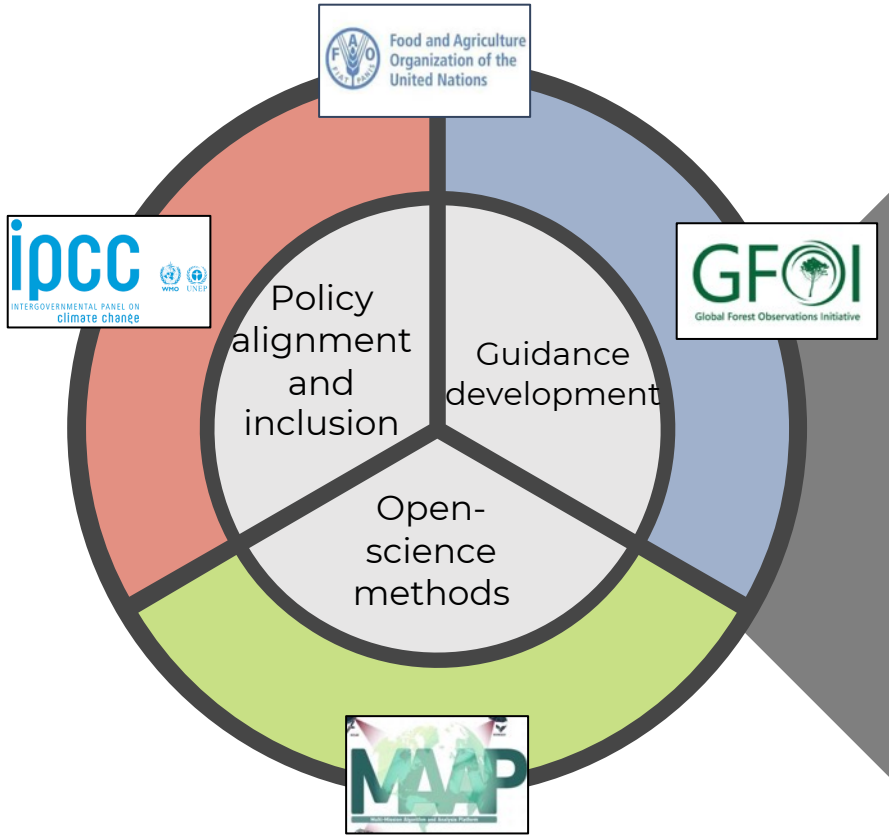
Environmental Research Letters, Volume 18, Number 3

Citation Joana Melo *et al* 2023 *Environ. Res. Lett.* **18** 034021

DOI 10.1088/1748-9326/acba31

Biomass Harmonization Activities



NASA Carbon Monitoring Systems 2022

In-review, Feb 2024

IPCC Tier 1 AGBD estimates from EO data

- Delivers AGBD estimates, in the format of Intergovernmental Panel on Climate Change (IPCC) Tier 1 values for natural forests.
- Sourced from NASA GEDI mission and ESA CCI Biomass initiative

Direct use:

- **IPCC Emissions Factors Database**

esa JRC EUROPEAN COMMISSION

20-22 March, 2024

Biomass to Policy workshop

- How to communicate policy requirements to map makers, and product integration with (ground)NFI data to map users
- Toward new guidance documentation for using EO biomass products

Use Cases:

- **Mexico:**
- **Mozambique**
- **West Africa**

CONAFOR · WAGENINGEN · USFS · JAXA · USGS

Updated daily

Public source codes for AGB map and NFI integration

- The ESA-NASA Joint Multi-Mission Algorithm and Analysis Platform (MAAP) is a collaborative cloud-computing environment.
- The open-source Biomass Harmonization public Gitlab repository is regularly updated and maintained.

Use case:

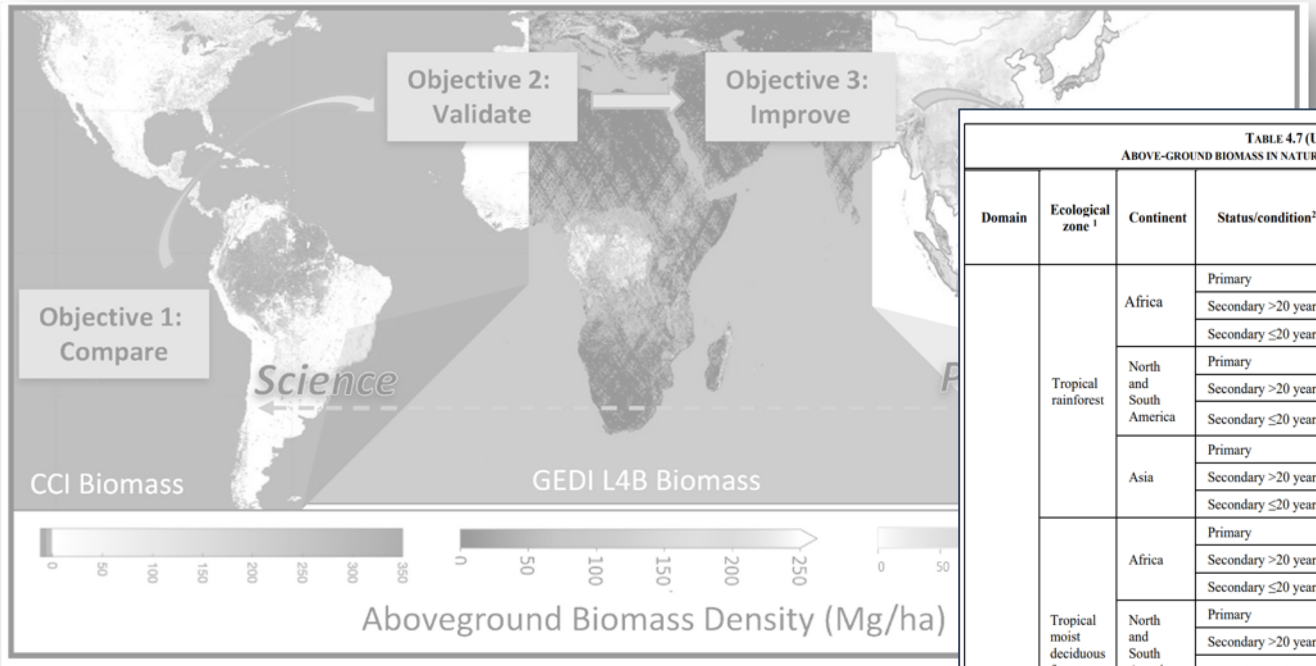
- **Country summaries of AGB density and stock with EO maps**

NASA · University of Maryland

Biomass Harmonization Activities

- Biomass product intercomparison framework and paper
- Creating policy-relevant (IPCC) tables with EO biomass products instead of default means to facilitate uptake

Harmonizing maps with policy needs



2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

TABLE 4.7 (UPDATED)
ABOVE-GROUND BIOMASS IN NATURAL FORESTS (TONNES D.M. HA^{-1})

Domain	Ecological zone [1]	Continent	Status/condition [2]	Above-ground biomass [tonnes d.m. ha^{-1}]	Uncertainty	Uncertainty type	References
Tropical	Tropical rainforest	Africa	Primary	404.2	120.4	SD	1-12
			Secondary >20 years	212.9	143.1	SD	5-7, 11, 13-16
			Secondary ≤20 years	52.8	35.6	SD	9-11, 14, 15, 17
		North and South America	Primary	307.1	104.9	SD	3, 4, 9, 10, 18-21
			Secondary >20 years	206.4	80.4	SD	9, 10, 22-28
			Secondary ≤20 years	75.7	34.5	SD	9, 10, 14, 22, 23, 28-32
		Asia	Primary	413.1	128.5	SD	3, 4, 9, 10, 33-35
			Secondary >20 years	131.6	20.7	SD	9, 10, 36, 37
			Secondary ≤20 years	45.6	20.6	SD	9, 10, 37-39
	Tropical moist deciduous forest	Africa	Primary	236.6	104.7	SD	1, 2, 16
			Secondary >20 years	72.8	36.4	SD	9, 10, 16, 40-47
			Secondary ≤20 years				
		North and South America	Primary	187.3	94.0	SD	3, 4, 9, 10, 18-21
			Secondary >20 years	131.0	54.2	SD	9, 10, 22-26
			Secondary ≤20 years	55.7	28.7	SD	9, 10, 22, 23, 25, 26
		Asia	Primary	67.7	93.4	SD	9, 10, 35, 48-50
			Secondary >20 years				
			Secondary ≤20 years				

Variable	Description	Equation from the IPCC 2006 Guidelines
$B_{AFTER,i}$	Biomass stocks on land type *i* immediately after conversion [t d.m. ha^{-1}]	Equation 2.16
$B_{BEFORE,i}$	Biomass stocks on land type *i* before conversion [t d.m. ha^{-1}]	Equation 2.16
ΔC_G	Annual increase in carbon stocks due to growth on land converted to another land-use category or in land remaining in the same land-use category by vegetation type and climatic zone [tC y^{-1}]	Equation 2.7, 2.9
ΔC_L	Annual decrease in carbon stocks due to losses from harvesting, fuel wood gathering and disturbances on land converted to other land-use category or in land remaining in the same land-use category [tC y^{-1}]	Equation 2.7 and 2.11
C_{t1}	Carbon stock in the pool at time t1 [tC]	Equation 2.5 and 2.8
C_{t2}	Carbon stock in the pool at time t2 [tC]	Equation 2.5 and 2.8

Hunka et al. (*in review*)

Biomass Harmonization Examples: Creating an EO-based version of IPCC Tier 1 Biomass Estimates

- Example of creating **policy-relevant tables with EO biomass estimates**
- AGBD estimates are provided in the format of Intergovernmental Panel on Climate Change (IPCC) Tier 1 values for natural forests, sourced from NASA GEDI and ICESat-2, and ESA CCI.
- A classification of global forests by ecozones, continents and status (primary, young and old secondary) also provided.
- Open-science activity on the Multi-mission Algorithm and Analysis Platform (MAAP) – ***updatable, reproducible, transparent***
- Collaboration between EO map producers, GFOI, IPCC, others

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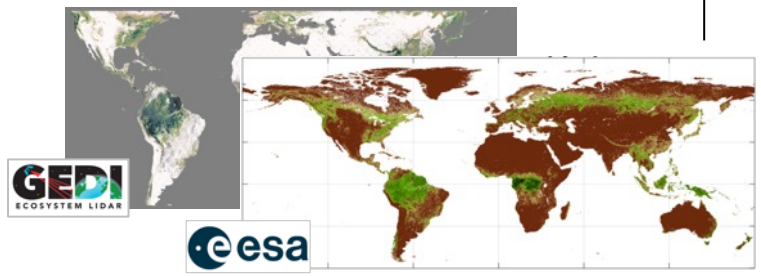
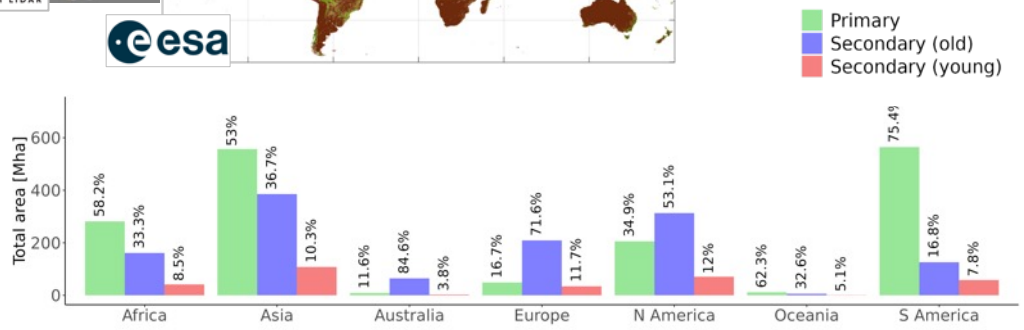
	Tropical rainforest	Africa	Primary	404.2	120.4	SD	1-12	
			Secondary >20 years	212.9	143.1	SD	5-7, 11, 13-16	
			Secondary ≤20 years	52.8	35.6	SD	9-11, 14, 15, 17	
		North and South America	Primary	307.1	104.9	SD	3, 4, 9, 10, 18-21	
			Secondary >20 years	206.4	80.4	SD	9, 10, 22-28	
			Secondary ≤20 years	75.7	34.5	SD	9, 10, 14, 22, 23, 28-32	

Useful proof of concept, potentially useful for some countries or reviewers, but most countries do not use the Tier 1 Tables





Hunka et al., in review (preprint available)

Biomass Harmonization: Understanding and Overcoming Roadblocks Toward EO Product Uptake

What have we learned about appetite for EO Biomass Products

1. Countries have **multiple needs for biomass data**: national reporting for UNFCCC, national and sub-national carbon credits, stocks, fluxes and degradation estimation, conservation and restoration impacts, etc.

2. **Countries with robust NFIs unlikely to use EO Biomass maps directly for national reporting** on stocks, but may want to enhance precision, gap-fill NFIs, report on degradation, participate in EO product validation, use as independent reference data, and/or use for sub-national reporting / carbon market activities

3. **Most countries have some forest biomass data** (complete or incomplete NFIs, field plots, maybe airborne lidar) – usually not starting from nothing

4. Different countries have different data availability and needs, **no one solution fits all**, need solutions custom tailored for the country, co-created with the country's technical teams

Biomass Harmonization: Understanding and Overcoming Roadblocks Toward EO Product Uptake

What have we learned about barriers to use of EO Biomass Products

1. **Trust in data product quality**
   - no globally representative reference dataset exists (GEO-TREES, others working on it…)
   - national validation of products typically required to pass review

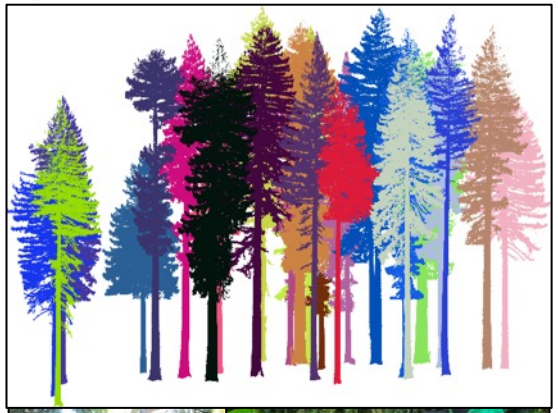
2. **Trust in data product continuity**
   - developing reporting frameworks around EO data is expensive and time consuming
   - many reporting frameworks require consistency in methods, therefore time series required; long-term continuity of key EO missions / sensors is critical

3. **Transparency, repeatability, consistency required**
   - No black boxes
   - Consistency in methods and data streams
   - Open science critical and timely!
   - capacity development important – countries need to lead (and defend) the technical work

4. Countries look to follow published **guidance documents** from IPCC, GFOI, others and this is generally lacking for use of EO biomass data

Trust in Product Quality: Linking to GEO-TREES

Updated Reference Data Remain Critically Important for Improved Biomass Mapping



Committee on Earth Observation Satellites

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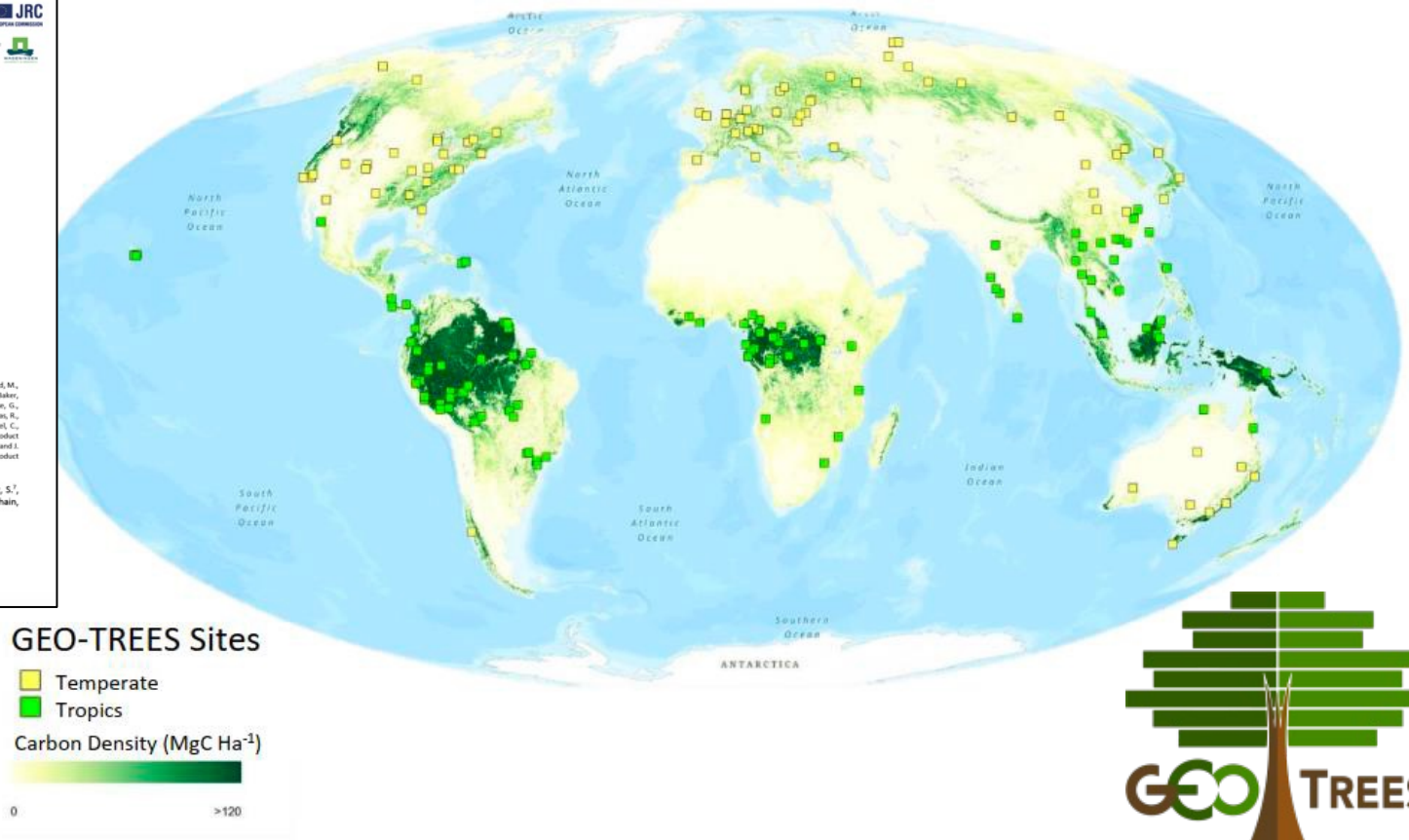
Global Aboveground Biomass Product Validation
Best Practice Protocol

Version 1.0 – 2020

Editors: Laura Duncanson, Mat Disney, John Armston, David Minor, Jaime Nickeson

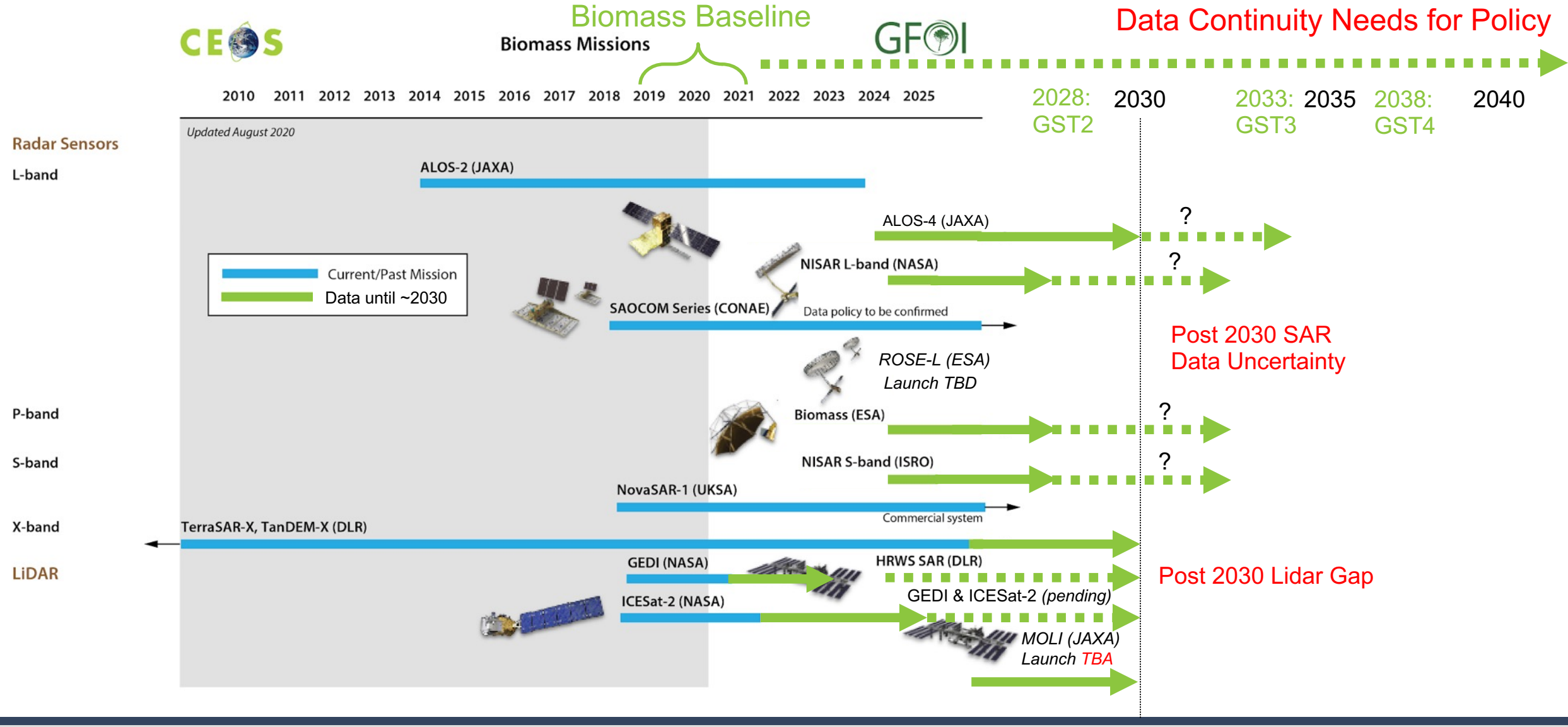
Citation: Duncanson, L., Armston, J., Disney, M., Avitabile, V., Barbier, N., Calders, K., Carter, S., Chave, J., Herold, M., MacBean, N., McRoberts, R., Minor, D., Paul, K., Réjou-Méchain, M., Roxburgh, S., Williams, M., Albinet, C., Baker, T., Bartholomeus, H., Bastin, J.F., Coomes, D., Crowther, T., Davies, S., de Bruin, S., De Kauwe, M., Domke, G., Falkowski, M., Fatoyinbo, L., Goetz, S., Jantz, P., Jonckheere, I., Jucker, T., Kay, H., Kellner, J., Labriere, N., Lucas, R., Morsdorf, F., Phillips, O.L., Quegan, S., Saatchi, S., Schaaf, C., Schepaschenko, D., Scipal, K., Stovall, A., Thiel, C., Wulder, M.A., Camacho, F., Nickeson, J., Roman, M., Margolis, H. (2020). Global Aboveground Biomass Product Validation Best Practices Protocol. Version 1.0. In L. Duncanson, M. Disney, J. Armston, D. Minor, F. Camacho, and J. Nickeson (Eds.), Best Practice Protocol for Satellite Derived Land Product Validation, (p. 222): Land Product Validation Subgroup (WGCV/CEOS), doi:10.5067/doc/ceoswgcv/lpv/agb.001

Duncanson, L.[1], Armston, J.[1], Disney, M.[2,3], Avitabile, V.[4], Barbier, N.[5], Calders, K.[6], Carter, S.[7], Chave, J.[8], Herold, M[9]., MacBean, N.[10], McRoberts, R.[11], Minor, D.[1], Paul, K.[12], Réjou-Méchain,



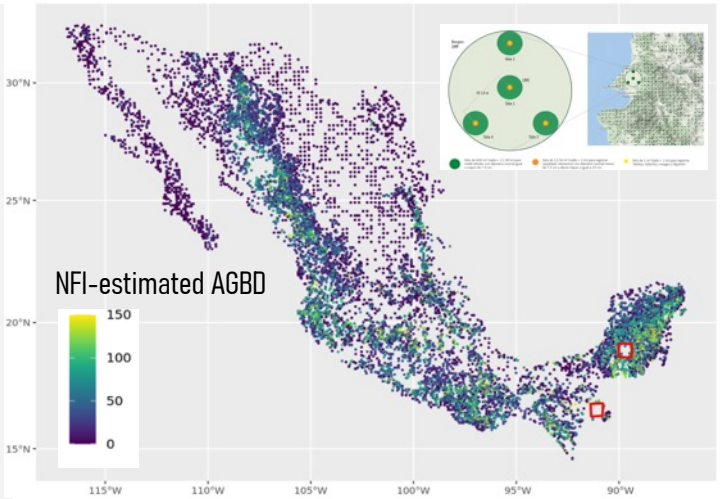
GEO-TREES is collecting new field and lidar reference data for biomass product calibration and validation. Primary funding from Bezos Earth Fund (BEF, $12M for tropical sites).

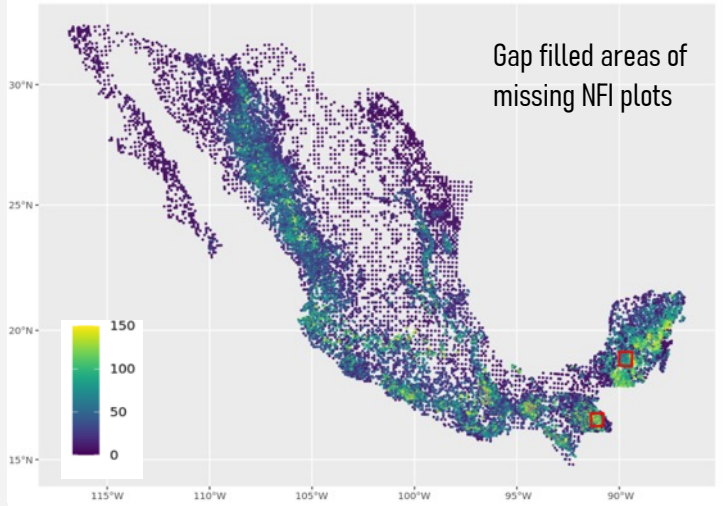
CEOS Biomass Missions: Trust in Data Continuity

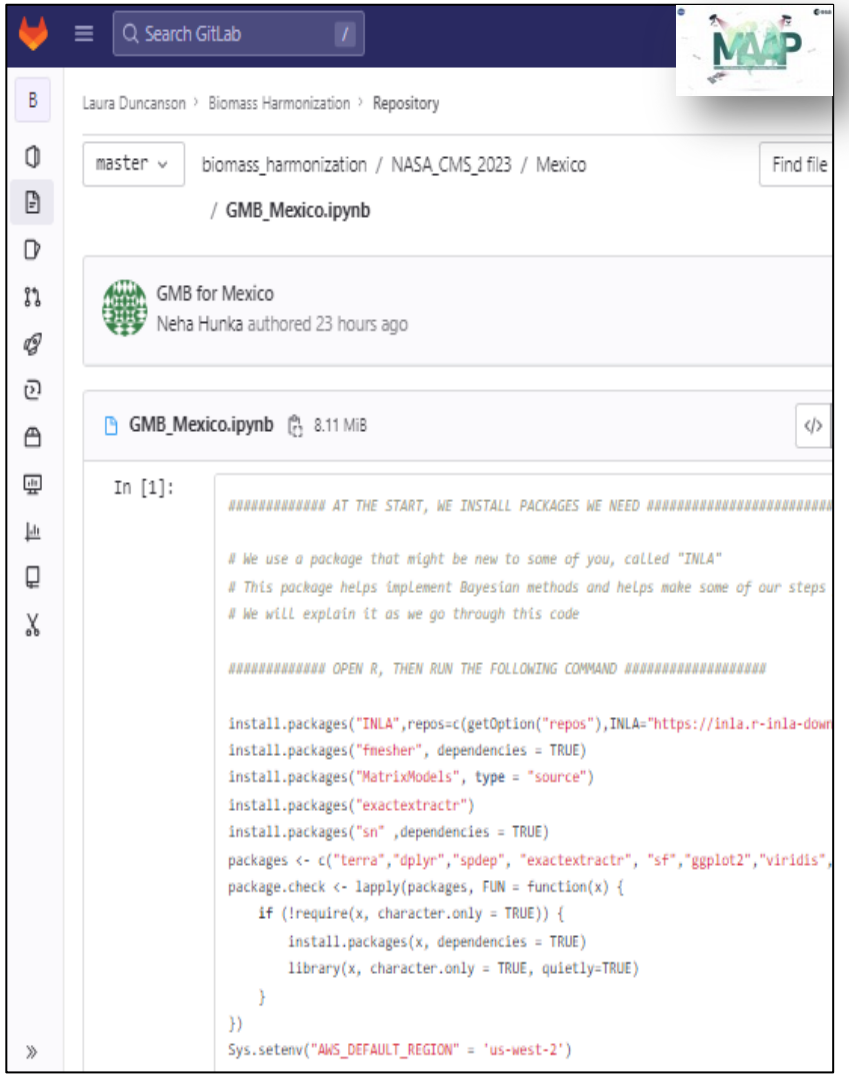


Biomass Harmonization: Open Source Tools for Integrating EO and NFI data For National Reporting

- Biomass Harmonization activities include efforts to include EO biomass products in national reporting frameworks.
- An **open-science** case-study for Mexico using model-based estimators is being developed.
- The objectives are to:
    1. Gap-fill areas where Mexico's 3rd NFI cycle is incomplete
    2. Enable prediction of baseline biomass in potential areas of disturbance (e.g. sites of deforestation)
    3. Use **integrated NFI and EO-based biomass** estimates in reporting.
- Work in progress and underlying source codes are publicly accessible through NASA MAAP Gitlab repository







Available at public [Biomass Harmonization Gitlab repository]

Biomass Harmonization: Integrating EO Biomas and NFI data For National Reporting

Global comparative study including a range of AGB density and NFI sampling designs (Peru, Guyana, Tanzania and **Mozambique**)

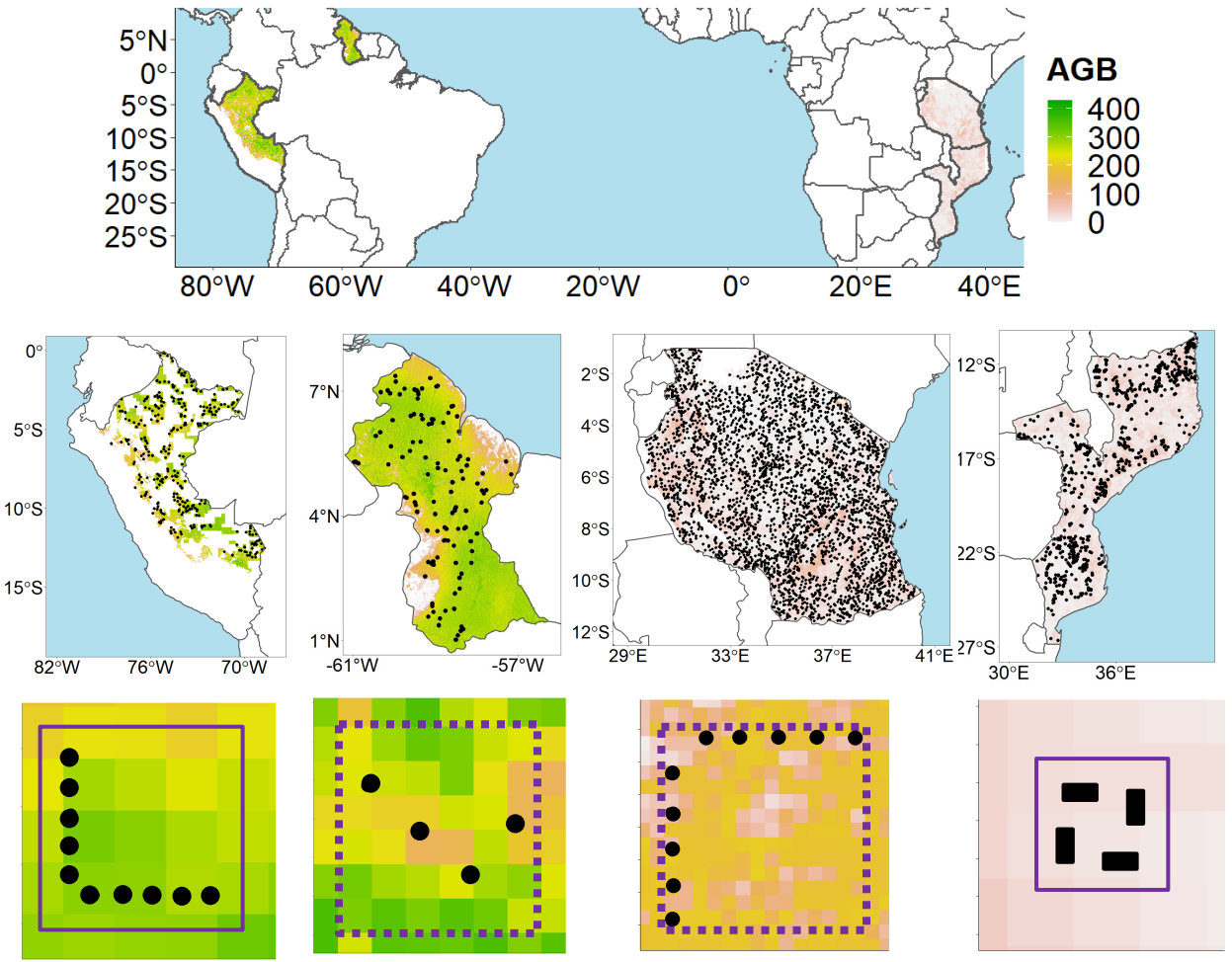
The objectives are to:

1. Assess how a locally calibrated global biomass product increases the precision of (sub)national AGB estimates in different biomes
2. Identify the main map-to-plot harmonization challenges that countries face when integrating biomass map information with NFI data under the model-assisted framework

In benefit of:

Countries struggling to complete or update their NFIs (often in the tropics), or wanting to report with greater confidence

Making the case study of Mozambique fully open-access (data & code)

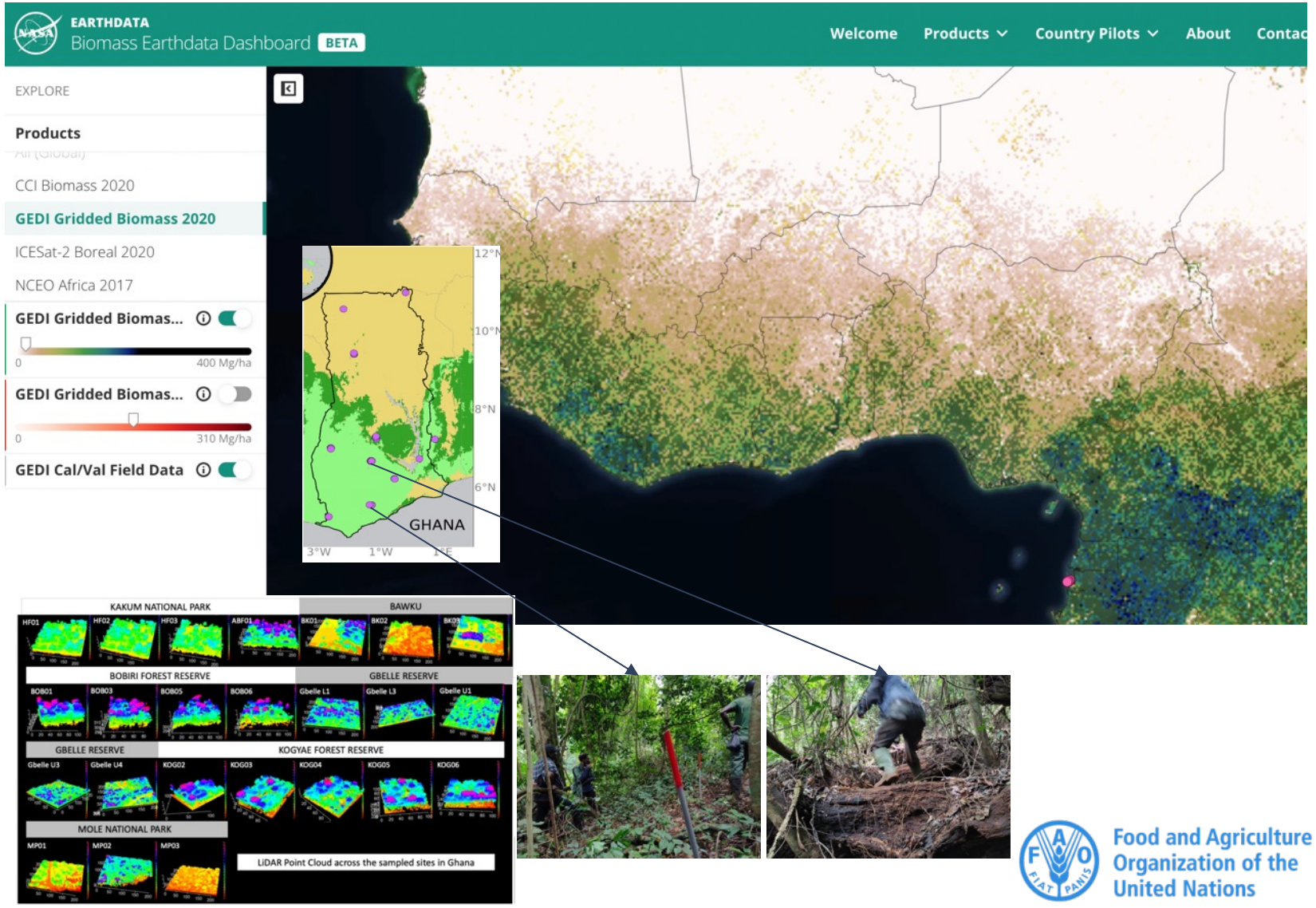


Málaga et al., in review

Biomass Harmonization:
Country Use Cases, Ghana / West Africa

Objectives:

- FAO supported effort to use GEDI Biomass Data toward national reporting in West Africa.
- 5-year collaborative product 'Global Transformation of Forests for People and Climate: a focus on West Africa' between UN FAO, SIDA, ECOWAS
- Little forest biomass data are available in the 15 participating West African countries – can we use GEDI to gap-fill?
- **Collection of regional reference data critical to calibrate / validate GEDI**
- **Showcase how EO-based estimates can be used to fill gaps in current guidance in the policy domain**, such as biomass estimates in lands outside 'forests' and EO-based estimates for refining IPCC Tier 1 defaults.



Food and Agriculture Organization of the United Nations

Biomass Harmonization: Understanding and Overcoming Roadblocks Toward EO Product Uptake

1) Trust in data product quality	→	1) GEO-TREES and allied projects are collecting new reference data. **Space agencies are encouraged to collaborate and bolster these efforts**
2) Trust in data product continuity	⇢	**2) Space agencies are encouraged to work toward continuity of lidar and SAR missions and associated biomass mapping activities**
3) Transparency, repeatability, consistency required	→	3) – Open data and code increasing. **Space agencies are encouraged to continue supporting Open Science (products, source data and code).** Co-development of use cases with countries in progress with links to FAO, USGS Silvacarbon, others (Mexico, Mozambique, Ghana, Cambodia, more)
4) Need for guidance documentation and examples using uptake of EO biomass products	⇢	4) GFOI MGD module on emissions factors to be updated / drafted. Country case studies, data and code to be integrated into guidance. **Space agencies are encouraged to support researchers to participate**

Biomass Harmonization: Ongoing Roadblocks and Recommendations

- We are still in early days of new generation of biomass map availability; **trust needs to be built in data quality and continuity**

- Open-source science and clear communication is key

- Country examples are expanding; work is ongoing to overcome some barriers. Continued space agency support it critical.

Thank you

Biomass Harmonization Team:

For Supporting Biomass Missions and/or GEO-TREES: