Committee on Earth Observation Satellites

# WGCV LPV Biomass Validation Protocol and Implementation Considerations

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College Park, WGCV LPV Biomass

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# CEOS WGCV LPV Biomass Validation Protocol

**Protocol Authors:**

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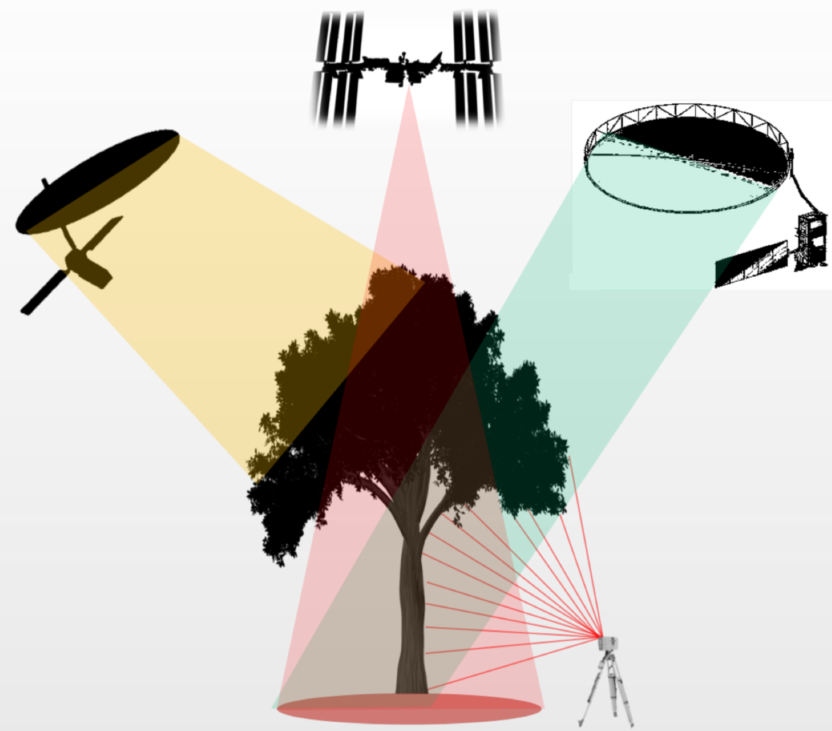
Avitabile, V., Barbier, N., Calders, K., Carter, S., Chave, J., Herold, M., MacBean, N., McRoberts, R., Minor, D., Paul, K., Réjou-Méchain, M., Roxburgh, S., Williams, M., Albinet, C., Baker, T., Bartholomeus, H., Bastin, J.F., Coomes, D., Crowther, T., Davies, S., de Bruin, S., De Kauwe, M., Domke, G., Falkowski, M., Fatoyinbo, L., Goetz, S., Jantz, P., Jonckheere, I., Jucker, T., Kay, H., Kellner, J., Labriere, N., Lucas, R., Morsdorf, F., Ong, C., 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.



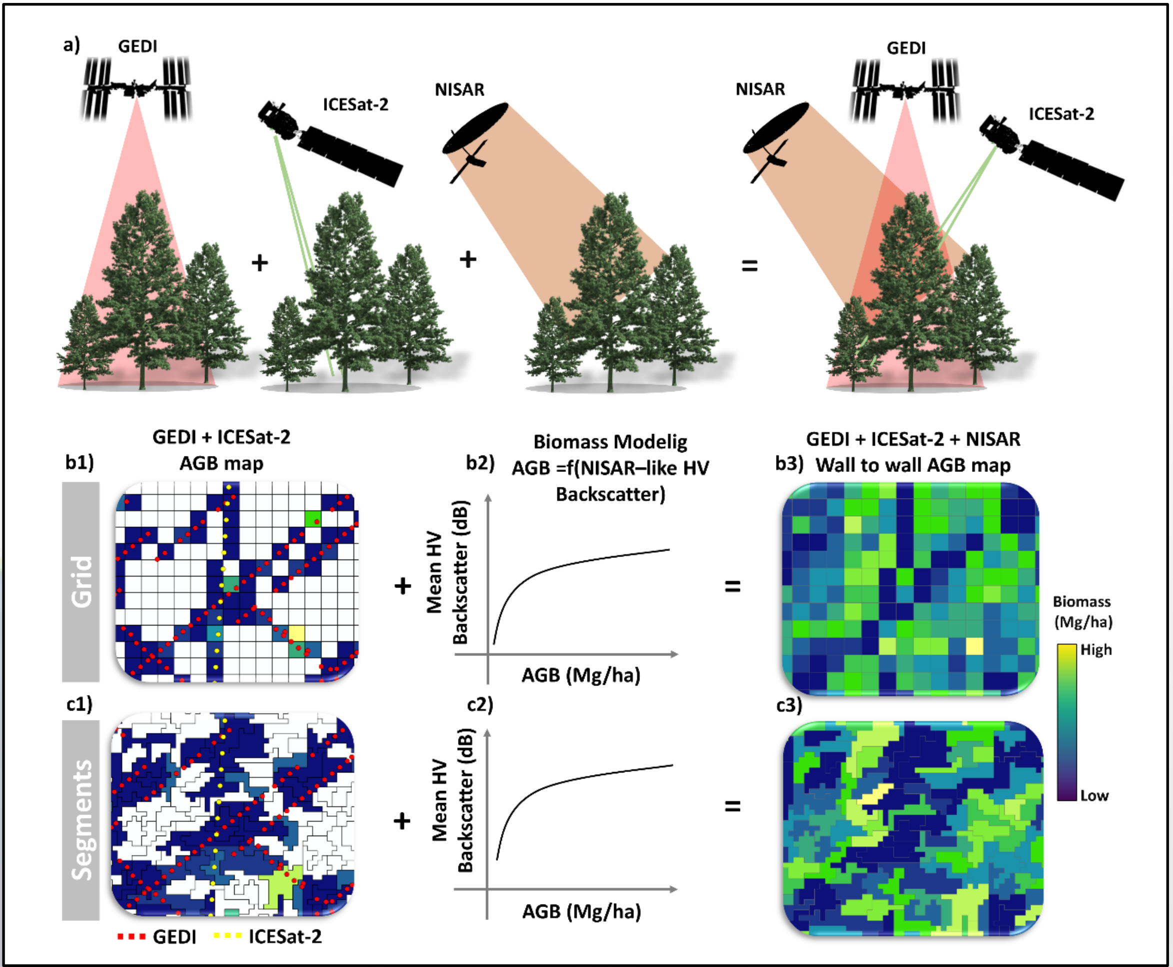
**Business Case Authors:**

Jerome Chave, Stuart Davies, Laura Duncanson, Nicolas Labrière, Oliver Phillips, Sassan Saatchi, Dmitry Schepaschenko, Klaus Scipal, Shaun Quegan

# Many Upcoming Missions will Provide Data Used to Map Biomass

| Mission | Funding Agency | Launch Date (Expected) | Data Type | Measurement resolution | Biomass map Resolution | Geographic Domain | Accuracy Requirement |
|---|---|---|---|---|---|---|---|
| ICESat-2 | NASA | 09/2018 | 532 nm photon counting lidar | 13m footprint aggregated to 100-m transect | NA | Global | NA |
| SAOCOM 1A | CONAE | 10/2018 | L band SAR | 10-100m depending on mode | NA | Global | NA |
| GEDI | NASA | 12/2018 | 1064 nm waveform lidar | 25 m circular footprint | 1 km | ISS (+/- ~51.6°) | <20% standard error for 80% of forested 1 km cells |
| SAOCOM 1B | CONAE | 08/2020 | L band SAR | 10-100m depending on mode | NA | Global | NA |
| ALOS-4 | JAXA | (2022) | L-band SAR | 1-25 m depending on mode | NA | Global | NA |
| NISAR | NASA/ISRO | (2023) | L-band SAR | 3 - 10 m (depends on mode) | 1 ha | Global | <20% RMSE for <100 Mg/ha |
| BIOMASS | ESA | (2023) | P-band SAR | 60 x 50 m with >6 looks | 4 ha | Global except western Europe and North America | <20% RMSE for AGB >50 Mg/ha; 10 Mg/ha for AGB ≤50 Mg/ha |
| MOLI | JAXA | (2023) | 1064 nm waveform lidar | 25 m circular footprint | NA | ISS (+/- ~51.6°) | NA |
| TanDEM-L | DLR | (2023) | L-band SAR | TBD | 1 ha | Global | 20% accuracy or 20 Mg/ha |
| Copernicus HPCM ROSE-L | ESA/EC | (2027) | L-band SAR | TBD | 1 ha | Global | TBD |

# Many Biomass Mapping Approaches Through Fusion




Silva et al., in revision at RSE

Combining Multiple Data Streams (e.g. GEDI, ICESat-2, NISAR, BIOMASS, ALOS4) allows:

- Reduced errors
- Higher resolution maps

Open source tools enable production of many global maps (e.g. Google Earth Engine)

Thousands of ways to combine these data streams to map biomass

# WGCV LPV Biomass Protocol in Public Review

***The protocol is a good practices guide to biomass model calibration and product validation at a global (or near global) scale***


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

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

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## Guidance for:

- **Map producers** on how to estimate, propagate and report errors
- **Map users** on how to interpret errors
- How to collect reference data (field and airborne lidar)
- How to use reference data to conduct independent biomass product validation

## Summary of:

- State of knowledge of biomass mapping
- Community identified research and tool development priorities
- Recommendations for creating a **CEOS Forest Biomass Reference System**

# Definition of Biomass

"We define biomass as the dry mass of live or dead matter from tree or shrub (woody plant) life forms, typically expressed as a per area density (e.g. Mg of aboveground biomass per hectare). Thus, we do not include non-woody or belowground biomass. When discussing individual tree or plot total biomass (not density), the definition is Aboveground Biomass (AGB), whereas for plot or pixel level densities, as commonly estimated in mapped products, the definition is Aboveground Biomass Density, usually per hectare (AGBD/ha)."

# Biomass Protocol Structure

**Chapter 2: Good Practices for Field Biomass Estimation in the Field** (K. Paul, J. Chave, K. Calders)
- Allometric Error
- Field Measurement Error
- Terrestrial Laser Scanning

**Chapter 3: Linking Remote Sensing Observations to Field Estimates** (M. Réjou-Méchain, N. Barbier, J. Armston, L. Duncanson)
- Geolocation & Spatial Scale
- Using airborne data to scale from field to spaceborne data

**Chapter 4: Error Propagation** (S. Roxburgh, R. McRoberts)
- Sources of Uncertainty
- Extrapolating models to global maps

**Chapter 5: Utility of Protocol for Other Communities**
- Modeling community (M. Williams)
- Policy communities (M. Herold, S. Carter)
- Non-forest communities (N. MacBean)

**Chapter 6: Recommendations for User-led validation** (Valerio Avitabile)
- Harmonization of definitions
- Screening of Data
- Considerations of Scale

**Chapter 7: Knowledge Gaps**
- Experiments that will advance the field
- Airborne / Field data gaps
- Development of validation tools

**Chapter 8: Implementation Considerations**
- Data collection in global network of reference sites with field and airborne lidar
- Creation of CEOS Forest Biomass Reference System

**+ Appendices**
- Data collection protocols
- Proposed reference sites

**+ Executive Summary**

**Chapter 8 links to separate 'Business Case' Document**

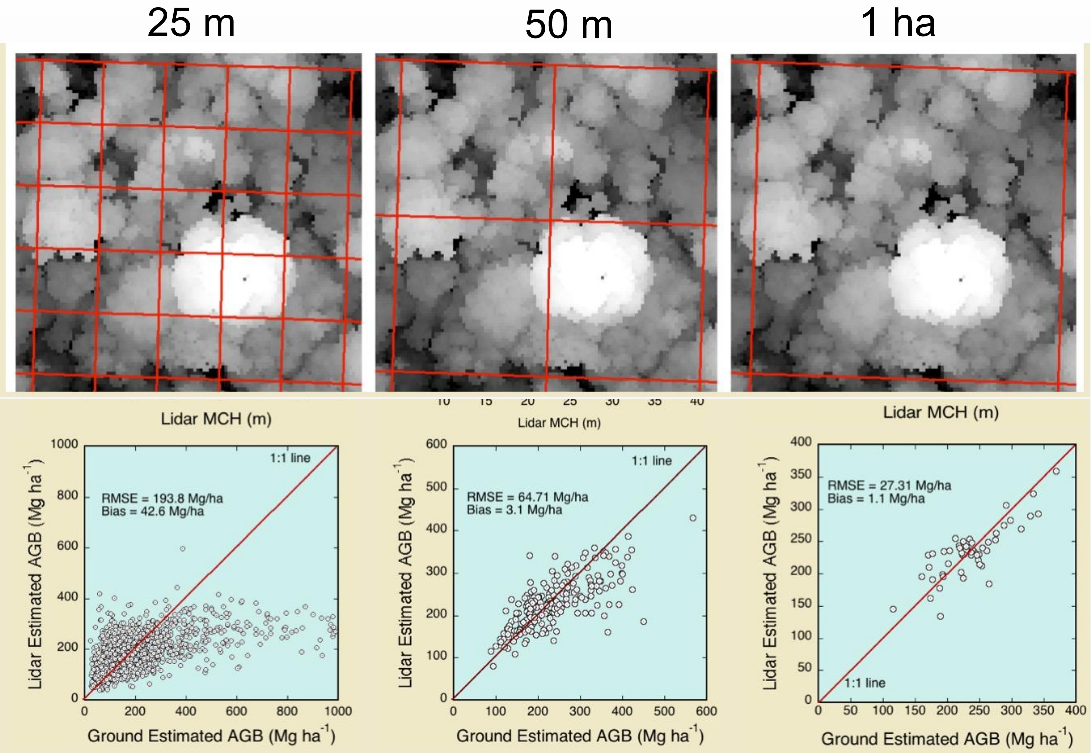
# Recommendations for Field Measurements

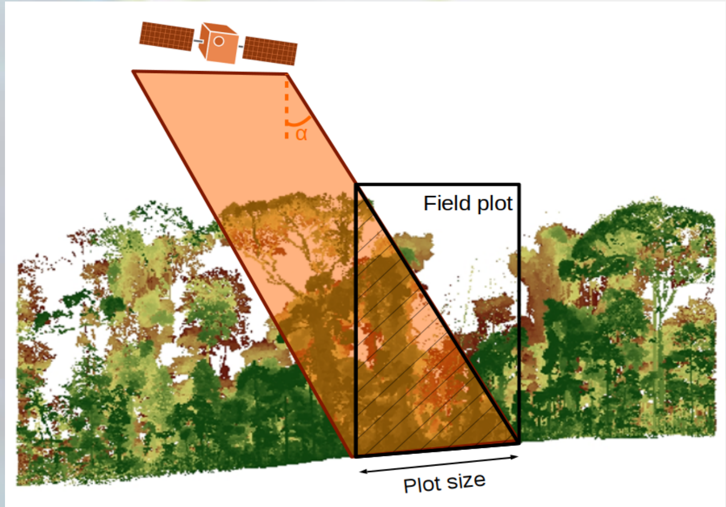
***Field Measurements and derived estimates are not truth – there can be large errors.***

- **Need transparent handling and reporting of errors, consistent definitions**
- **Recommendations for measurements**
- **Summary of uncertainties in allometric models, recommendations for improving allometries**
- **Terrestrial Laser Scanning (TLS) where possible**

# We Recommend Large Plots in Closed Canopy Forests (Especially Tropics)

- Small plots with poor geolocation are not useful for validation at the pixel-level
- Large plots reduce errors, particularly from large crowns/edge effects and geolocation

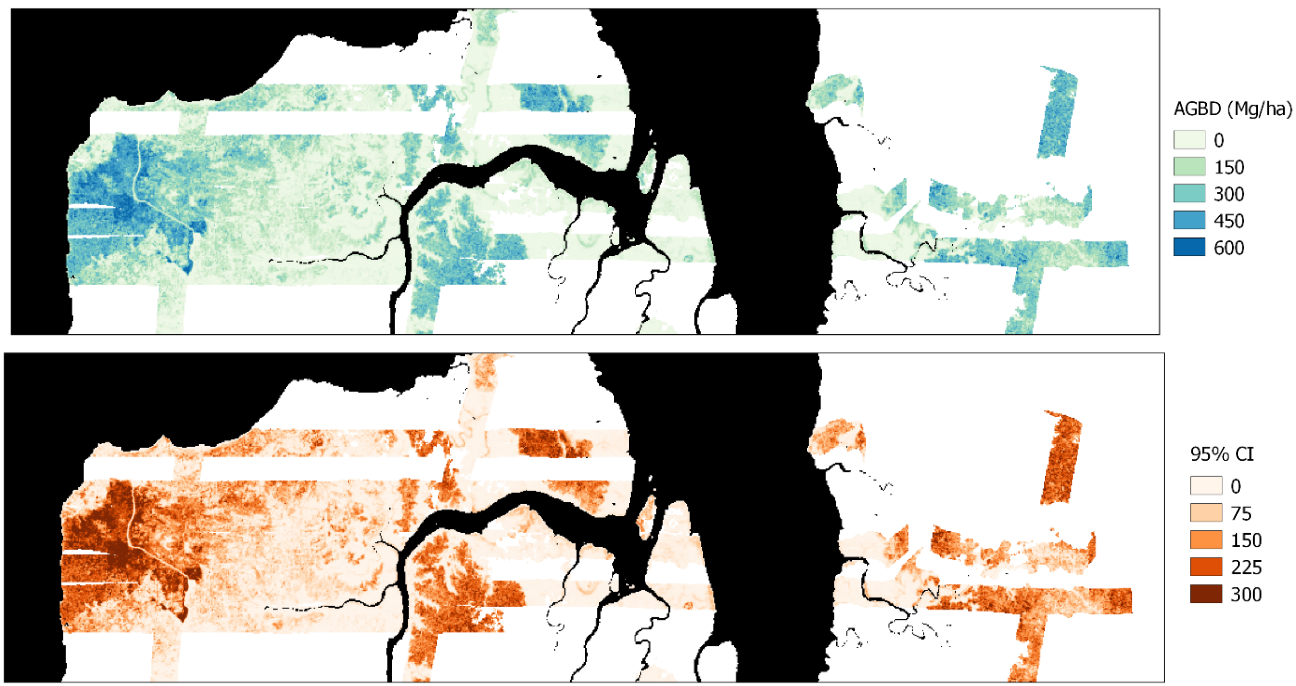


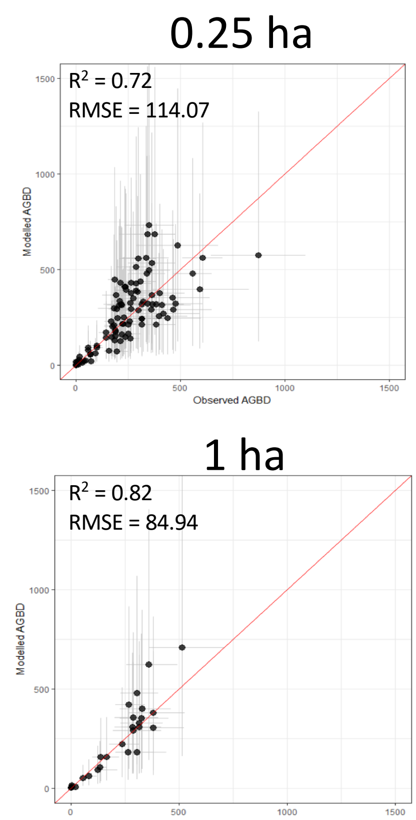




- 0.25 ha – 1 ha in tropics; smaller (~25 m) sufficient in temperate/boreal assuming good geolocation

# Airborne Lidar is Critical for Multi-mission Validation & Fusion

## Airborne lidar maps can provide multi-resolution validation (provided they are calibrated with local high-quality field plots over the range of environmental conditions covered by the lidar)



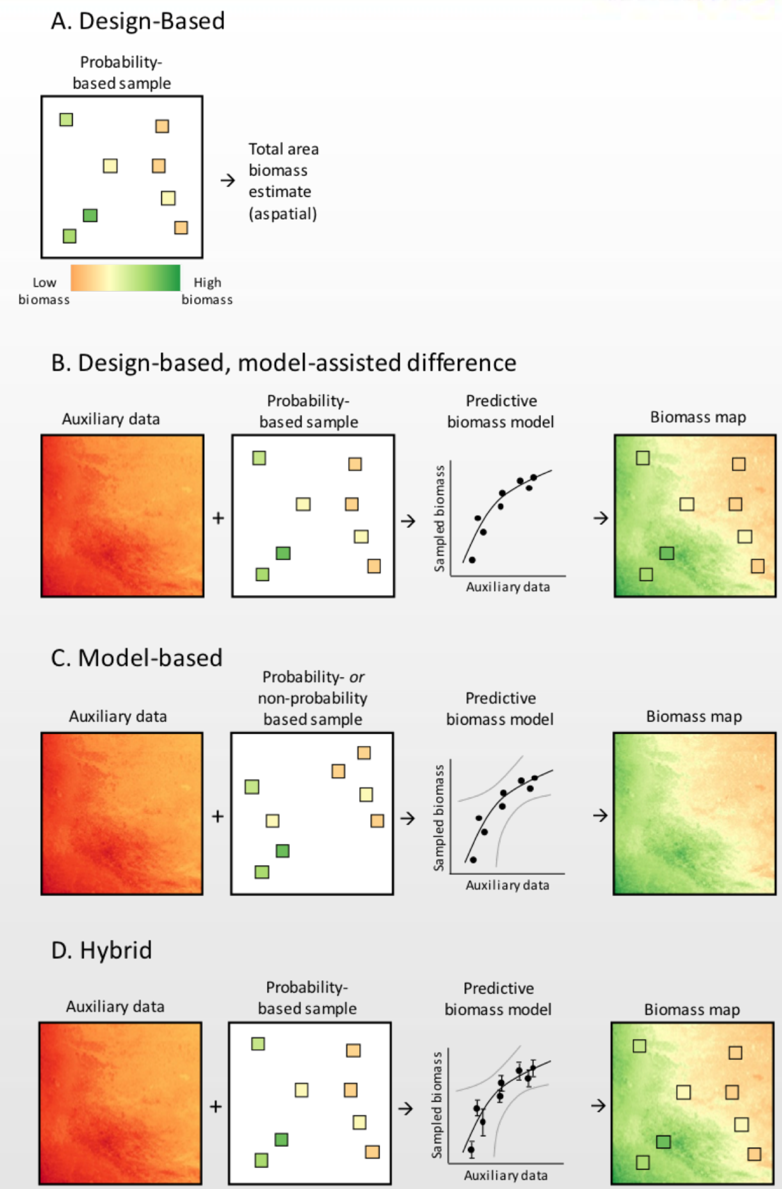

Armston et al., 2020; Fatoyinbo et al., in revision

# Uncertainties and Errors Should be Estimated as Consistently as Possible

Error reporting should comply with IPCC Good Practices Guidelines.

Measurement and modeling errors should be estimated following appropriate inference method and propagated to mapped products (both reference and satellite)

Stephen Roxburgh and Ron McRoberts



# Protocol Implementation Considerations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CEOS Endorsed Biomass Product Validation

Updated Reference Datasets

Validation Tools

# Proposal of a CEOS Forest Biomass Reference System

We propose the creation of a **CEOS Forest Biomass Reference System** as an equitable and sustainably-funded system of recurrent site-based measurements that will serve as a lasting interface between the Earth Observation agencies and ground-based tree-by-tree measurement initiatives.

No single EO mission or agency would alone support the costs of this implementation; this infrastructure is designed to become **a common good for the entire EO community**. With this project, CEOS has the opportunity to coordinate this effort, and liaise with the ground research and forestry community.

Jerome Chave et al., CEOS Validation Strategy Document

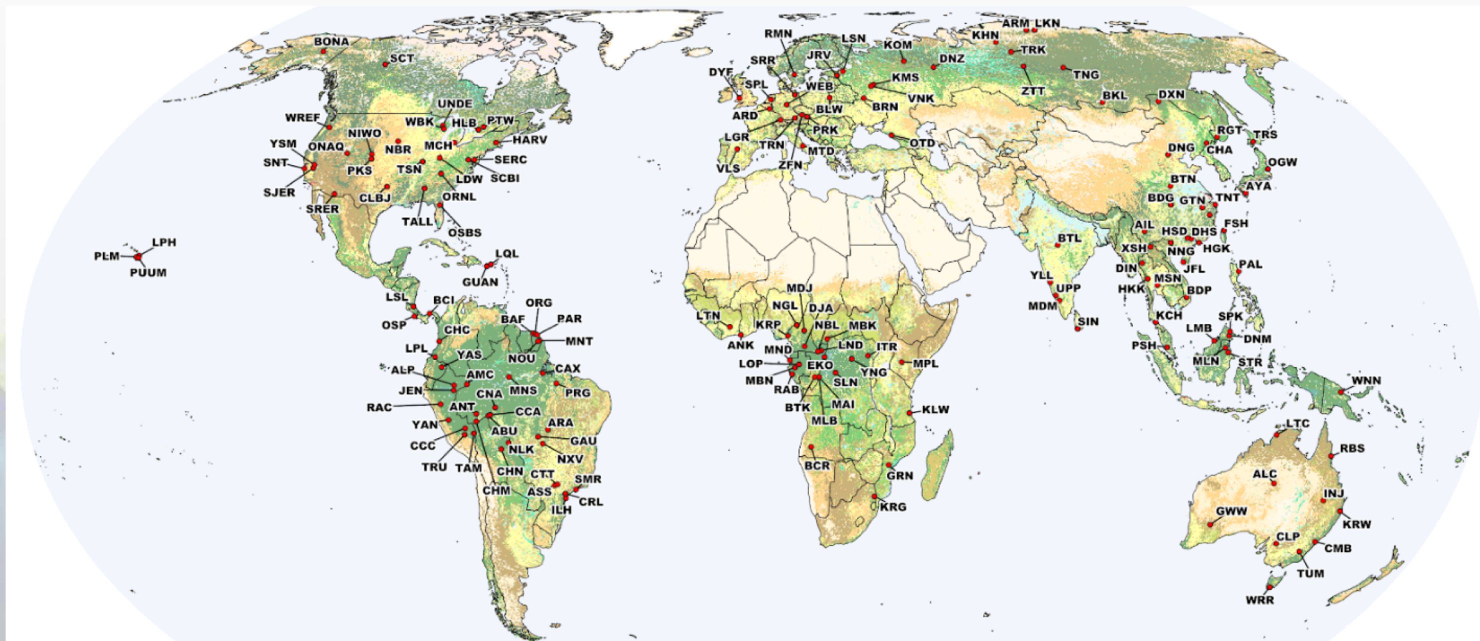
# Benefits of a CEOS Forest Biomass Reference System

- **The greatest value for the enormous EO investment will be gained if products are trusted**
- **Helps the missions achieve their ultimate goals** by allowing users to apply biomass products with confidence for science and applications
- **Would leverage existing investments** by agencies, missions, and established ecosystem and forest networks; we are not starting from scratch
- Develops a framework for **lasting contributions** to the advancement of the field, independent of grant cycles, mission lifetimes or shifting agency priorities
- Added value for training and validation of other land products (e.g. LAI, LCLUC)
- **Enables open forest reference data** by providing ongoing support to local researchers and field stations

# Proposed Biomass Reference Sites Require Funds for Upkeep

To minimize the cost, selected sites should preferably belong to existing plot networks

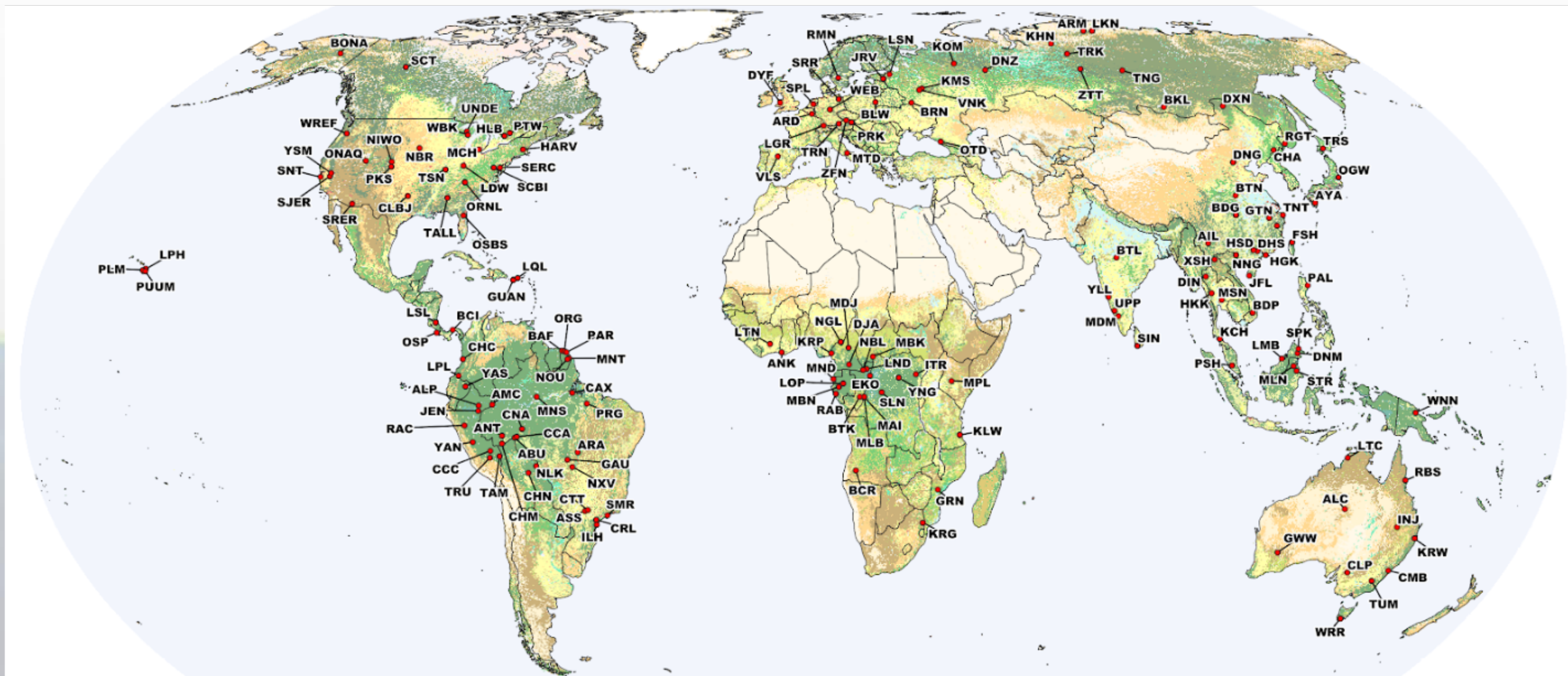
**These sites are *potential* reference sites; many need augmentation (+lidar, +TLS), and will be outdated by the 2022/2023 missions. They require significant funding (~34M € **) for coordinated re-measurement to meet protocol standards for validation of forthcoming biomass products.**




**Costs are higher in the biomass-rich tropics (remote sites, challenging species ID, limited long term support of plot networks). **This is an estimate for field collection, personnel time, airborne campaigns, data curation and processing**

# Requested Support

*We propose the creation of a CEOS Forest Biomass Reference System, a network of **100 Biomass Reference Measurement (BRM) sites**, plus **210 additional** distributed sites (distributedBRM). Such an infrastructure is needed to provide confidence in the outputs of biomass EO missions. Its estimated cost is 33.75 M€ over a 5-year period.*




If most agencies **each sponsor ~5-10 sites** we can meet this goal. Cost estimates will vary by region, and can be reduced through leveraging existing cal/val investments

# Conclusions and Recommendations from Biomass Community

No Space Agency alone can fund the required work to establish a global network of biomass reference sites but each Agency can make a contribution by e.g. funding national supersites or by adopting reference sites (i.e. by making a binding commitment to finance the collection and delivery of ground data over a certain period).

Space Agencies are encouraged to collaborate with established networks (e.g. ForestGEO, Rainfor, NEON, TERN, Afritron, TMFO, IIASA, etc) and their local collaborators.

**We welcome feedback on how to achieve the proposed creation of a Forest Biomass Reference System.**

# Notional Contribution Concept

**We welcome feedback on how to achieve the proposed creation of a Forest Biomass Reference System.**

CEOS Agencies → Plot Networks ⇄ In country measurements

**OR**

CEOS Agencies → In country measurements → Plot Networks

**OR… ?**

# Conclusions and Recommendations from Biomass Community

1. The **large number of new biomass data** and products **could reduce product uptake** by user community unless validation activities are user-friendly, transparent, and well-coordinated.

2. **Significant funding for new and updated reference datasets is required. We propose establishment of a CEOS Forest Biomass Reference System** of new and ongoing field, terrestrial and airborne lidar acquisitions

3. **Particular support is needed in the tropics** because this is where most biomass, tree growth, and diversity is located, and this is where long-term security for measurements is lacking.

4. The proposed system **enables all CEOS member agencies to contribute** to a global and lasting effort for forest carbon monitoring

5. Biomass reference **data should be free and open** to enable transparency in product validation.

# Thank you to the many data collaborators and protocol co-authors – this is a community driven activity!

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NAU Northern Arizona University
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Université de Toulouse
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