StatEO

5–7 May 2026 | ESA–ESRIN | Frascati (Rome), Italy

Integrating EO biomass maps with NFI to enhance the precision of forested-related biomass estimates

GFZ Helmholtz-Zentrum für Geoforschung

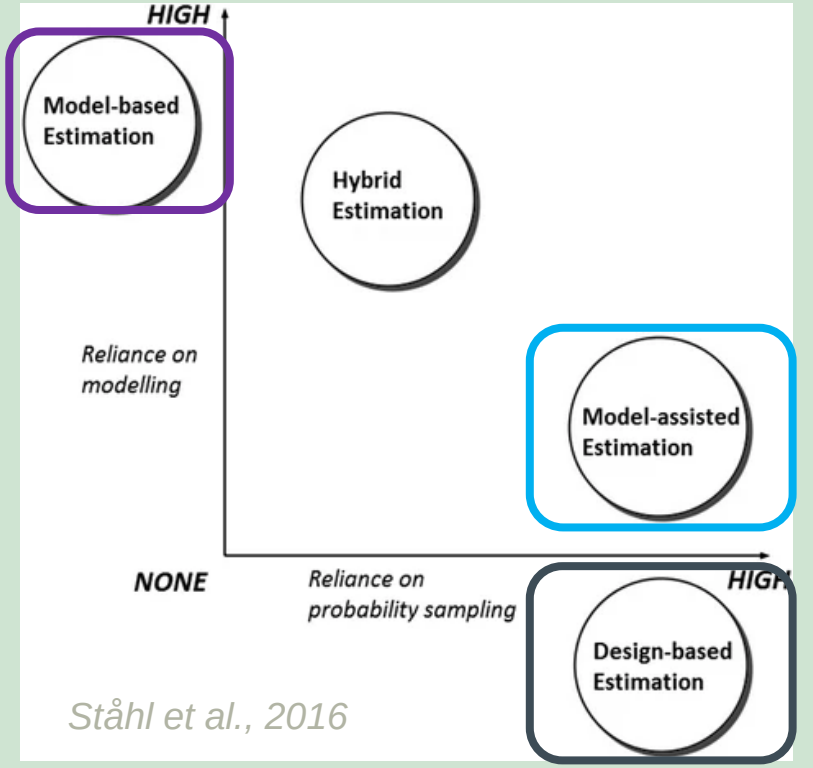
Natalia Málaga, Daniela Requena Suarez, Martin Herold

ESA UNCLASSIFIED - For ESA Official Use Only

Why should we enhance the precision of forest-related biomass estimates?

- Greater confidence in (sub)national AGB estimates: In line with IPCC guidelines → good practice to reduce uncertainties as far as practicable
- Address implementation challenges of ground surveys that include: incomplete NFIs, inaccessible areas (i.e., gaps), limited funding for implementation, etc.
- Improve sampling efficiency → Same targeted precision can be achieved with a reduced number of samples (saving money)

Existing country-case studies integrating EO biomass products with NFIs to increase the precisión of estimates

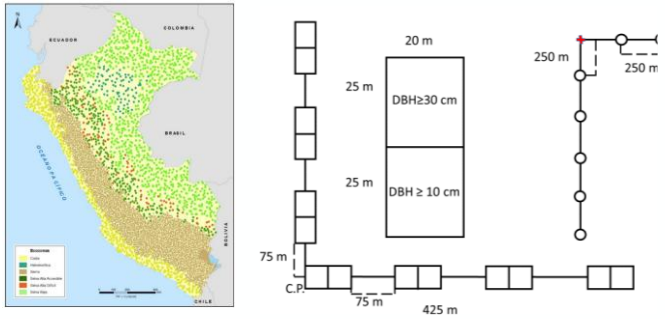


Design-based inference

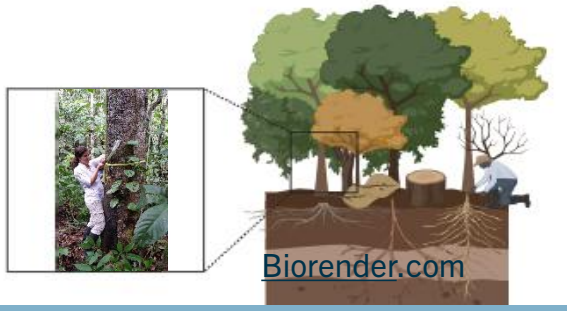
How do we estimate biomass stocks and changes within forests?

Using ground-based reference data → National Forest Inventories (NFIs)

1. Define a [probabilistic] sampling design (i.e., number, location and array of plots) based on the NFI's desired level of precision
2. Collect information from the ground (e.g., tree species, DBH, tree height) and used an allometric equation to estimate biomass/carbon
3. Estimate the mean biomass/carbon per AOI (e.g., stratum)
4. Estimate the standard error / CI of biomass/carbon per AOI



Peru's sampling frame - SERFOR



DESIGN-BASED

Sampling design

Probability sample

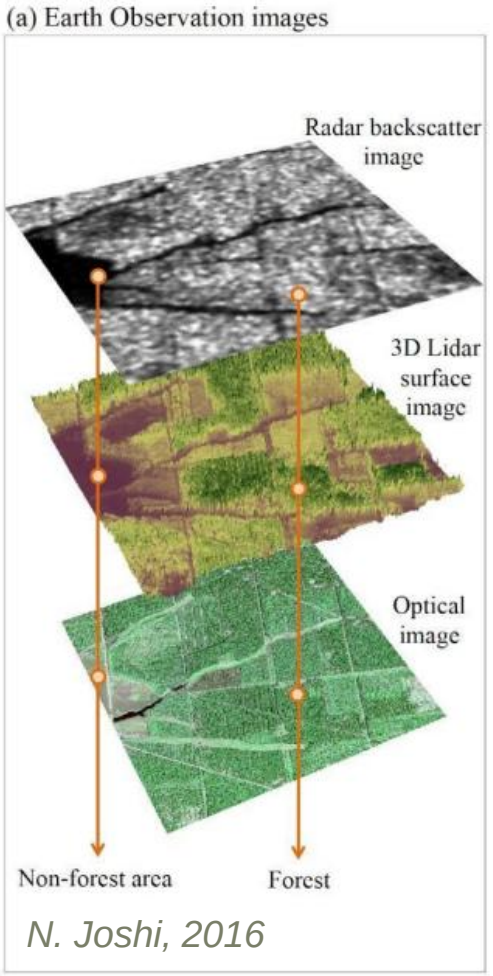
Estimators of the mean and *variance (e.g.,* Horvitz–Thompson*)*

Advantages:
Unbiased estimators to estimate means, totals, changes and their variances

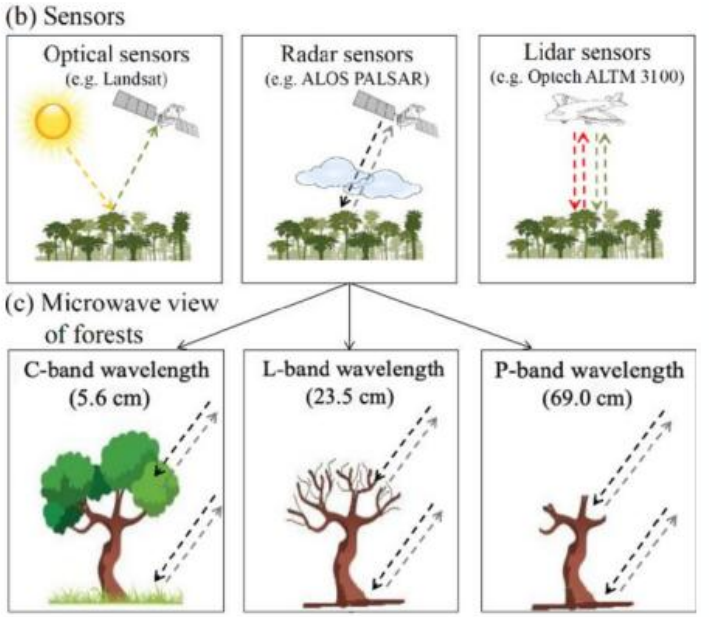
Disadvantages:
Challenges on the completion and continuous remeasurement of plots

Introducing EO biomass products as auxiliary information

Raw EO data



Optical **Radar** **Lidar**



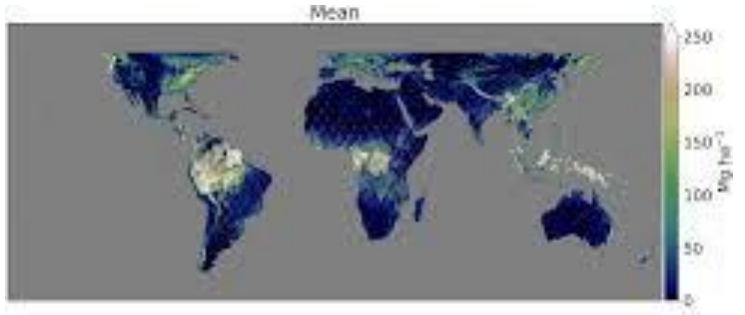
Spectral characteristics of the vegetation

Vegetation **structural** parameters

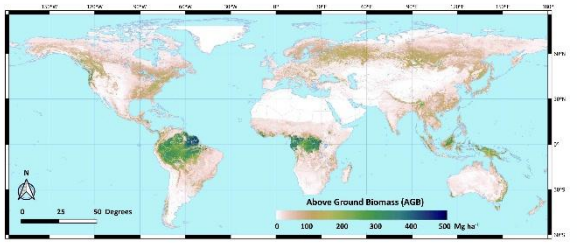
EO - derived biomass products

biomass cci

GEDI ECOSYSTEM LIDAR



Jet Propulsion Laboratory
California Institute of Technology



Model-assisted estimators

Once we start incorporating EO-data, what estimators can we use to increase the precision of biomass estimates?

MODEL-ASSISTED

Probability sample

Sampling design

Build a relationship between map units and NFI data

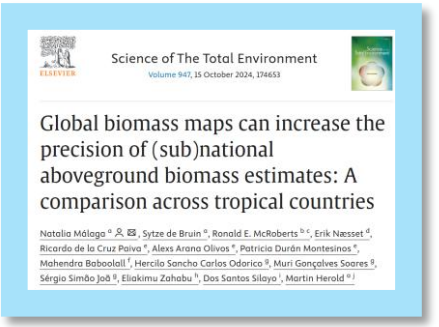
Estimators of the mean and variance (e.g. GREG)

Advantages:
Unbiased or asymptotically unbiased to estimate means, totals, changes and their variances

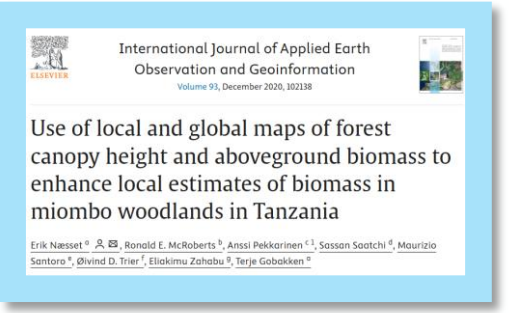
Disadvantages:
Probability samples are still needed


Remote Sensing of Environment
Volume 281, November 2022, 113168

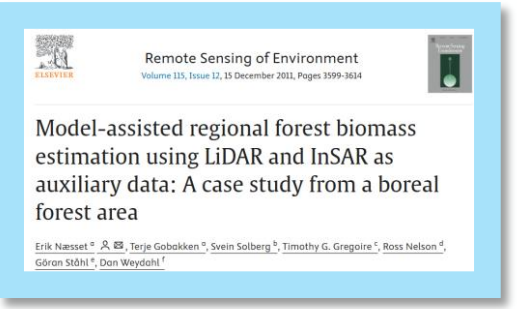
On the model-assisted regression estimators using remotely sensed auxiliary data


Science of The Total Environment
Volume 947, 15 October 2024, 174653

Global biomass maps can increase the precision of (sub)national aboveground biomass estimates: A comparison across tropical countries


International Journal of Applied Earth Observation and Geoinformation
Volume 93, December 2020, 102138

Use of local and global maps of forest canopy height and aboveground biomass to enhance local estimates of biomass in miombo woodlands in Tanzania


Remote Sensing of Environment
Volume 115, Issue 12, 15 December 2011, Pages 3599-3614

Model-assisted regional forest biomass estimation using LiDAR and InSAR as auxiliary data: A case study from a boreal forest area

Model-based inference

Once we start incorporating EO-data, what other inferential strategies can we use to increase the precision of biomass estimates?

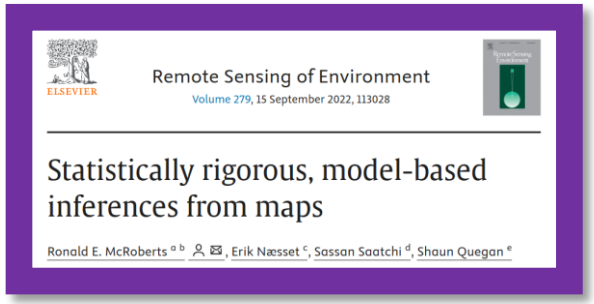
MODEL-BASED *Representative reference data* *Map unit (co)variances*

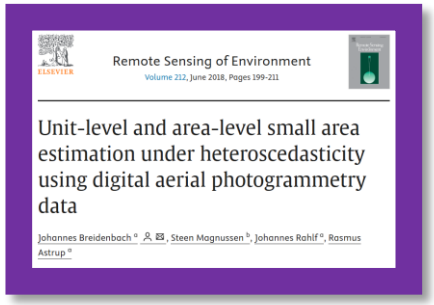
Builds a model between map units and NFI to predict

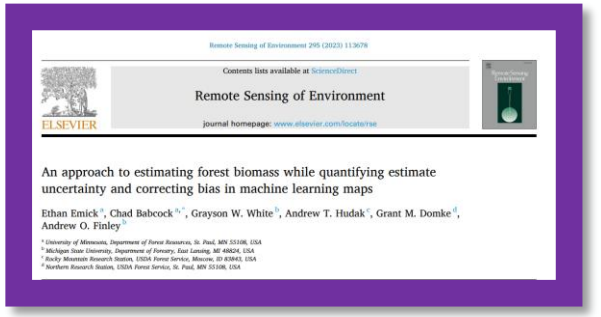
Estimate means and SE based on the model assumptions

Advantages:
Unbiased or asymptotically unbiased to estimate means, totals, changes and their variances

Disadvantages:
Increase risk of bias, specially when reference data of suitable quality and distribution are not available

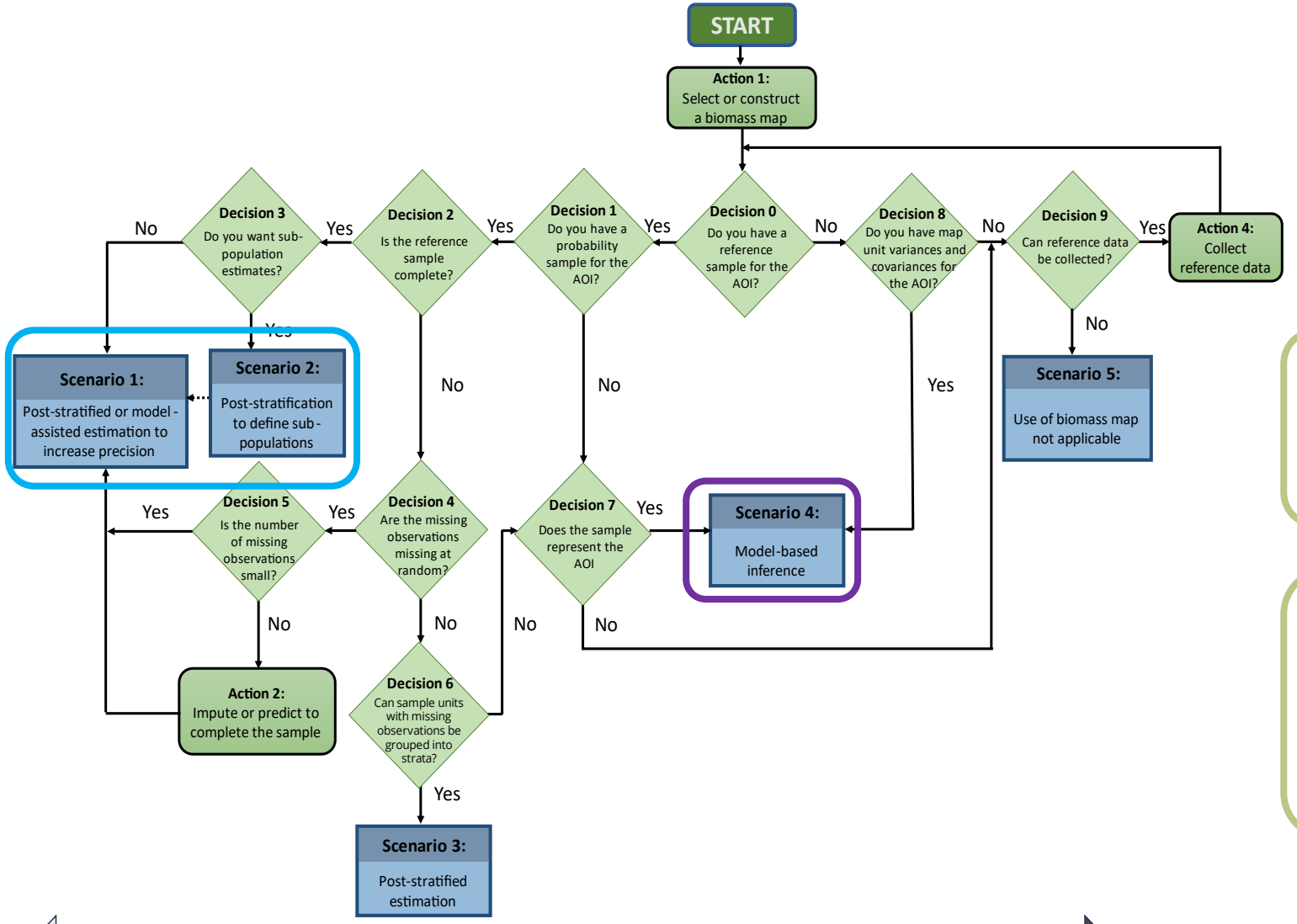

Remote Sensing of Environment
Volume 279, 15 September 2022, 113028
Statistically rigorous, model-based inferences from maps
Ronald E. McRoberts, Erik Næsset, Sassan Saatchi, Shaun Quegan


Remote Sensing of Environment
Volume 212, June 2018, Pages 199-211
Unit-level and area-level small area estimation under heteroscedasticity using digital aerial photogrammetry data
Johannes Breidenbach, Steen Magnussen, Johannes Rahlf, Rasmus Astrup

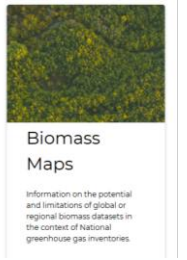

Remote Sensing of Environment
An approach to estimating forest biomass while quantifying estimate uncertainty and correcting bias in machine learning maps
Ethan Emick, Chad Babcock, Grayson W. White, Andrew T. Hudak, Grant M. Domke, Andrew O. Finley


MethodsX
Volume 11, December 2023, 102321
Three-phase hierarchical model-based and hybrid inference
Svetlana Saarela, Petri Varvia, Lauri Korhonen, Zhiqiang Yang, Paul L. Patterson, Terje Gobakken, Erik Næsset, Sean P. Healey, Göran Ståhl

Existing guidance on data integration



GFOI Global Forest Observations Initiative



Ground reference data are **vital**, biomass products are auxiliary data

Methods are dictated by the **quantity** and **quality** of the reference data and the **sampling design** used to acquire it.

GFOI R&D Session on integrating EO and ground data for enhanced forest-related biomass estimation

Acknowledgements:

GFZ Helmholtz-Zentrum für Geoforschung
esa
FAO FIAT PANIS
WorldForest

Collaboration:

JRC EUROPEAN COMMISSION
NIBIO
GAFAG an e-GEOS (ASI / Telespazio) Company
NMBU
eng