GFZ Helmholtz-Zentrum für Geoforschung

GFOI Global Forest Observations Initiative

PLENARY 2025

Overview:
Integrating biomass data with ground data for MRV needs

Natalia Málaga, Neha Hunka and Chad Babcock

20.10.2025

Joint Meeting of the GFOI Components

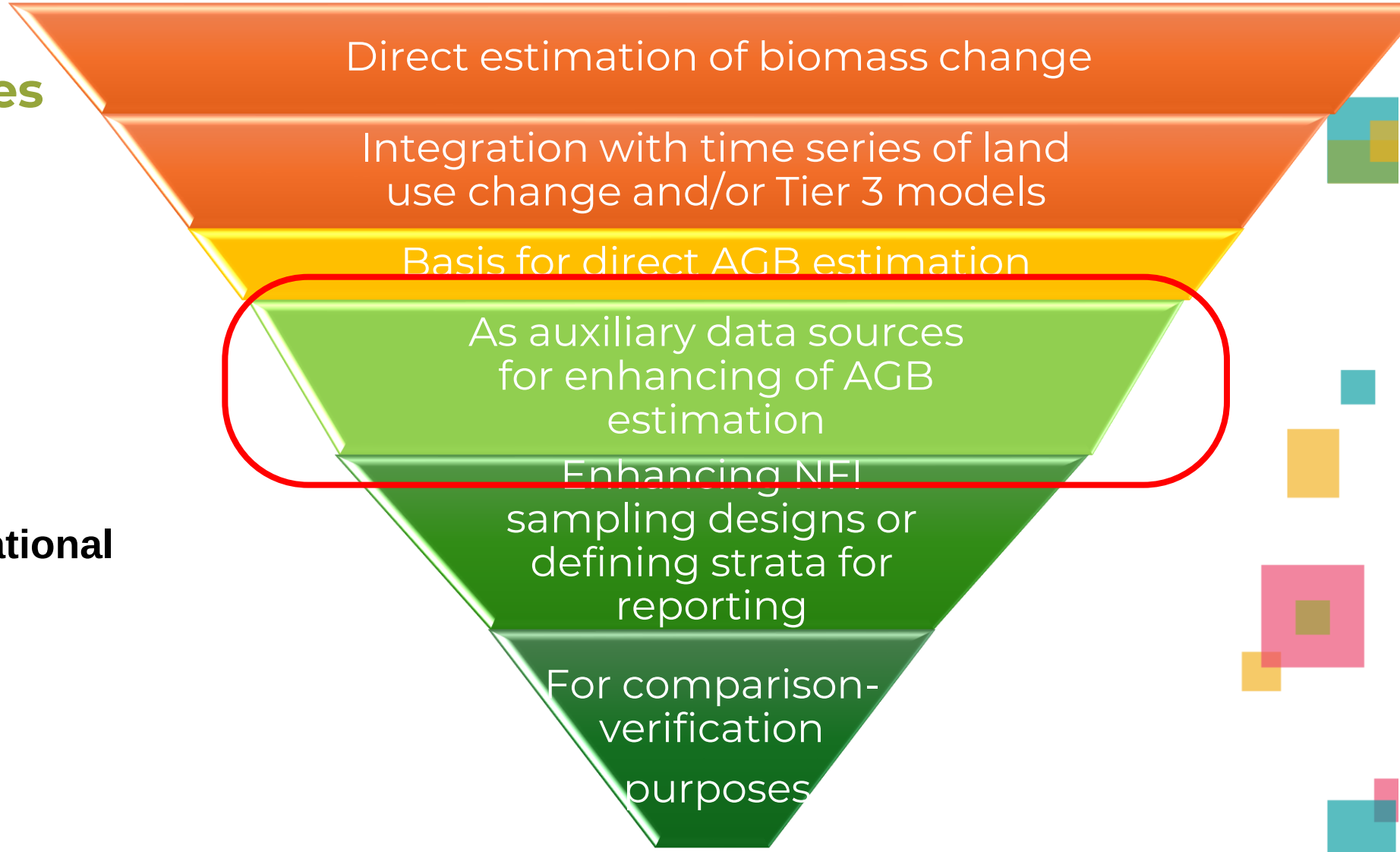
Assessing the maturity level of Potential Applications

And opportunities & challenges

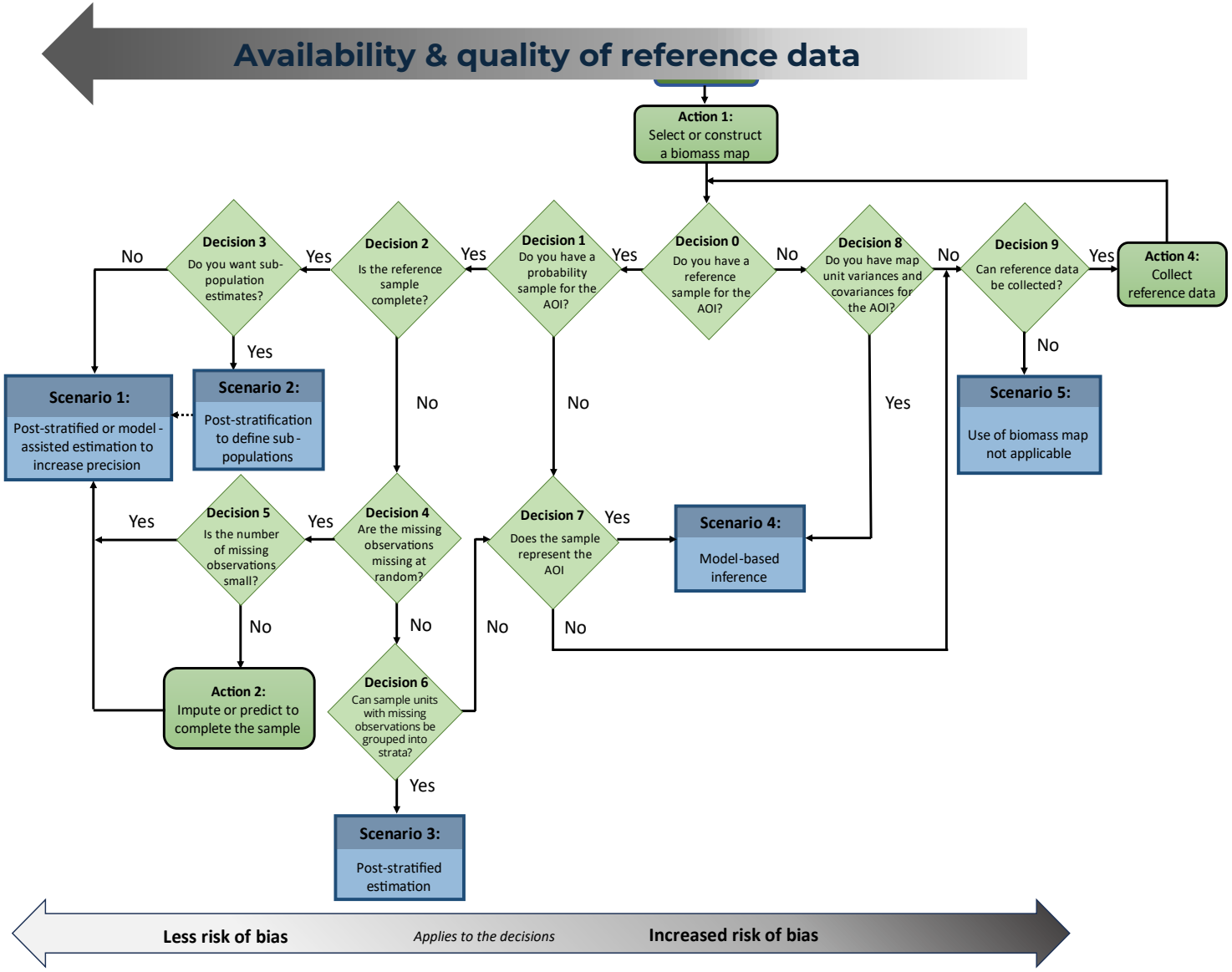
Research

Pre-operational

Operational



Enhancing forest-related biomass stock estimates



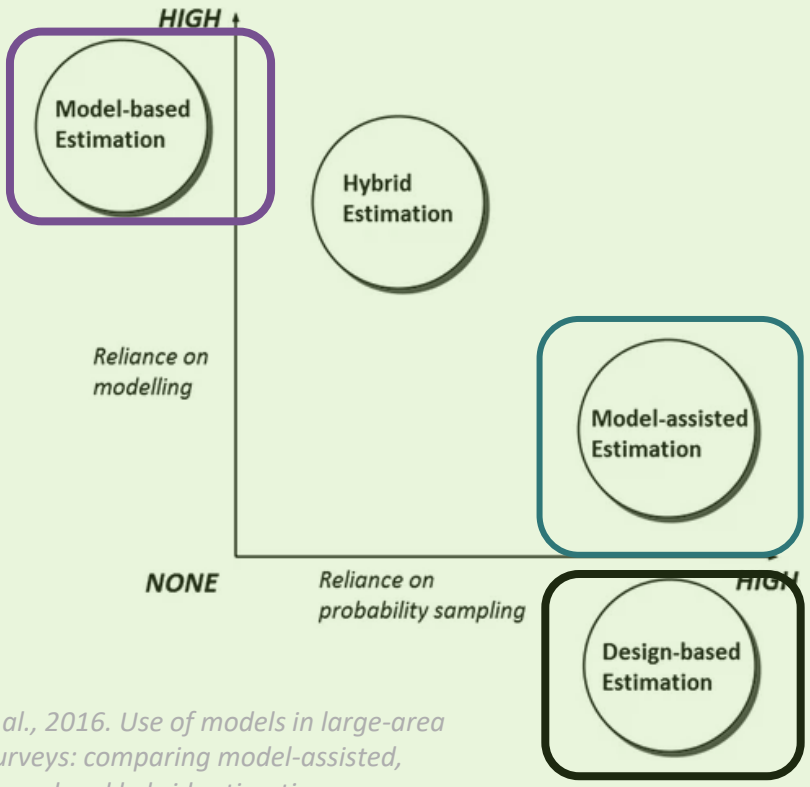
Ground reference data are **vital**, biomass products are auxiliary data

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

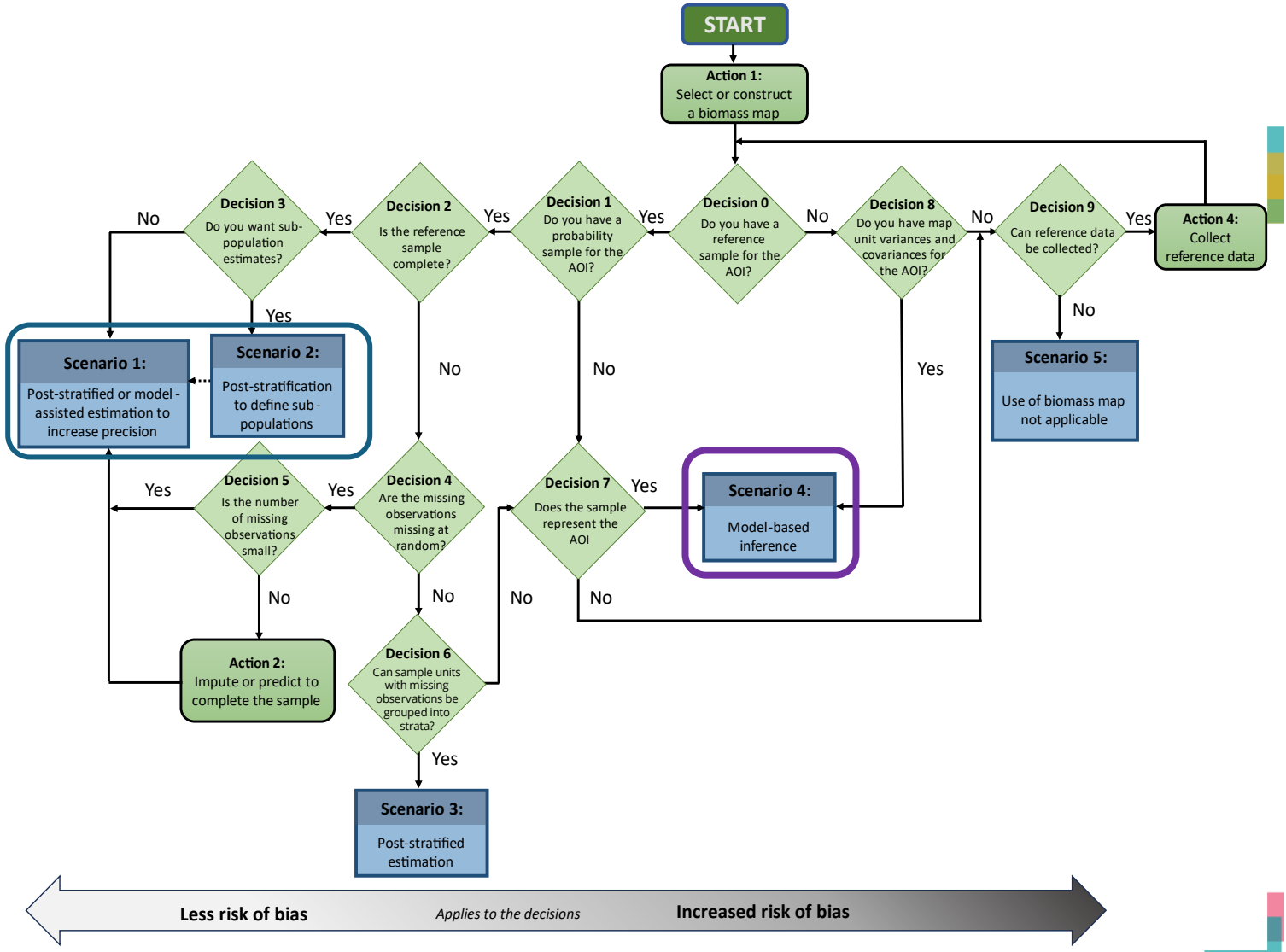
The **risk of bias** decreases toward the left side of the tree (when a probability sample –e.g., NFI- is available) and increases to the right (where reference data become limited)

Methodological approaches

Inferential strategies

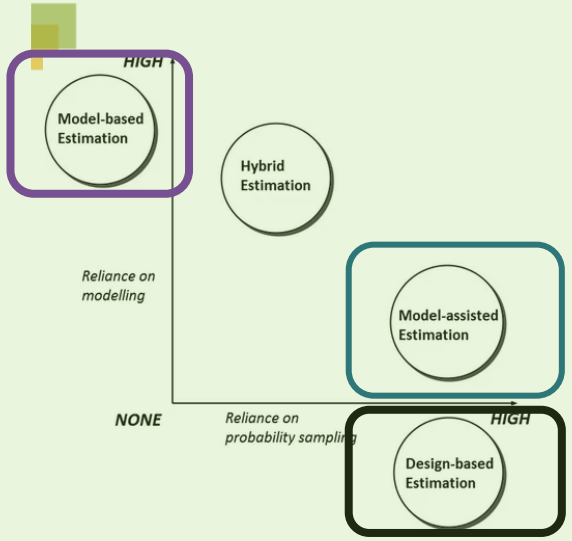


Ståhl et al., 2016. Use of models in large-area forest surveys: comparing model-assisted, model-based and hybrid estimation



Methodological approaches

Inferential strategies



Ståhl et al., 2016. Use of models in large-area forest surveys: comparing model-assisted, model-based and hybrid estimation

DESIGN-BASED: Sampling design | Probability sample

Estimators of the population mean and variance

Introducing EO biomass products are used as additional source of information

MODEL-ASSISTED: Sampling design | Probability sample

Builds a relationship between map units and field data

Estimators of the population mean and variance

MODEL-BASED:

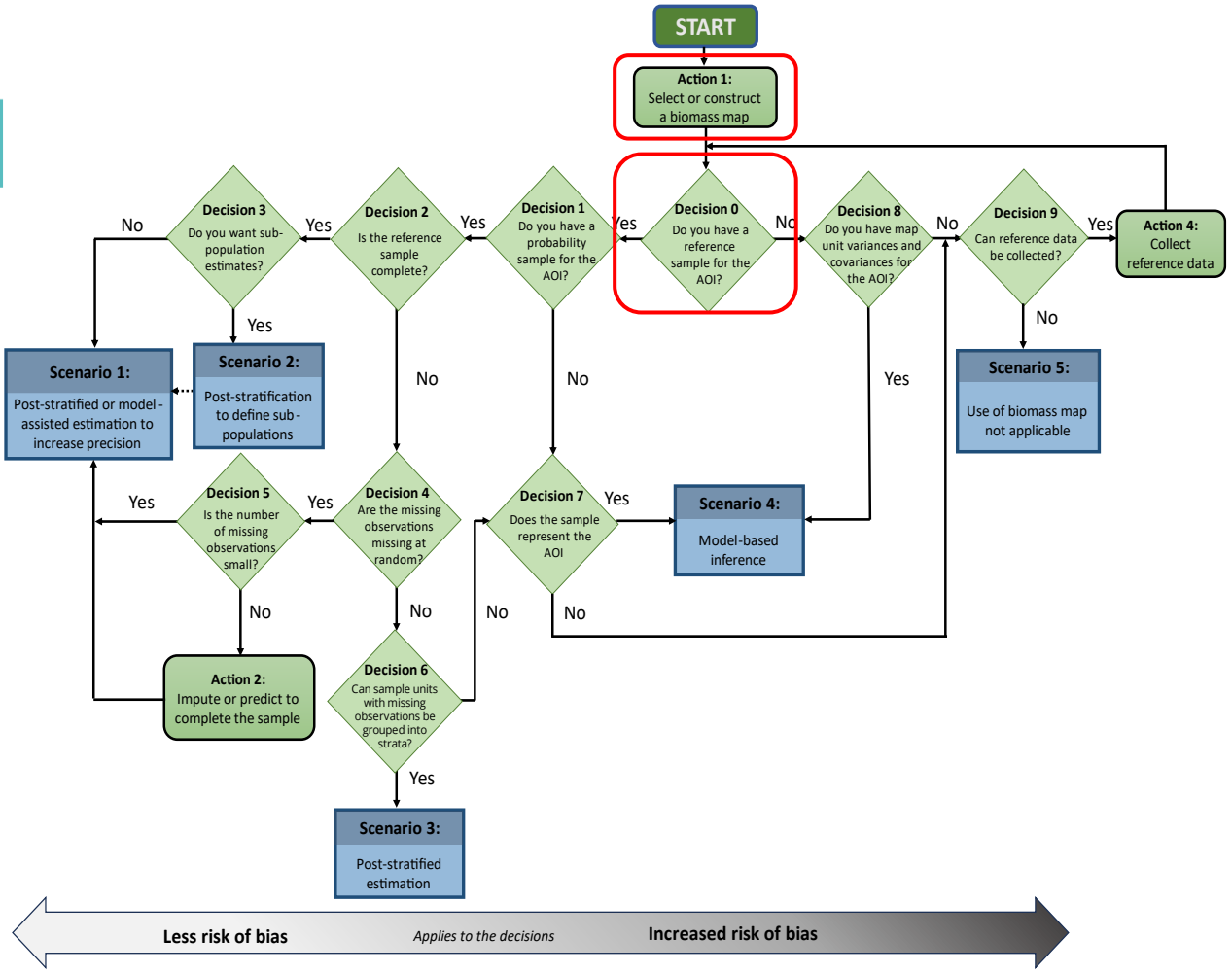
Map unit (co)variances

Balanced reference data

Builds a relationship between map units and field data

Model-based estimators of the population mean and variance

Walking through the tree



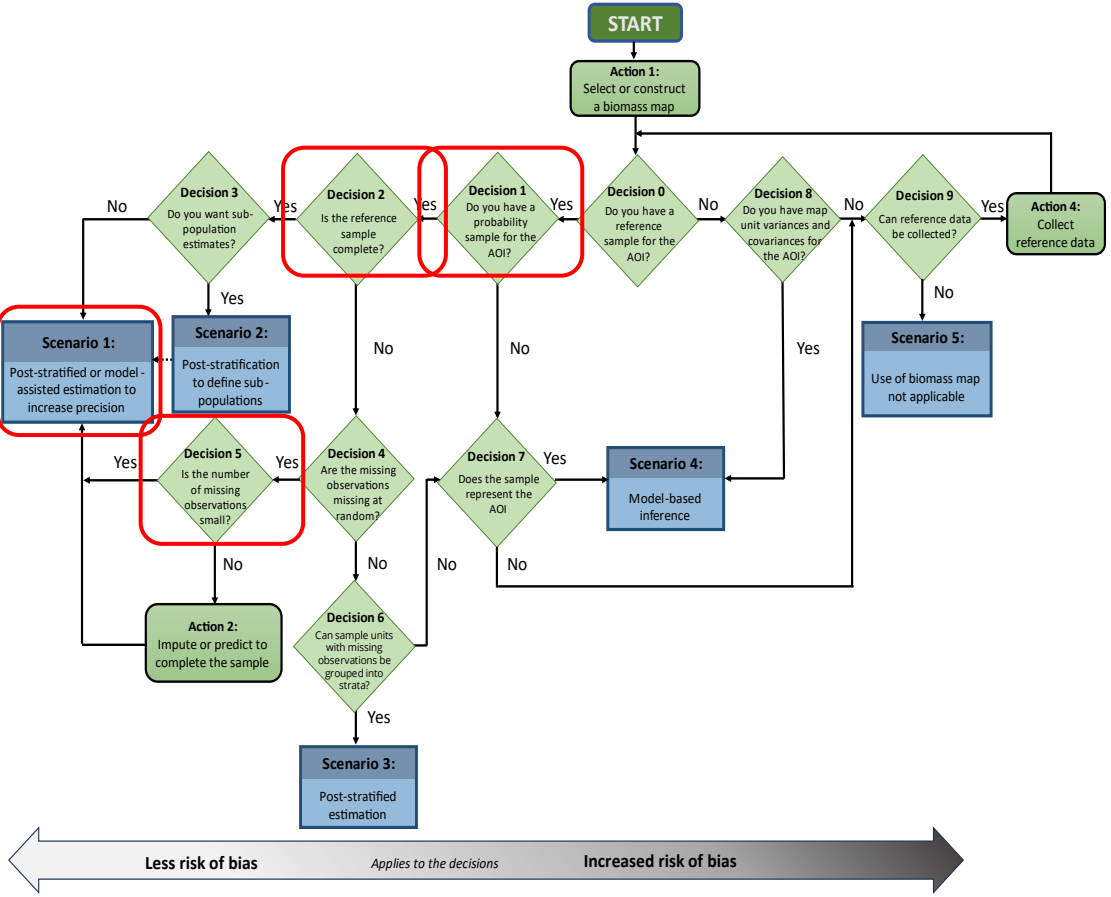
Action 1:

- If using an existing map→ the decision of *which* space-based biomass map to select for the described approaches must be made by the user
- If constructing a new map→ Map unit variances and covariances are estimated directly when constructing the map.

Decision 0:

For the left side of the tree, reference samples are **required**. For model-based inference, reference samples are preferred but not required, given that map unit variances and pairwise covariances estimated using data for the AOI are available.

Walking through the tree



Decision 1:

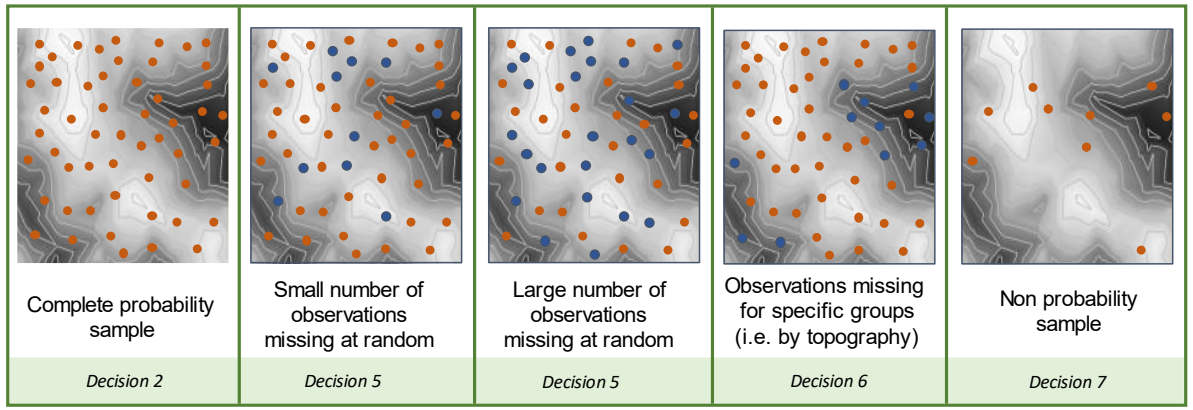
Probability samples (e.g., NFI) are required for design-based/model-assisted estimators.

Decision 2

Probability samples may be missing observations.

Decision 5

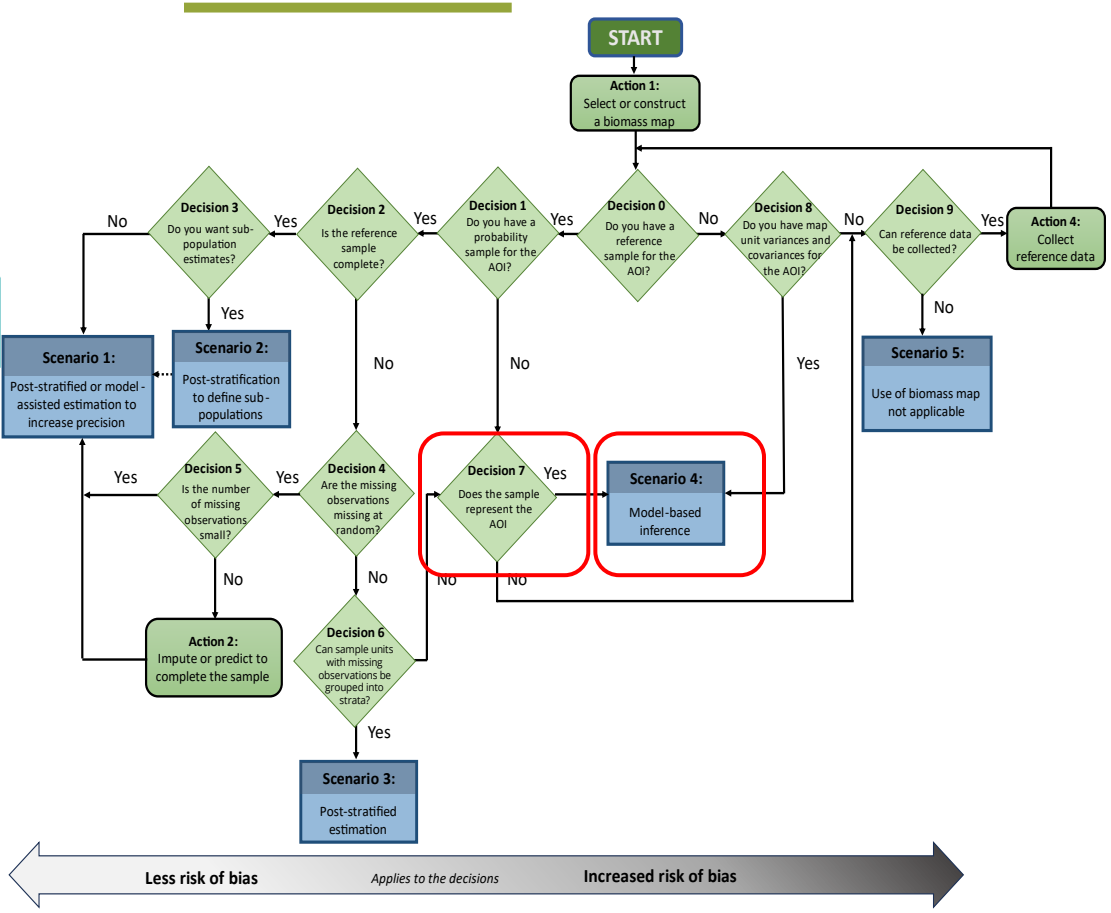
In some cases, the number of missing observations is small in comparison to the total sample size



Scenario 1

Use the biomass map as auxiliary data to increase the precision of the estimate of the population mean.

Walking through the tree



Decision 7

- Model-based inference does not rely on probability samples, but the sample should be balanced (adequately represent the range of the distribution of AGBD expected). Local expert knowledge of the biomes and vegetation types in the region may assist to assess the representativeness of the sample in the area of interest.
- An important consideration of model-based inference is that the estimator of the mean is not necessarily unbiased.

Scenario 4

- The mean is estimated using the standard model-based synthetic estimator (mean over all map unit predictions). To estimate the variance, the user requires map unit variances and pairwise map unit covariances.
- A model is fitted using the reference data and auxiliary variables (biomass maps). The fitted model is then used to predict biomass values for each map unit

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THANK YOU

GFZ Helmholtz-Zentrum für Geoforschung

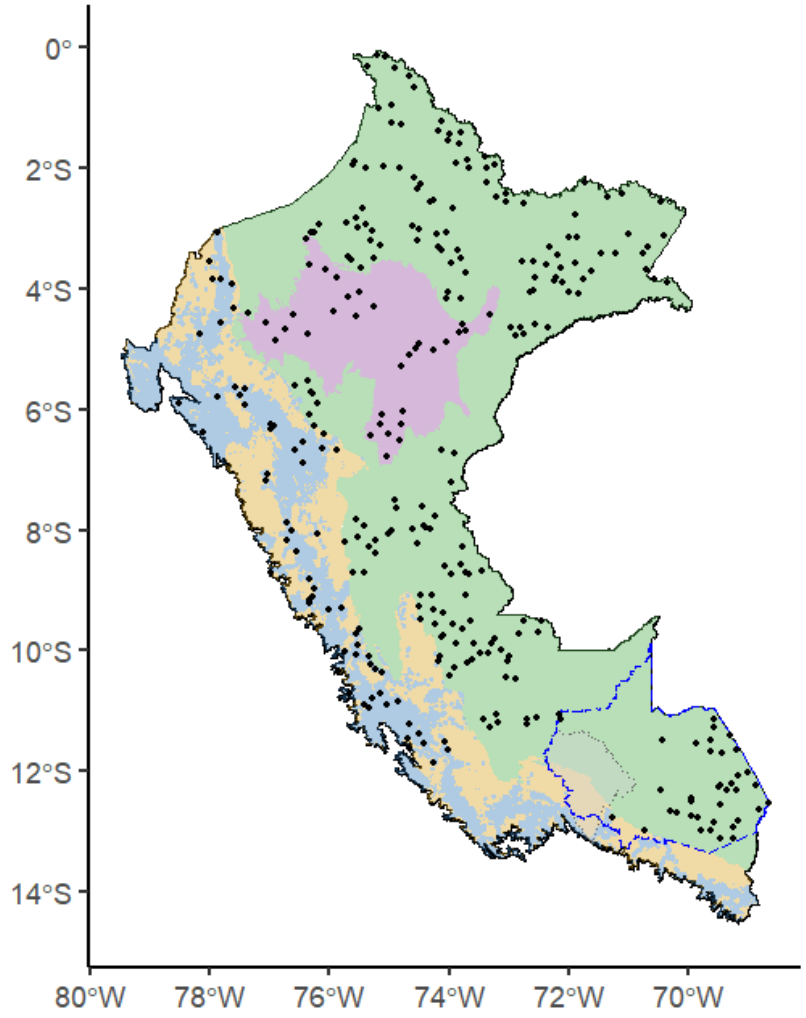
GFOI R&D Component

esa

DYNAMIC SESSION

PERU

Country-case study: Peruvian Amazonia



Incomplete NFI

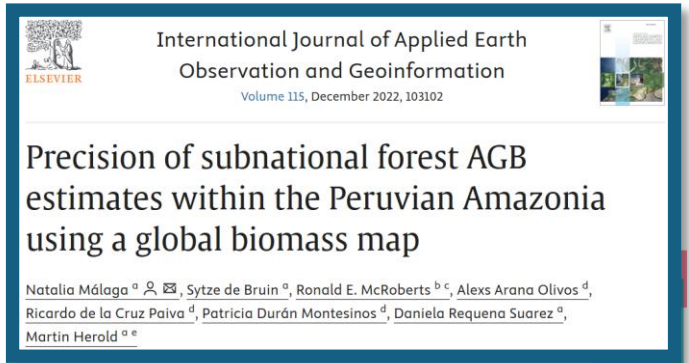
- Observations missing at random
- Number of missing observations relatively small within the strata

Interest in exploring EO information to enhance the precision of their **country/ strata-wise** biomass estimates for:

- International reporting mechanisms (e.g., NGHGI, NDCs, REDD+, etc.)
- National statistics

Strata

- Hydromorphic zone (HZ)
- Accessible montane forest (AMF)
- Inaccessible montane forest (IMF)
- Lowland forest (LF)
- NFI plot


International Journal of Applied Earth Observation and Geoinformation
Volume 115, December 2022, 103102

Precision of subnational forest AGB estimates within the Peruvian Amazonia using a global biomass map

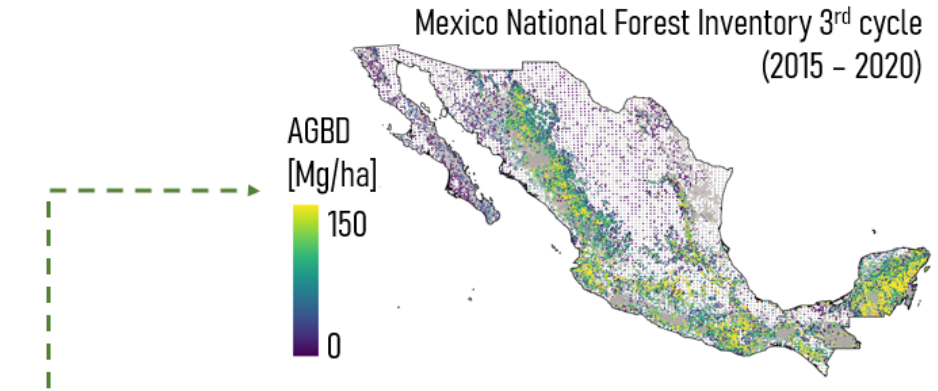
Natalia Málaga [a], Sytze de Bruin [a], Ronald E. McRoberts [b c], Alexs Arana Olivos [d], Ricardo de la Cruz Paiva [d], Patricia Durán Montesinos [d], Daniela Requena Suarez [a], Martin Herold [a e]

MEXICO

National Forest Inventory (NFI) estimates of aboveground biomass (AGBD)

Computationally-efficient geostatistical model with open-source code

Global Earth Observation (EO) based maps of vegetation biomass and heights

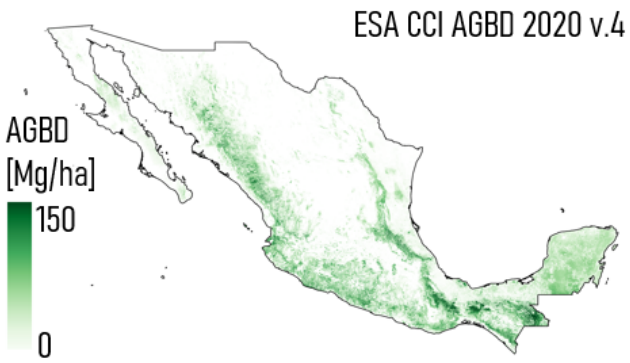


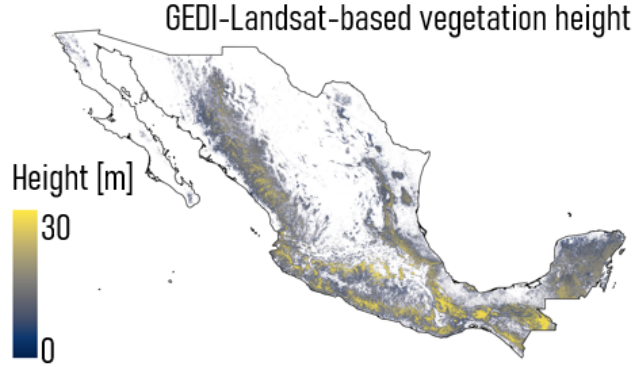
Spatially-varying random effects

$$NFI\_AGBD = (\alpha + \tilde{\alpha}) + (\beta + \tilde{\beta})\, ESA\_CCI + (\eta + \tilde{\eta})\, NASA\_GEDI + \varepsilon$$

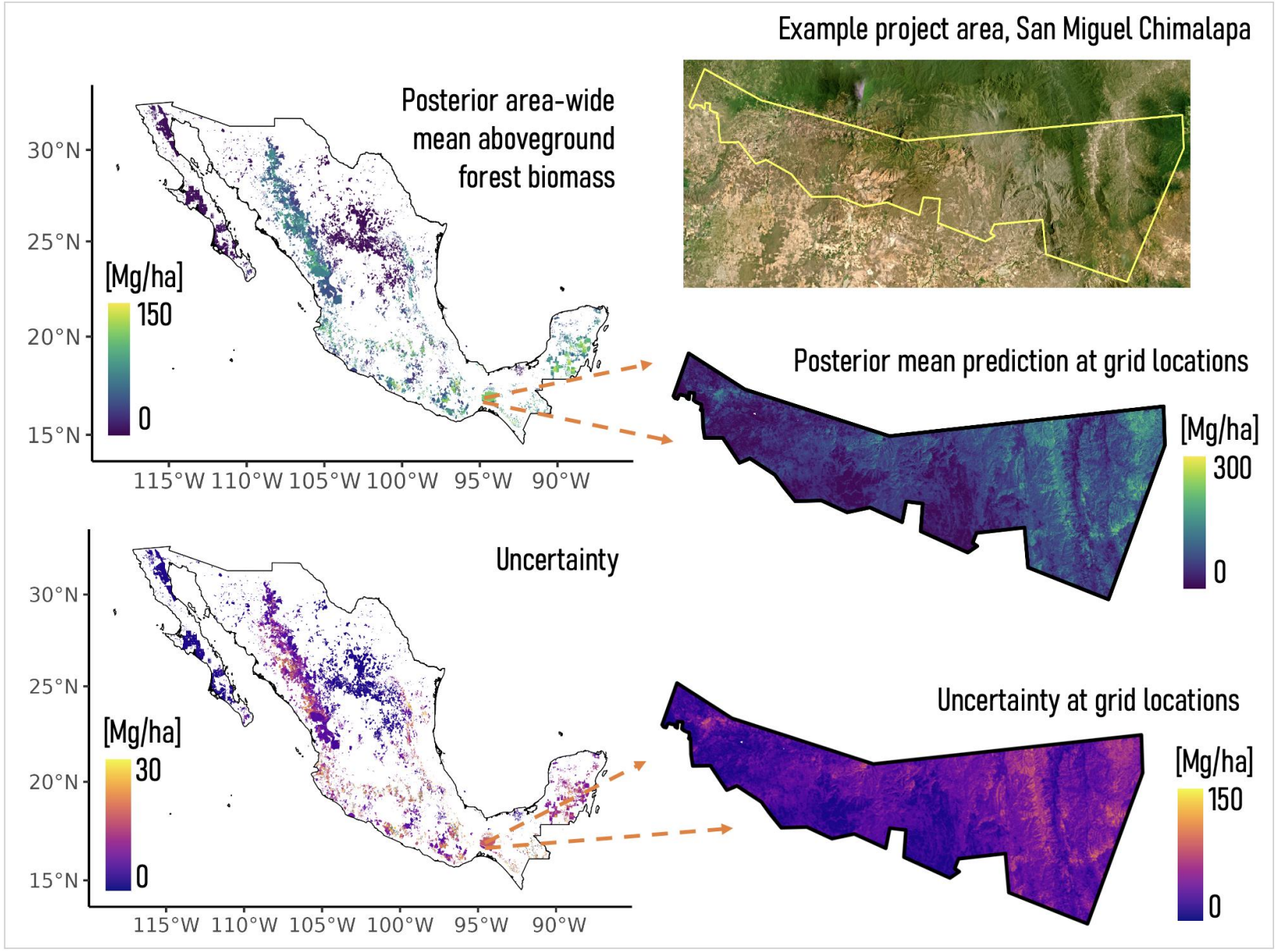
Random error

Fixed effects





MEXICO

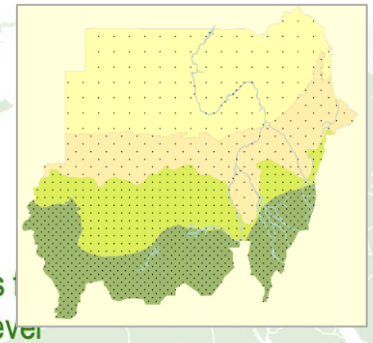

Example project area, San Miguel Chimalapa
Posterior area-wide mean aboveground forest biomass
[Mg/ha]
150
0
30°N
25°N
20°N
15°N
115°W 110°W 105°W 100°W 95°W 90°W
Posterior mean prediction at grid locations
[Mg/ha]
300
0
Uncertainty
[Mg/ha]
30
0
Uncertainty at grid locations
[Mg/ha]
150
0

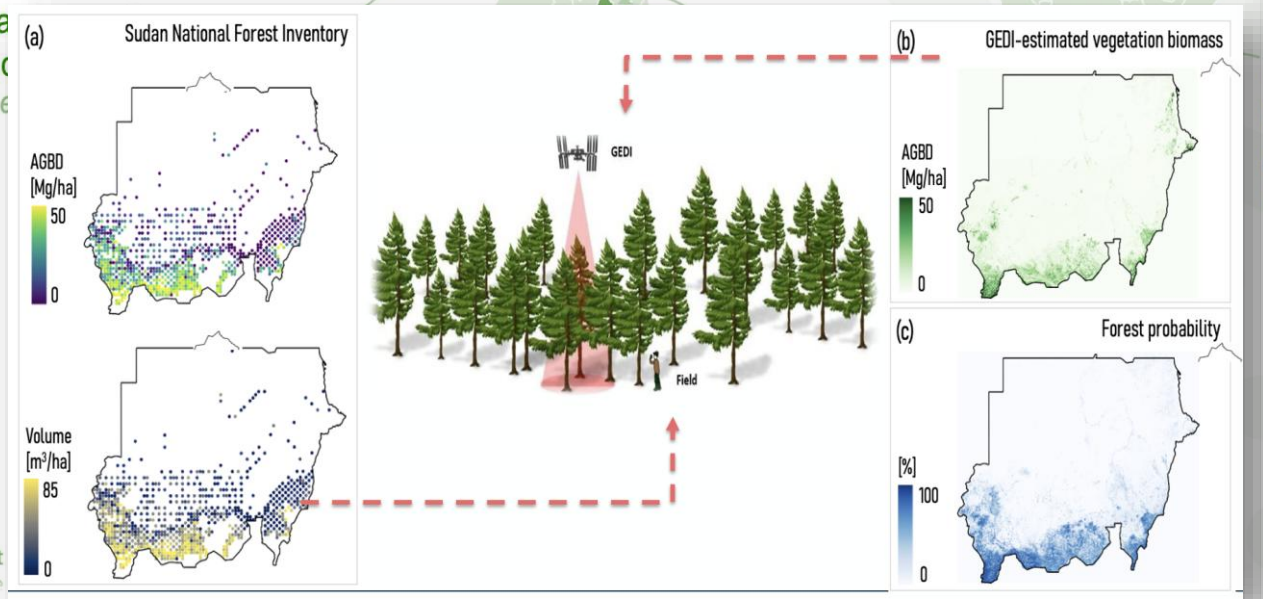
Global Forests Observations Initiative (GFOI)

Mexico
Address NFI Gaps for national stratum-level AGB estimations and predict AGB for specific AoIs
Hunka et al., 2024

♦ **Sudan**
Address NFI Gaps f
national stratum-level
AGB estimations
Republic of Sudan FRL, 2025

♦ **Guatemala**
Defining stra
Emission Fac
Gómez Xutuc e





Global Forest Observations Initiative

THE REPUBLIC OF SUDAN
FOREST NATIONAL CORPORATION

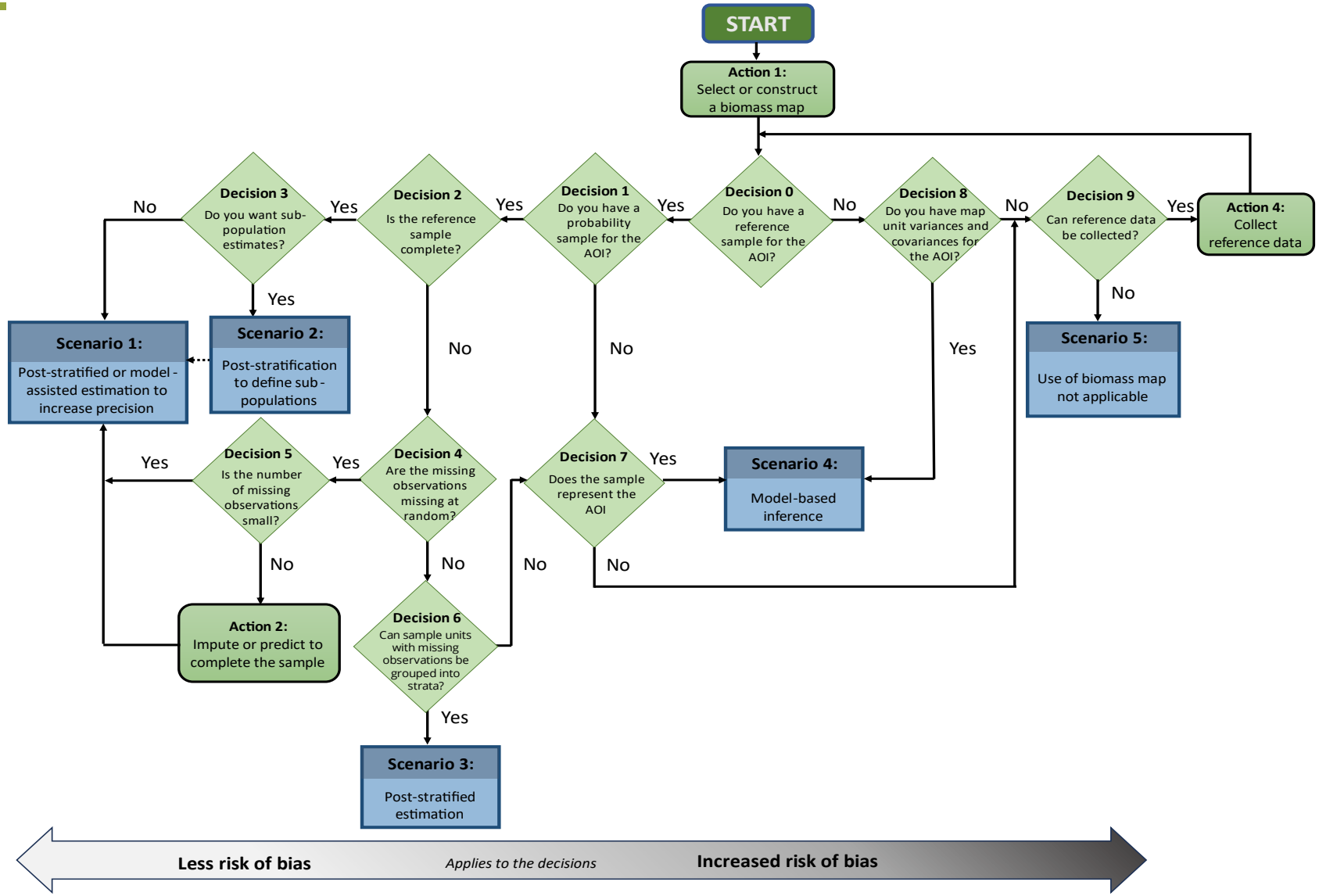
FOREST REFERENCE LEVEL SUBMISSION TO THE UNFCCC

Food and Agriculture Organization of the United Nations

GREEN CLIMATE FUND

June 2025

Enhancing forest-related biomass stock estimates



Self-reflection exercise

- Would you be interested in using biomass maps or have you already been using them?

Self-reflection exercise

- For what purpose?

Self-reflection exercise

- Would you be interested in using space-based biomass maps **for any of the objectives/scenarios here described**?

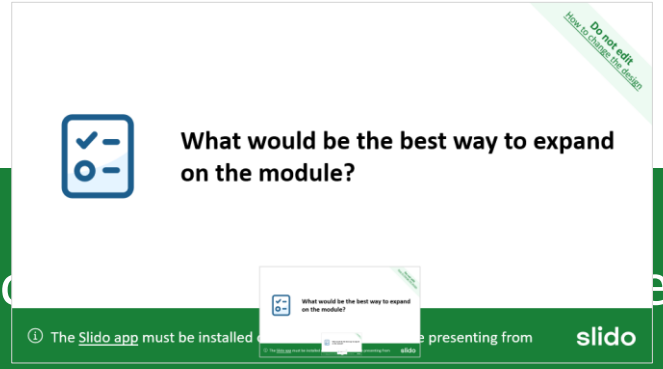
Self-reflection exercise

- Considering the country’s circumstances and needs, would you see yours needs reflected in the tree?

Do you find the decision tree clear?

From your perspective, what are the challenges of using the tree?

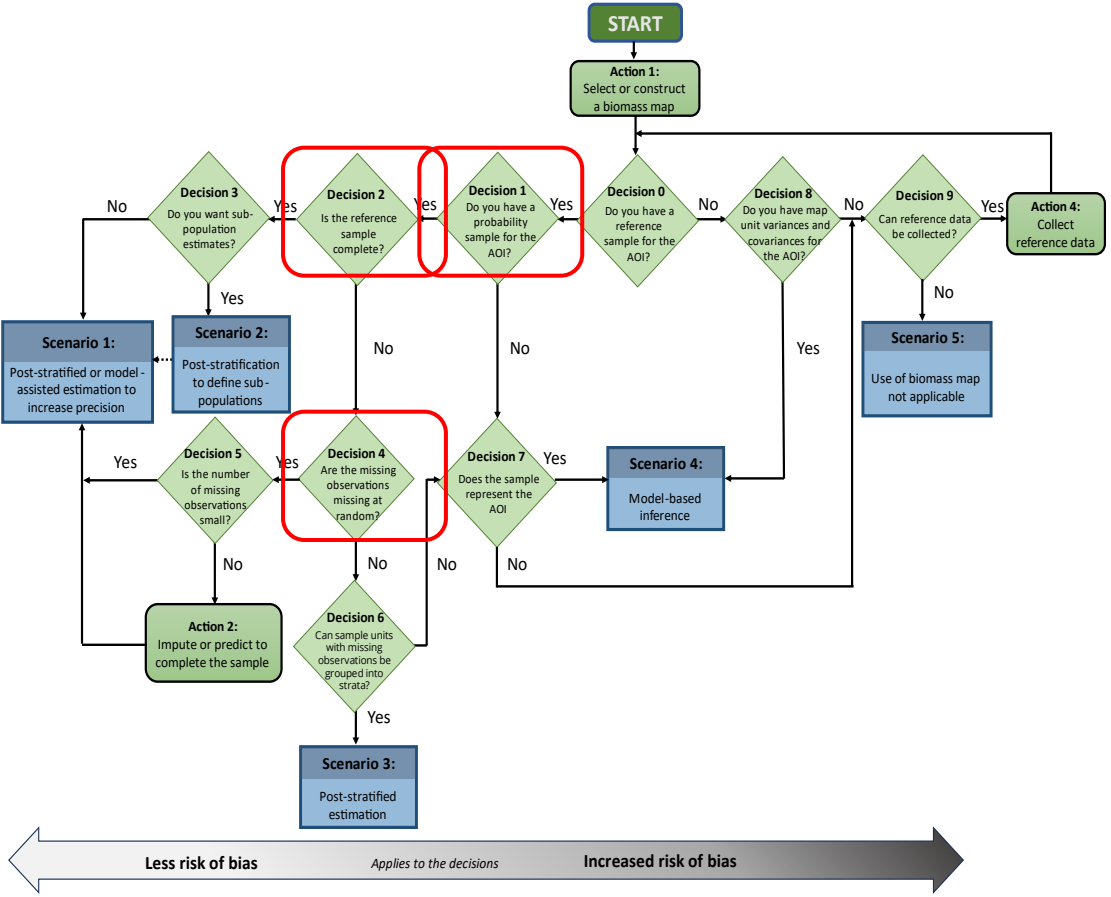
What would be the best way to expand on the module?



Survey 2 min

- Do you find the decision tree clear?
- What would be the challenges on implementing it on your side?
- In your opinion, what would be the best way to communicate this information (webinar, workshops, tutorials, code, other)
- Would you be interested in having supporting exercises explaining step by step the implementation?
- If so, what format would you prefer? (R, Excel, Python, etc.)

Walking through the tree



Scenario 1

Use the biomass map as auxiliary data to increase the precision of the estimate of the population mean.

The model-assisted *difference* estimator uses the map unit values directly as the model predictions and the reference data as the observations. Further enhancement in precision could be achieved by calibrating the map, i.e., by constructing a model of the relationship between the reference data as the dependent variable and the map values as the independent variable and then applying the model to predict a new value for each map unit