StatEO

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

Strengthening Land Cover Validation: From Community Guidelines to Supporting (Sub)National Applications

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Good Practice Protocol: Land Cover and Change Validation and Area estimation

Committee on Earth Observation Satellites
Working Group on Calibration and Validation
Land Product Validation Subgroup
Land Cover Focus Area

Land Cover and Change Map Accuracy Assessment and Area Estimation Good Practices Protocol

Version 1.1 - 2025

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Scope of the guidelines

Updating previous CEOS LPV global land cover validation guidelines (2006)

- Novel sources of reference data (airborne lidar, high-frequency optical)
- ↓ Emerging issues in accuracy assessment (operational updates, near real-time validation)
- ↓ Focus on global- to continental-scale maps, not regional specifics
- ↓ Covers land cover class area estimation from reference samples

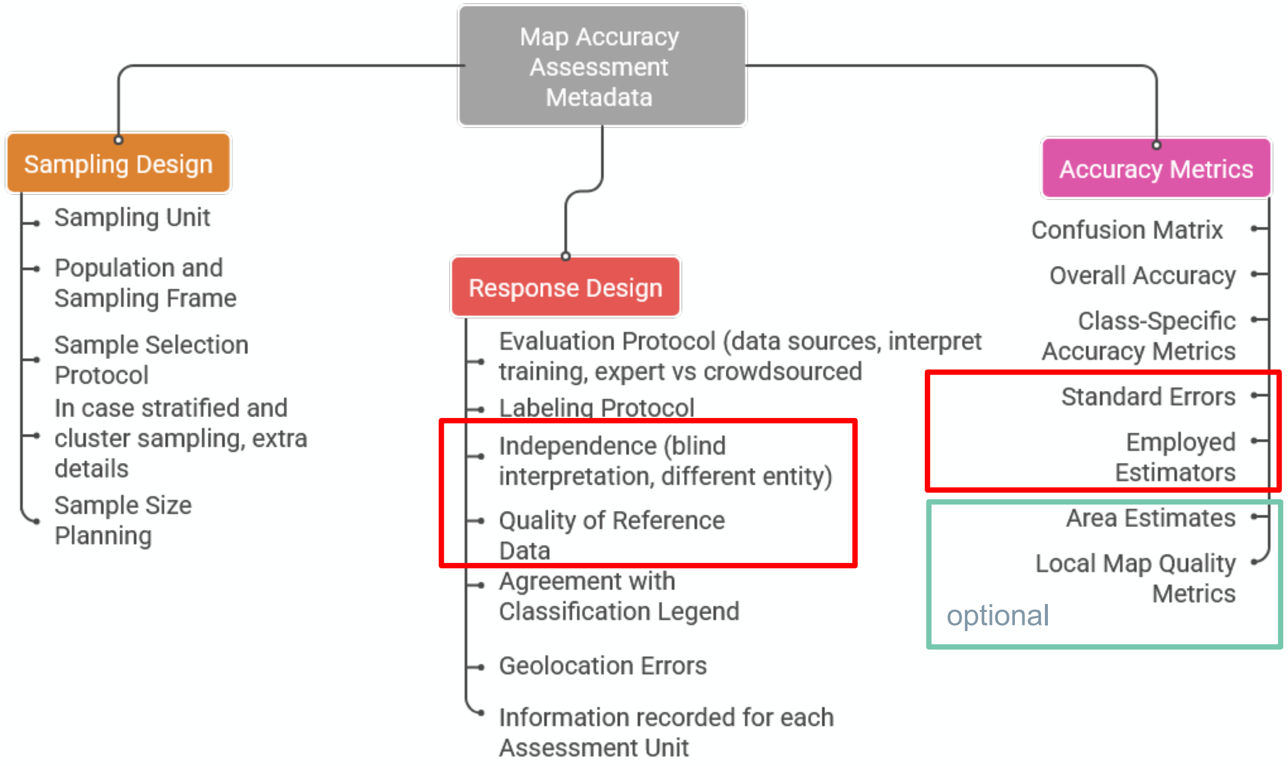
High-level community guidance for project planning

- Validation needs to be planned before map production
- ↓ Points to relevant publications and textbooks for detailed methods
- ↓ Provides an overview of methods, not an end-to-end manual
- ↓ Helps select appropriate estimators
- ↓ Enables map users to evaluate reported accuracy and select maps

Overarching goal: Increase awareness and encourage correct implementation

- Highlights complexity and constant development of validation methods
- ↓ Identifies potential limitations and caveats of each method
- ↓ Emphasizes no universal solution or single 'best practice'
- ↓ Stresses importance of transparent and standardized documentation of methodology

Reporting recommendations and key messages



- Reference data uncertainty needs to be minimized or incorporated in the estimates.
- The area of land cover class should be estimated from the reference sample, not derived via pixel counting.

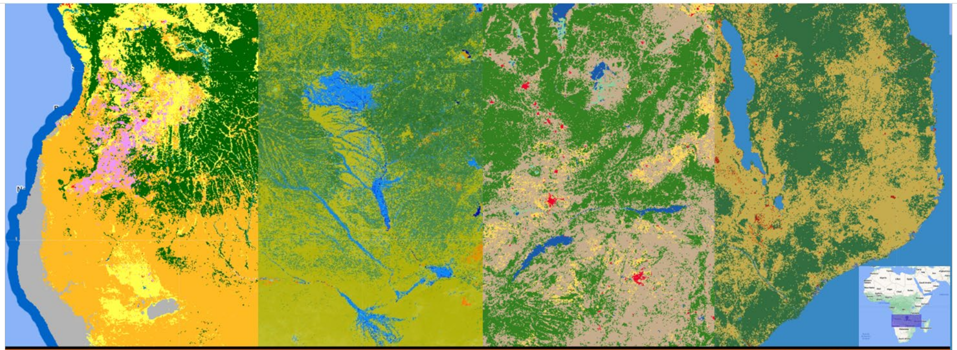
- All maps contain errors; their accuracy needs to be assessed using an "independent reference sample".

  Unvalidated map = untested hypothesis

- Accuracy assessment is a critical component that requires serious investment.
- The recommended approach is a **probability-based sampling design** (i.e design-based inference).
- Maps validated only at the global scale should be used with caution for regional applications, as map accuracy varies in space.

Accuracy comparison at global and continental levels

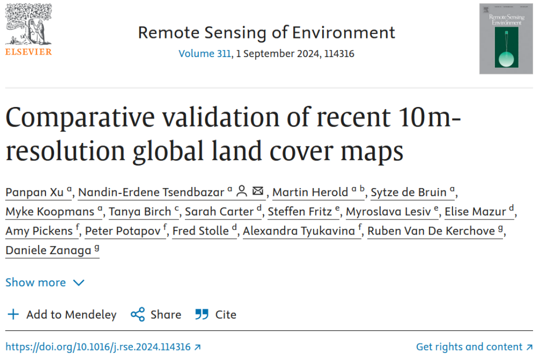
Legend harmonization to 7 generic classes: water, trees, mixed vegetation, crop, built-area, bare ground and snow/ice



ESA- WorldCover	GLAD	ESRI LULC	Dynamic World
10m	30m	10m	10m
2021	2020	2021	2021 (annual aggregate)

Validation data: matching map resolution and year

- A global validation dataset originally produced for the CGLS-LC100; updated for WorldCover Validation (2020/2021).
- 21 K sample units supporting statistical (design-based) validation; applicable to maps with 10-100m resolution
- One-stage cluster estimator


Remote Sensing of Environment
Volume 311, 1 September 2024, 114316

Comparative validation of recent 10m-resolution global land cover maps

Panpan Xu [a], Nandin-Erdene Tsendbazar [a], Martin Herold [a b], Sytze de Bruin [a], Myke Koopmans [a], Tanya Birch [c], Sarah Carter [d], Steffen Fritz [e], Myroslava Lesiv [e], Elise Mazur [d], Amy Pickens [f], Peter Potapov [f], Fred Stolle [d], Alexandra Tyukavina [f], Ruben Van De Kerchove [g], Daniele Zanaga [g]

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Land & Carbon Lab

Global Land Cover Maps' Accuracy and Applications Explained

NOVEMBER 26, 2024 • 11 MINUTES

AUTHORS
Sarah Carter, Nandika Tsendbazar, Panpan Xu, Martin Herold, Fred Stolle, Alexandra Tyukavina, Peter Potapov

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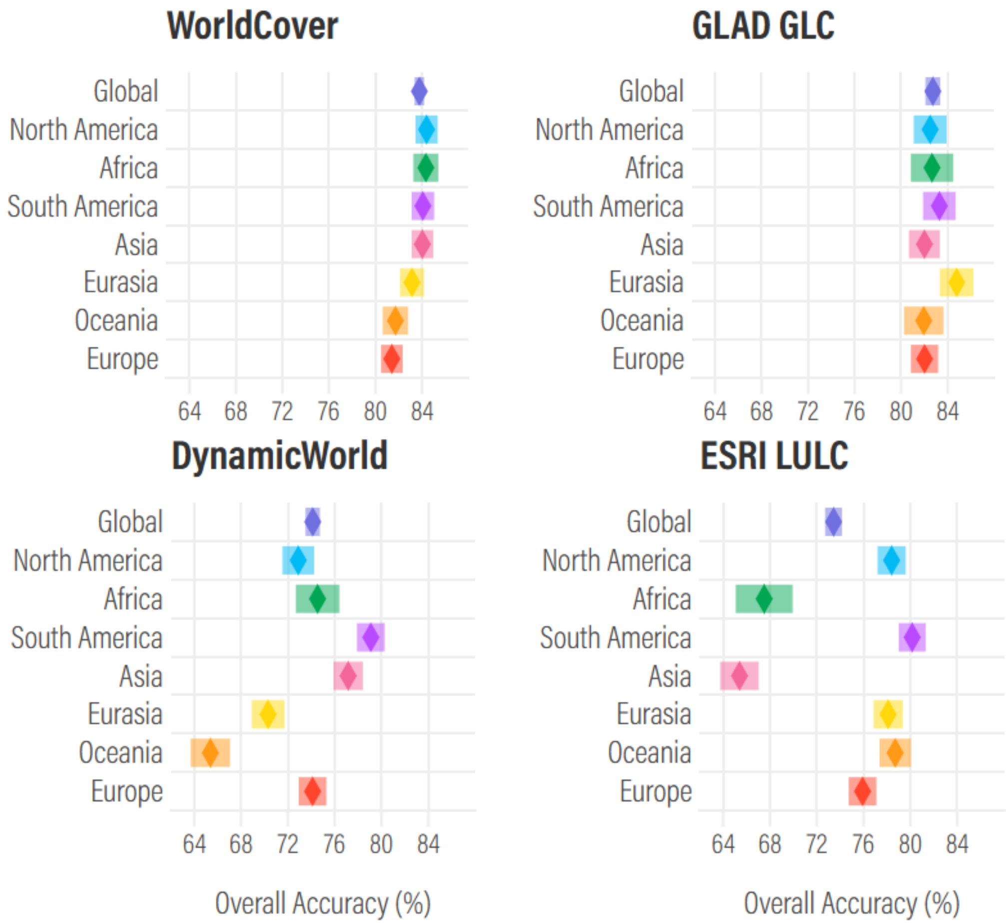
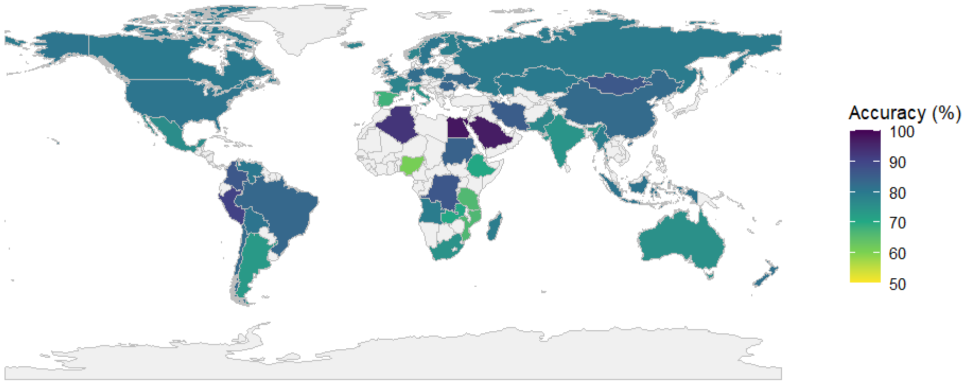


- WorldCover, followed by GLAD GLC, showed the highest overall accuracy.
- GLAD GLC performed best in Europe, Eurasia, and Oceania, and WorldCover for the rest.

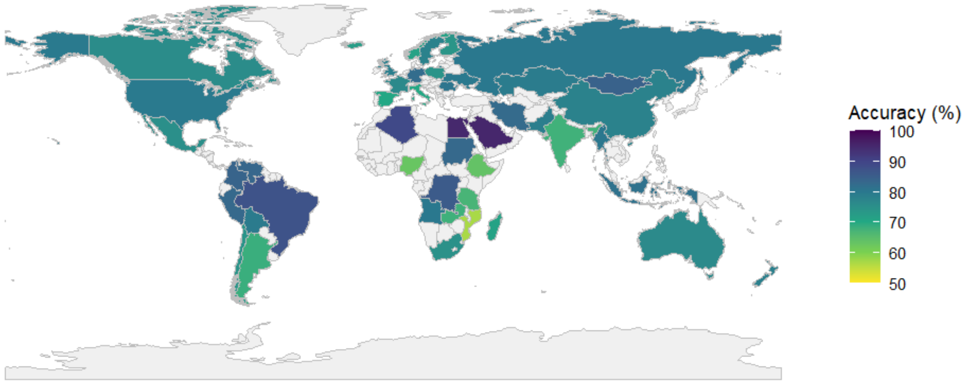
County-level accuracy comparison – 47 countries

Accuracy for countries where >100 PSUs are available.

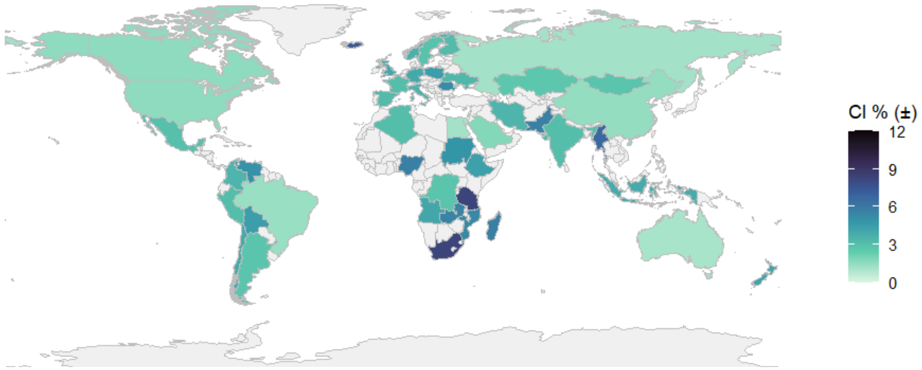
WorldCover: country accuracy



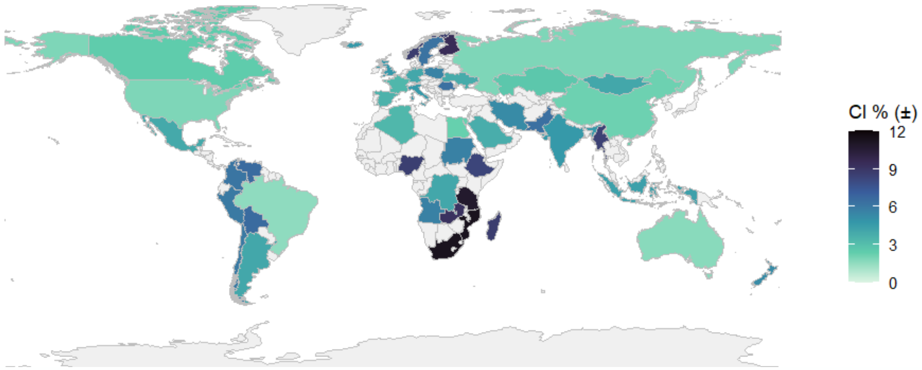
GLAD: country accuracy



WorldCover: confidence interval



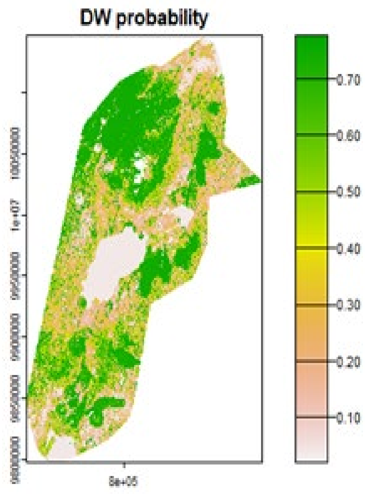
GLAD: confidence interval

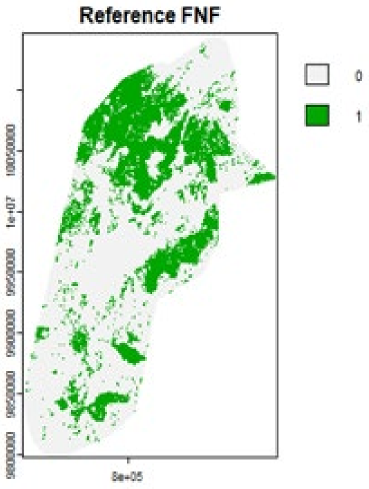


- Variation in accuracy highlights the need for map accuracy information at the scales at which the maps are utilized.
- Available sample size was key limitation for assessment for all countries.

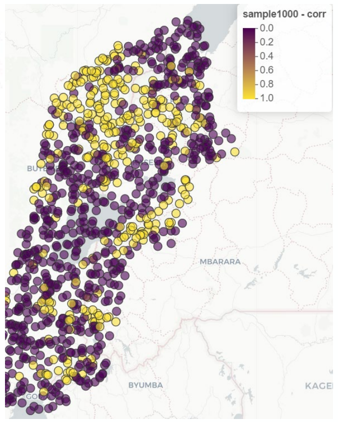
Local area and uncertainty estimation to support subnational applications: model-based approach

- Model-based approach as a complementary tool for subnational applications
- Forest area estimation at the regional scale.
- The reference map (Szantoi et al 2020) was used to draw samples.
- Using sampled data and spatial predictor: the Dynamic World forest probability as a predictor





SRS sample

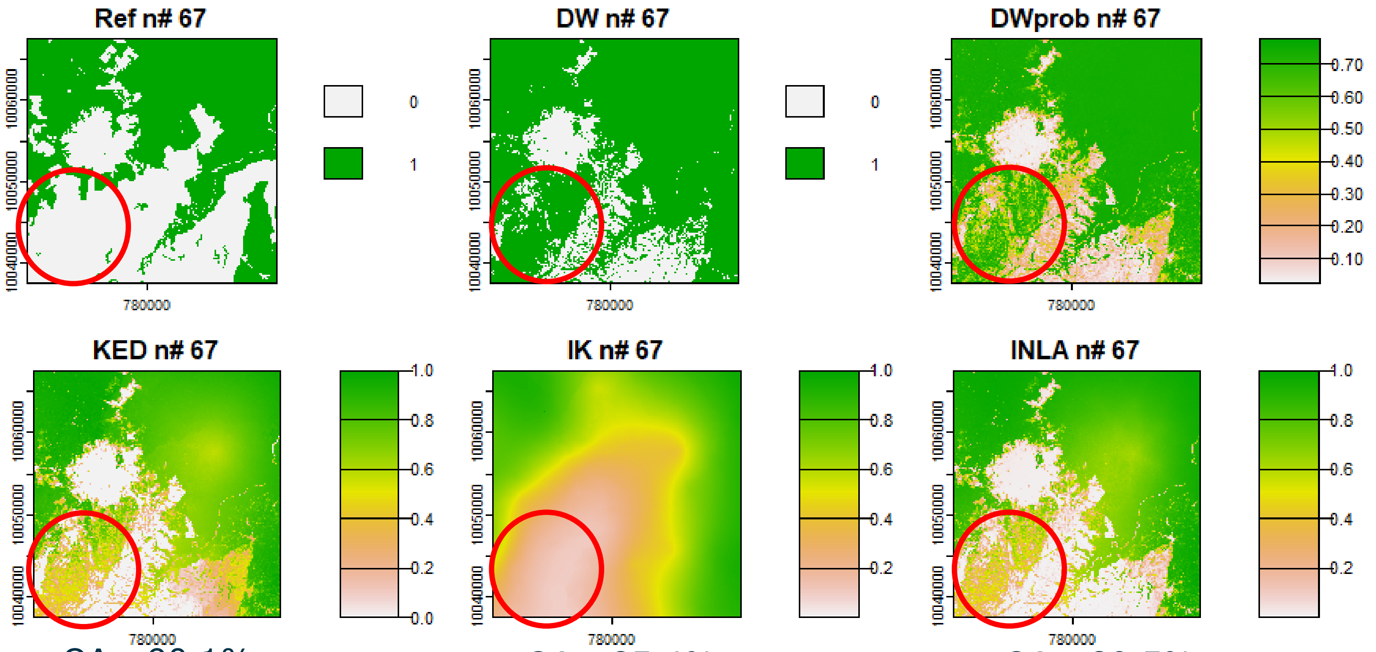


	Indicator Kriging	Kriging with external drifts	INLA-SPDE
Spatial predictor	No	Yes: forest probability	
Prediction	Provides spatially explicit prediction and uncertainty estimates		
Aggregates over an area	Block kriging		Posterior sampling for uncertainty propagation

Szantoi, Z., Brink, A., Lupi, A., Mammone, C., and Jaffrain, G.: Key landscapes for conservation land cover and change monitoring, thematic and validation datasets for sub-Saharan Africa, Earth Syst. Sci. Data, 12, 3001–3019

Spatial prediction and block estimates and its uncertainty

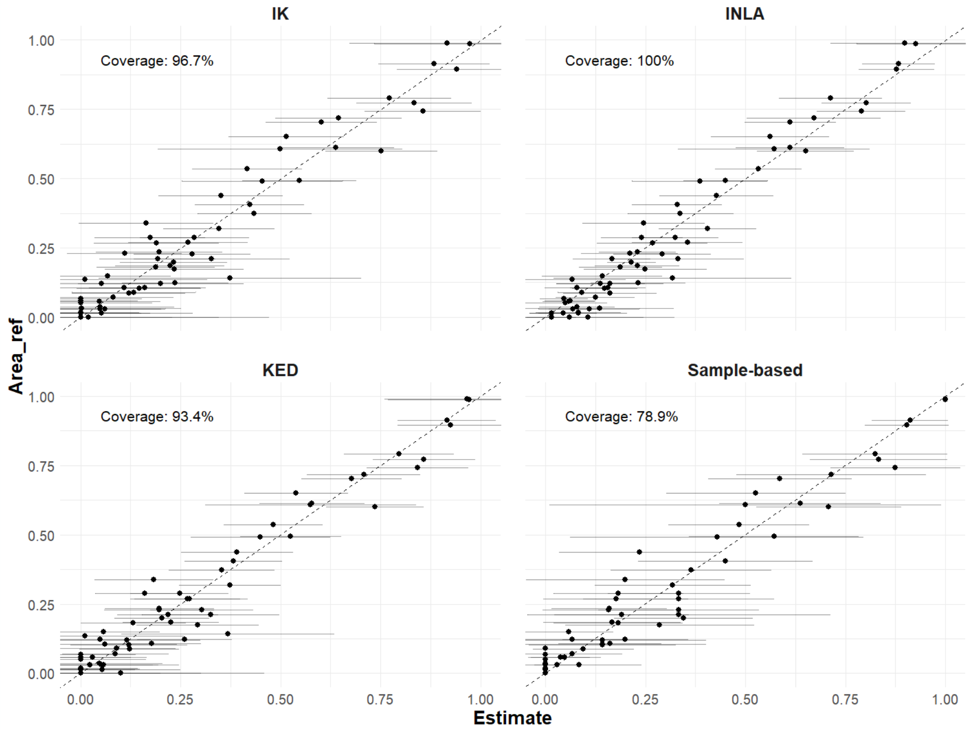
- Model prediction over 61 grid blocks (30 x30km).
- KED and INLA aligned well with the ground reference.
- Can be used for local map accuracy assessment.



OA =90.1% OA =85.4% OA= 89.5%

Grid level estimation

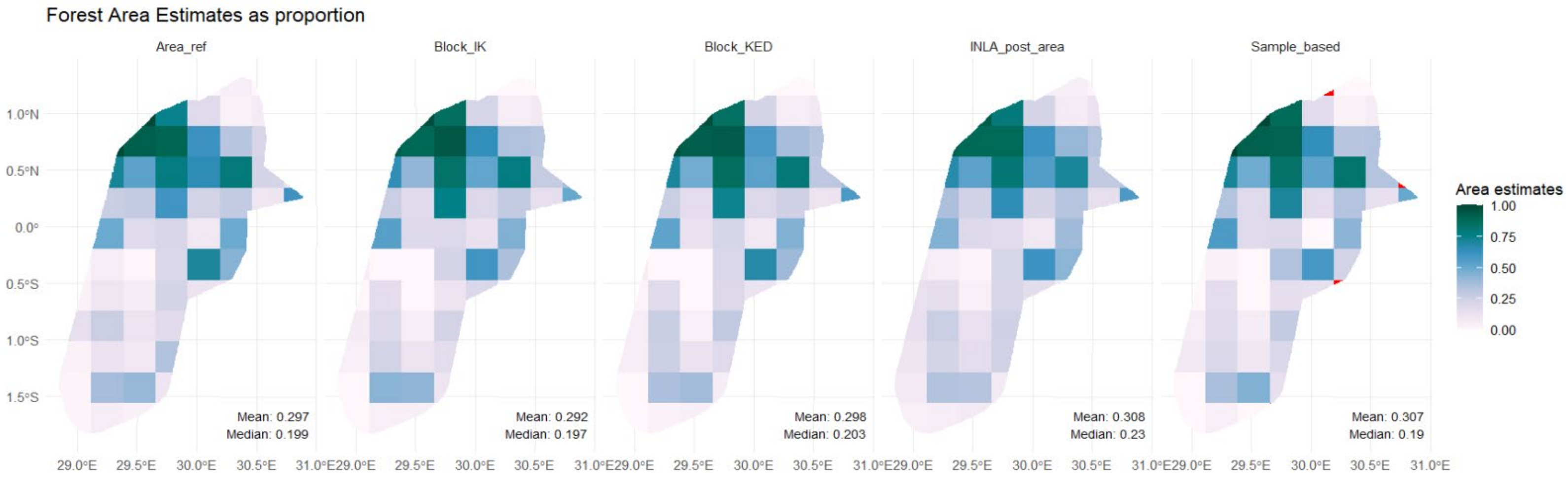
Proportion of instances where the reference value is contained within the 95% prediction interval

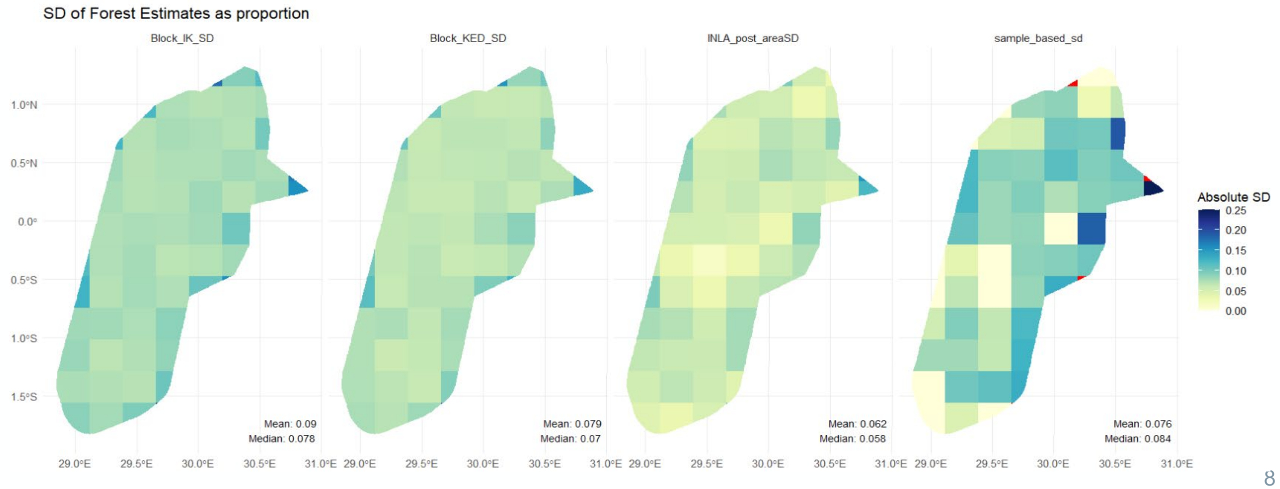


- The model-based methods produced higher PICP than the sample-based method (SRS).

Comparison of the area estimates: model and design based methods

- Compared to the reference, generally, the model-based and sample-based methods produced similar estimates.
- All model-based estimates generally have a smaller median SD than sample-based estimates.
- Block KED and INLA performed generally well.
- Further analysis is required to assess their general applicability.





Conclusion

1. The community-endorsed guidelines recommend using statistically rigorous methods that rely on independent, probability-sampled reference data.

2. Map comparison showed varied accuracy, particularly at the country level. There is a need for map accuracy information at the scales at which the maps are utilized.

3. Model-based area estimation approaches produced spatially consistent regional estimates compared to the sample-based method. Further investigation is needed to assess their general usability.

4. Critical challenges remain for spatially and temporally detailed validation of LC maps.

Thank you

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PhD in Validation Frameworks for Near-Real-Time Land Cover Change Monitoring

Application Closing date: 16th May

Your job

Are you fascinated by the rapid evolution of Earth Observation (EO) and eager to shape the next generation of validation methods for near-real-time land change monitoring? Do you hold an MSc (or equivalent) in Remote Sensing, Geoinformation Science, Statistics, or a closely related discipline, and feel comfortable programming in Python/R? Are you a critical thinker who can assess EO products, question their assumptions, limitations, and usability in operational contexts? If so, we have an exciting PhD opportunity for you! If so, we have an exciting PhD opportunity for you!

Recent advances in EO, such as dense satellite time series, rapid data access, and machine learning, have enabled the detection of deforestation, fires, floods, agricultural activities, and land cover transitions at sub-annual or near-real-time intervals. However, validation methods for assessing the monitoring products have not developed at the same pace, creating a gap between what monitoring systems can produce and what policymakers and enforcement agencies can confidently use. The current validation frameworks were designed for annual or static products and fail to address several key areas:

- Time-evolving assessments: both predictions and reference data change over time, requiring methods that account for temporal misalignment.
- Variable observation density: seasonal cloud cover, satellite revisit times, and sensor changes lead to inconsistent data availability.
- Reference data uncertainty: besides temporal misalignment, geolocation errors, and unclear class definitions affect validation reliability.