

Responses to the Comments and Suggestions of Referee #2

We appreciate the time and effort by the referee #2 in reviewing our manuscript. Your constructive and insightful comments and suggestions help us to further improve the manuscript. To help see the improvements in the revised manuscript, we included all the comments and suggestions at the corresponding locations in the revised manuscript and labeled all the changes using the tracking change mode. Please see our point-to-point response below to your comments and suggestions.

Referee #2' Comments to Author:

General Comments:

This paper presents an interesting approach regarding the mapping of tree cover in Africa around year 2020 from the use of two datasets of satellite imagery (PALSAR-2 and Landsat) along period 2015-2023 and a GEDI LiDAR dataset for year 2020.

Two main issues need attention before publication: (1) the thematic scope of the paper need to be corrected (mapping tree cover instead of forest cover) and (2) the temporal scope of the paper need to be revisited (the study does not seem to provide robust valid information on changes in tree cover).

Response: We appreciate and understand your concerns. Your two major issues are embedded in the specific comments. Our responses to your specific comments may serve the same role in responses to your two major issues.

Specific Comments:

1. The authors “generate annual forest cover maps in Africa at 30 m resolution from 2015 to 2023”. However they use only the structural parameters (i.e. tree cover percentage and tree height) of the FAO definition of forest. They do not consider the land use criteria of FAO definition.

Ref: FAO, 2023 FRA 2025 Terms and Definitions

“Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use.”

The FAO definition of forest excludes “land that is predominantly under agricultural or urban land use”. In particular it excludes tree plantations such as cocoa or oil palm plantations. The maps that are generated by the authors is more corresponding to a tree cover map (trees > 5m) than a forest map as defined by FAO. This can explain partly the differences with datasets such as the JRC GFC2020 map and the FAO FRA 2020 statistics. In particular in regions with large areas of tree crop plantations such as in Ivory Coast/Ghana as illustrated in site c of Figure 6 where most of the land is covered by cocoa plantations that appear as tree cover in PALSAR-2/Landsat, JAXA FNF4 and Landsat-GFW datasets whereas the JRC GFC2020 v2 displays only forest cover.

See in particular explanation of difference between forest and tree cover from WRI GFW blog: <https://globalnaturewatch.org/blog/data-and-tools/global-forest-watch-and-the-forest-resources-assessment-explained-in-5-graphics-2/>

Response: We appreciate this important comment and agree that FAO-defined forests should be distinguished from tree cover based mainly on remote sensed biophysical properties. FAO forest definition consider three major aspects: (1) forest biophysical metrics (traits) or land cover type (canopy coverage of > 10%, tree height reaching 5 meter or higher at the observation time or having the potential reaching 5 meter or higher), (2) minimum mapping unit (more than 0.5 ha), and (3) land use aspect (excluding forests in agricultural areas, urban areas). The minimum mapping unit aspect is often addressed by geographical information system (GIS) and mapping procedure. The land use aspect is also dealt with after the land cover maps are generated and then reclassified, based on the land use categories. Satellite remote sensing is largely on identification and classification of land cover types or vegetation biophysical metrics (e.g., canopy coverage, tree branch and trunk, tree height).

In this revision, we made a clarification that our forest cover map only considers the forest biophysical traits or land cover types. In addition, we also refer our PALSAR-2/Landsat forest cover product in Africa as part of the University of Oklahoma Global Forest Cover (OU GFC) dataset, which was developed based on land (forest) cover perspective, or the biophysical structural criteria, and does not explicitly consider and report the minimum mapping area or land use criteria.

“Forest” and “tree plantation” are two terms that reflect the effort to introduce land use concept. Forest (primary, secondary) is composed of multiple tree species. Plantation is a planted forest that is intensively managed and meets conditions: one or two species, even age class, and regular spacing. Depending on land use, plantations can be classified as tree crop plantation (e.g., oil palm, coconut, olive, cashew, cocoa, and fruit orchards) and plantation forest (e.g., eucalyptus, pine, teak), which established primarily for forestry purposes can be included within the forest category. In addition, many commercial plantations for timber production are also often called “forest”, which are popular in Europe, North America, and Asia. As also explained in the GFW/WRI blog website, satellite-based tree cover products primarily observe the physical presence and extent of trees and cannot, by themselves, determine the intended land use.

Regarding “forest cover” or “tree cover” term to be used for this manuscript, we appreciate the comments from the reviewer. However, in the literature, for some researchers, “tree cover” term does offer a way to reconcile “forest” and “tree plantation” terms. For researchers using “forest” or “tree plantation”, individual pixels in the maps are binary map (1 for forest or plantation, 0 for non-forest or plantation. For other researchers, the term “tree cover” generally refers to the proportion of an area occupied by tree crowns and is commonly represented as a continuous variable ranging from 0 to 1 or as a percentage.

Consequently, the term used in remote sensing papers and existing global products is not always strictly separated into “forest cover” and “tree cover”. For example, the UMD Global Forest Change (GFC) product characterizes “global forest extent and change,” and its change layers have historically been described as forest-cover loss and gain, whereas its baseline `treecover2000` layer is a continuous measure of canopy closure

(0–100%) for vegetation taller than 5 m (Hansen et al., 2013). At high spatial resolutions (meter to sub-meter level), individual tree crowns can be delineated, allowing tree density, crown size, and percentage tree cover to be quantified. Brandt et al. (2020) demonstrated individual tree mapping using sub-meter imagery in West African drylands, while Reiner et al. (2023) used 3-m PlanetScope imagery to map tree cover across Africa, including scattered trees outside conventional forest areas. JAXA GFC data product relies primarily on the backscatter data from the L-band Palsar-2 sensor to distinguish between forest vegetation and other land cover types. OU GFC data product depends on the L-band PALSAR-2 backscatter signal providing sufficient response to the woody components of forests and the Landsat optical signal providing sufficient response to the forest canopy.

In short, “Tree cover”, “Forest”, and “Tree plantation or plantation” terms are to some degree confused terms, and the research and application communities have not reached a common definition, yet (Chazdon et al., 2016; Sexton et al., 2016). Therefore, in the revised manuscript, we use the term “forest cover” for the OU GFC product in the context of remote sensing, which is a binary land cover class that meets specific forest structural thresholds, while explicitly noting that it does not consider the land use and minimum area criteria. To avoid ambiguity, in the first iteration of the OU GFC, we described it as a forest (tree) cover product based on two biophysical criteria from the FAO definition, while explicitly noting other two criteria that are not considered.

Specifically, we made the following revisions:

(1) We added a clear description of the meaning and limitations of the term “forest” as used for OU GFC (Pages 4–5, Lines 125–132):

“First, we developed and reported annual forest (tree) cover maps at 30-m spatial resolution in Africa, using both PALSAR-2 and Landsat imagery from 2015 to 2023, which is part of our global forest cover data product, referred as the University of Oklahoma Global Forest Cover (OU GFC) dataset. Second, we assessed and compared our OU GFC map with multiple existing satellite-based forest cover products using the canopy height and canopy coverage datasets derived from GEDI and clarified differences among the forest products when the FAO forest stand definition (tree

height > 5 m, canopy coverage > 10 %) is used. Note that OU GFC dataset was developed based on forest biophysical (structural) metrics, and it does not consider the minimum mapping unit (0.5 ha) metrics and land use metrics.”

(2) We revised the description of “FAO forest definition” to “biophysical metrics of FAO forest definition” in the main text.

(2) We expanded the Material Section to clarify the forest definition used by individual satellite-based product (Page 10, Lines 236–253).

“JAXA GFC provides annual global forest/non-forest maps (version 2) at 25 m spatial resolution from 2017 to 2020, generated from ALOS-2/PALSAR-2 L-band SAR backscatter coefficients using a rule-based approach and a random forest classifier (*Shimada et al., 2014*). The product adopts three aspects of FAO forest definition, with these criteria incorporated into the interpretation of training and validation data (JAXA/EORC, 2022). We used JAXA GFC for 2020 over Africa and merged the classes “dense forest (> 90% crown cover)” and “non-dense forest (10–90 % crown cover)” into forest (Fig. 3b).

JRC GFC provides a spatially explicit forest and non-forest map for 2020 (version 2) at 10 m spatial resolution by combining multisource datasets, including ESA WorldCover (*Zanaga et al., 2022*), UMD Global Tree Cover and Loss (*Hansen et al., 2013*), Global Forest Canopy Height (*Potapov et al., 2021*), and JRC Tropical Moist Forest Transition Map (*Vancutsem et al., 2021*) using Boolean decision rules (*Bourgoin et al., 2025*). The product adopts the FAO and European Union Deforestation Regulation (EUDR) forest definition by considering tree cover and tree height, applying a minimum mapping unit of 0.5 ha, and excluding agricultural and urban land uses. We used the JRC GFC dataset over Africa (Fig. 3c).

UMD GFC provides percent tree canopy cover for 2000 (*treecover2000*), annual forest cover loss from 2001 onward, and forest cover gain for 2000–2012 at 30 m spatial resolution using multiyear Landsat data and a decision-tree approach (*Hansen et al., 2013*). The product does not explicitly incorporate minimum mapping unit or land use criteria. Tree cover is defined as canopy closure of vegetation taller than 5 m, and forest

extent can be derived by applying user-defined thresholds. We used GFC version 1.8 (2000–2020) dataset for Africa. Specifically, we retained pixels with a lossyear value of 0, indicating no detected forest cover loss during 2001–2020, and applied tree cover thresholds of > 10 % and > 30 % to treecover2000 to generate forest extent maps for 2020 with tree cover > 10 % (Fig. 3d) and > 30 % (Fig. 3e), respectively.”

(3) We revised the Discussion to explicitly acknowledge this limitation and outline future improvements (Page 23, Lines 528–531).

“As a forest cover dataset, OU GFC uses only two GEDI-derived structural parameters to align with the two biophysical criteria of FAO definition. Future improvements will incorporate minimum area and land (forest) use criteria by integrating existing datasets on agricultural land, urban areas, and tree crop plantations.”

2. The authors claim that their “annual forest cover maps complement FRA reporting and support a better understanding of the magnitude, dynamics, and drivers of forest gain and loss across Africa”. This statement needs to be revisited as, to my view, the study does not provide a robust assessment of changes of forest cover (gain or losses). The differences between annual maps can be due to a combination of (i) variability / error range in the individual annual maps, (ii) transition from forest to tree crops plantations (loss then gain) and (iii) changes in forest cover (mostly losses). To my view the ‘dynamic’ between annual maps (as displayed in Figure 4) is mainly due to (i), partly to (ii) and only for a very limited extent to (iii). A comparison with FAO national data on changes would be useful to indicate if the outcomes of the study could be meaningful. The authors are reporting an increase of forest (tree cover) of $+0.3 \times 10^6 \text{ km}^2$ for Africa from 2016 to 2022 (from $8.6 \times 10^6 \text{ km}^2$ in 2016 to $8.9 \times 10^6 \text{ km}^2$ in 2022) whereas FAO FRA 2025 is reporting a loss of forest of c. 30 million ha ($-0.3 \times 10^6 \text{ km}^2$) for Africa over period 2015-2025. The TMF dataset is also reporting a decrease of tropical humid forests at $-0.016 \times 10^6 \text{ km}^2 / \text{year}$ over period 2015-2019 (in Vancutsem et al that can be updated to 2024 from <https://forobs.jrc.ec.europa.eu/TMF/data#stats>).

This opposite trend between the study results (positive trend) and FAO or TMF outcomes would need to be supported (through a robust accuracy assessment) or at least explained (as related to error range in the annual maps).

Response: We appreciate your comments and agree with your explanation and likely paths on the differences in forest area estimates among annual maps. In the revised manuscript, we revise the statement to “annual forest cover maps complement FRA reporting (5-year interval)) and can be used to support analyses of the magnitude, dynamics, and drivers of forest area gain and loss across Africa” in the Abstract Section.

We agree with the reviewer’s previous comment on the forest definition and reporting categories used by different data products. The differences you mentioned here are likely to attribute those issues. In accordance with the scope of ESSD dataset journal, the detailed analyses of the magnitude, dynamics, and drivers of forest area gain and loss across Africa are beyond the scope of the data paper and journal. In Section 3.4, we changed the subtitle to “Spatial-temporal consistency of forest cover during 2015–2024” and reported the percentage of forest pixels frequency at the continental scale, rather than specific forest area change over years and comparison with FAO national data on changes in the revised manuscript.

Your comments pointed out our future research directions. We will conduct region-specific, targeted analyses of forest dynamics and related comparison for different forest types, such as the Congo Basin tropical forest, and forests in dry savanna, the phenomenon of woody plant encroachment, and regions transiting from forests to tree crop plantations in agricultural areas.

3. The Accuracy assessment using GEDI footprints (section 2.3.2) is very robust and valid for the assessment of the map of year 2020 (tree cover) but does not provide information on the accuracy of changes between years nor on the dynamics. A specific accuracy assessment (from a statistical sample of reference plots) would be needed to assess the accuracy of annual changes. See Olofsson et al (2014) for good practices

and Vancutsem et al (2021) as example of accuracy assessment of changes (disturbances)

References:

Olofsson P et al. Good practices for estimating area and assessing accuracy of land change. Remote Sens. Environ. 148, 42–57 (2014).

Vancutsem et al., Long-term (1990–2019) monitoring of forest cover changes in the humid tropics. Sci. Adv. 2021; 7 : eabe1603;

Response: We appreciate your positive comments on the use of GEDI footprint data for accuracy assessment of the map in 2020. To provide information on the accuracy of annual forest cover maps in different years, we have added the analysis that uses available GEDI footprint data from 2019, 2021, 2022, and 2023 to assess the accuracy of annual forest cover maps in those years. The OU GFC maps for 2019–2023 were assessed whereas the OU GFC maps for 2015–2018 were not assessed because there were no GEDI observations available for those years. Table S1 lists the confusion matrices of OU GFC maps from 2019 to 2023 in the revised supplementary material.

We agree that sampling design is a critical component of land cover accuracy assessment. The publication from Olofsson et al., 2014 has been widely cited in the literature on accuracy assessment of land cover maps, particularly for accuracy assessments that use in-situ field samples or other limited reference samples. In the situations described by Olofsson et al, 2014, random, systematic, or stratified sampling schemes are commonly designed to account for the proportions of different land cover types in study area. This is especially important for *in-situ* sampling, which is often time-consuming and costly, as the result, sample sizes are often in the order of hundreds to thousands. For example, Vancutsem et al. (2021) used a total of 5,250 reference samples. Such sampling strategies are well suited to the studies with relatively limited reference data and smaller spatial domains.

In contrast, GEDI provides a very large number of samples through a systematic spatial sampling format (please see Fig. 1 below), which is expected to yield reliable results for accuracy assessment in a statistical analysis context. For example, in this study, the

number of quality-controlled annual GEDI samples over Africa between 2019 and 2022 exceeded 120 million for each year. At large scales, such as continental and global, it is often difficult to determine the proportions of different land cover types within a study area, and extensive *in-situ* sampling in remote forest regions is particularly challenging. Therefore, one advantage of our approach is the use of massive, systematically distributed GEDI structural observations to support accuracy assessment at large scale. We agree, however, that sampling design remains important, and our intention is not to suggest that large sample size eliminates the need to consider sampling representativeness, but rather that GEDI provides an alternative framework that is particularly useful for continental- and global-scale assessment.

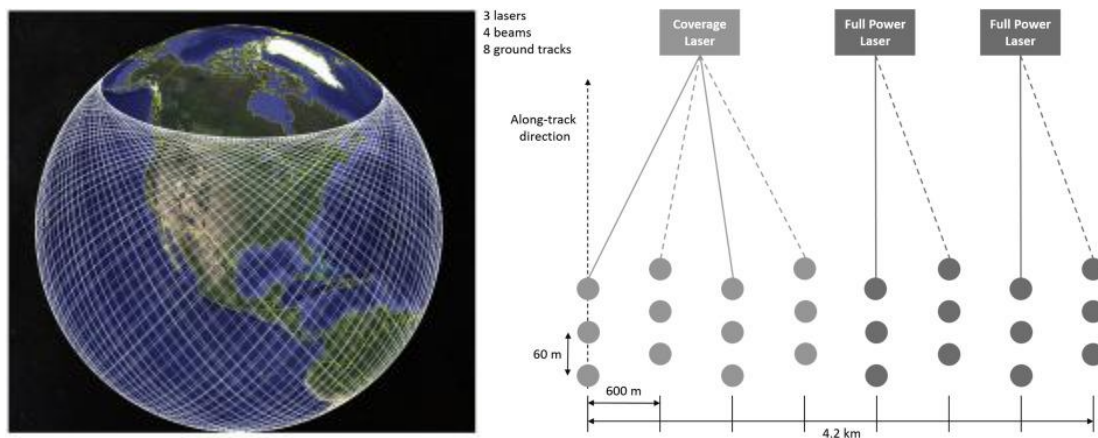


Fig. 1. Two weeks of GEDI orbital tracks (left). Each line represents one track (around which the 8 laser tracks are arranged). (right) GEDI beam pattern. Note that the along-track and across-track distance are not to scale (across track distance is about 10x larger). At any one instant, four laser pulses from the 3 lasers hit the ground. These are then dithered across-track to produce a complement of 8 tracks, with a gap of one shot along-track (Dubayah et al., 2020).

We also appreciate the reviewer for sharing Vanculsem et al., 2021 paper to our attention. It is an inspiring work with TMF dataset and GFC dataset. In the future, we will try to do similar work and publish the results. As the TMF dataset was generated with Landsat images, a comparison between the TMF dataset and our forest cover dataset

(derived from both PALSAR-2 and Landsat) could provide useful insights into the consistency and differences between optical-sensor approaches and multi-sensor approaches for forest cover mapping. Such a comparison may also be of interest to the forest research, management, and conservation communities.

Specifically, we made the following revisions in the revised clean manuscript:

(1) We revised the description of the GEDI data from 2019 to 2023 in Section 2.2.3 (Page 9, Lines 216–224):

“We used GEDI-derived canopy height and canopy cover as data sources for accuracy assessment. Specifically, we extracted rh98 (relative height metric at 98 %) from the version 2 of GEDI02_A product (Dubayah et al., 2021a) and total canopy cover from the version 2 of GEDI02_B product (Dubayah et al., 2021b) from 2019 to 2023 over Africa on GEE.”

“After quality control, the total number of high-quality GEDI footprints from 2019 to 2023 over Africa was 121×10^6 , 175×10^6 , 142×10^6 , 129×10^6 , and 39×10^6 , respectively”

(2) We revised the description of the method on accuracy assessment using GEDI footprints in Section of 2.3.2 (Page 12–13, Lines 285–293):

“Using the forest biophysical (structural) metrics in FAO forest definition, we first divided all high-quality GEDI footprints for each year into two subsets. The first subset satisfied both the canopy height (> 5 m) and canopy cover (> 10 %) thresholds, whereas the remaining footprints did not meet at least one of the two thresholds. We then overlaid the two annual GEDI-based datasets with the corresponding OU GFC maps for each year from 2019 to 2023 to generate annual confusion matrices and calculated overall accuracy (OA), user’s accuracy (UA), producer’s accuracy (PA), and Kappa coefficient. Taking 2020 as a representative year, we further overlaid the two GEDI-based datasets for 2020 with five satellite-based forest cover datasets over Africa for the same year (binary forest/non-forest map; see Sect. 2.2.4). Confusion matrices were generated for each dataset, from which OA, UA, PA, and the Kappa coefficient were calculated.”

(3) We revised the description of the result of accuracy assessment in Section 3.2 (Page 14, Lines 317–319):

“We assessed the accuracy of OU GFC for 2019–2023 and other satellite-based forest cover datasets for 2020 using GEDI-derived canopy height and canopy coverage and the FAO forest stand definition. OU GFC showed consistently high and stable annual accuracy from 2019 to 2023, with OA of 89.8–91.0 % and Kappa coefficients of 0.66–0.70 (Table S1).”

(4) We revised the statement in Discussion 4.1 (Page 21, Lines 476–478):

“A limitation of this study is that the annual accuracy assessment of OU GFC data product was limited to 2019–2023. The OU GFC maps from 2015 to 2018 could not be evaluated because no GEDI observations were available for those years.”

(5) We added the statement in Section of Data availability (Page 25, Lines 563–565):

“The OU GFC datasets for Africa from 2019 to 2023 were assessed by using GEDI LiDAR footprints and FAO forest definition (forest stand metrics) and OU GFC datasets for 2015–2018 were not assessed due to GEDI data availability limitation.”

Technical corrections

Response: We appreciate your patience and careful attention to detail in identifying these issues and providing suggestions to improve the quality of the manuscript. We have addressed all these technical corrections, as detailed below.

In introduction

Previous work regarding land cover mapping in Africa to be mentioned:

Mayaux, P., De Grandi, G.F., Rauste, Y., Simard, M., and Saatchi, S., 2002. Large Scale Vegetation Maps Derived from the Combined L-band GRFM and C-band CAMP Wide Area Radar Mosaics of Central Africa, International Journal of Remote Sensing, 23: 1261-1282.

Mayaux, P et al, 2003. A Land-cover Map of Africa . European Commission, EUR 20665 EN

308 **Response:** We briefly summarized and added these two citations into introduction
309 Section (Page 3, Lines 75–78) in the revised manuscript.

310 In section 2.2.4 (Other forest products)

311 Use of FAO forest statistics: update the statistics of year 2020 from FAO FRA 2020 with
312 statistics (of same year 2020) from FAO FRA 2025 (FAO. 2025. Global Forest
313 Resources Assessment 2025. Rome. <https://doi.org/10.4060/cd6709en>)

314 **Response:** We agree that the 2020 forest statistics reported in FAO FRA 2025
315 represent updated estimates for the same reference year previously reported in FAO
316 FRA 2020, reflecting revisions incorporated in the latest assessment cycle. We updated
317 Figure 5 to include the 2020 forest area estimates from both FRA 2020 and FRA 2025
318 and used the FRA 2025 estimates as the primary one for comparison with the other
319 forest products.

320

321 Add reference to JRC Tropical Moist Forest Transition Map (Vancutsem et al 2021)
322 when describing JRC GFC2020 v2 dataset

323 **Response:** We added this citation (Page 10, Line 243) into Section 2.2.4 in the revised
324 manuscript when describing JRC GFC dataset.

325

326 In Figure 6:

327 Colours of panels a5 and b5 to be verified (green and black seem inverted)

328 Order in legend to be corrected as “The subsequent columns present forest cover maps
329 from PALSAR-2/Landsat, JAXA FNF4, JRC GFC2020 v2 and Landsat-GFW”

330 **Response:**

331 We appreciate you pointing out this issue. We reprocessed the UMD GFC version 1.8
332 (2000–2020) dataset and carefully double-checked the zoom-in panels. We confirm that
333 the colors in Figure 8 of the revised manuscript are now displayed correctly.

We have corrected the legend as “The subsequent columns present forest cover maps from OU GFC, JAXA GFC, JRC GFC, UMD GFC (tree cover > 10 %), and UMD GFC (tree cover > 30 %), respectively.” in the revised manuscript to match the corresponding forest cover maps.

Reference

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