

Response to reviewer: Jonathan P. Sheppard

GENERAL RESPONSE

We would like to express our gratitude to both reviewers of our manuscript for their thoughtful and constructive comments. Their feedback has been invaluable in improving the clarity, quality, and overall presentation of our manuscript.

Our detailed responses to each of their points are provided below, as shown in the accompanying tables. We have carefully considered all suggestions and implemented revisions where appropriate. In cases where we have retained the original wording, we have explained our reasoning. We hope that our responses satisfactorily address our reviewers' concerns and demonstrate our commitment to producing a rigorous and transparent manuscript.

GENERAL POINTS

1) Title: consider this adjustment – ForestScan: a unique multiscale dataset of tropical forest structure integrating terrestrial, UAV, and airborne LiDAR with in-situ forest inventory data across three continents	Thank you for your suggestion. We appreciate your input; however, we have chosen to use the term 'census' rather than 'inventory', in line with the terminology adopted by ForestPlots.
2) Use of the word "census": Consider changing this to "inventory" in every instance (also in the title), I find inventory is more commonly used in forest research and remote sensing fields. In any case you can use census as a keyword.	Thank you for your suggestion. We appreciate your input; however, we have chosen to use the term 'census' rather than 'inventory', in line with the terminology adopted by ForestPlots.
3) There are lots of authors, and I suspect lots of contributions – sections need to be unified in style and language. Language is generally good, but often sections could be more concise. Please consider	Thank you for your valuable feedback. We have made a concerted effort to unify the style and language across sections and to improve conciseness wherever possible. At the same time, we needed to balance this with the first reviewer's request for additional detail and the inclusion of more tables. Our revisions aim to address both sets of comments while maintaining clarity and completeness.

<p>4) Acronyms: please check every acronym throughout the whole manuscript, there is a lot of repetition – acronym after the first instance only (e.g., DBH, TLS, ALS, AGB, EO, VOLS, ...).</p>	<p>Done, only repeated once for subsection titles: 2.2.2 Terrestrial Laser Scanning (TLS) 2.2.3 Unpiloted Aerial Vehicle laser scanning (UAV-LS) 2.2.4 Airborne Laser Scanning (ALS)</p>
<p>5) Please pay attention to the technological limitations (e.g. accuracy of LiDAR – refer to Morhart et al. 2024 https://doi.org/10.1007/s10342-023-01651-z), this is touched upon in line 311. Also consider elements of quality assessment of data processing (e.g., wood/leaf class extraction as shown in Fig. 7). I would like to see a section devoted to discussing possible methodological/processing errors within the dataset. I would also like the methodological/equipment limitations to be discussed, this is touched on in line 271. I would argue that the tilted scan is nice to have but an extra step (and all the extra workload) that might not be essential (dependent on the size of the trees scanned). Did you scan outside the plot to better capture the trees on the plot boundaries?</p>	<p>Thank you for your comment. We have also addressed uncertainty in response to our first reviewer's feedback (see below). Tilted scans are particularly beneficial for improving coverage in the upper canopy of tall trees, as demonstrated by Wilkes et al. (2017) and Verhelst et al. (2024). Where possible, scans positioned along plot edges were placed slightly outside the boundary to ensure that edge trees were fully captured; tilt scans along the baseline further support this objective.</p> <p>We have extensively revised subsection 2.2.2 TLS data processing section 3. Recommendations for aligning and matching datasets for UAV-LS and ALS for clarity and conciseness and to address your and our first reviewer's comments.</p>
<p>6) Plot/sub-plot numeration becomes confusing between FBRMS and their individual subplots – consider making this more transparent/unified.</p>	<p>We thank both our reviewers for these valuable suggestions on this topic. We have completely redesigned all three site figures to ensure consistency and improve clarity about the different FBRMS plot/subplot layouts and have also revised the appropriate text for each site:</p> <p>Comment 3 (Coherent style and content): All three site maps now follow a standardised three-panel format: (a) continental overview showing the country location, (b)</p>

	<p>country/regional view showing the research station, and (c) detailed site map with high-resolution satellite imagery. All figures use consistent fonts, legend styles, colour schemes (orange for FBRMS-01 TLS plots, treatment-specific colours for census plots, yellow tones for ALS coverage, purple for UAV-LS coverage), scale bars, north arrows, and boundary styling.</p> <p>Comment 4 (World map showing all three sites): Each site map now includes a continental-scale overview panel that clearly shows the country location. The three figures together provide complete geographic context across South America (French Guiana), Africa (Gabon), and Southeast Asia (Malaysia), making it straightforward for readers to understand the global distribution of our study sites across three continents.</p> <p>Comment 5 (Fig. 1 - Paracou improvements): We have added the three-panel layout with South America overview and French Guiana regional maps, plus a scale bar in the detailed panel. The three FBRMS-01 TLS plots (plot 5-subplot 1, plot 6-subplot 2, plot 8-subplot 4) are now prominently displayed in bright orange with white borders and are directly labelled with their subplot IDs. A comprehensive legend shows all plot types, experimental treatments, and data coverage areas (ALS and UAV-LS).</p> <p>Comment 6 (Fig. 2 - Lopé improvements): We have significantly increased all label sizes for better readability and the elevation image is not used. All census plots are now clearly shown as semi-transparent coloured polygons according to their treatment type, TLS plots are prominently marked in orange with white borders, and the UAV-LS coverage area is shown as a semi-transparent overlay.</p> <p>Comment 7 (Fig. 3 - Malaysia plot clarification): We have clarified in both the figure caption and legend that the field sites consist of 4 ha "plot groups," each containing four 1 ha census plots arranged in a 2×2 grid. The caption now explicitly states: "Each 4 ha plot group contains four 1 ha subplots (shown as individual coloured squares)." The individual 1 ha subplots are clearly visible in the detailed satellite imagery view, making the spatial arrangement unambiguous.</p> <p>These comprehensive revisions ensure all site maps are publication-ready with consistent, professional presentation that enhances reader comprehension of the study locations and data collection infrastructure.</p>
<p>7) Consider adding a summary table in section 2 outlining the study sites, country, coordinates, area, climate, ... this could considerably shorten the section which is a bit wordy. I would also like to know something about the stands that were scanned, tree</p>	<p>Thank you for this helpful suggestion. We have revised different subsections within Section 2 to improve clarity and conciseness. While we appreciate the value of a summary table and additional stand-level details, we have opted not to include these in the manuscript to avoid further increasing its length, which is already substantial. Instead, we encourage users of the dataset to consult the accompanying metadata and site-specific tree census resources for comprehensive information on plot characteristics, including tree density, mean DBH, and top height. This approach ensures that the manuscript remains focused while still enabling access to detailed site information through the dataset.</p>

density, mean DBH, top height,	
<p>8) Figures 1, 2 and 3 would be nicer if they had a unified style and similar content. For example, Figure 1 is really detailed and figure 2 is very vague. Some of the figures are missing basic mapping elements. It looks like they have been provided by separate people from the author consortium. Make sure the legends and captions are clear and correlate with the text body (e.g., lines 141 and 142 refer to treatment 1,2 and 3 – I guess this is T1, 2 and 3 in Fig 1? Also Line 230. Mapping could also show the areas within each FBRMS that was scanned with each method. This is relevant, for example, to lines 589/590.</p>	<p>We have addressed all these issues, pls see our response to comment 6)</p>
<p>9) The methods sections (lines 281 – 332) could be condensed, call it data collection – the same or similar methods were applied for all TLS campaigns. One table for scanners used and their settings, one table for plot overviews. This part is very repetitive. E.g., Lines 318 and 328 (use of targets).</p>	<p>Thank you for your suggestion, we have revised different subsections within section 2. Methodology for clarity and conciseness and to address both our reviewers helpful comments.</p>
<p>10) Line 766-775: Linking TLS trees to their census (inventory) counterparts. Plot marking is a valid point. Your examples are specific (e.g. Elephants). We too have tree tags that are destroyed by</p>	<p>Thank you, using the anchor trees is still a work in progress, we are also following closely the development of new tree census protocols using LiDAR in iphones and ipads which can make this matching possible.</p>

birds pecking at their shiny surface, we know the problem! We are also trialling QR codes on alu/foam board, plots can also be marked with a steel ground stake that can be found with a metal detector. The idea of anchor trees is good.	
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SPECIFIC POINTS

Lines 44-46: define acronyms EO, AGB, cal/val, ...	Done
Lines 78-80: Better description needed – particularly on the need for better intercalibration.	This is addressed in more detail in section 4. Recommendations for data collection in FBRMS
Line 86: the acronym for Spacebourne LiDAR is not LiDAR. Also be careful in this section ESA Biomass is Radar not LiDAR – it has also already been launched (line 90), update needed.	Thank you for your comment, we have corrected the acronym and updated the launch date
Line 93: make – undertaken.	We have revised “make” to “collect”
Lines 107-108: selection based on discussions is vague (people will always discuss), stick to the criteria.	Discussions among the teams has been removed.
Lines 112-114: Bullet points – note the acronym after the site name in brackets. E.g., Paracou Research station, French Guiana (FBRMS-01). Also see the general comment	Thank you for your suggestion. We would prefer to retain our current naming as used throughout the manuscript.

above about plot codes/names.	
Line 122: define Cirad-UMR EcoFoG.	Done
Line 125: thousand separators, additionally please check all.	Done
Lines 135: remove "in the early 1980's".	Thank you for your suggestion, but we prefer to keep the date as it provides context.
Line 138: done – carried out.	This line was deleted.
Line 148: 9 – nine.	Thank you for your suggestion, but using the numeral with units of measurements is correct. This is standard convention in both British and American scientific styles as the unit (ha, m, km, °C, etc.) makes it a technical specification, and numerals improve clarity and consistency.
Lines 135-149: lots of (possibly) irrelevant detail that could be cut to make the section more focused (e.g., flux tower, fertilisation experiments). Please consider revising. Compare with the description of FBRMS 02 and 03 where there is much less.	Thank you for this suggestion, this paragraph has been cut down from 15 to 8 lines.
Figure 2: a, b, c and d need defining in the caption (but consider first my general comment above).	Pls see our response to comment 6)

Line 190: replace "laser-scanning" with "LiDAR" approaches	We have standardised and now use "laser scanning" across the entire manuscript to address similar requests on this from both reviewers.
Lines 190-192: Sentence "species identity...." needs a rephrase. This and the next sentence can be made more precise. I think you mean the determination of tree species is critical since wood density x TLS derived volume = biomass.	This line has been revised: Species identity plays a key role in determining tree biomass through its strong influence on wood density. While laser-scanning techniques provide excellent measurements of tree dimensions (such as height and volume), they still require wood density estimates to convert these volumes into accurate biomass values (see Fig. 4)
Figure 4: remove – it is secondary information – just direct the reader to the right place.	It has been removed.
Lines 201-202: Remove the sentence about ForestPlot.net – it is not needed.	Thank you for your suggestion. We appreciate your perspective, however, we believe that mentioning ForestPlots.net is important because it highlights the scale and collaborative infrastructure underpinning the data archive used for two of our FBRMS plots. This context helps readers understand the robustness and credibility of the ForestPlots archive. For this reason, we would prefer to retain this line.
Line 218: at 1.3m – this is DBH you have defined it before.	Thank you for your suggestion, however, we're providing the height here to give context, as buttresses can change the height at which DBH is measured.
Lines 221-228: do you mean trees were recorded by their common names and then (as written in lines 226 – 228) trained botanists returned to identify species? If so try to combine these paragraphs.	Thank you for your suggestion, they have been revised to: New recruits -trees that have grown beyond 10 cm DBH since the previous survey- are recorded by the field team using vernacular names, and their positions are measured relative to the original trees. To ensure accurate identification, periodic botanical campaigns are conducted by one or two experienced botanists, who also correct any misidentifications. When species cannot be identified in the field, samples are collected and examined at the EcoFoG herbarium in Kourou or the IRD herbarium in Cayenne. All identifications follow the APG IV plant classification system.

Line 228: Explain APG IV	Done
Line 233: Remove "referenced by a DOI"	Done
Line 231 and 236: ask the journal how to display the hyperlinks, especially since the second is linked to a reference.	<p>The first link has been revised to: https://dataverse.cirad.fr</p> <p>The second link has remained the same.</p>
Line 240: Plot numbering/labelling confusion for the reader – link to map figure	This line has been revised to: During June - July 2022, these 13 plots plus one additional 1 ha plot (LPG-02) were re-censused, making a total of 11 x 1 ha forest plots, plus 3 x 1 ha plots in savanna (see Fig. 2)
Lines 238-241: much less detail shown here than FBRMS 01, why?	<p>Census data for FBRMS-02 and FBRMS-03 are managed and archived by ForestPlots. We have included the below two paragraphs in the FBRMS-03 section that apply to both sites, in order to avoid duplication.</p> <p>Plot meta-data, including geography, institution, personnel and historical context, as well as tree-level census attributes (tag, identity, diameter, point of measurement, stem condition, height, sub-plot, and, where measured x, y coordinates of 5 x 5 m subplots) and multi-census attributes (tree demography and measurement trajectory and protocols, including growth, point of measurement changes, recruitment, mortality, and mortality mode) were recorded for all Gabon and Malaysia FBRMS plots.</p> <p>The ForestScan Project data package, includes data from the 2022 tree census collected during February and March for the Gabon FBRMS plots and the Malaysian FBRMS plots census data collected in October 2020 for FBRMS plot SEP-11, in March 2020 for plot SEP-12, and in June 2021 for plot SEP-30. This data package can be accessed via https://doi.org/10.5521/forestplots.net/2025_2 (Chavana-Bryant et al., 2025a).</p>
Lines 241 and 245: TLS was conducted not collected (TLS point cloud data was collected).	Done
Line 242: "most" = vague.	Thank you for your comment. We understand your concern regarding the term "most." However, this is a commonly used and accepted

	expression in scientific writing to indicate a majority without specifying an exact proportion, which is appropriate in this context.
Line 244: Same plot numbering problems as above.	This paragraph has been revised to: In the Kabili-Sepilok FBRMS, tree census data was collected during 2020 - 2022 for a total of 9 x 4 ha plots (IDs RP291-1, RP292-3, etc. see Fig. 3) each containing four 1 ha subplots numbered 1 – 4 and covering most of the long-term plots at this site. The three FBRMS subplots SEP-11 (subplot 2 of plot RP292-3, sandstone soil), SEP-12 (subplot 2 of plot RP292-1, alluvial soil) and SEP-30 (subplot 3 of plot RP508-4, kerangas soil) were scanned using TLS during March 2017 and tree census for all subplots was collected in Jan, Mar of 2020 and Jun 2021. The 2020-2022 census was overdue as these plots had not been censused since 2013.
Line 251: Gabonese and Malaysian FBRMS plots	Corrected
Line 260: insert - chain sampling "protocols"	Done
Line 261: QSMs needs describing	This is covered in subsection 5. TreeQSM: quantitative structural models and results
Figure 5a and b can be combined into one grid. Consider using axis labels to define scan position, the legend to the left must be much bigger to be legible.	The left legend has been removed and the figure enlarged for clarity.
Line 273: figure 5c?? missing.	Corrected to: panel b (right)
Line 279: Working day is arbitrary – person hours give a better idea of workload.	A full working day = 8 hours. It has been added to the text.
Line 280: Maybe give the time needed for one scan.	This is later discussed in subsection TLS data acquisition in section 4. Recommendations for data collection in FBRMS

Line 284: 16 quarter ha plots – that's seems like a complicated way of expressing area.	Done, revised to: (i.e. two x ha plots)
Line 319: give detail on the RTK equipment	This is later covered in subsection 1. Individual scan registration into plot-level point cloud
Tables 1, 2 and 3: the Lat. Long. coordinates are very approximate.	Yes, this is a ForestPlots requirement. Pls note KMZ files for plots in Gabon and French Guiana provide more accurate locations.
Lines 338-339: delete bottleneck sentence. It is true but not needed here.	Done.
Lines 351: Maybe specs are needed for HPC cluster and CPUs? Time reference (ca. 4 days) is ok here as the reader knows no break is needed.	Thank you for your suggestion. We appreciate the point regarding HPC and CPU specifications, however, these setups vary greatly across institutions and there are no universal standards. Processing time depends not only on the resources available to the user but also on how many users are simultaneously accessing those resources. For this reason, we have provided an approximate time reference (around 4 days) as a practical guide.
Line 362: Precision of person hours vs. days (see comments above).	This has already been addressed, see our previous response: A full working day = 8 hours. It has been made explicit.
Line 366: "potentially containing more than 5.42 billion points" impressive, but too accurate and irrelevant to the reader, please delete.	Thank you for your comment. We appreciate your perspective, however, we consider this level of detail relevant as it illustrates the scale and complexity of the dataset being processed. Including the figure helps convey the computational challenges and the significance of the methods applied.
Line 366: Insert – one small "exemplary" section of	This figure has been deleted.
Line 447, 552, 586, 599 and 616: delete "data access".	Done, and the section number has also been corrected to 5

Lines 455-459: please condense.	Revised to: Table 5: Summary statistics for 10 FBRMS ForestScan TLS plot datasets. AGB estimates use wood density values from the DRYAD global database (Zanne et al., 2009): (1) TLS2Trees pantropical mean, (2) Tropical Africa mean (TAF, Gabon), (3) South-East Asia mean (TS-EA, Malaysia), (4) Tropical South America mean (TSA, French Guiana), (5) Guyana community mean (GF, French Guiana), and (6) allometric AGB estimates based on Chave et al. (2014).
Figure 10: a nice figure but too much content, if only representative maybe just choose one plot row for e.g., 10 trees.	Thank you for your comment. We appreciate your suggestion; however, we would prefer to retain the figure as it is, it illustrates an important point: the largest trees, which contribute most to AGB estimates, vary significantly in size and structure across plots. Showing all plots together provides essential context for this variability and highlights differences in maximum tree height, which was also raised in your comments. Reducing the figure to a single plot would limit this comparative perspective.
Line 476: an overview table might help the reader interpret the similarities and differences between flights (across all plots and flights) – Table 5 should be used and referred to earlier, and could be expanded for the other plots.	<p>Thank you for your suggestion. We appreciate the idea of providing an overview table; however, this section already contains three tables, including Table 6 (previously Table 5), which summarises the similarities and differences across plots and flights as requested. Additionally, Tables 7 and 8 have been standardised to ensure consistency and clarity (see below table captions). For these reasons, we believe the current structure sufficiently addresses the need for comparison without adding redundancy.</p> <p>The captions for tables 7 & 8 (previously 6 & 7) now clarify which flights can be considered part of a single acquisition while being provided as individual point clouds which users can merge according to their needs (see table captions below). We have also added the extra characteristic “Flights merged into single acquisitions” to Table 6: UAV-LS sensor systems used at ForestScan FBRMS-01 and FBRMS-02.</p>
Line 477: VLOS stipulation is a repeat.	It has been removed
Line 480-481: irrelevant, I would not suggest anything other than adherence to the flight rules given.	This line has been removed.
Line 487-488: delete cherry-picker (above canopy platform is	Thank you for your suggestion. We would prefer to keep the example, as not all readers are familiar with this type of equipment.

sufficient as a description).	
Figure 12: legend entries need defining e.g., AOI, DSM	For clarity, the figure caption has been edited to: Figure 10: UAV-LS flight trajectories over the FBRMS-01 site at Paracou, showing coverage of the experimental 4 ha plot 6 (red dashed outline) and the area of interest (AOI; yellow dashed outline). The criss-cross flight pattern results from multiple flight lines oriented in different directions (e.g., N–S, E–W, NE–SW) to improve point density and reduce occlusion in dense tropical forest canopies. The background shows a digital surface model (DSM) with elevation values (m), colour-coded by elevation classes as indicated in the figure legend (–23 m to 50 m). The inset map shows the regional location of Paracou within French Guiana (© OpenStreetMap contributors, available at https://www.openstreetmap.org).
Table 6 and 7: is something up with the UTC date and time in the tables??	Please see response for previous comment for Line 476
Table 6: define AGL (assumed above ground level).	Please see response for previous comment for Line 476
Line 555: please rephrase and be specific that you are referring to FBRMS02.	Thank you for your suggestion. We would prefer to keep the wording as it is, since this is the opening line of the subsection ‘UAV-LS: FBRMS-02: Lopé, Gabon,’ which already makes it clear we are referring to FBRMS-02.
Line 556: DELAIR DT26X drone platform	Done
Line 561: "different" can you be specific?	Thank you for your suggestion. We understand the desire for more specificity; however, the term ‘different angles’ cannot be made more precise as the exact angles vary depending on real-time wind conditions and operational constraints during each flight. These variations are not fixed or standardised, thus, using a general term accurately reflects the flexibility required to maximise canopy coverage.
Figure 13: Please label the panels and use fitting captions, I am not sure	Done

what all photos are showing me.	
Line 609: ALS	Done
Line 611: approximately = vague.	Thank you for your comment. We have used the term ‘approximately’ as pulse density can vary slightly across the plot due to flight path overlaps and terrain effects. Providing an exact figure might imply uniformity, which is not the case, so ‘approximately’ appropriately conveys a realistic level of precision without misleading the reader.
Line 620: WD, I don't think this is the first instance?	We have removed (WD) as it is not necessary.
Lines 664 & 668: rephrase – much as/far as possible.	<p>This section has been revised:</p> <p>Aligning ALS data with TLS and UAV-LS datasets presents significant challenges. Despite the use of high-quality GNSS positioning, meter-scale geolocation discrepancies between sensors can occur. Co-locating LiDAR datasets acquired at different scales - TLS, UAV-LS, and ALS- remains complex, with no standard or “turn-key” solution currently available. Manual intervention is often required, and the approach varies by site and sensor combination. While plot-level AGB estimation is relatively tolerant to these discrepancies, finer-scale applications (e.g., matching to tree-level census data) demand more precise alignment. This can be partially addressed through manual co-registration using common tie points across datasets.</p> <p>Achieving meaningful alignment also depends on the internal characteristics of ALS point clouds. Acquisition parameters such as point density, scan angle distribution, and footprint size influence comparability and should be controlled as far as possible. Post-processing can regularise point density and scan angles within or across campaigns, improving consistency. Homogeneous scanning geometry enables more stable structural metrics and enhances AGB prediction performance. Similarly, parameters such as transmitted pulse power (which co-varies with pulse repetition rate) and flight altitude (affecting footprint size and canopy penetration) should be standardised across acquisitions to minimise bias (Vincent et al., 2023). These steps are critical for reducing alignment errors and ensuring robust comparisons between TLS, UAV-LS, and ALS datasets.</p>
Line 673: EO	Done

Line 677: "This may sound obvious" too chatty.	Revised to: This might seem obvious
Line 687: replace "types" with "sources"	Done
Line 715: clearing – cleaning?	Revised to: cleaning
Line 716: what is (h)?	It was a corrupted reference which has now been corrected.