# ForestScan Manuscript: essd-2025-67

## Reviewer 1 — Hannah Weiser

**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 COMMENTS**

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| **1)** The dataset is very extensive with three study sites and three LiDAR platforms plus census data, making it difficult to review and also difficult to follow the manuscript and find relevant information. While I do support describing the dataset as a whole and including the various sub-datasets, the authors are advised to improve the organization of the dataset (cf. 5. Data Access) and the description and presentation, e.g., by improving and adding figures and tables. This will make it easier for readers/users from different fields to find the relevant information and to access the data they are interested in. | Most suggested new tables have been added and previous Tables 8a & b in section 5. Data Access have been separated into three tables arranged by FBRMS site with column 1 displaying each site's datasets, Acquisition date and Data license type; column 2 displaying the Data type (tree census, TLS, UAV-LS or ALS); and column 3 displaying the Citable as information which now includes both the URL and DOI for each dataset. There are now a total of 11 tables. Site figures have also been completely redesigned to standardise them. These new site figures include several panels providing continental, country and/or regional (Research station/National park/Forest reserve) perspectives together with their detailed site maps which now display TLS plots + census plots + UAV-LS coverage + ALS coverage and the dates of their collection. More detailed descriptions of these additions are provided in responses for later comments. |
| **2)** The manuscript should state more clearly which analyses were undertaken and which can be addressed (by others) in the future — especially in | Section 3 has been renamed "3. Recommendations for aligning and matching datasets". For clarification, we have added the two below paragraphs at the beginning this section:<br><br>We provide data that are internally consistent in terms of pre-processing, geo-referencing, and exported in formats compatible with |

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| Section 3 (Aligning and matching datasets). For this, it may help to modify the section title. | open-source tools. Any further processing will depend largely on the intended application, such as individual tree analysis or plot-level studies.<br><br>For TLS data, all point clouds within a single plot are co-registered into one unified point cloud. These are subsequently processed into individual tree point clouds, to which quantitative structural models (QSMs) are fitted to estimate volume.<br><br>UAV-LS and ALS datasets are geo-referenced in each case, however, they are not explicitly aligned or matched to one another. Alignment can be performed, but it requires manual identification of control points in each dataset and, as noted above, will depend on the intended use of the resulting data. |
| **3)** The authors should provide users with more information on the quality of the dataset (e.g., accuracies, error estimates or possible error sources, etc.). | We agree and have made some effort to do this for each dataset. See responses below to specific comments. |

**SPECIFIC COMMENTS**

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| **1)** It would be interesting to get more information about possible error sources as well as accuracy estimates, e.g., of alignment of scan positions and flight strips. | We have added/amended text in subsection 2.2.2 TLS data processing 1. Individual scan registration into plot-level point cloud for TLS data and section 3. Recommendations for aligning and matching datasets for UAV-LS and ALS:<br><br>**1. Individual scan registration into plot-level point cloud**<br>This process was carried out using retro-reflective targets positioned between scan locations to facilitate coarse registration for data collected with the RIEGL VZ-400 or in a near-automated manner using the RIEGL VZ-400i's GNSS RTK positioning capabilities in conjunction with the enhanced RIEGL RiSCAN Pro software (versions 2.14–2.17). The integrated Auto Registration 2 (AR2) function employs GNSS RTK data to update the scanner's position and orientation, including in tilt mode, thereby enabling real-time automated coarse registration during scanning. Major registration errors are easily detected, typically occurring during pre-processing in RiSCAN Pro when individual scans fail to register (i.e., no coherent solution is found) or are incorrectly positioned, which is visually apparent. In cases where coarse registration/auto-registration fails, unregistered scans can be identified, adjusted, and refined using Multi Station Adjustment 2 (MSA2). Following this workflow, the co-registration of all TLS point clouds achieves sub-centimetre accuracy, as confirmed through post-registration inspection. Wind and occlusion are key sources of uncertainty for the scan registration process, |

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| | highlighting the necessity of scanning under low or zero wind conditions and capturing both tilt and upright scans at each location.<br><br>**3. Recommendations for aligning and matching datasets**<br>UAV-LS and ALS datasets are geo-referenced in each case, As positional accuracy depends on the IMU and GNSS measurements, which can introduce errors manifesting as height biases between individual flightlines. Although we did not observe such discrepancies in our data, a rigorous comparison with ground control points would be required to confirm this definitively -a step we have not undertaken. These datasets have are not been explicitly aligned or matched to one another. Alignment can be performed, but it requires manual identification of control points in each dataset and, as noted above, will depend on the intended use of the resulting data. |
| **2)** Do you have a way of judging the quality of the segmentation of the TLS data and the quality of the reconstructed QSMs? Also here, can you state limitations and possible sources of error? | We have included details about this in subsection 5. TreeQSM: The overall QSM fit is controlled by three parameters, which are iterated into 125 different parameter sets, each generating five models. This yields a total of 625 candidate models per segmented tree. The optimal model is then selected by minimising the point-to-cylinder surface distance (Burt et al., 2019; Martin-Ducup et al., 2021). Estimates of morphological and topological traits such as volume, length, and surface area metrics, along with their mean and standard deviation, are derived from the five models that share the same parameters as the optimal model. This approach provides an estimate of the uncertainty associated with the resulting volume (Wilkes et al., 2023). In a HPC system, QSMs for a 1 ha plot can take up to 2 days to complete.<br><br>Uncertainty estimates are reported for each ForestScan FBRMS plot and included alongside the final modelling outputs for every tree in a 'tree-attributes.csv' file, generated at the end of the modelling process. Sources of error in QSM fitting can arise from data acquisition (e.g., wind, leaf occlusion, understory vegetation) and from assumptions inherent in segmentation and fitting processes. Wilkes et al. (2017) discuss issues related to data acquisition and methodological choices, while Morhart et al. (2024) quantify their effects on branch size and volume under controlled conditions. Although these impacts are difficult to assess without reference (harvest) data, Demol et al. (2022) show that, where TLS and harvest data have been compared, agreement is generally within a few percent of AGB per tree. The report CVS file also includes tree- and plot-level carbon and AGB estimates, the latter based on a mean pantropical wood density value of 0.5 g $cm^{-3}$ derived from the DRYAD global database of tropical forest wood density (2009). Plot-level AGB was also estimated using DRYAD-derived regional mean wood densities and is presented in Table 5. |
| **3)** Study site figures: It would be easier for the reader if all the study site figures would be coherent | We thank the reviewers for these valuable suggestions. We have completely redesigned all three site figures to ensure consistency and improve clarity: |

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<tr><td>in style (font, colours, etc.) and content (overview map, map elements, legend, background map type to show elevation, etc.). Please find some further detailed comments below.</td><td rowspan="5">Comment 3 (Coherent style and content):<br>All three site maps now follow a standardised three-panel format: (a) continental overview showing the country location, (b) 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.<br>Comment 4 (World map showing all three sites):<br>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.<br>Comment 5 (Fig. 1 - Paracou improvements):<br>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).<br>Comment 6 (Fig. 2 - Lopé improvements):<br>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.<br>Comment 7 (Fig. 3 - Malaysia plot clarification):<br>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.<br>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.</td></tr>
<tr><td>4) Consider adding a world map that shows a marker for all the three sites on the three continents.</td></tr>
<tr><td>5) Fig. 1 would benefit from an overview map and a scale bar. It might also be better to mark the three ForestScan plots all by the same colour very prominently and label them by their plot ID directly in the figure.</td></tr>
<tr><td>6) Fig. 2 needs bigger labels, and a label for the colour scale would be useful. Also, it would be useful if the census and TLS plots as well as UAV areas were shown here.</td></tr>
<tr><td>7) Fig. 3: It is confusing that the legend mentions "4 ha" plots but the caption says "1 ha" plots, please clarify this. Please also add to the caption that there are always 4 plots in the corners of a "plot area".</td></tr>
<tr><td colspan="2">Data</td></tr>
<tr><td>8) Tree census: I think a tabular overview or a timeline would make sense here so the user can quickly find the census times for each FBRMS.</td><td>Please see our response to General Comment 1)</td></tr>
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| **9)** Generally: If feasible, a timeline for all measurements (per study site) would be useful. | Please see our response to General Comment 1) |
| **Terrestrial laser scanning (TLS)** | |
| **10)** Can you also add tables with scanner specifications (cf. Table 5 for UAV-LS)? | Done, Table 1: TLS sensor systems used at ForestScan FBRMS has been added to subsection 2.2.2 Terrestrial LiDAR Scanning (TLS) |
| **12)** Pre-processing: Please mention and describe the downsampling of point clouds (cf. line 427), i.e., which algorithm and parameters were used. Was any filtering performed, e.g. in the RiSCAN Pro Import Wizard by reflectance or deviation, or outlier filtering? If so, please add this information. | The data processing section has been revised for clarity and conciseness.<br><br>The highlighted detail was also added to item 1 in subsection TLS datasets:<br>1. Raw terrestrial LiDAR data from each scan (no filtering was applied in RiSCAN PRO), stored in the RXP data stream format developed by RIEGL. |
| **12)** Can you explain why the files are provided as .ply and not as .las/.laz? | Files are provided in **PLY format** as it supports full 3D object representation, including polygons and geometric primitives, in addition to point data. This is essential for storing quantitative structure models (QSMs), which go beyond point clouds to describe tree geometry. In contrast, LAS/LAZ formats are designed specifically for point cloud data and do not accommodate object-level information. The PLY format is open, widely supported in Python and R, and the CloudCompare software and can be converted to/from LAS/LAZ when only point data are required.<br><br>An explanation has been added to the TLS datasets subsection as item 7 shown below:<br>7. We provide pre-processed and segmented terrestrial LiDAR data in PLY format as it supports full 3D object representation, including polygons and geometric primitives, in addition to point data. This is essential for storing quantitative structure models (QSMs), which go beyond point clouds to describe tree geometry. The PLY format is open, widely supported in Python and R, and can be converted to LAS/LAZ when only point data are required. |
| **13)** Are additional point cloud attributes provided (e.g., Intensity/Reflectance, GPSTime, etc.)? When | Description of these fields have been added in subsection TLS datasets items 3a, 3b and 5 as shown below:<br>3. Pre-processed terrestrial LiDAR data: |

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<tr><td>checking the dataset, I noticed that the .ply files have further fields, e.g., scan position index, reflectance, deviation and for the segmented point clouds the segmentation results and classification probabilities. This is very valuable information that should be included in the dataset descriptor.</td><td>a. full-resolution 10m tiled plot point clouds including attributes such as XYZ, scan position index, reflectance, deviation, etc. stored in polygon PLY format.<br>a. downsampled 10m tiled plot point clouds including attributes such as XYZ, scan position index, reflectance, deviation, etc. stored in polygon PLY format.<br>4. Wood-leaf separated tree-level point clouds including segmentation results and classification probabilities for each point are stored in polygon PLY format.</td></tr>
<tr><td>14) Line 429: Is that classified point cloud also downsampled?</td><td>No, downsampling is only performed once on during pre-processing as now clarified in the revised TLS data processing section.</td></tr>
<tr><td>15) Line 443f.: "GNSS coordinates [...] for all scans …" ? do you mean the coordinates of the scan positions, i.e., the scanner location? Please clarify.</td><td>Yes, for clarification, item 10 in subsection TLS datasets has been revised as: 10. GNSS coordinates (geographical coordinate system: WGS84 Cartesian) for all scan positions stored in KMZ zip-compressed format. These files are available for the seven French Guiana and Gabon FBRMS plots.<br><br>This is also clarified in the revised TLS data processing section.</td></tr>
<tr><td>16) Figure 11: So TLS almost consistently overestimates the DBH compared to the census? Can you state this explicitly in the text/caption?</td><td>The caption for Figure 11 has been revised: Figure 11: Quantile-Quantile (QQ) plots comparing the distribution of diameter at breast height (DBH) measurements collected by tree census and TLS methods at each of the 10 ForestScan FBRMS 1 ha plots. TreeQSM measures DBH at the standard height of 1.3 m for each TLS-extracted tree, whereas census DBH measurements are routinely adapted to account for tree buttresses found among larger trees. Generally, census and TLS DBH measurements are in good agreement but consistently overestimated by TLS. Deviations for larger DBH values can be improved by adapting the DBH extraction of large buttressed trees once these trees are matched to their census counterparts. The 1:1 reference line (dotted black line) represents perfect agreement between census and TLS-extracted DBH measurements.</td></tr>
<tr><td>17) In which coordinate system is the point cloud data provided?</td><td>Assuming this comment refers to the GNSS scan position coordinates, pls see reply to comment 15).</td></tr>
<tr><td colspan="2">UAV-borne laser scanning (UAV-LS)</td></tr>
<tr><td>18) Lines 499-508: Is this relevant for the data publication? Please either make the connection clearer (e.g., because</td><td>This paragraph has been removed.</td></tr>
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| flights have not been possible as planned due to restrictions) or leave this section out. | |
| **19)** L. 522 / Table 6: maybe add an explanation like "a double grid plus an additional double grid at a 45° angle" to the term "criss-cross" and refer to Figure 12. | The captions for both Figure 10 (previously Figure 12) and Table 7 (previously Table 6) have been revised for clarity:<br><br>**Figure 12:** UAV-based LiDAR (UAV-LS) flight trajectories over the FBRMS-01 site at Paracou, showing coverage of experimental 4 ha plot 6 (see Fig 1; red dashed line). 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 depicts a digital surface model (DSM) with elevation values (m). The inset map shows the regional location of Paracou within French Guiana (© OpenStreetMap contributors, available at https://www.openstreetmap.org).<br><br>**Table 7:** Overview of 2019 VUX-1 UAV-LS flights at FBRMS-01 (Paracou), including plot ID, acquisition date/time, flight height above ground level (AGL), velocity, and pulse repetition rate. Flight patterns refer to the orientation of flight lines: N–S (north–south), E–W (east–west), NE–SW (northeast–southwest), and “criss-cross” indicates multiple orientations flown over the same area as seen in Fig. 12. All flights listed can be considered part of one acquisition, they are provided as individual point clouds in this dataset. Users may merge them according to their needs. |
| **20)** The plot IDs from the tables vs. in the text are confusing. Is FG6c2 the same as "P6". What does 200 and 100 mean in Table 6? | FG6c2 and P6 are partly the same. In Paracou, there are 15 experimental 4 ha plots with 4 subplots each containing four 1 ha subplots numbered 1 – 4, the three 1 ha ForestScan FBRSM are subplots FG5c1, FG6c2 and FG8c4 correspond to subplots 1, 2 and 4 in plots 5, 6 and 8, respectively. This is now fully explained in the revised manuscript in the caption for Figure 1 displaying the Paracou site map (see below), and in subsections TLS: FBRMS-01: Paracou, French Guiana and UAV-LS: FBRMS-01: Paracou, French Guiana<br><br>**Figure 1:** Multi-scale map depicting the location and spatial distribution of research plots at Paracou Research Station, French Guiana. (a) Location of French Guiana (green) within South America. (b) Location of Paracou Research Station (green) within French Guiana. (c) Detailed site map showing the spatial distribution of research plots with treatment-specific colours, UAV-LS coverage (orange), and ALS coverage (yellow). The map displays 15 experimental 4 ha plots, each containing four 1 ha subplots numbered 1 - 4 (60 subplots in total; plots 1 - 12: silvicultural treatments; plots 13 - 15: Biodiversity monitoring), one large 40 ha Biodiversity plot (plot 16; red), and 10 GuyaFlux plots (solid green). Treatment categories include: Biodiversity monitoring plots (plots 13, 14, 15, 16; red), T0 Control (plots 1, 6, 11; green), T1 Selective logging (plots 2, 7, 9; dark blue), T2 Selective logging + thinning by timber stand improvement (TSI; plots 3, 5, 10; cyan), and T3 |

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| | Selective logging + TSI + fuelwood harvesting/FW (plots 4, 8, 12; pink). The three FBRMS-01 subplots -FG5c1 (subplot 1 of plot 5), FG6c2 (subplot 2 of plot 6), and FG8c4 (subplot 4 of plot 8)- are shown in solid orange and were surveyed using terrestrial laser scanning (TLS) with corresponding tree census data. The GuyaFlux tower location is indicated by a black triangle with radiating transmission waves, and the Base Camp location is marked with a white square. Scale bar: 800 m. Map data: Natural Earth 10 m cultural vectors. Satellite imagery basemap: Imagery ©2024 Google. Map projection: WGS84 (EPSG:4326). |
| **21)** Table 6 and 7: Please make clearer which flights belong together and can be considered one acquisition (meaning that resulting point clouds are merged to one point cloud before further processing) | Please note these two tables have been renumbered to Table 7 & Table 8. Their captions 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.<br><br>**Table 7:** Overview of 2019 VUX-1 UAV-LS flights at FBRMS-01 (Paracou), including plot ID, acquisition date/time, flight height above ground level (AGL), velocity, and pulse repetition rate. Flight patterns refer to the orientation of flight lines: N–S (north–south), E–W (east–west), NE–SW (northeast–southwest), and "criss-cross" indicates multiple orientations flown over the same area as seen in Fig. 12. All flights listed can be considered part of one acquisition, they are provided as individual point clouds in this dataset. Users may merge them according to their needs.<br><br>**Table 8:** Overview of UAV-LS flights using a YellowScan Vx20 system (RIEGL Mini-VUX scanner and Applanix 20 IMU) mounted on a DJI M600 during the 2019 mission at the FBRMS-01 site. Automated flight plans were performed using flight plans with the UgCS route planning software in grid mode. The table lists plot ID, acquisition date/time, flight parameters (direction, interline spacing, altitude and speed). Altitude values are reported as specified during flight planning with some missions using Above Ground Level (AGL), while others used Above Mean Sea Level (AMSL) due to differences in mission planning and operational requirements. These original specifications are retained to accurately reflect acquisition parameters. Pulse repetition for the RIEGL Mini-VUX scanner is fixed at 100kHz. Flights cover multiple experimental plots: 4 & 5 (single flight), 6 (8 flights), 7, 8, 10, 15, and the Tower plot (two flights) within the Paracou Research Site. All listed flights are provided individually; users may merge flights covering the same plot if needed for analysis.<br><br>For clarification, the characteristic "Flights merged into single acquisition" was also added to Table 6 covering the three UAV-LS sensor systems used at ForestScan FBRMS plots. |

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| **22)** Please harmonize Tables 6 and 7, i.e., use the same "Date & Time" format (check ESSD author guidelines for preferred format), the same term for the velocity, and ideally the same specifications for the pattern (e.g., directions, interline distance, ..) | Tables 7 & 8 (they have been renumbered) have been standardised to:<br>Date: UTC ISO 8601<br>Direction: in degrees<br>Interline<br>Alt<br>Speed<br>Pulse repetition<br><br>Their captions have been revised for clarity as detailed in comment 21. |
| **23)** L 548ff.: Please improve the documentation of the LAStools processing steps and also explain what the mentioned commands do. | The text included in subsection UAV-LS data processing has been revised to include the requested details:<br>All collected raw data underwent processing with standard tools. For VUX-1UAV data, this included processing recorded global navigation satellite system (GNSS) and base station data to flight trajectories with POSPac Mobile Mapping Suite 8.3 (Applanix, Richmond Hill, Ontario, Canada), laser waveform processing to discrete returns and geolocation in world coordinates with RIEGL RiProcess 1.8.6. For miniVUX-1UAV, waveform processing is performed online in the sensor. Point cloud processing and geolocation was performed with the CloudStation software (Yellowscan, Montpellier, France), using the Strip Adjustment option. For all UAV-LS data, only points with a reflectance larger than -20 dB were kept for further processing. Points with reflectance smaller than -20 dB consist mainly of spurious points caused by water droplets under high humidity conditions (Schneider et al., 2019).<br><br>LiDAR point clouds were processed using the *LAStools* suite (rapidlasso GmbH). First, a 1-m resolution digital surface model (DSM) was generated with **lasgrid** using the highest return within each cell. Ground points were then classified with **lasground** (wilderness settings, 15-m step), and a 1-m digital terrain model (DTM) was derived from ground-classified points using **las2dem**. Heights were normalized by subtracting ground elevation with **lasheight**, producing a set of height-normalized point clouds. A 1-m canopy height model (CHM) was computed with **lascanopy**, retaining the maximum height in each grid cell after removing noise and low-confidence classes. Finally, a point density map (1-m resolution) was created using **lasgrid** with the *counter* option. This workflow produced consistent DSM, DTM, CHM, and density layers suitable for subsequent ecological analyses. These UAV-LS datasets are freely available via the Centre for Environmental Data Analysis (CEDA) with DOIs provided in section 5. Data access. |
| **24)** L 572ff: This paragraph is quite general and it is not clear what "must" or "can" be done | This text has been revised to:<br>Flight trajectories were reconstructed using GNSS/IMU measurements and adjusted with differentially corrected base station data in Applanix POSPac software. The corrected flight paths and |

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| and what was actually done for the specific published dataset. Did you use RiProcess? | laser data were then integrated using the RIEGL software package, RiPROCESS, to generate the initial three-dimensional point cloud. Residual trajectory errors—such as discrepancies in GPS tracking and elevation—were corrected by using small buildings as reference points to refine the relative position and orientation of individual flight lines and scans. Further adjustments were made using ground control points: square targets (1–2 m²) composed of alternating black and white material arranged in a checkerboard pattern. This process resulted in a LiDAR-derived point cloud with a geometric accuracy of 1.8 cm. All elevation data were calculated as ellipsoidal heights (m) within the UTM 32S coordinate system. Each flight was processed separately, and all datasets were merged prior to export. Subsequent point cloud processing was carried out using elements of the lidR package (v3.1.0; Roussel et al., 2020). This UAV-LS dataset is freely available via the Centre for Environmental Data Analysis (CEDA) with DOIs provided in section 5. Data acquisition characteristics can be found in Table 6. |
| **25)** L 582ff: Please make it clearer which steps CAN be performed and which WERE actually performed (e.g., ground filtering, individual tree detection). This is currently not clear from the text. | |
| **26)** In which coordinate reference system is the point cloud data provided? | |
| **Airborne laser scanning (ALS)** | |
| **27)** L589ff.: This information could be summarised in a table, then it would be easier to find. | A new Table 9 has been added and referenced. Its Table caption is: **Table 9:** Comparison of ALS acquisition characteristics for two ForestScan sites: FBRMS-01:Paracou, French Guiana and FBRMS-03: Kabili-Sepilok, Malaysian Borneo. These key flight and sensor characteristics can support alignment and comparability across sites. |
| **28)** L617 – Section 3. Aligning and matching datasets: It is unclear if any of that was done. It should be stated more clearly what was done by you and what you recommend can be done with the dataset (by others) – Maybe also change the section header to something like "Recommendation ..." | Aligning and matching of these datasets has not been done. We have changed the name of this section to "3. Recommendations for aligning and matching datasets" to help clarify this. |
| **29)** L664-670: This sections seems unrelated to the alignment topic, please clarify (or leave out). | Section 3. Has now been renamed to: Recommendations for aligning and matching datasets which should help clarify that users are free to align these datasets according to their needs. Both paragraphs in subsection 3.3 Aligning TLS and UAV-LS to ALS data referred to in this comment have been revised for clarity:<br>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 |

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| | 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.<br><br>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. |
| **30)** For further use of the data, can you refer to free software and tools to visualize and analyse the point cloud data (e.g., LAStools, CloudCompare, etc.)? This might be especially relevant for the QSM data, which is provided in a rather non-standard format (.mat files). Here, it would be interesting for the user, how they can open and further analyse the files (e.g., to export the tree models as .OBJ, etc.). It would also be helpful to guide the users how to transform the TLS data into georeferenced coordinate using the .DAT files and/or GNSS coordinates of the scan positions. | For clarification, we have added the below paragraph at the end of the TLS datasets subsection:<br>QSMs can be converted to PLY format using ope-source tools such as *mat2ply* (Wilkes and Yang, 2025b) and then read by various tools such as the widely-used free GUI tool CloudCompare (CloudCompare Development Team, 2025; https://www.cloudcompare.org), via Python using PDAL (PDAL Contributors, 2025; https://zenodo.org/records/4031609) or O3d (Open3D Development Team, 2025; https://www.open3d.org/docs/0.9.0/tutorial/Basic/file_io.html#mesh), or via the R Geomorph package (Adams et al., 2025; https://rdrr.io/cran/geomorph/man/read.ply.html). In the Geomorph R package, the function Read mesh data (vertices and faces) from PLY files can be used to read three-dimensional surface data in the form of a single PLY file (Polygon File Format; ASCII format, from 3D scanners). Vertices of the surface may then be used to digitise three-dimensional points. The surface may also be used as a mesh for visualising 3D deformations using the warpRefMesh function. The function opens the PLY file and plots the mesh, with faces rendered if file contains faces, and coloured if the file contains vertex colour. Vertex normals allow better visualisation and more accurate digitising with digit.fixed. The KMZ files containing the GNSS scan position coordinates can be uploaded to Google Earth or read into a GIS tool such as QGIS (QGIS Development Team, 2025; https://qgis.org).<br><br>We're not quite sure what the last part of this comment means in that the GNSS scan position coordinates are georeferenced and provided in KMZ files which can be uploaded to Google Earth or read into a GIS tool such as QGIS (https://qgis.org). |

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| **31)** Please add a "Conclusion" section as per the author guidelines (https://www.earth-system-science-data.net/submission.html#manuscriptcomposition) and check if a "code availability" section is needed. | Thank you for your suggestions. Regarding the **Conclusion** section, ESSD data papers do not necessarily require a separate conclusion, as their primary purpose is to describe the dataset and its accessibility rather than present research findings. Including such a section would add length without providing additional value for readers. Furthermore, another reviewer specifically recommended shortening the manuscript due to its length, thus, adding a new conclusion would conflict with that advice. We believe the current structure, which aligns with ESSD's emphasis on data description and availability, is appropriate for this data paper.<br><br>As for the **Code Availability** section, the three repositories (rxp-pipeline, TLS2trees and PDAL) relevant to this work have now been cited in the first paragraph of the TLS data processing subsection in the manuscript and included in the reference list. These scripts are utilities not required to access or use the dataset. Therefore, we do not deem a separate Code Availability section is not necessary. This approach is consistent with ESSD guidelines, which recommend including this section only when code is essential for data use, and also helps us respect the other reviewer's recommendation to keep the manuscript concise. |
| **32)** Can you make it clearer that all entries in Table 8 are included in the dataset collection from the first row (if that is the case)? | The Data Type for the ForestScan Collection was required and generated by the CEDA archive. It has been included in the Table 10 in section 5. Data Access. For clarity, its Data type is: Collection (multi-type composite of all ForestScan CEDA datasets) |

**TECHNICAL CORRECTIONS**

| **General** | |
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| **1)** Specification of coordinates: Please specify the coordinates always in the same format, i.e., either using minutes, seconds (like in lines 120-121) or using decimals (like in line 156). | Done, both coordinates are in Degrees, Minutes, Seconds (DMS) format without seconds. |
| **2)** Make sure to add spaces before units consistently (where applicable). | Done |
| **3)** When referring to Figures and Tables in the text, consider omitting the word "below". | Done |

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| **4)** L. 231 and 236: Is there the same DOI on purpose or is this an error? | The first URL has been revised to (https://dataverse.cirad.fr) |
| **5)** L. 240: Do you mean "10 x 1 ha" here? | No, 4 x 1 ha is correct as it refers to the 4 ForestScan FBRMS Lope plots |
| **6)** L. 244-245: The plot sizes are confusing here. Were there 9 x 4 ha plots and additionally 3 x 1 ha plots and 1 x 2 ha plot? | This paragraph was revised to clarify the size of the plots and the mention of a 2ha plot which was not included in the ForestScan project was removed:<br>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. |
| **Terrestrial laser scanning (TLS)** | |
| **7)** Terminology: Decide for either "Terrestrial LiDAR Scanning" or "Terrestrial laser scanning" | Terrestrial laser scanning is now used throughout the manuscript. |
| **8)** Fig. 5:<br>8.1) Please call "Figure 5" and not "Figure 5a & 5b".<br>8.2) Labels for "upright" and "tilt" scan seem do not match the images.<br>8.3) Increase label font size.<br>8.4) Please, fix the labels in the caption, where 5b and 5c (which does not exist) are referred to.<br>8.5) The subplots a and b seem redundant (since only the labels differ). Can they be combined into one figure? | 8.1) Figure has now been renamed Figure 5 and a and b are now referred as panels in the caption.<br><br>8.2) The labels for the upright and tilt scans have been removed to avoid confusion.<br><br>8.3) The figure is now larger with label fonts also larger. Labels cannot be larger as labels will then overlap.<br><br>8.4) See response for 8.1)<br><br>8.5) Panel (a) and (b) cannot be combined as they are not redundant, (a) keeps track of the line positions and (b) keeps track of the scan position number, both of which are part of the chain sampling protocol. |
| **9)** Chapter "TLS data processing" (Line 333ff): Using Arabic numbers for the subsections might be confusing to the reader | This entire section has been revised for clarity and conciseness and this numbering has disappeared. |

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| (cf. Section numbering), so please consider using letters (a, b, c) or Roman numbering (I, II, III) instead. | |
| **10)** The TLS data acquisition section has a lot of repetition: Maybe the three sites can be summarized into one section (and the tables into one table) | This section has now been shortened and a new Table 1 (as requested in comment 10 in the TLS section of the SPECIFIC COMMENTS section. As the Paracou site has different columns according to specific forest treatment categories, we can't join the 3 FBRMS site tables and we prefer to maintain these tables separate for clarity. |
| **11)** Can you add acquisition dates to the tables? | These dates have not been added to these tables to avoid redundancy as acquisition dates have already been added to the each of the site figures (Figures 1 -3 in the Methodology section) and for each dataset in all three tables in section 5. Data Access. |
| **12)** Table 3: The caption seems incomplete ("Note: subplot 2 was"). | This text has been deleted. |
| **13)** Fig. 6: Add scale bar or colour bar legend. | In response to both our reviewers' comments, we have removed this figure from the manuscript, as it was deemed unnecessary and contributed little to the overall paper. Figure numbers have been amended accordingly. |
| **14)** Fig. 7: Add scale bar; add labels a) and b) and some descriptive captions. The colours are rather difficult to distinguish, can you adapt the style? | Thank you for the suggestion, the figure caption has been revised so it is clear that no continuous colour scale is required as colours represent discrete classes rather than a quantitative variable.<br><br>**Figure 7:** Tree-level point cloud of the largest *Baillonella toxisperma* (Maobi) tree (~40 m tall with an almost circular canopy ~50 m wide) in plot LPG-01, FBRMS-02: Lopé, Gabon. Points are classified and displayed by category only: **wood points in brown and leaf points in green**. |
| **15)** Figs. 8 and 9: It would be great if the point clouds and the derived QSMs used the same colour scheme for the tree instances, so clouds and QSMs can be better connected by the reader. | Please note these figures have been renumbered to 7 and 9. Thank you for your suggestion regarding colour consistency. We fully appreciate the rationale; however, the figures are designed to illustrate distinct aspects of the dataset. Figure 7 presents individual tree-level point clouds segmented by tree instance, whereas Figure 8 displays the corresponding QSMs derived from the segmented point clouds. The differing colour schemes are intentional, serving to emphasise that these are separate data representations. Harmonising the colour schemes would require additional processing and would not materially enhance the scientific interpretation, as the figures are primarily illustrative of structure and complexity. We believe the current approach is clear and aligned with the objectives of the paper. |

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| **16)** Table 4: Can you add the numbers from the caption to the table columns, so that it is clearer for the reader what you are referring to? | To improve clarity, the caption for this table has been revised and the numbers from the caption added to the table:<br>**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). |
| **17)** Figures 10, 11: Please increase the font size for the y-axis labels. | Done |
| **UAV-borne laser scanning (UAV-LS)** | |
| **19)** Figure 12: Please make the colour scale for the DSM in the legend continuous. | Thank you for the suggestion, the figure caption has been revised so it is clear that no continuous colour scale is required, as this is a qualitative visualisation and because the legend already provides the colour mapping.<br><br>**Figure 12:** UAV-based LiDAR (UAV-LS) flight trajectories over the FBRMS-01 site at Paracou, showing coverage of experimental 4 ha plot 6 (red 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). |
| **20)** Table 7: Can you consistently use AGL and convert the amsl values to AGL in the table? (Alternatively explain to the reader why different height specifications are used here)? | Thank you for your suggestion. We have retained the original altitude specifications as they reflect the actual flight planning parameters used during data acquisition. For some flights, altitude was specified as Above Ground Level (AGL), while others were specified as Above Mean Sea Level (AMSL) due to differences in mission planning and operational requirements. Converting all values to AGL would require assumptions about ground elevation that could introduce inaccuracies. To avoid confusion, we have clarified this in the table caption and text, explaining why both specifications appear and what they represent. Please note this table is now Table 8.<br><br>**Table 8:** Overview of UAV-LS flights using a YellowScan Vx20 system (RIEGL Mini-VUX scanner and Applanix 20 IMU) mounted on a DJI M600 during the 2019 mission at the FBRMS-01 site. Automated flight plans were performed using flight plans with the UgCS route planning software in grid mode. The table lists plot ID, acquisition date/time, flight parameters (direction, interline spacing, altitude and speed). Altitude values are reported as specified during flight planning with some missions using Above Ground Level (AGL), |

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| | while others used Above Mean Sea Level (AMSL) due to differences in mission planning and operational requirements. These original specifications are retained to accurately reflect acquisition parameters. Pulse repetition for the RIEGL Mini-VUX scanner is fixed at 100kHz. Flights cover multiple experimental plots: 4 & 5 (single flight), 6 (8 flights), 7, 8, 10, 15, and the Tower plot (two flights) within the Paracou Research Site. All listed flights are provided individually; users may merge flights covering the same plot if needed for analysis. |
| **21)** Fig. 13: Labels a, b, c, d would be useful here and could then also be used correspondingly in the text. | Adding labels obstruct details in the images or are difficult to see. Pls note this figure has been renumbered to Figure 11 and we have revised its caption:<br>**Figure 11:** UAV-LS acquisitions at FBRMS-02: Lopé using a fixed-wing system. This UAV employs a conventional take-off and landing (CTOL) procedure, with launch aided by a catapult (top). Once airborne, the UAV is controlled from a laptop connected to the UAV via an antenna (middle). The flight trajectory is corrected to centimetre precision using data collected from a static GNSS receiver placed within 10 km of the UAV operating area (bottom left). Additional refinements and corrections are possible via ground control points located across the study area (middle bottom), the positions of which are measured using a ‘rover’ GNSS receiver (right bottom). Image originally published in McNicol et al. (2021). |
| **Recommendation for data collection in FBRMS** | |
| **22)** L 704: 300 kHz is a specification of pulse repetition rate, not LiDAR power, please rephrase. | This line has been revised to: TLS data were collected using a pulse repetition rate (PRR) of 300 kHz on RIEGL VZ-400 and VZ-400i scanners, trading longer scan times for a fixed angular resolution to maximise coverage at the tops of tall trees. In the RIEGL configuration, PRR and emitted laser power are intrinsically linked: increasing the PRR reduces the available power, and vice versa. Consequently, the choice of PRR determines the power setting, and adjustments to one parameter necessarily influence the other. |
| **23)** L 719: What does "harder to access" refer to, i.e., compared to what? | Thank you for your comment. In this sentence, “harder to assess” refers to the inherent difficulty of evaluating the accuracy of automated tree extraction methods when the true structure of trees is unknown. This limitation is widely recognised in the literature and is precisely what the sentence conveys. We believe the current wording is clear and accurately reflects this challenge. |
| **Data access** | |
| **24)** Tables 8a and 8b: Why not make it Table 8 and 9? Can you add columns for "Category" (i.e., Census, TLS, UAV-LS, ALS) and for "FBRMS no."? This would make it easier for users to find | Done, these two tables have been divided into three tables -10, 11 and 12- arranged by FBRMS site and data type. Pls see our response to comment 1) in the GENERAL COMMENTS section and to comment 11) in the TLS subsection of the TECHNICAL COMMENTS section. |

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| datasets. Are both URL and DOI needed or can the URL be omitted? Or even both, since the DOI is already included in the column "Citable as"? Please make the reference style in Table 8a and 8b the same. | |
| **25)** You refer to "Section 4. data access" several times. Please correct this to "Sect. 5" (as per the author guidelines; please also check other section references). | These corrections have been made throughout the manuscript. |
| **References** | |
| **26)** Add access date to webpages included in the References. | Done |