Land-cover change alters stand structure, species diversity, leaf functional traits, and soil conditions in Cambodian tropical forests

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Response to Referee's comments (RC1)

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Comment 1. I congratulate the authors on their work. The manuscript presents a broad assessment of forest structural characteristics across different land uses in Cambodia. However, the authors have not fully explored the potential of this extensive dataset.
For instance, the introduction should clearly justify the importance of sampling these variables, which range from functional traits to climatic factors. As it stands, the study is primarily **descriptive and lacks a hypothesis-driven approach.** Strengthening these aspects would significantly improve the manuscript.
Response 1 (previously posted). Thank you for your thoughtful feedback and for recognizing the value of our work. We appreciate your suggestion to strengthen the justification for sampling key ecosystem characteristics. In response, we have revised the third paragraph of the introduction to better highlight the significance of the collected variables, including forest inventory, leaf functional traits, leaf area index (*LAI*), fraction of photosynthetically active radiation (*fPAR*), and soil conditions, supported by additional references (Page 3, Lines 45–59).
We find it difficult to convert the study into a having a more hypothesis-driven approach, given that there are so many different variables that are measured. But, we fully agree that the aims and objectives should not be primarily descriptive, but to more focus on the analysis of impact of the land cover conversion. Hence, we have rewritten the fourth paragraph of the introduction to clearly articulate the study's objectives. Specifically, we now emphasize our primary aim of assessing differences in stand structure, species diversity, leaf functional traits, and soil conditions between pristine tropical forests and the land cover types resulting from deforestation (regrowth forests and cashew plantations). Our second objective was to analyse the relationships between the characteristics and how these are influenced by land cover conversions. Lastly, we highlight our final objective of presenting and sharing this unique dataset to contribute to broader ecosystem research (Page 3, Lines 60–68).
Response 1 (updated). We would like to update our response related to this comment, as this issue has been pointed out by all three reviewers.
We appreciate the reviewer's comments. We agree that a clearer articulation of scientific questions and hypotheses strengthens the manuscript's alignment with *Biogeosciences*' scope. We have therefore substantially revised the manuscript to frame it around explicit scientific objectives and testable hypotheses regarding the impacts of land-cover change on ecosystem characteristics. Specifically:

- We revised the research objectives to emphasize analytical aims and formulated hypotheses. We now explicitly hypothesize that land-cover change reduces stand structure, species diversity, and leaf functional traits, and marked changes in soil conditions. Additionally, we evaluate whether locally calibrated *DBH*–height relationships significantly improve *AGB* estimates compared to generalized models. (Lines 86–96)
- The Abstract has been revised to emphasize the analytical objectives rather than focusing on dataset description (Lines 15–18), and references to data-sharing links have been removed.
- The Introduction section was comprehensively rewritten to support the updated research objectives and hypotheses. (Lines 45–85)

- We revised each Results subsection to align with our revised objective, which emphasizes how land-cover change alters key ecosystem characteristics. Specifically, we revised the following sections:
    - Soil conditions (Lines 256–261)
    - Species diversity (Lines 277–289)
    - Leaf traits (Lines 311–317)
    - Stand structure attributes
        - *DBH* and tree height (Lines 320–327)
        - Aboveground and deadwood biomass (Lines 329–332)
        - Stem density and basal area (Lines 334–339, Fig. 3)
- We introduced a new main section, "Estimated Aboveground Biomass Based on DBH-Height Relationship," in both the Results and Discussion to support our second hypothesis of applying locally calibrated DBH–H relationships for improving aboveground biomass estimation. (Lines 371–391, 564)
- We also updated the Discussion sections to support the revised results above: section 4.2 species diversity (lines 437–442), 4.3 Leaf functional traits, 4.4 Stand structure attributes: DBH and tree height (Lines 488–495), Aboveground and deadwood biomass (lines 500–511)

Comment 2. Abstract: L16: "Reduction in ecosystem characteristics" is unclear—consider rephrasing.
Response 2 (previously posted). We agree. We have rephrased "Reductions in several ecosystem characteristics" to "differences in these ecosystem characteristics" (Page 1, Lines 16–18).
Response 2 (updated). The response remains unchanged; the updated text is now located at Lines 18–20.

Comment 3. Graphical Abstract: Avoid abbreviations without prior explanation (e.g., *fPAR*).
Response 3 (previously posted). Thank you for pointing this out. We have replaced "*fPAR*" with "fraction of photosynthetically active radiation" in the graphical abstract (Page 1, Line 26).
Response 3 (updated). The response remains unchanged; the updated text is now located at Line 27.

Comment 4. Introduction: L33: Consider citing Pan et al. (2024, Science) for a more up-to-date reference.
Response 4 (previously posted). Thank you for this suggestion. We have updated the reference to Pan et al., 2024 and revised the text from "store approximately 60 % of the global terrestrial biomass (Pan et al., 2013)" to "account for approximately 70 % of the global forest gross carbon sink (Pan et al., 2024)" (Page 2, Lines 30–31).
Response 4 (updated). The response remains unchanged; the updated text is now located at Lines 31–33.

Comment 5. Methods: L75: Clarify the source of the carbon sink information.
Response 5 (previously posted). We have added a new reference (Kim et al., 2023) to support our statement that Kulen is a potential carbon sink (Pages 3–4, Lines 73–74).
Response 5 (updated). The response remains unchanged; however, we have moved these sentences from the Study Area section to the Introduction section to respond to Comment 9 from Reviewer 3. (Lines 77–85)

Comment 6. L94: The characterization of this area would be more useful in the main file rather than as supplementary material.
Response 6 (previously posted). We agree. Table S1.1 has been modified and moved to the main text as Table 1 (Pages 5–6, Line 92), and all table numbers in the main text and supplementary material have been updated accordingly.
Response 6 (updated). The response remains unchanged; the updated text is now located at Line 115.

Comment 7. L158–L162: Since plots have different sampling efforts, use rarefied richness instead of raw species number.
Response 7 (previously posted). We disagree with the comment that our plots have different sampling efforts. and prefer to use raw species numbers instead of rarefied richness. Rarefaction methods are typically applied when there are differences in sampling effort (Staudhammer et al., 2018). Our forest inventory for each land cover consisted of three plots with the same plot size, and all inventories were conducted within the same week in December 2020 following the same protocol of the National Forest Inventory of Cambodia (Page 4, Line 86; Page 6, Line 98). Therefore, we believe that raw species counts are suitable and more straightforward comparisons between land covers.

Response 7 (updated). The response remains unchanged; the updated text is now located at Line 109 for the date when conducting the forest inventory and at Lines 122–124 for the inventory plot size.

Comment 8. L175: I recommend using genus/family values before the mean plot value.
Response 8 (previously posted). Thanks for this great suggestion and have revised the methods accordingly (Page 8–9, Lines 176–178). The results in both the main text and supplementary material have been updated to reflect this methodological change. However, this adjustment had a minimal effect on the overall analysis, as only four species (*Agave sisalana, Dialium cochinchinense, Syzygium formosanum,* and *Madhuca elliptica*) had missing trait values.
Response 8 (updated). The response remains unchanged; the updated text is now located at Lines 198–200.

References

Kim, S., Horn, S., Sok, P., Sien, T., and Yorn, C.: Ecosystem Carbon Stock Assessment in Upland Forest: A Case Study in Koh Kong, Mondulkiri, Preah Vihear, and Siem Reap Provinces, Environmental and Rural Development, 61, 2023.

Pan, Y., Birdsey, R. A., Phillips, O. L., Houghton, R. A., Fang, J., Kauppi, P. E., Keith, H., Kurz, W. A., Ito, A., Lewis, S. L., Nabuurs, G.-J., Shvidenko, A., Hashimoto, S., Lerink, B., Schepaschenko, D., Castanho, A., and Murdiyarso, D.: The Enduring World Forest Carbon Sink, Nature, 631, 563-569, https://doi.org/10.1038/s41586-024-07602-x, 2024.

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Staudhammer, C. L., Escobedo, F. J., and Blood, A.: Assessing Methods for Comparing Species Diversity from Disparate Data Sources: The Case of Urban and Peri-Urban Forests, Ecosphere, 9, e02450, https://doi.org/10.1002/ecs2.2450, 2018.

Response to Referee's comments (RC2)

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Comment 1: Sovann and others describe a unique forest dataset from Cambodia. The measurements are largely interesting and certainly novel, but as presented I was left wondering why scientific questions were not asked and/or why hypotheses were not addressed? As noted, it made me wonder if the manuscript fits the scope for BG or if it's better placed in ESSD? Having read the paper however I'm convinced that it would be relatively straightforward to focus more strongly on scientific aspects of the dataset that would make the analysis appropriate for BG.

Response: We appreciate the reviewer's comments. We agree that a clearer articulation of scientific questions and hypotheses strengthens the manuscript's alignment with Biogeosciences' scope. We have therefore substantially revised the manuscript to frame it around explicit scientific objectives and testable hypotheses regarding the impacts of land-cover change on ecosystem characteristics. Specifically:

- We revised the research objectives to emphasize analytical aims and formulated hypotheses. We now explicitly hypothesize that land-cover change reduces stand structure, species diversity, and leaf functional traits, and marked changes in soil conditions. Additionally, we evaluate whether locally calibrated DBH–height relationships significantly improve AGB estimates compared to generalized models. (Lines 86–96)
- The Abstract has been revised to emphasize the analytical objectives rather than focusing on dataset description (Lines 15–18), and references to data-sharing links have been removed.
- The Introduction section was comprehensively rewritten to support the updated research objectives and hypotheses. (Lines 45–85)
- We revised each Results subsection to align with our revised objective, which emphasizes how land-cover change alters key ecosystem characteristics. Specifically, we revised the following sections:
    - Soil conditions (Lines 256–261)
    - Species diversity (Lines 277–289)
    - Leaf traits (Lines 311–317)
    - Stand structure attributes: DBH and tree height (Lines 320–327), Aboveground and deadwood biomass (Lines 329–332), Stem density and basal area (Lines 334–339, Fig. 3)
- We introduced a new main section, "Estimated Aboveground Biomass Based on DBH-Height Relationship," in both the Results and Discussion to support our second hypothesis of applying locally calibrated DBH–H relationships for improving aboveground biomass estimation. (Lines 371–391, 564)
- We also updated the Discussion sections to support the revised results above: section 4.2 species diversity (lines 437–442), 4.3 Leaf functional traits, 4.4 Stand structure attributes: DBH and tree height (Lines 488–495), Aboveground and deadwood biomass (lines 500–511)

Comment 2: 45: This statement may be a bit of an oversell…quite a lot is known about the deleterious impacts of clear-cutting primary tropical forests. To me, this is the opportunity to direct the reader to the particular questions that this study will address.

Response: Thank you for pointing this out. We agree and have revised the sentence to more accurately reflect the scope of existing literature and clarify our research objective. The revised sentence now reads: "While the ecological consequences of forest conversion are broadly recognized, relatively few studies have comprehensively examined how transitions from primary to secondary forests and plantations influence multiple ecosystem characteristics, particularly through detailed field-based observations that may inform our understanding of ecosystem functioning." (Lines 45–48)

Comment 3: The introduction makes me wonder if the manuscript in general is more appropriate for ESSD given the focus on data. But in my opinion the authors can have it both ways…if they simultaneously describe the dataset and its major findings as it relates to a question or hypothesis clearly articulated in the introduction (as one would expect), the manuscript would in my opinion be more in scope with the journal to discuss interactions between biological, chemical, and physical processes. One idea would be to ask questions about and focus more of the results and discussion about the interesting variation between AGB methods where AGB_wd gives a far greater CP biomass than the other methods. The statistics in describing this in Figure 4b was rather weak (e.g. no p-value on page 332, what test was used?). Strengthening this will make the important methodological study more scientifically rigorous. In my opinion, the science can focus on important methodological challenges and the

meteorological instrumentation and discussion of other measurements wouldn't be a distraction because these things are partly responsible for forest growth in the first place.
Response: Thank you for your suggestions. We agree that stronger integration of our dataset descriptions with clearly articulated scientific questions and hypotheses is essential to position the manuscript within the scope of Biogeosciences, which is strongly related to forest biodiversity and ecosystem function. In response:

- We substantially revised the Introduction to focus on research questions and hypotheses that assess (i) how land-cover conversion alters ecosystem characteristics and (ii) the implications of using different allometric approaches for AGB estimation (Lines 86–96, See comment response 1).
- We strengthened the Discussion of the notable AGBwd overestimation in cashew plantations (CP). We now clarify that this is primarily driven by the wood density value (0.45 g cm^{-3}) used in AGBwd, compared to 0.18 g cm^{-3} in the original AGBf function. This likely reflects differences in cashew wood properties or in the wood density measurement protocols used between the two studies. (Lines 598–600)
- Regarding the statistical analysis in Figure 4b, despite clear differences in mean AGB estimates among the methods, formal statistical comparisons were not conducted due to the limited number of plots per class (n = 3), which restricts statistical power. We now explicitly acknowledge this limitation in the Discussion. (Lines 601–602)
- We appreciate your recognition of the meteorological data as valuable context for understanding forest growth, and we have retained this data description in the revised manuscript.

Comment 4: 4.3: noting in the intro the importance of these comparisons of biodiversity across different forests and asking questions or stating hypotheses to test would help move the manuscript from purely descriptive to more of a scientific study.
Response: Thank you. We have major revised the Introduction to include research objectives and hypothesis (See comment response 1).

Comment 5: Fig. 1: It is a bit difficult to see from the figure where the site is in Cambodia…making the subplot to the upper right focus more clearly on the Thailand/Cambodia/Vietnam region would help place a stronger focus on Cambodia's geography.
Response: Thank you for pointing this out. We have updated the upper-right subplot in Figure 1 to provide a closer view of the Thailand–Cambodia–Vietnam region, improving geographic context and emphasizing the location of the study site in Cambodia. We also used our detailed land cover map, recently published by Sovann et al. (2025), as the background layer. (Line 106)

Comment 6: 82: of the 13% forested area, how much is primary and how much is secondary?
Response: Thank you for your comments. We have revised the recently updated land cover statistics in Kulen based on our recently published paper as the following "In 2021, 72 % of Phnom Kulen National Park was forested, dominated by nearly intact tropical evergreen forests (EF) (30 %) and forests that regrow naturally after clear-cutting (RF) (7 %). The remaining 35 % of forest cover consisted of semi-evergreen, deciduous, and bamboo stands. Non-forest areas were dominated by household-scale cashew plantations (CP) (15 %), with the remaining 13% consisting of croplands, paddy fields, settlements, and tree and rubber plantations (Sovann et al., 2025)." (Lines 101–105)

Comment 7: The Discussion as a whole is relatively strong with lots of good comparisons from the literature, which only further makes the point that the study could be converted to a scientific analysis relatively easily.
Response: We sincerely appreciate your kind recognition of the Discussion and the comparative analysis provided. Please refer to our comment response 1.

Comment 8: Why were the differences in AGB values from the different methods not discussed in the discussion? The analysis of this relatively more important component of the work needs to be improved.
Response: Thank you for pointing this out. Please refer to our comment response 3.

References

Sovann, C., Olin, S., Mansourian, A., Sakhoeun, S., Prey, S., Kok, S., and Tagesson, T.: Importance of Spectral Information, Seasonality, and Topography on Land Cover Classification of Tropical Land Cover Mapping, https://doi.org/10.3390/rs17091551, 2025.

Response to Referee's comments (RC3)

Manuscript DOI: https://doi.org/10.5194/egusphere-2024-3784
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Comment 1: The tropical forest ecosystem represents a vital ecological entity that sustains unparalleled biodiversity while delivering essential ecosystem services. This study provides a groundbreaking contribution through its comprehensive dataset encompassing multiple ecosystem characteristics - the first of its kind for this ecologically sensitive region. The wealth of empirical evidence collected from this biodiversity hotspot within a natural reserve renders the work scientifically valuable and worthy of publication consideration. However, the current manuscript adopts a descriptive cataloguing approach, which may limit its engagement value for readers. Furthermore, the structural organization requires refinement to enhance logical coherence, particularly through the development of a conceptual framework that systematically connects observed ecological patterns to their underlying processes. I suggest the authors to restructure the paper focusing on land-use/cover change impacts, and prioritize hypothesis-testing over pure data reporting. It would be better to tell a question-driven story rather than report a conventional data inventory.

Response: We appreciate the reviewer's comments. We agree that a clearer articulation of scientific questions and hypotheses strengthens the manuscript's alignment with Biogeosciences' scope. We have therefore substantially revised the manuscript to frame it around explicit scientific objectives and testable hypotheses regarding the impacts of land-cover change on ecosystem characteristics. Specifically:

- We revised the research objectives to emphasize analytical aims and formulated hypotheses. We now explicitly hypothesize that land-cover change reduces stand structure, species diversity, and leaf functional traits, and marked changes in soil conditions. Additionally, we evaluate whether locally calibrated DBH–height relationships significantly improve AGB estimates compared to generalized models. (Lines 86–96)
- The Abstract has been revised to emphasize the analytical objectives rather than focusing on dataset description (Lines 15–18), and references to data-sharing links have been removed.
- The Introduction section was comprehensively rewritten to support the updated research objectives and hypotheses. (Lines 45–85)
- We revised each Results subsection to align with our revised objective, which emphasizes how land-cover change alters key ecosystem characteristics. Specifically, we revised the following sections:
    - Soil conditions (Lines 256–261)
    - Species diversity (Lines 277–289)
    - Leaf traits (Lines 311–317)
    - Stand structure attributes: DBH and tree height (Lines 320–327), Aboveground and deadwood biomass (Lines 329–332), Stem density and basal area (Lines 334–339, Fig. 3)
- We introduced a new main section, "Estimated Aboveground Biomass Based on DBH-Height Relationship," in both the Results and Discussion to support our second hypothesis of applying locally calibrated DBH–H relationships for improving aboveground biomass estimation. (Lines 371–391, 564)
- We also updated the Discussion sections to support the revised results above: section 4.2 species diversity (lines 437–442), 4.3 Leaf functional traits, 4.4 Stand structure attributes: DBH and tree height (Lines 488–495), Aboveground and deadwood biomass (lines 500–511)

Comment 2: This title sounds too general, "Characteristics of ecosystems under various anthropogenic impacts in a tropical forest region of Southeast Asia".

Response: Thank you for pointing this out. In response, we revised the title to more clearly reflect the specific ecosystem characteristics examined, the land-use change context, and geographic focus. The new title is: "Land-cover change alters stand structure, species diversity, leaf functional traits, and soil conditions in Cambodian tropical forests". (Line 1)

Comment 3: At line 10 in the abstract: "anthropogenic pressure", which specific pressure? I would rather point out the importance of land-use/land cover change.

Response: Thank you for pointing this out. We have replaced "anthropogenic pressure" with the more specific term "land-use and land-cover change" to improve clarity and accurately reflect the main driver examined in this study. (Line 10)

Comment 4: At line 11, “both in pristine tropical forests and in the converted deforested” As you mentioned, what was done in this research, land-cover change may be the main focus?
Response: Thank you for your comment. We agree that land-cover change impact on ecosystem characteristics is the main focus of this study. To clarify this, we revised the manuscript as follows:

- Updated the abstract (Line 10) and introduction (Lines 86–96) to clearly state the research questions and hypotheses, explicitly highlighting land-cover conversion as the core driver of ecosystem change;
- Revised the title to reflect this emphasis (See our response to Comment 2);
- Reframed the manuscript around explicit scientific objectives and testable hypotheses concerning the impacts of land-cover change on ecosystem characteristics (See our response to Comment 1).

Comment 5: At line 20, suggested replacing “filling data gaps” with “enriching databank”.
Response: We agree with the suggestion and have revised the sentence as recommended. (Line 22)

Comment 6: At line 21, suggested deleting “addressing global environmental challenges”.
Response: We accepted the suggestion and deleted “addressing global environmental challenges”. (Line 22)

Comment 7: At line 36, as mentioned, “resulting in a decrease in biodiversity”, suggested adding “The last sentence of a paragraph should call for your research focus/significance, which is not "biodiversity" I guess?”
Response: Thank you for pointing this out. In response, we revised the sentence from “resulting in a decrease in biodiversity” to “Such disturbances have resulted in significant structural and functional degradation in tropical forests, highlighting the urgent need to assess how land-cover change alters key ecosystem characteristics.” This revision more accurately reflects the study’s focus on the impacts of land-cover change on ecosystem characteristics. (Line 35–37)

Comment 8: At line 46, suggested deleting “biodiversity and” for clarity.
Response: We agree, and the sentence has been revised (Line 45–48, also see our response to Comment 2 from Reviewer 2).

Comment 9: At line 47, suggested replacing “environmental challenges” with “land cover?” and adding “it is necessary to conduct…” to the sentence. Also recommended revising “data are necessary to assess the dynamic…” to “in order to investigate the…”.
Response: Thank you for pointing this out. We agree with your comment and have revised the manuscript accordingly (Lines 60–61).

Comment 10: At lines 59-62, suggested deleting the sentence in the lines and writing sth about the importance of your study region/object, show the readers why you do studies here.
Response: Thank you for the suggestion. We have deleted the original sentence at lines 60–63 and added a brief explanation of the importance of our study region, adapted from the Study Area section. This change clarifies why Phnom Kulen National Park was selected and now appears at lines 77–85 of the revised manuscript.

Comment 11: At line 65, “ecosystem level”, are you sure? some also at plot level?
Response: We revised the research objectives to emphasize analytical aims and explicitly formulated hypotheses; therefore, the original sentence at line 65 was deleted. (Lines 86–96)

Comment 12: Can you come up with specific scientific questions and also give hypotheses?
Response: See our response to Comment 1.

Comment 13: At lines 74-81 in the section “2.1 Study area and selection of plots”, move the sentences at the lines to the introduction.
Response: We agree, and have moved the sentence to the introduction as noted in our response to Comment 9.

Comment 14: At line 295 in section "3.4.1 DBH-H relationship", no need to discuss every result, just focus on your key findings.
Response: Thank you for the suggestion. We revised the DBH-H relationship section (Lines 320–327) to highlight only the key findings relevant to structural changes among land-cover types. We streamlined the presentation by removing excessive detail and focusing on the main trends in DBH and height, aligning the section more closely with our revised hypotheses.

Comment 15: At line 378, there are too many subsections in the section "4 Discussions". I would suggest going with three major aspects: Meteo, plant, and soil. Also, maybe discuss these aspects linking with your main scientific questions (land-cover change)?
Response: Thank you for your comments. In response, we substantially revised both Results and Discussion sections to better reflect our revised research objectives and hypotheses. Specifically:

- We removed Section 4.1 ("Importance of tropical field data"), integrating relevant content into the Introduction to improve narrative focus. (Line 389, 48–63)
- To address the excessive sub-sectioning in the Discussion section, we simplified the structure by:
    - Removing subsection numbering under the result section "3.4 Stand structure attributes" and discussion section "4.4 Stand structure attributes" (Lines 319, 328, 333, 347, 487, 499, 512, 538)
    - Merging "LAI and fPAR" section to be a subsection of "Stand structure attributes" for both results and discussion sections. (Lines 347, 538)
- We restructure the paragraphs in both Results and Discussions to focus on the revised hypotheses and remove less relevant information from the manuscript (See our response to Comment 1).

Comment 16: At line 379, in section "4.1 Importance of tropical field data", no need to discuss here; you already told this in the introduction.
Response: Thank you for pointing this out. We removed Section 4.1 ("Importance of tropical field data"), integrating relevant content into the Introduction to improve narrative focus. (Line 410, 60–76)

Comment 17: At line 576, in section "5 Conclusions", looks like a summary rather than conclusions, and it's too long. Here it's better to provide your key findings, further instructions, or more practical suggestions for the future. At lines 577-585, shorten the sentences at these lines into one sentence showing the background of this work.
Response: Thank you for your suggestions. In response, we revised the conclusion to emphasize key findings and research gaps for future studies, rather than repeating a summary of results. Specifically:

- We condensed the original background sentences (Lines 577–585) into a single sentence summarizing the study's rationale and objectives. (Lines 622–625)
- We added recommendations for future research, such as conducting destructive sampling to validate locally calibrated AGB equations and expanding field data collection across a broader range of land-cover types in Southeast Asia. (Lines 634–638)