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Interactive comment on "Landscape-scale changes in forest canopy structure across a partially logged tropical peat swamp" *by* B. M. M. Wedeux and D. A. Coomes

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We thank M. Disney, R. Hill, F. Espirito-Santo and M. Hayashi for their comments, which have helped improve the manuscript. We thank the handling associate editor A. Ito for considering the revised manuscript and hope he will now find it suitable for publication. We respond to the comments in detail below. Additions to the manuscript are marked in blue, both in this response and the manuscript.

Response to R. Hill's comments

[Referee comment] This manuscript investigates the dual effects of peat depth and logging disturbance on canopy structure in peat swamp forest in Central Kalimantan,

Indonesia. The emphasis is on canopy height, shape and various gap size metrics. Data are drawn from 100 plots of 1 sq. km size extracted from airborne lidar data. Overall, this manuscript is very well written, is thoroughly researched, well referenced and fully contextualised. The main article is well supported by supplementary material, although in places some of this information should to be included (or at least summarised in more detail) in the main article itself to provide a fuller justification of some of the methodological decisions. Also, perhaps the abstract would benefit from a final sentence highlighting specifically what the findings contribute to the understanding of tropical peat swamp forest ecology and management.

[Author response] A sentence was added as suggested: These findings improve our understanding of tropical peat swamp ecology and provide important insights for managers aiming to restore degraded forests.

Specific comments

[Referee comment] 10986 lines 6-7 (and 10988 line 20): what is meant by high fidelity ALS data?

[Author response] This word was removed in the abstract and replaced by 'detailed' in the main text (10988 l. 20): Airborne Laser Scanning (ALS) has opened new avenues for canopy research, as it provides detailed information on canopy height, layers and the location of canopy gaps over entire landscapes (Drake et al., 2002; Dubayah et al., 2010; Kellner and Asner, 2009; Lefsky et al., 2002).

[Referee comment] 10986 line 13: this should probably be 'consistent with' rather than 'consistently with'.

[Author response] Corrected.

[Referee comment] 10988 lines 17-19: this sentence relates specifically to satellite optical data. Perhaps an additional sentence should be added here to mention studies which have used satellite radar data for tropical forest structure assessment.

[Author response] We clarify the difference between optical and radar satellite imagery and add a reference to a radar study analysing canopy openness in our study area: Optical satellite studies have had limited power in measuring logging effects as they lack information about the intricate three-dimensional structure of canopies, and only recently have researchers used satellite radar data to delineate degraded forests (e.g. Schlund et al., 2014).

[Referee comment] 10989 lines 25-26: perhaps edit to read 'high fractions of soil or dead vegetation' [Author response] Edited: ClasLite [...] the identification of logging routes characterised by high fractions of soil or dead vegetation (Asner, 2009).

[Referee comment] 10990 lines 2-6: mean canopy height maps were used to determine that logging takes place within 500 m of a logging route, and therefore this was used as a generic buffer to determine selectively logged forest. However, a buffer of 5 km was applied to forest around the Kapuas River. Does the same decision rule of mean canopy height support this buffer size? If so, it is worth adding this to the manuscript, as the methods here do not seem to be quite consistent.

[Author response] Local communities have traditional rights to use land within 5 km of settlements (this being accepted by local governments), and probably make use of forests far away from the rivers. So we could not classify these forests as 'old-growth'. We know that 54% of the land used by communities overlapped with areas we had identified as logged by companies. The remainder of this land continues to be used. Therefore, the approach used to determine the buffer around the logging roads would not be suitable. We have improved the text:

Forest within 5 km of the Kapuas river, could not be classified as 'old-growth' because local villagers have traditional land rights in that area, and make use of the forests (KFCP, 2009). Since 54% of the area was interspersed with logging routes, it was classified as 'logged'.

[Referee comment] 10990 line 10: it is probably worth specifying how many returns

were recorded per pulse in the main text, to help contextualise the figure of 2.8 points per sq. m.

[Author response] This information was not provided with the data, and could not be provided by main contact person after request. So unfortunately we cannot provide readers with this information.

[Referee comment] 10990 line 18: perhaps it is worth stating why the lidar point data were voxelised at a 20 x 20 m horizontal spatial scale (i.e. how does this relate to crown and gap size).

[Author response] The size of 20 x 20 m was chosen in order to have sufficient returns within each voxel (20 x 20 x 1m) to provide a robust estimate of the percentage of returns within each voxel relative to the column (1120 returns within column, split into 40 height layers, thus an average of 28 returns per voxel).

[Referee comment] 1091 line 4: why extract height metrics from 10,000 randomly selected pixels of the CHM. Why not simply use all pixels in the CHM? This decision should be justified.

[Author response] This was chosen arbitrarily but allowed optimising computing time while providing a robust subsample of the plot, suitable to calculate the metric of interest. We added: Within each plot, canopy height was extracted from 10,000 random selected pixels (to optimise computing time and provide a representative sample) . . .

[Referee comment] 10991 section 2.2.2. It is perhaps worth stating how gaps at the edge of the 1 sq. km plots were treated (e.g. gap size measurement was truncated at the plot edge, or gaps were only counted if the centre was in the plot, or gaps were measured if any part was within the plot, etc).

[Author response] Gap size measurement was truncated at the edge of the plot, but the effect on gap size distributions is small because we used large plot sizes (1 km2). We made a note in the text: Gaps were truncated at the edge of the plot.

[Referee comment] 10993 section 2.3.1. The validity of the relationship between peat depth and both canopy top height and distance to river is fully demonstrated by the supplementary material. However, given that the effects of peat depth on canopy structure is a key aspect of this manuscript, then perhaps a little more information is required in the main article in this section – in particular to state how peat depth was inferred from the two relationships and with what accuracy level.

[Author response] This issue was also raised by M. Disney, we have addressed it by adding more information from SI in the methods section of the main text, as follows: 10993 l.10: We disposed of an independent data set of more than 300 peat depth measurements across the study area and measured canopy top height (99th quantile of height) within a 100 m neighbourhood. We first tested for the effect of logging on canopy top height in this independent dataset by fitting generalised linear models containing peat depth and additive or multiplicative effects of logging as a factor (yes, no). No significant logging effect was detected. We found that canopy top height was closely related to peat depth (R2=0.79) except on shallow peat within 3000 m of the Kapuas river (Fig. S3a). On shallow peat, distance to river was linearly related to peat depth (R2 = 0.59; Fig. S3b). Peat depth for our study plots was thus inferred as (Eq. 3): Peat depth= {(26.0-0.7$\times$top.height for dist.riv>3000 m, or 0.31+0.002$\times$dist.riv for dist.riv$\leq$3000m)} (3) where top.height is canopy top height (99th quantile) and dist.riv is distance to the large Kapuas river. The inference of peat depth from canopy top height was thus done from an independent data set to the plot data further used for analyses. This approach was validated, as it yielded a fit going through the origin and with an R2 = 0.88 between predicted and measured peat values in 33 plots where peat data was available.

[Referee comment] 10995 line 9: was data normality tested or assumed in these cases?

[Author response] Text modified to clarify: All other analyses assumed normal distributions, as supported by visual inspection of residuals.

[Referee comment] 10995 line 23 (and 10997 4): should p values also be stated here?

[Author response] P-values added: Note that LPIs did not significantly co-vary with peat depth (r = 0.05–0.25, p > 0.05). Negative correlations were found between α and θ in cross-sections $\geq$ 6 m height (Pearson correlation coefficient r = -0.25—0.35, p = 0.02 – 0.67);. . .

[Referee comment] 10996 lines 27-28: was the relationship between the GSFD transition parameter and peat depth tested statistically? (If so, it would be useful to give the r and p values in the text).

[Author response] We rephrased the sentence to include 'statistically significant' and refer to Table S3, clarifying that this analysis was based on generalized linear modelling. The sentence now reads: The GSFD transition parameter, θ, decreased significantly with peat depth for cross-sections up to 8-m height above ground (Fig. 4d, Table S3), but the trend was not statistically significant in the 8-m cross-section (Table S3).

[Referee comment] 10997 line 23: should an R2 value also be quoted in this sentence for canopy top height?

[Author response] Canopy top height is the explanatory variable here, and is related once to mean gap area and once to α. This is clarified by rewording the sentence to: Because of unequal effects on canopy top height and gaps, we no longer observed the tight relationships (marked decrease in R2) among canopy top height as an explanatory variable and mean gap area (Fig. 5a, R2 = 0.28, p < 0.001) or α (Fig 5 b, R2 = 0.38, p < 0.001) which we found in old-growth forest (Table S5).

[Referee comment] 10998 line 1: edit to 'in areas that we had identified as logged'

[Author response] Added 'that'.

[Referee comment] 10998 lines 11-15: In the first half of this sentence it should be made more clear that this relates to gap structural characteristics rather than structure in general.

[Author response] Inserted ‘gap’ to clarify: In all cases, canopy gaps showed . . . exhibited a more strongly altered canopy gap structure. . .

[Referee comment] 10998 line 20: ‘landscape-scale coordination’. Perhaps this should be correlation, correspondence or relationship instead of coordination?

[Author response] Indeed, ‘coordination’ is not the right word here. We have replaced it by ‘relationship’. The sentence now reads: As such, the landscape-scale relationship between forest height and natural disturbance patterns was lost in selectively logged forests.

[Referee comment] 11000 line 23: should be forest communities (rather than forests communities).

[Author response] Corrected.

[Referee comment] 11002 line 10: ‘take long to recover’ - reword this.

[Author response] Reworded as: This effect did not vary with the age of logging routes which suggests that existing logging routes have slow structural recovery or continue to be used for informal timber harvesting.

[Referee comment] 11002 line 18: note that variation in logging pressure did not affect canopy structure, but logging pressure itself clearly did (i.e. this sentence could be interpreted to mean that logging does not affect canopy structure).

[Author response] Addressed as: Since the logging pressure was relatively homogenous along the peat depth gradient and canopy structure did not respond to variation in logging pressure, we can interpret . . .

[Referee comment] 11003 line 9: perhaps specify which satellite images Franke et al. are referring to.

[Author response] We specified the type of sensor and its spatial resolution: For instance, Franke et al. (2012) report that canopy disturbance of peat swamp forest from

selective logging and small logging trails became invisible in RapidEye satellite images with 5 m spatial resolution only a year after they were active, likely due to leaf cover rather than biomass recovery (Asner et al., 2004a).

[Referee comment] 11007 line 18: delete ‘replace by’

[Author response] Corrected.

Interactive comment on Biogeosciences Discuss., 12, 10985, 2015.