

Interactive comment on “Life cycle of bamboo in southwestern Amazon and its relation to fire events” by Ricardo Dalagnol et al.

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General comment: This manuscript uses Landsat and MODIS imagery over the MODIS time period (2001 to 2017) to map bamboo patches (living and dead) in the SW Amazon. The authors then estimate patch age based on change over time and test the ‘bamboo-fire hypothesis’ by comparing presence of dead bamboo to active fire maps from MODIS. Overall I think that this is an interesting and well researched exploration of an important and understudied part of tropical forests - the presence of large patches of bamboo. My main criticism, however, is in the overall clarity of the description of analyses and results - as I note specifically below, there are many places where it is not clear, at least to me, whether the analysis is at the single pixel, pixel over time, or patch scale, what certain terms mean, and how the analyses support or do not support the

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conclusions. One other general comment is on the use of active fire detection to conclude that 'most bamboo cohorts did not burn after die-off' (abstract). While this may be the case, this conclusion is based on the assumption that the MODIS Aqua satellite detects 100% of pixels on fire, while in reality it's likely that fire in some pixels was blocked by clouds, was too small to be detected by MODIS, or wasn't burning as the satellite passed overhead. I'm not sure if/how these uncertainties were incorporated into the INPE database, but this source of uncertainty should at least be acknowledged.

Response: We thank the reviewer for the fruitful comments and suggestions. We improved the text clarity regarding the units (pixel, patch) and terms, and the description of analysis as specifically pointed out. We have also included some new statistics regarding the omission errors of the presented bamboo die-off detection method as a result of a comment from the reviewer. We agree that the fire dataset (the one we used, but also all MODIS-derived in general) underestimate the total fire occurrence because of its coarse spatial resolution and high cloud cover in Amazon, and, thus, we properly acknowledged that in the discussion. We should miss only 5% of the fire occurrence for fires bigger than 0.09 km², or approximately 10% of MODIS spatial resolution. The MODIS-INPE fire dataset that we used does not have a source of uncertainty product, but it has been validated in a previous paper (cited in the specific comment below) and showed similar results to a product by NASA-EOS also based on MODIS observations. It also presented fairly good results when compared to a finer scale active fire retrievals from ASTER (30 x 30 m spatial resolution) – detailed in the specific comment below. Nevertheless, we don't believe that the underestimate of total fire frequency has affected the conclusions, because, as pointed out by the reviewer, and acknowledged by us, only a small fraction of bamboo-dominated forests burned during the 16 analyzed years, and dead bamboo did not burn more than live bamboo, so the "bamboo-fire" hypothesis was clearly not supported.

Specific comments:

1- p. 1 lines 1-5: I don't think it's necessary to describe this other study in the abstract.

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I would just cut the sentences "In southwest Amazon...quantities of necromass."

Response: We agree with the reviewer. We have shortened the first few sentences to: "Bamboo-dominated forests comprise 1% of the world's forests and 3% of the Amazon forests. The *Guadua* spp. bamboo that dominate the southwest Amazon are semelparous, so flowering and fruiting occur once in a lifetime before death. These events occur in massive spatially organized patches every 28 years and produce huge quantities of necromass."

2- p. 1 line 8: "the fire hypothesis" -> "the bamboo-fire hypothesis"

Response: Corrected.

3- p. 1 line 9: "the MODIS thermal anomalies product"

Response: Corrected.

4- p. 2 line 7: I'm not an expert in Amazon landforms, but I think this should be 'terra firme' throughout (not 'terra fime') - if 'terra firme' is right it probably deserves a short definition since this appears to be an uncommon land type.

Response: Yes, you are correct, it was a typing error, we corrected it to "terra firme" in both p. 2 line 7 and p.4 line 7.

5- p. 2 line 20: "In the region" which region is being described here?

Response: It is the southwest Amazon. To improve clarity, we adjusted the sentence to "A total of 74 different bamboo populations, that is, patches having individuals of the same internal age, have been so far identified in the southwest Amazon, with a mean patch area of 330 km², and up to 2,570 km² for the largest patch (Carvalho et al., 2013).

6- p. 2 line 22: "in" -> "as"

Response: Corrected.

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7- p. 2 line 28: "forming a small" -> "forming small"

Response: Corrected.

8- p. 2 line 30: "maximize once in a lifetime chance..." - I read the Carvalho paper but I still don't totally understand how a temporal offset would maximize the chance of cross pollination.

Response: We re-read the papers that discuss the mast-flowering patches (Franklin, 2004) and realized that this sentence was not making sense with the paragraph idea, which was to give background on flowering waves, dead biomass production, and a brief explanation on why they happen. Thus, we decided to remove the sentence. Franklin, 2004. <https://doi.org/10.1111/j.1365-2699.2003.01057.x>

9- p. 4 line 21: it's helpful to refer to the actual MODIS codes, like MC19A1 (v006, I assume) for consistency

Response: Agreed. The text was adjusted to: "Daily surface reflectance data were obtained from the MODIS product MCD19A1-C6, acquired from Terra and Aqua satellites, from 2000 to 2017 (Lyasputin and Wang, 2018), corrected for atmospheric effects by the MAIAC algorithm (Lyapustin et al., 2012)." Lyapustin, A., Wang, Y. (2018). MCD19A1 MODIS/Terra+Aqua Land Surface BRF Daily L2G Global 500m, 1km and 5km SIN Grid V006 [Data set]. NASA EOSDIS Land Processes DAAC. doi: 10.5067/MODIS/MCD19A1.006

10- p. 4 line 22: Do you actually use all of these bands in the analysis?

Response: Yes, they were used on empirical bamboo-age reflectance curves analysis (Figure 6) to explore the spectral variation according to bamboo age and demonstrate that NIR band is the most useful to detect die-off.

11- p. 4 line 28: How did you handle the daily vs 8 day product mismatch?

Response: We don't think there is a possible correction to be done here, as we applied

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the BRDF correction as it is described in Lyasputin et al. (2012) paper. During the 8-day window, the MAIAC algorithm integrates daily observations with different view angles and retrieve the parameters for BRDF correction of daily observations. The paper report that robust and consistent retrievals are obtained with at least 4 observations. It also tests and corrects the parameters for potential land surface change within the window (Lyasputin et al., 2012). Besides that, variations in sun illumination geometry during the 8-day window are insignificant. We adjusted the sentence in the text to better describe this to the reader: “Parameters of the RTLS model and BRDF kernel weights are part of the MAIAC product suite with a temporal resolution of 8 days – a period which daily observations of different view angles were integrated and used for BRDF parameters retrieval”. Lyasputin et al., 2012. <https://doi.org/10.1016/j.rse.2012.09.002>

12- p. 5 line 4: Awesome that this was done in R! Is the code available?

Response: The MAIAC atmospheric corrections and creation of BRDF parameters were performed and made available by NASA, led by Dr. Alexei Lyasputin. However, the rest of processing (BRDF normalization, composite, mosaic) for the whole South America during 2000-2017 was coded by me, and yes, in R. It was quite a challenge and took some months. The code is available here https://github.com/ricds/maiac_processing. The code is not clean as my specialization is not on programming, but whoever would have the interest to use it to process MAIAC data into composites by himself can contact me and I can help.

13- section 2.2.2: More detail would be great in this section - did you use 1 image per year?

Response: Yes, it was one image per year. In this section, we described the Landsat data that was used in the section 2.3.4 to visual interpret die-off events and validate the prediction model. We adjusted the sentence to make it clearer that we used one image per year: “A time series of Thematic Mapper (TM)/Landsat-5 data was obtained from 1985 to 2000 (one image per year) in order to visually detect die-off events that oc-

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curred in the last life cycle of bamboo and validate age predictions – further described in the die-off prediction section.”. By the end of the paragraph, we added the information on which scenes (path/row) were analyzed: “The path-row (World Reference System 2) of the time series were: 006-065, 003-066, 002-067, 003-067, 005-067, and 003-068.”

14- p. 6 line 22: What is a 'percentile' in this context? I've tried pretty hard to figure it out, but I really don't get it, and it's pretty critical to the rest of the manuscript. Is it based on the distribution of values in a pixel? in a patch? This term is also not used in the Carvalho paper.

Response: We analyzed the 1st, 50th and 99th percentile of tree cover product (Hansen et al., 2013) considering all pixels inside the bamboo map delineated by Carvalho et al. (2013). We reworked the paragraph to improve clarity: “In order to analyze the tree cover variability in forests with and without bamboo, we used the bamboo map from Carvalho et al. (2013) as a mask to analyze the tree cover product (Hansen et al., 2013) considering all pixels inside the bamboo map. This map was obtained in the previous study by visual interpretation of live-adult bamboo using two Landsat mosaics 10 years apart from each other (1990 and 2000), supported by the known locations and dates of five bamboo dominated areas. Considering only the pixels inside the bamboo-dominated map, we calculated the 1st, 50th and 99th percentiles of the tree cover product and generated a map of areas below the 1st, between the 1st and 99th, and above the 99th percentiles of tree cover.”

15- p. 6 lines 26 - 29: What are these distributions telling us? Again, in a given pixel across time? or...?

Response: They are telling us about the average, standard deviation and skewness of NIR signal overtime for all pixels in each tree cover percentile class in order to compare the NIR signal between forests with and without bamboo. For normal distribution, the average and standard deviations were calculated. When different than normal,

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we applied a more appropriate method to estimate average, standard deviation and skewness parameter (Fernandez and Steel, 1998). As we discussed in the results, for example, if the distribution has a higher NIR average value and is right-skewed, the pixels are likely belonging to bamboo-dominated forests, because of higher NIR values from adult bamboo. We adjusted the text to improve clarity: “In order to compare the NIR signal between forests with and without bamboo, we analyzed the MODIS NIR-1 reflectance for all pixels overtime in the tree cover classes: below 1st, between 1st and 99th, and above the 99th percentile. We tested the distribution of NIR values for normality using a two-sided Kolmogorov-Smirnov test at a 1% significance level. For normal distribution, the average and standard deviation of distributions were computed. For skewed distribution, a more appropriate method was applied to estimate the average, standard deviation and skewness parameter (ξ) (Fernandez and Steel, 1998).”

16- section 2.2.4: as mentioned above, can uncertainty be quantified in the fire data?

Response: Unfortunately, the MODIS-INPE active fire dataset we used does not have an uncertainty parameter. However, Morisette et al. (2005) conducted a validation of MODIS active fire retrievals from both (1) NASA EOS and (2) INPE, comparing their results to active fire retrievals from ASTER satellite (finer resolution, 30 x 30 m) and concluded that they were both fairly good. The MODIS-INPE dataset presented high accuracy (95%) for active fires bigger than 0.09 km², which correspond to 9% of the MODIS spatial resolution. Even though, as the reviewer pointed out in the review introduction, Morisette et al. (2005) highlighted that MODIS active fire detections should be treated as a lower bound of total fire occurrence, as it underestimates small fire occurrences due to the coarse spatial resolution, high cloud cover, and when having high viewing angles (> 15 °). We added this limitation to the discussion in section 4.6, p. 22, line 23: “The MODIS active fire detections should be treated as a lower bound of fire occurrence, as it underestimates fire occurrences, mainly the small ones with less than 0.09 km², due to the coarse spatial resolution, high cloud cover, and when

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having high viewing angles ($> 15^\circ$) (Morisette et al., 2005). Morisette et al., 2005. <https://journals.ametsoc.org/doi/abs/10.1175/EI141.1>

17- p. 7 line 13: not sure what $Y=x$ means here.

Response: It was a failed attempt to describe the linear equation between bamboo age and NIR signal, but we agree that it was confusing and not helpful, so decided to remove it. We reworked the sentence to improve clarity of the bilinear model: “A linearly increasing NIR reflectance vector (1 to 28%) with bamboo age (1 to 28 years), followed by an abrupt NIR decrease to 0% at 29 years of bamboo age.”

18- p. 7 line 23: are 'geolocations' the patches of 5 pixels? if there are 390 here, why are there fewer in Fig 4c and d? (I think these should be the same?)

Response: Good question. For each patch (of several pixels), 5 pixels' geolocations were acquired. So, 78 patches equal to 390 pixels/geolocations for validation. Now, there are two explanations: First, if you mean the number of circles in Fig 4c and 4d, it is because we aggregated the samples when they hit the same observed and estimate die-off year. We did this as a way to improve visualization of the agreement, or otherwise, samples would just overlap. To improve clarity, we changed “Samples” to “Pixels”, and added this sentence to the caption of Fig 4 (and also Fig 8, which is the prediction): “Size of circles is related to the number of pixels that hit the same observed/estimate die-off year”. Second, in order to map the die-off (Fig 4a and 4b), we selected only the pixels with significant relationship with the bilinear model ($p < 0.001$). When we compared our validation dataset (390 pixels) with the resulting maps, for NIR-1 (Fig 4c) and NIR-2 (Fig 4d) there were actually only 334 and 362 pixels available ($p < 0.001$), respectively. Thus, a total of 56 and 28 pixels were not classified as die-off, so they were not included in the accuracy assessment. However, now that you pointed this out, we decided to include this information in the results to represent the omission errors of $56/390 = 14.4\%$ and $28/390 = 7.2\%$ for NIR-1 and NIR-2, respectively. When the two maps are merged, the omission error was reduced to 4.1%, while accuracy

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was maintained (80%). Thus, we added this sentence after p.11 line 5: “From the 390 pixels in the validation dataset, 334 and 362 pixels were detected as bamboo die-off by the bilinear model ($p < 0.001$) using the NIR-1 and NIR-2, respectively. The missing 56 (14.4%) and 28 (7.2%) pixels were considered as omission errors for NIR-1 and NIR-2. When we merged the two maps into a single die-off detection map, a total of 374 pixels from the validation dataset were successfully detected, resulting in only 16 (4.1%) missing pixels not detected as bamboo die-off, while accuracy and RMSE were 80% and 0.51 yr, respectively.”

19- p. 7 line 30: "it" = "a bamboo dominated pixel" (I think?)

Response: Yes, it is. We rephrased to improve clarity: “We used two assumptions to map the live bamboo. Over the 18 years’ period, a live bamboo dominated pixel should present: (i) mean NIR reflectance equal to or greater than the median signal of bamboo-free forests; and (ii) an increasing NIR reflectance over time.”

20- p. 8 line 24: ‘geolocations’ = ‘patches’? pixels? random samples?

Response: The multiple terms were indeed confusing. Geolocation and pixels meant the same thing, so we decided to change the term geolocation for pixel in all paper, so it is easier to understand. A total of 2 occurrences were found and adjusted.

21- p. 9 line 27: ‘followed a normal distribution ($p=0.33$)’ -> this is a K-S test, right? if yes, ‘did not significantly differ from normal’ would be more clear, I think.

Response: Yes, corrected.

22- Figure 3 caption: "(hatched)" -> "(hatched in Figure 1)"

Response: Corrected to “(hatched in Figure 2)” as the bamboo area in Figure 1 is not hatched.

23- section 3.2.3: I’m having a hard time grasping exactly how this cohort age analysis using NIR reflectance fits with everything else, especially given that the results differ

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when different bands are used...

Response: We believe the cohort analysis was important to improve the understand of remote sensing signal variability with bamboo growth overtime, that is, when the signal changes and why, in order to validate our simple bilinear model that we applied to detect the die-off events. The empirical curves showed the “true” remote sensing signal variation with bamboo age, not only for NIR, but in diverse wavelengths. We extracted the ages using the NIR bands, but we were able to reconstruct the time series of the other bands, which, we believe, is a unique and very interesting result. We discussed the implications of such variations, for example, in the Red band, which is related to chlorophyll content. The first paragraph from section 2.3.3, p.8, l.10, was adjusted to improve the clarity of the analysis: “In order to validate the simple bilinear model that was applied to detect the die-off events and improve the understand of remote sensing signal variability with bamboo growth overtime, that is, when the signal changes and why, we used the die-off map to analyze the remote sensing signal variability. Data from all MODIS bands were extracted using the estimated die-off year with very significant correlation ($p < 0.001$) as a starting point. Bamboo cohort age was then calculated backwards and forwards in time during the 2000-2017 period. Reflectance percentiles (1st, 50th and 99th) per age were calculated obtaining, what we called, empirical bamboo-age reflectance curves.”

24- (Figure 7) and the accuracy seems low (p 13 line 10)? Is this meaningful? If patches of dead bamboo are being mapped visually, is this fitting necessary to estimate future dieoff?

Response: In our understanding, the reviewer is commenting on Figure 8, instead of Figure 7, which present the map and accuracy of die-off predictions. We agree with the reviewer that the accuracy on predicting the exact die-off year is fairly low. However, we think that the importance here is that the correlation of predicted and reference die-off is actually moderately strong and statistical significant ($r = 0.41$ and $p < 0.01$ for NIR-1), with RMSE less than 3 years, which, we think, is meaningful. Regarding

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the last part of the question, we tested the prediction of future die-off to increase our sampling of die-off areas to test the fire hypothesis. Since MODIS data only span the 2000-2017 period, a big portion of bamboo patches did not undergo die-off during that period and, thus, does not present the decrease in NIR with die-off. Mapping all the die-off patches manually would be time consuming and probably less precise, with bias toward identification of big patches.

25- Figure 5: These colors are really hard to see even for a non visually impaired person -> check out colorbrewer2.org for color schemes that are colorblind friendly.

Response: Agreed and corrected. You can check the adjusted figure in the updated manuscript.

26- p. 17 line 15: 'did show' what?

Response: We complemented with "statistical significance on area-normalized mean active fire detections".

27- p. 17 line 19: "...in dead and live bamboo" in non drought years?

Response: The comparison was between dead and live bamboo in drought years. The sentence was not written correctly, so we adjusted it to: "For severe drought years, the area-normalized active fire detections in 2005 (0.32 and 0.18 fires ha⁻¹), 2010 (0.22 and 0.12 fires ha⁻¹), 2015 (0.35 and 0.20 fires ha⁻¹) and 2016 (0.57 and 0.33 fires ha⁻¹) over dead and live bamboo, respectively, were not statistically different between the two bamboo life stages ($p = 0.127$)."

28- p. 18 line 3: 96.95 to 99.89% of what?

Response: Tree cover. We rephrased to improve clarity: "We found that the bamboo-dominated forests had a narrow range of tree cover values (96.95 to 99.89%)".

29- p. 18 line 6: "that" -> "where"

Response: Corrected.

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30- p. 18 line 9: "The presence of canopy trees could explain why the tree cover is so high." I'm not sure what this is saying that isn't obvious?

Response: Agreed and removed.

31- p. 21 line 29: it seems like there also might be some interesting carbon cycle implications to this work?

Response: We partly agree, but we are not sure if we should add something to the paper. The bamboo-dominated forests have lower aboveground biomass (AGB) (212 Mg/ha) than dense forests (272 Mg/ha) (e.g. Saatchi, et al., 2007). However, it has more AGB than open forests (200 Mg/ha), probably due to bamboo AGB contributing to that stock. It is interesting that, in this paper, the AGB map shows even lower AGB (100-150 Mg/ha) in bamboo-dominated forests of southwest Amazon. Bamboo may limit aboveground biomass stocks through resources competition and increases in tree mortality (Castro et al., 2013), because of the physical harm it causes on trees (Griscom and Ashton, 2003), while the die-off dynamics may trigger something similar to gap dynamics - because of the suddenly more open canopy and increased sun illumination input. However, we don't expect these dynamics to have implications for carbon cycle in long-term, because the die-off events occur every bamboo cohort life cycle, and, thus, that ecosystem should be already adapted to this. It is expected, though, short-term responses such as pulses of net CO² emissions after die-off, followed by a period of net C uptake as trees and bamboo grow back. Saatchi, et al. 2007. <https://doi.org/10.1111/j.1365-2486.2007.01323.x>

32- p. 21 line 32: I don't know if Keeley and Bond would insist on ALL patches burning to confirm the bamboo-fire hypothesis

Response: We haven't considered that before, but we agree. The need for all patches burning is not commented in the Keeley and Bond (1999) paper. What we observed in the results was that the total fire frequency was so low that it wouldn't be feasible that fire should be a driver of bamboo dominance in the study area. We adjusted the

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first two sentences in discussion in order to highlight the small magnitude of burning areas compared to the total bamboo area: “Fire occurred only in a small fraction of bamboo-dominated areas during the 16 years of fire analysis (Fig. 5), equivalent to 2371 km² of burnt area or 0.0955% of the total bamboo area (155,159 km²) burning each year. Besides that, the statistical tests comparing dead and live bamboo fire frequency showed that dead bamboo did not burn more than live bamboo (Fig. 11). Thus, we cannot support the ‘bamboo-fire hypothesis’ from Keeley and Bond (1999).”

33- p. 22 line 35: "nearby" -> "near"

Response: Corrected.

34- p. 23 line 11: "not fully supported"? not at all supported, right? I think the uncertainty in the fire observations is an important caveat here, but these results really refute the bamboo-fire hypothesis at least in this setting.

Response: Yes, we agree with the reviewer. We adjusted the text to: “The ‘bamboo-fire hypothesis’ was not supported by our results, because only a small fraction of bamboo areas burned during the analysis timescale, and, in general, bamboo did not show higher fire probability after the reproductive event and die-off.” The uncertainties were discussed specifically in the fire section. We believe that even though we have an underestimate of the “true” fire frequency, the observed fire frequency was so small that it shouldn’t affect the conclusions.

Please also note the supplement to this comment:

<https://www.biogeosciences-discuss.net/bg-2018-207/bg-2018-207-AC1-supplement.pdf>

Interactive comment on Biogeosciences Discuss., <https://doi.org/10.5194/bg-2018-207>, 2018.

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