

# ***Interactive comment on “Drought resistance increases from the individual to the ecosystem level in highly diverse neotropical rain forest: a meta-analysis of leaf, tree and ecosystem responses to drought” by Thomas Janssen et al.***

**Thomas Janssen et al.**

t.a.j.janssen@vu.nl

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Response to Referee #2

In this study, Janssen et al perform a meta-analysis to look to drought impacts on carbon and water exchange across scales ranging from leaf, to plant, to ecosystem in neotropical rainforests. In particular, the authors contrast physiological responses from seasonal water stress versus ‘episodic’ drought events. In doing this, the authors also look at wood density as a proxy for plant physiological responses. Its clear that the

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authors put in a significant amount of work through compiling 138 studies across 229 sites and this study will clearly contribute to the physiological literature on forest drought responses. I do have some major revision suggestions before publication which are summarized here and, in some cases, elaborated in the line specific comments below.

Response: thank you for your elaborate review of our manuscript and acknowledging the work that was put into creating the database behind the meta-analysis. We believe that your comments and suggestions will greatly enhance the quality of the manuscript. Below we will respond to the major and minor comments raised by you in your report.

1) I think that the manuscript would benefit from reframing of the dry season ‘drought’ as a routine period of decreased water availability. When I think of droughts, I think of a prolonged period of abnormally low rainfall. Given that dry seasons occur every year, I don’t see them meeting this definition. This reframing would provide a nice platform to discuss physiological responses to routine (seasonal) stress, such as phenology, versus episodic stress and can help get at important physiological mechanisms. This would involve some substantial reworking of the text, but I think it would really help the story line.

Response: we agree that seasonal drought would not meet the criterium of being a prolonged period of abnormally low rainfall and we highlight this distinction with episodic drought and multi-year drought in the Introduction (L50-L54). However, the term “seasonal drought” is widely used in the literature (Esquivel-Muelbert et al., 2017; Rowland et al., 2013; Stahl et al., 2013) and leaf, tree and ecosystem processes similar to episodic drought are operating during seasonal drought. We discuss the differences between seasonal and episodic drought in the Discussion section 4.3 and mention how for example phenology is likely driving the observed seasonal responses in leaf flushing, shedding and stem growth. In the revised version of the manuscript we will highlight this distinction between seasonal and episodic drought from the start and we will, where needed, adapt the text to improve the story line.

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2) Some of the methods are confusing and I think elaborating a bit more, providing and providing a table might help. See line specific comments below

Response: referee #1 also provided suggestions to improve the readability of the Methods, we will adapt this in the revised version. Concerning the table, see specific comments below.

3) The Figure legends need to be more descriptive of all the features in the figures

Response: we will improve the figure legends and captions in the revised version, see also specific comments about figures and comments on figure captures by referee #1.

4) Overall the manuscript does an impressive job discussing a range of processes, but the reader might be more attentive if it were a little shorter. Where possible, I would suggest the authors minimize extraneous discussion. In particular, I think talking about isohydricity requires significant motivation for a general audience (which is not provided), so I would cut this text.

Response: thank you. We agree that the readability of the paper would improve if it were shorter. While preparing the revised version we will critically examine every paragraph to reduce the length of the manuscript. In the revised version of the manuscript we will no longer use the concept of isohydric and non-isohydric behaviour because, as you mention, it is not suitable for the broad audience of Biogeosciences (specific comment L121). We will instead focus on the mechanisms behind the observed drought responses because this is more interesting to the audience and does not constrain us to refer to two strategies so we can focus on the continuum of hydraulic behaviour.

Line-specific comments:

L21-22 There is nothing to back up this statement on LSMs. I suggest the authors remove it

Response: See also specific comment of referee #1. The statement will be rephrased to: ““We present new insights into the functioning of tropical forest in response to

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drought and present novel relationships between wood density and drought responses that can help guide the parametrization of land surface models.”

L35 Khanna et al 2017 Regional dry-season climate changes due to three decades of Amazonian deforestation

Response: thank you for the literature suggestion, Khanna et al. 2017 will be added in the revised version of the manuscript.

L50 after going through the MS, I am confused about where the multi-year drought is presented in the authors analysis

Response: no it is not presented, see for the justification of omitting multi-year droughts L70-71

L53-54 This is exactly why I would argue that ‘seasonal drought’ is a misnomer

Response: see response to major comment #1.

L121 The concept of isohydricity/anisohydricity will likely not be familiar to a broad audience at Biogeosciences. I would encourage the authors to eliminate the jargon and focus on the mechanisms of interest (see Martinez-Vilalta 2016 “Water potential regulation, stomatal behaviour and hydraulic transport under drought: deconstructing the iso/anisohydric concept”) or else devote more space to describing isohydric behaviour

Response: See response to major comment #4.

L131-132 But the authors actually try and demonstrate that wood density is usable as a proxy first, so isn't this more of a hypothesis?

Response: we agree this is a confusing sentence. We will reformulate this sentence.

L145 where does the multiyear drought aspect come in that the authors mentioned in the intro? Intro overall: The introduction is on the longer side (as is the manuscript) and the three separate sections do not have a smooth transition. I would try to com-

bine 1.2 and 1.3 and streamline the text. Given that sections 1.2-1.3 are more about the mechanisms, I would put these sections first and then say that different types of physiological stress also impact C and W fluxes including seasonal, routine decreases in water availability versus droughts

Response: thank you for your suggestions on restructuring the Introduction. We will shorten and restructure the Introduction in the revised version of the manuscript.

L152 ERA5 citation?

Response: a citation to the ECMWF website will be provided in the revised version.

L153-155 It would be good for the authors to say how many studies were associated with each of these diagnostics and how many studies had multiple observations, maybe a table would be useful?

Response: we will add a table with a summary of the database in the Supplement of the revised version of the manuscript.

L157-159 I am confused about how observations were calculated/recorded across scales? Could the authors elaborate? For example, were ecosystem-level measurements independent from leaf level, or were different levels calculated using observations from different scales by the authors? Both more details and a table detailing number of measurements for each diagnostic and number of studies that cover multiple diagnostics and scales would help

Response: the scales refer to the native “resolution” on which measurements were provided in the source papers. Many studies that measured leaf and tree scale responses provided data on the individual tree level, giving also a species and genus name. For these studies we could link these individual observations to a wood density value. However, many studies reporting ecosystem level responses provided data on the ecosystem level, e.g. 1 ha of forest. This will be elaborated on in the revised version of the manuscript.

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L161-162, this doesn't need to be included

Response: agree, this can be omitted. See also specific comment by referee #1.

L166-167 This is a huge amount of work, I commend the authors

Response: thank you.

L170 it would be good to say the spatial resolution and include a citation for on ERA5 (30km?)

Response: yes indeed, 0.25 degrees is 27.75 km at the equator. This information will be added in the revised version.

L171 monthly average midday VPD?

Response: yes, this is the monthly averaged VPD at midday (12:00), see comments by referee #1 on VPD.

L187 how was this error estimated?

Response: this was estimated as the RMSE ( $3.25 \text{ kg dm}^{-2} \text{ d}^{-1}$ ) divided by the mean daily transpiration rate ( $9.56 \text{ kg dm}^{-2} \text{ d}^{-1}$ ) =  $0.34 = 34\%$ . This will be elaborated on in the revised version.

L219 Figures should be renumbered so Fig 2 comes after Fig 1

Response: this reference to Figure 4 is not necessary and will be omitted in the revised version of the manuscript.

L208-209 It would be good to include a possible caveat about uncertainty associates with ERA5 soil moisture (which I presume is modeled)

Response: this will be included in the next version of the manuscript.

L212-213 why the 65% and 10% quantiles? Did the authors test the sensitivity of their results to this assumption?

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Response: we opted for a threshold that provided a reasonably strict episodic drought definition while still yielding a large enough sample size for the statistical analysis to differentiate between episodic drought and a regular dry season. We also tested a wide episodic drought threshold of 15% and a narrow episodic drought threshold of 5%. The wider episodic drought definition resulted in a decline of the sample size for the wet season – dry season comparison as more dry season months were classified as episodic drought. Furthermore, the p-values of 14 out of 23 variables declined but none of the previous significant variables became not significant in the wide (15%) threshold wet season – dry season comparison. The wide episodic drought definition resulted in the increase of the sample size in the dry season - episodic drought comparison but also a decline in the p-values of 15 out of 23 variables, while none of the previously significant variables became not significant in the dry season – episodic drought comparison. The narrow episodic drought definition (5%) resulted in larger sample size for the wet season – dry season comparison compared to the baseline (10%) definition because more episodic drought months are now classified as dry season, and the increase of p-values in about half (12 out of 23) of the variables, while one variable (soil-leaf hydraulic conductance) became not significant in the wet season – dry season comparison. Furthermore, the narrow definition resulted in a decline in sample size for almost all variables (19 out of 23) and a decline of the p-values in 15 out of 23 variables in the dry season – episodic drought comparison with 4 previously significant variables now showing no significant change (soil-leaf hydraulic conductance, leaf transpiration, leaf photosynthesis and ecosystem water use efficiency). These results confirm that our analysis of seasonal drought is quite robust, with no major changes in the magnitude and direction of change of any variables in response to seasonal drought with different threshold values for episodic drought. Also the responses to episodic drought show no major changes in direction or magnitude but we observe a decline in significance levels in some variables, mainly because of a reduction in sample size. We will add these results to the supplementary material and discuss the implication of the threshold in the discussion.

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L220 Could a study be both a dry season and episodic drought? I am a little confused about the partitioning. Also, where does multi-year drought come in?

Response: the partitioning is mentioned in L214, 10% of the driest dry season months were classified as episodic drought (and not anymore as dry season). We will elaborate on this in the next version of the manuscript.

L225 did the authors check to see if it was necessary to log the response? Where did the ENSO data come from?

Response: the log-response ratio was calculated because this is the standard in the method used: the log transformed ratio of means (Lajeunesse, 2011). The ENSO data was retrieved from NOAA, a reference to this dataset will be included in the revised version.

L254 how can predawn wp be positive 0.22?! Please check for a typo

Response: the minus sign unfortunately ended up on the previous page.

L281 Could the authors include Reco in some of the figures, they refer a change in Reco several times in the text but no visuals are provided

Response: Reco is the same as Ecosystem respiration in Figure 3 and 4. We will consider removing the abbreviation altogether.

L363 typo include 'us'

Response: yes, this is a typo. This will be corrected.

L370 denoted iWUE previously

Response: yes, this will be corrected.

L401 it is also true that there are more observations post 2000. The authors should discuss how this might impact their results

Response: this is discussed in response to the first main comment of referee #1. We

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will elaborate on this sampling bias in the revised version of the manuscript.

L419 it would be nice to put these numbers in a physiological context

Response: it is not entirely clear what is meant by this comment. Could you clarify?

L451-458 I think there is a really nice opportunity to contrast tree physiological strategies when exposed to routine stress (the dry season) versus drought that the current narrative doesn't allow for when both are classified as drought

Response: We agree that this comparison is important and, although we prefer sticking to the term seasonal drought (see further), comparing seasonal drought (routine stress) to episodic drought is one of the main objectives of the meta-analysis. There are basically two reasons why we use the term seasonal drought: 1) the term "seasonal drought" is commonly used in the literature and 2) the difference in drought conditions between the wet season and dry season is comparable to the difference between a regular dry season and episodic drought (Figure 2).

L461 is it the short timescale, or that fact that the plants are used to this type of stress and use phenology to deal with it?

Response: it is not clear what is driving these tree scale responses to drought and on which time scale these responses operate (Doughty et al., 2015; Hofhansl et al., 2014). The purpose of this sentence was to give a potential explanation for the lack of leaf litterfall and leaf flushing responses during episodic drought. We argue that this could be the result of the phenology time-scales and the amplitude of leaf exchange overwriting the more subtle responses to drought, if there are any. This is quite speculative and will be reformulated in the revised version of the manuscript.

L464 Or maybe title: how do we scale from the leaf to the ecosystem? This is a universal problem in ecology that researchers across many subdisciplines will sympathize with

Response: thank you for the nice suggestion. We will adapt this subtitle in the revised

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version.

L502 see previous suggestion about isohydricity

Response: noted.

L536 This isn't a great comparison. The authors of this manuscript analyze site-specific data whereas the spatial scale of the Konings study is  $\approx 100\text{km}$ . For me, this paragraph does not contribute much to the study and in general I think the isohydricity framework is not useful here (and otherwise)

Response: we agree this is not a great comparison, it will be omitted in the revised version.

L575 LSMs are brought up only in the abstract and conclusion. It doesn't add to the discussion and I would remove this

Response: noted, this will be removed.

L582 How should they be used to benchmark LSMs? If the authors insist on including this, please spell out the methodology rather than throwing it in as a concluding sentence Other relevant citation: Detto 2018 "Resource acquisition and reproductive strategies of tropical forest in response to the El Niño-Southern Oscillation"

Response: the reference to LSMs will be removed.

Figures: Fig. 1 panel a make lat/lon bigger b) its really hard for me to wrap my head around what the authors mean by this metric, can they elaborate? d) What do the dots mean? Please describe this in the legend and also detail what dark and light gray correspond to legend (e) it would be good to remind the reader what the positive/negative ENSO index means

Response: we will include these suggestions in the revised version of the Figure caption.

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L1131 “terrestrial” isn’t capitalized

Response: noted, this will be changed.

Fig. 2 can the authors denote the sample size above each category in the figure? For example, does  $n=3$  for Episodic drought soil-leaf hydraulic conductance in panel b? Make sure to describe the figure fully (detail quantile boxes, median line, error bars, and outliers) in the legend

Response: the suggested changes will be made in the next version. See also comments on this figure by referee #1.

Fig. 3-4 I would combine these two figures into 1 2-column 3-row figure. I generally really like this format and found it very effective in the Ainsworth review. Great job describing all aspects of the figure in the legend

Response: we will look into merging Figure 3 and 4 in the revised version of the manuscript.

Fig 5-6 I would combine these figures into a 2-c 3-r figure

Response: we will look into merging Figure 5 and 6 in the revised version of the manuscript.

The point size is the inverse of the sample standard error of the effect size in the study.–  
> so studies with a smaller SE have a larger dot? Moderator= independent variable?

Response: this will be changed and explained in the text, see also the response to the final comment of referee #1.

Fig 5 legend, make sure to walk the reader through each panel Response: we will reformulate the Figure 5 legend in the next version.   References

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