Biogeosciences Discuss., 12, C9113–C9127, 2016
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Biogeosciences Discussions
Open Access

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Interactive Comment

Interactive comment on "Structural effects of liana presence in secondary tropical dry forests using ground LiDAR" *by* A. Sánchez-Azofeifa et al.

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Received and published: 15 January 2016

REVIEWER COMMENTS TO AUTHOR

Referee 1

Comments to the Author

In their Discussion paper Sánchez-Azofeifa et al. present a study on the effect of liana presence on forest structure in secondary dry forest in Costa Rica. They use the VEGNET ground LIDAR system to study the vegetation structure of forest stands (with and without lianas) along a successional gradient. The topic of the paper is important, the idea has merit and I believe that terrestrial LIDAR scanning has a lot of potential in this context. However, the study setup is rather limited, the methods and analysis are not well presented and some important information is missing. The analysis is too weak to support the conclusion that the authors make. I can therefore not recommend this manuscript for publication in Biogeosciences.

Response: We thank referee 1 for the comments. In effect LiDAR has a lot of potential to identify lianas and vegetation structure in forest of different stands, but few studies have been conducted assessing the potential of ground LiDAR to differentiate among stand ages or stands that differ in composition of functional groups such as woody vines, thus where the contribution of the paper lies.

We believe our data shows solid evidence of the capabilities of LiDAR technology and its measured variables (PAI, RG) to detect and differentiate forest with lianas and forest with no lianas, over a successional gradient. This evidence has positive implications for the use of ground remote sensing platforms in long term forest monitoring, and for the future use of airborne point cloud data to detect liana infestation over large areas in tropical dry forests.

After addressing major comments from referee 1 below, we believe our paper deserves publication. Moreover, as of today, no studies have been conducted in tropical dry forest environments to understand the effect that lianas, from a structural point of view, can have on succession, and our study is intended to provide new insights on how to understand these processes using remote sensing

Major comment 1 There is some important background information missing on the setup of the study. In the first place it is not clear why some stands have lianas and others not. Have they been artificially removed? Or has the presence/absence a natural cause? It is important to describe why lianas are present or absent. The factor that is determining the presence of lianas (e.g. the soil) might also influence the forest structure independently from the lianas. . . This would mean that the observed patterns might be caused by other factors than lianas.

Response: We have not conducted any removal of lianas. The study area is part of a long-term project conducted by the Tropi-Dry Research network at Santa Rosa National Park (http://tropi-dry.eas.ualberta.ca). Thanks to our previous work there, we have been able to identify areas within the park with and without lianas that we were able to use for the current study. We do not have soil data on the plots sampled with the Vegnet to disentangle the different factors influencing the presence of liana in the region. However, we considered this does not necessarily preclude the understanding of our findings, as one of the goals is to evaluate whether terrestrial laser scanning can be used to evaluate whether liana presence could cause a change in the successional trajectory.

Major comment 2

- The stands in the study area have been classified in different age classes. This classification is done in a rather non-transparent way (page 17158, lines 14-23). Multiple criteria have been used for this classification, but it is not clear how much weight is given to each of the criteria. And in addition, forest structure appeared to be an important factor in determining the age classes! This is not really a good setup to test differences in forest structure afterwards.

Response: The stands in the study area have been classified in a transparent way. We mentioned on page 17158 that sites were classified based on land use history, age since land abandonment, using remote sensing data and field inventories. We provided a brief description because we cited previous studies where the methodology of site selection is explained. Nonetheless, we can expand the description of the study sites for the next version of the manuscript to improve clarity. Here, it is also important to highlight that the criteria to select plots were the same for sites with lianas and no lianas, so there should not be any biases for comparison across stand ages. The selected plots and their characterization are the core elements of several papers published over the last 15-years such as the papers by Arroyo-Mora et al (2005), Kalacska et al. (2004, 2005), Sánchez-Azofeifa et al. (2009 Forest) and Castillo et al. (2012), which are currently cited in the manuscript.

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Major comment 3

The story needs more focus. Currently the results are describing both the impact of succession and the impact of lianas. However, none of both topics is well developed. Maybe the authors should choose one of both topics to be developed in detail.

Response: We disagree with the reviewer in that the paper needs more focus. The paper deals with both succession and the impact of lianas. If the editor considers it is needed to broaden the introduction, we can do that in the next version of the manuscript. However, we consider the scope of the paper is very clear, as we are using our sampling design with plots of lianas and no lianas to evaluate whether the presence of lianas, over a chronosequence, could be detected by the terrestrial laser scanning. Our method is also intended to get insights about the role of lianas in succession, by assessing whether lianas could be modifying the trajectory of succession in tropical forests as previously hypothesized by Schnitzer et al (2000), Paul &Yavitt (2011). This is another contribution of the study, as research on lianas in secondary forests is rather scarce (see Paul &Yavitt 2011, Duran & Sánchez-Azofeifa 2015).

Major comment 4

- In that respect I also wonder if the number of studied stands is statistically sufficient to study both patterns (succession and liana presence) simultaneously. The studied stands differ in a lot of aspects (age. . .), I doubt if they can be really considered as repetitions.

Response: We disagree with the referee in the sense that these plots cannot be really considered as repetitions since they have been extensive studied and information from these plots has been already published on several ecological journals. In fact these plots have been monitored every year over the last 10-years as part of our long-term studies at the Santa Rosa National Park. We will clarify this on the next version of our paper. Furthermore issues such as age, structure and composition have been already been published in several journal as indicated above. As per the number of plots, the small number is similar to other studies from other tropical dry forests in the Americas, specifically those studies conducted for example by Balvanera et al. (2002) in Mexico. We will acknowledge this in the manuscript specifically in the discussion and also on the conclusions of the paper.

Balvanera, P. E. Loot, G. Segura, C. Siebe, A. Islas. Patters of Beta Diversity in a Mexican Dry Forest. Journal of Vegetation Science. 13(2): 145-158.

Major comment 5

- Why are the VEGNET test measurements done at night? (page 17160, line 17) are the actual measurements also done at night? Why?

Response: All measurements conducted by the Vegnet, are performed using a visible wavelength of 635 nm. Measurements must be conducted at night, in order to avoid sunlight irradiance interference at the same wavelength with the VegNET laser light. Night time measurements ensure an optimal environment for recording all returns and avoiding interference. We will clarify this in the paper.

Major comment 6

- The RG metric is introduced technically in detail. But for me it was not clear what the actual meaning of this metric is in terms of forest structure. It is not clear why the authors hypothesize that RG would increase with succession but not in case of liana presence. Is RG used here mainly a proxy of biomass or as a measure of vertical canopy structure? It would be interesting to relate the lidar data to actual biomass data (based on inventories) of the stands.

Response: The idea of conducting a linkage to the site biomass to the vertical profiles of the Lidar is very interesting but we think that it is out the scope of the paper. In addition, to conduct a vertical study of the vertical distribution of biomass is something that we have not done; therefore we cannot integrate this component in the current the study. In the case of our scope and our data, Plant Area Volume density (PAVD) provides a measure of the area covered by photosynthetic and non-photesynthetic material present in a given forest height. The PAVD vertical profile (Figure 2) then describes the distribution of the plant volume in the forest. We then use RG as a single measure to describe the distance between all PAVD values and the centroid of the vertical profile. This single measure provides a proxy to general forest volume. The greater the overall height, stratification and biomass of the forest (as a function of succession), the larger the RG value. The relation between RG and succession is evidenced in the RG values obtained in Early, Intermediate and Late sampling plots with no lianas (Table 1). The presence of lianas affect forest structure, and this is registered in the distances between PAVD values and the centroid of the vertical profiles of liana infested plots, therefore affecting RG values. We will insert a better explanation of this hypothesis in the next version of the manuscript.

Major comment 7

- Related to the comment above, it is a bit confusing why PAI as a function of RG is studied in order to study successional trajectories (fig 3). Why where the indices not studied along an axis of stand age? What does the PAI-RG relation actually mean?

Response: Forest structure changes as a function of succession. PAVD and RG are proxys of forest strcuture. See explanation above, in t, in the response to comment 6.

Major comment 8 - On page 17163 (line 17) the authors observe that there is no significant trends in fig 3 for stands with lianas. And that there is a trend for stands without lianas. However the liana stands are only available in intermediate and late succession: : : I suspects there will also not be a significant trend for the non-liana stands if you only consider the two oldest succession stages.

Response: We assess the pathway by using all the available plots, and we found that the regression for the plots where lianas are absent show a statistically significant trend ($P<0.05$), while the trend with plots where lianas are present do not show any significant trend. We can improve clarity in this point by adding the regression equation.

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What is interesting here is that for the plots with lianas despite the regression is not significant; the slope is negative, while for the plots without lianas the slope is positive and significant. We acknowledge our small sample size, and as stated above we make suggestions rather than stating that our data confirms that lianas in fact are modifying the pathway. We can add the equations, P-value and R square for both trends to improve this section.

Major comment 9

In the discussion the authors state that they "evaluated the role of VEGNET as a methodology to assess... However, the presented study is not an evaluation of the VEGNET tool. An evaluation of a tool should include a comparison with other methods, or at least one other method. And this is not the case in this study. The VEGNET methodology has probably been tested/evaluated in other studies, but this study should in my opinion not be presented as an evaluation of the VEGNET methodology.

Response: We appreciate the comment. We will remove it rephrase this in the discussion, to specify that the laser terrestrial scanning was useful to detect changes in structure among plots, rather than the results are showing the utility of Vegnet to assess successional changes.

Major comment 10

- The authors conclude on page 17165 (line 11) that their results suggest that lianas may be modifying the successional path for these forests. Although I believe that this phenomenon is very likely, the presented results are not strong enough and the setup is too limited to support this conclusion (see my comments above).

Response: We acknowledge our small sample size, and the limitations of our study and that's why our conclusions in the manuscript are stated as suggestions and hypothesis. The fourth paragraph in the discussion suggests that lianas may be modifying the successional pathway, and we state the reasons of why this may be happening, and as mentioned in the introduction this is a hypothesis previously formulated in the literature. We could moderate the writing in this part if the editor considers it necessary to improve clarity.

Minor comments:

- Also refer in the introduction to the recent paper of van der Heijden et al. 2015 inPNAS

Response: We will include this paper in the revised version of the manuscript.

Referee 2

We thank Referee No. 2 for his/her comments and suggestions. They mirror the comments from Referee No. 1 in some aspects and we will refer to our previous responses when appropriate.

General comments:

The authors have undertaken an interesting study of the structural effects of lianas in-tropical dry forests and the extent to which structural changes may be detected using ground based lidar at different stages of forest succession. Furthering our understanding of the role of lianas in forest successional processes is of great merit in terms of-forest management in general and carbon accounting in particular. The use of ground based lidar (terrestrial laser scanning, TLS), as a structural measurement tool is reasonable in the context of the study. There are some aspects of the study which need to be improved to make the manuscript suitable for publication. These can be divided into two main categories:

Comment 1

1. Description of the lidar metric 'Radius of Gyration' (RG) as a means of describingforest structure. The authors have given a conceptual description, but I still have troubleunderstanding what it means, ecologically or structurally. For example, what would an'increase in RG' look like in the forest? On page 17165, line 5: ": : :Stands

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without lianasshowed a significant gradual increase in the RG. This is consistent with accumulation ofbasal area, vegetation material and biomass accumulation. . .". How does an increasein RG relate to an increase in basal area? Some further descriptive words or illustrative(even simulated) examples of PAVD profiles with different RG values would help greatly.

Response: We thank you for the comments and we agree on the need to provide additional clarification. As described above, RG provides a proxy to general forest volume. The greater the overall height, stratification and biomass of the forest (as a function of succession), the larger the RG value. The relation between RG and succession is evidenced in the the RG values obtained in Early, Intermediate and Late sampling plots with no lianas (Table 1). More basal area in a forest, means more hits and returns registered in the laser scan, and higher PAVD values per forest height.

In a successional trajectory, basal area and tree height are low in a early stage forest, so RG is low as well. A PAVD profile will show a large concentration of biomass at lower heights in this case. If the forest increases in overall height, stratification and biomass, laser returns are received from greater distances and the distances between PAVD values and the centroid increase, and so the RG increases its value. So, basal area and tree height increases as trees increase their DBH towards a late stage forest, but since stem density decreases in the understory and a greater amount of hits and returns now come from branches located in the sub-canopy and the canopy, changes include not only an increase in RG value but also a change in the PAVD vertical profile where larger plant volumes can be observed in the canopy and subcanopy strata.

The presence of lianas affect forest structure, and this is registered in the distances between PAVD values and the centroid of the vertical profiles of liana infested plots, therefore affecting RG values.

We fully agree with the reviewer that descriptive works and probably an illustration are necessary and we will include it in the next version of our paper.

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Comment 2

2. Field plot selection and description. This is perhaps the biggest issue. A totalof fifteen plots were sampled across three different forest successional stages: early, intermediate and late. Of these, 9 sites had lianas and 6 did not. A detailed descriptionof these plots is critical as the basis for subsequent analyses. Specifically:

Response: We have tried to cover some of the points associated to this issue in the previous responses to the referee No. 1. We defined successional stages as classified in previous studies for the same study area (see Arroyo-Mora et al. 2005). Successional stages as classified based on forest structure using and age since land abandonment. Early successional stages comprise an area of sparse patches of woody vegetation and shrubs, and they only have a single stratum of tree crowns without lianas. The vegetation composition of this successional stage includes several species that lose most of their leaves during the dry season (Arroyo-Mora et al. 2005). The intermediate successional stage has 2 vegetation layers. The first one comprises fast growing deciduous tree species, shade-tolerant evergreen species and juveniles of tree species, which represent a second vegetation layer below the canopy. The late stage consists of 3 layers of vegetation. The upper layer consists of trees up to 30 m height, while the second layer consists of juveniles of all ages and heights, as well as a number of species that live entirely in the understory (Kalacska et al. 2004; Arroyo-Mora et al. 2005). We really appreciate the comments and we will include this section in the next version of the manuscript to improve the paper.

Comment 3

a. Describe the inherent between-plot variance within succession classes without-lianas. It is difficult to know whether statistically significant differences in PAI, PAVD orRG metrics could be observed between plots within the same succession class with-outlianas. This then makes it difficult to judge the significance of differences between plotswith- and without-lianas.

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Response: We conducted a Kruskal-Wallis test to compare the PAI, PAVD, and RG in plots without lianas, and we found no difference across stages for PAI. The RG and PAVD were also similar between intermediate and late stages. But the RG and PAVD were significantly lower in the early stages compared to the late stages. We can add this result to the manuscript to improve clarity. We consider this result of significant differences in RG reinforce our hypothesis that successional trajectories increased positively in plots without lianas, as this test also showed significant greater values for RG in late stages.

Comment 4

b. What is relative location of the plots? It is interesting to note in Figure 2 that theintermediate-aged plots with lianas are approximately 4 meters taller that the intermediateplots without lianas. Is this caused by lianas or geographical differences relatedto climate, topography or soil. A map illustrating the plot locations would be useful.

Response: Many thanks for this comment. A map with the location of the plots will be included in the next version of the manuscript. Forest are more or less of the same age since abandonment and therefore regeneration started right after the Santa Rosa National Park was created in 1971. The key element here is the pathway of succession: either controlled by vertebrates or by wind dispersal (Castillo et al. 2011, 2012). We will include a description of this on the paper and provide a map as requested.

Comment 5

c. In what way might the classification of age classes predetermine the observed differencesin PAI, PAVD or RG metrics? Page 17158, line 15 mentions that the numberof vertical strata" was one of the criteria used to differentiate age classes, a priori.

Response: Indeed, strata play a key role on the differentiation of succession as well as other elements such as LAI, PAI, canopy closure and species composition (all elements

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already described on several papers since 1998). We will include a better description of the plots based on our previous work.

Comment 6

d. How does liana density vary between plots? Is there any way to quantify this in termsof stems-per-hectare of lianas or liana-affected trees within the plots? On page 17165,the last paragraph discusses the general lower density of lianas in late, compared tointermediate, successional stages. This naturally raises the question “how does lianadensity vary within and between age classes in the sampled plots”?

Response: We conducted a Kruskal-Wallis test to compare the intermediate and late stages with lianas, and we did not find significant differences neither in the absolute number of lianas, neither in the number of lianas per hectare. We can add this information to the manuscript to illustrate the within-plot variation in sites where lianas are present.

Detailed comments:

âĂć p. 17154, line 18: “: : :distinction of vertical strata and the vertical height of accumulatedPAVD”. Suggest changing this to “distinction of vertical strata and canopy height”.

Response: We will do it as requested.

âĂć p. 17155, line 11: change “old growth forests” to “old growth tropical forests”.

Response: We we will do it as requested.

âĂć p. 17156, last paragraph.: “Ground LiDAR has demonstrated the capability to measurecanopy properties such as height and cover (Ramírez et al., 2013) and tree architecture(Lefsky et al., 2008), using terrestrial laser scanning systems (TLS): : :”. Suggest removing “: : :using terrestrial laser scanning systems (TLS)” as this is synonymous with ground lidar in the context of this study. p. 17157, line 2: “: : :Laser 65

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Scanners: : :”. Check.

Response: We will do it as requested.

âĂć p. 17157, line 3: “: : :pulses emitted in the visible or near-infrared comes into contactwith an object, part of that energy is reflected back toward the instrument: : :”. Technically,other wavelengths are reflected too. Lidar systems operating in the short-waveinfrared and even ultra-violet are common. Perhaps remove or qualify the wavelengthspecificity.

Response: We will specify the wavelength used.

âĂć p. 17157, line 23: “Significant increases in vertical structure with stand age (e.g., as aresult of increases in basal area, height and volume with stand age): : :”. Despite theexamples, I am a still confused by the terminology “increase in vertical structure”. Doyou mean “structural complexity”?

Response: Yes, we agree with this suggestion. We will change the phrase to "Structural complexity".

âĂć p. 17161, line 9: “we used the RG to relate the shape of the PAVD profile to forestbiomass at the footprint level (3600 m2 or 0.36 ha)”. At the fixed scan zenith angle of57.5 degrees the plot area is defined by the mean canopy height, as this dictates thehorizontal distance from the instrument when the laser exits the canopy. If the treeswere all exactly the same height (h), the laser would exit the canopy at a distance of (h * tan(57.5 degrees)), or approximately 1.6h from the plot center. At h = 33 m the laserhas reached its maximum effective range of 60 m as defined on page 17160, line 17.Based on the PAVD profiles in Figure 2, the minimum and maximum canopy heightsare approximately 10 m and 18 m, respectively. This translates to plot areas of 0.08hato 0.26ha.

Response: The footprint given was intended as a conservative overall approximation, but we will be more specific and include the footprints using real height measurements from the instrument as suggested.

âĂć p. 17162, line 9: “A change or no significant increase in PAI as a function of RG duringsuccession would suggest that lianas may be altering the successional trajectories: : :”.This is somewhat confusing. A change in what way?

Response: The rationale for understanding this statement is explained in the response to the first question. We will, however, clarify and be more specific in stating the way the trajectories are altered.

âĂć p. 17162, line 14: “: : :the radius of gyration (RG) showed a significant increase alongin succession in plots with no lianas (Table 1): : :”. First, consider removing the words“along in succession”. Secondly, the RG metric increases in plots with no lianas in thelate successional stage plots only. In the intermediate age class the reverse seems tobe true. Please clarify.

Response: We will remove or rephrase the sentence. We disagree with the latter comment. Although an internal variation in RG values in successional stages exists, the increase in RG between successional stages is evident in Table 1.

âĂć P. 17163, lines 14 & 15: Should the text refer to Figure 2?

Response: We we will make these changes in the next version of the manuscript.

âĂć p. 17166, line 12: The “vertical height of PAVD” is better described simply as “canopyheight”.

Response: We we will make these changes in the next version of the manuscript.

âĂć p. 17174: The Figure 2 caption refers to a “Time-series” of PAVD, yet there is notimescale or differentiation of scan dates in the figure. Suggest removing the “timeseries” terminology and simply state “Figure 2. Plant Area Volume Density (PAVD)values calculated by: : :”

Response: We we will make these changes in the next version of the manuscript.

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