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Biogeosciences Discussions
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Interactive comment on "Detecting tropical forest biomass dynamics from repeated airborne Lidar measurements" *by* V. Meyer et al.

V. Meyer et al.

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Dear Reviewer,

We are grateful for your review comments and recommendations. We have incorporated most of your suggestions and comments in our revised manuscript and we think the paper has improved significantly. Enclosed please find our responses to the review comments.

1. I worry that dividing the data into 20 x 20 m subplots is of questionable value. This is for two reasons: a) LVIS footprints are already 20 m. The authors have used the central point of the footprints to decide whether or not the LVIS footprint should be included in a subplot or not, which is sensible, but in reality much of the LVIS footprint

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at this resolution will include data from outside the 20 x 20 m subplot. I do not think it is appropriate to compare 20 x 20 subplots to LVIS data. This is different for the DRL system – as long as the geolocation is good then going to small subplots for DRL is fine.

Answer : We agree that 20m subplots are not appropriate to estimate forest biomass accurately. However, we have included the 20m analysis of the ground data and remote sensing data in order to demonstrate the importance of the scale of analysis in estimating forest biomass. There are many reported results in the literature, particularly in the REDD community that small plots are recommended for biomass estimation from field inventory and remote sensing data. Our results can shed some light in the errors associated with small plots and provide justification for the use of large plots. In the case of LVIS data, the lidar shots in general have overlaps and can be used in theory to capture forest height information at 20 m resolution. However, regardless of the density of LVIS data over BCI, we agree that large discrepancy between ground and LVIS shots can be a source of error. However, the same results are found when we used the 1-m footprint DRL data. For this reason, we are keeping the 0.04ha scale in our AGB estimation analysis. However, we agree that once it has been made clear that AGB estimation at scales below 1ha does not show any good relationship, there is no use of doing the AGB change analysis at these scales when using Lidar. We are now showing the Lidar-derived AGB change analysis at 1ha only.

b) Geolocation errors will dominate at the 20 x 20 m resolution. There will be errors in location of ground, DRL and LVIS systems; these are hard to quantify, but will be on the order of a few meters at best. These are relatively negligible at a 1 ha scale, and less dominant at the 0.25 ha scale, but at the 0.04 (20 m) scale they will dominate.

Answer : Error in location of the small footprint Lidar and LVIS data is at the range of 1-2 m as reported in the literature. The main issue at the 20m scale is that the crown of a tree located close to the edge of a subplot can contribute to the biomass of adjacent subplots and therefore contribute to the Lidar-derived estimation of biomass in these plots, whereas it only contributes to the estimation of biomass of its assigned subplot in the ground data (see Figure S7). This issue applies to both LVIS (depending on where the central of the footprint falls) and DRL. At the same time, ground estimation of biomass using allometric data at 20 m resolution can have large errors due to the small number of trees. Allometry, being a regression model, provides accurate estimation of biomass when the number of trees in the plot are large, hence at large plot size (Chave et al., 2004). Therefore, a combination of large errors of ground estimated biomass and geolocation and potential other remote sensing errors make the analysis at 20 m resolution difficult and subject to large uncertainty.

2. RS100max is not defined in the main paper. It is in the supplement, but I feel strongly that it should be explained in the paper as it is used in the LVIS regression equation (equation 1).

Answer : We are now using five metrics for each sensor : RH25, RH50, RH75, MCH and RH100. For LVIS, MCH was previously called "RH100" in the paper, while the new RH100 used to be "RH100max". We believe it makes more sense to use these names. We are describing these metrics in the main paper, as well as the two regression models that we use to estimate AGB. The first approach uses all five available metrics in a power law model, which fits the data better than a linear model. The second approach uses MCH as a single metric in a power law model. We are testing this approach because the regression models for LVIS and DRL are very similar when using this method. We are reporting the results for both approaches in the text and in the figures. Figure 2 shows the relationship between MCH and AGB.

3. In this Discussion, page 1969 line 23, you state that "Differences in one height metric derived from Lidar waveforms . . . had no significant relationship with differences in forest biomass derived from the analysis of field surveys." This is a critically important finding, but it is hidden away in the discussion and no calculations, p-values or results are shown.

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Answer : Our analysis did not show any relationship between ΔAGB ground and ΔRHs. We added a paragraph describing how we tested this approach first, as one would expect biomass change would correlate with change in height metrics. We explain that because the two Lidar datasets have many different characteristics, their respective height metrics are not directly comparable and it is not possible to get AGB change by directly looking at the change in RH metrics. A section comparing the two sensors and how these differences affect their respective height metrics is presented in the supplementary material. Furthermore, we are concentrating only on old growth forests where changes of biomass and changes of height may be difficult to correlate. In other studies, secondary forests are included in the data pool, helping with developing a better correlation between height change and biomass change. However, we are now comparing top canopy elevations (RH100E), which are not affected by ground finding errors and are comparable at the footprint level (Figure 1 and Figure 4). We used a 20m circular footprint to extract the DRL data for each LVIS shot within the 50ha plot. Although this analysis does not translate to AGB estimation, it gives valuable information in terms of canopy change. We are showing that RH100E DRL is lower than RH100E LVIS by 1m.

4. On page 1966 lines 16-20 and elsewhere the authors make much of the ability of LiDAR to see very similar change results at the scale of the whole plot as using the field data. However, this is not in the remotest surprising, and, unlike the results at a smaller scale, would be entirely expected given the inputs. The relationships between LiDAR and ground data were developed separately for 2000 and 2010, so any changes in the ground data would automatically be seen in the LiDAR data when the full plot is considered. These numbers can still be reported, but the text should clearly state that given the methodology (field data calibration available for both dates) an exact match it expected. This would be different if the calibration had been done using ground data from one time point only, or only a small subset of the plot data, but that is not the case.

Answer : We agree. Because the Lidar data is calibrated with the ground data at each date, it is expected that the Lidar-derived AGB change results at the plot scale would be similar to the ground AGB change. We are still reporting the numbers in the paper, but we specify that this result was expected, given the methodology that we used.

Minor comments 1) Abstract line 16 (and later) it would be good to put a p-value on this sign of 34 out of 50 plots detected correctly.

Answer : Our new results can predict the sign of 30 subplots (with the 5RH approach) and 32 subplots (MCH approach), which corresponds to p-values of respectively 0.1 and 0.033.

2) Page 1959 line 13, should be 'wood specific gravity' or 'wood density', not a mixture of both.

Answer : We are indeed meaning "Wood specific gravity".

3) Page 1966 line 3 – it's not stated but presumably the relative contributions of each metric is for the DRL data only? Could we see the figures for LVIS too?

Answer : LVIS metrics contributions have been added. It shows that RH100LVIS contributes more to the estimation of AGB than RH100DRL.

4) Page 1967 line 17 – I do not understand the meaning of 'amplitude of differences'.

Answer : "amplitude of differences" has been changed by "range of variance".

5) Page 1969 line 1-5 – there is no scientific validity in comparing one plot to the Baker et al. 2004 paper, which compared very many plots across the basin, a subset of which showed negative biomass change, but on average showed an increase in biomass. I do not think this sentence should be included – the comparison can be made, but this does not 'run against recently published results' because a single data point cannot possibly negate a study involving many plots. Pan et al. 2011 (Science) should probably also be cited here.

Answer : The comparison has been changed and Pan et al., 2011 is now cited.

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6) Page 1969 lines 18-21 – this paragraph could be extended to add in the evidence and theory that drought is associated with the death of large trees, so this is consistent with that hypothesis.

Answer : We extended this paragraph and included material and cited references that provide information on tree mortality and droughts in different tropical forests.

Supplementary information 1) Page 1: what altitude was LVIS flown at? Would be useful to include the incidence angle range for the two lidar datasets as well.

Answer : LVIS was flown at 1000m. Scan angle of LVIS is 12°, DRL is 17°. We added a table (Table S1) comparing the two instruments and we are analyzing the impact that these differences have on the two datasets and the ability to compare them in the supplementary material.

2) Page 6: Why is Figure S2 only shown for DRL data? Would be good and interesting to see this for LVIS too. Similarly it would be interesting to see the relationships between say RH75 or RH100 with AGB: all we have is the full model plotted against AGB. There is unlikely to be much relationship at the 0.04 ha, and this feeds into my major point about why the analysis was done at this resolution.

Answer : We are now also showing Figure S2 for LVIS data. We are showing the RH relationships at 1ha only. We also added a figure showing the relationship between MCH and AGB in the main paper (Fig. 2), and a figure (Fig. S4) showing the relationship between the relative height metrics (RH25, RH50, RH75, RH100) and AGB in the supplement.

Please also note the supplement to this comment:
http://www.biogeosciences-discuss.net/10/C2146/2013/bgd-10-C2146-2013-supplement.pdf

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Interactive comment on Biogeosciences Discuss., 10, 1957, 2013.

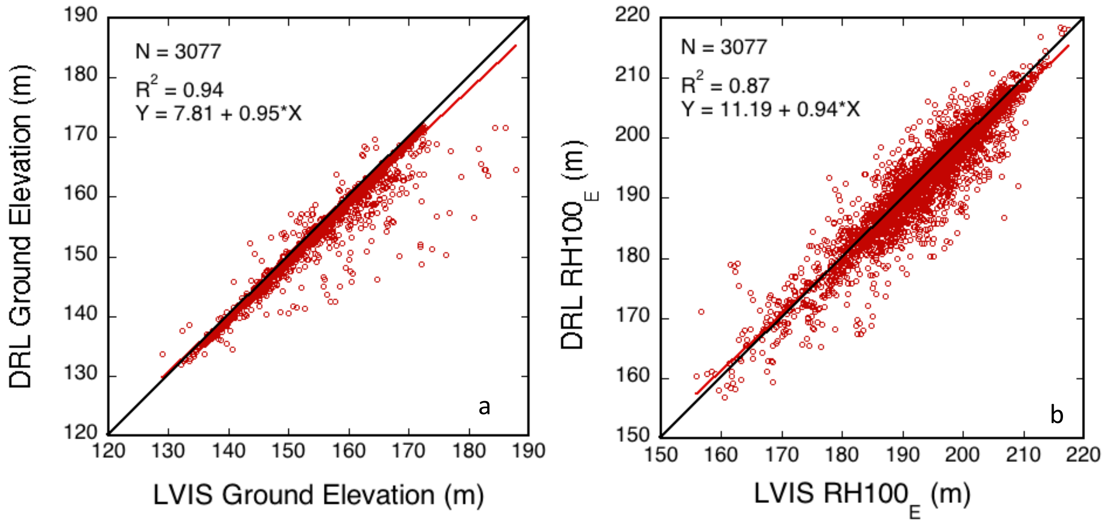

Fig. 1. Relationship between LVIS ground elevation and DRL ground elevation, and between LVIS top canopy elevation and DRL top canopy elevation.

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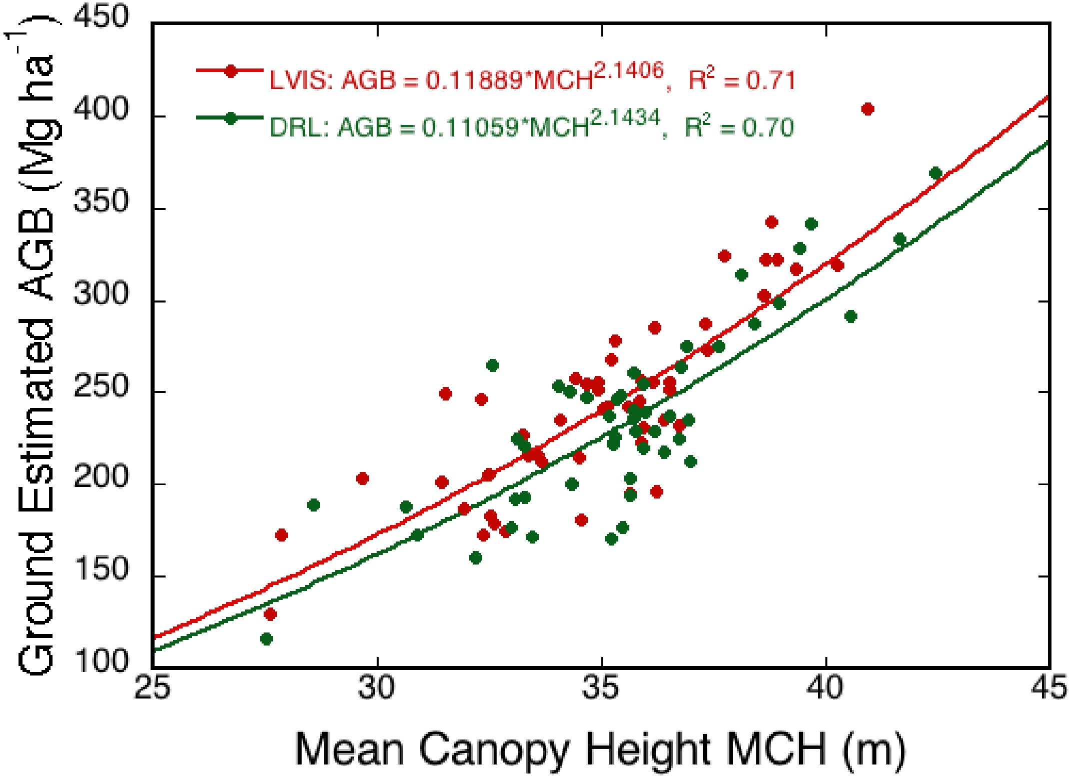

Fig. 2. Relationship between ground estimated AGB and MCH from LVIS and DRL, at 1ha.

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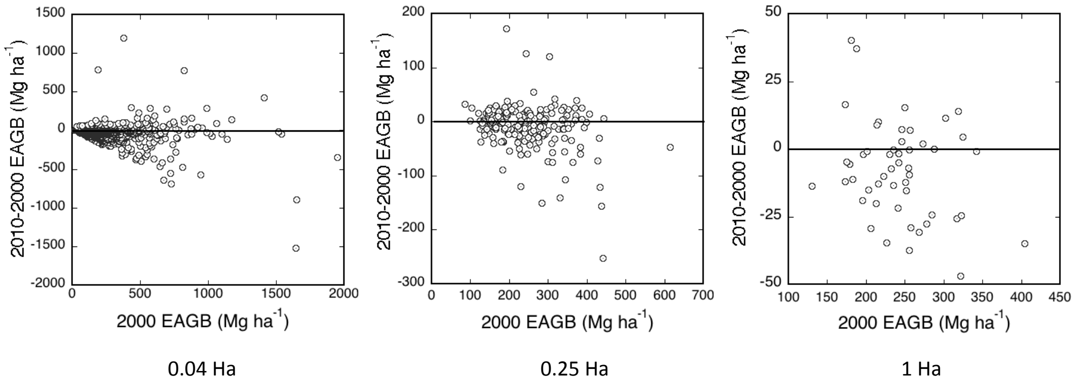

Fig. 3. Ground AGB change between 2000 and 2010 at 0.04ha (left), 0.25ha (center) ad 1ha (right).

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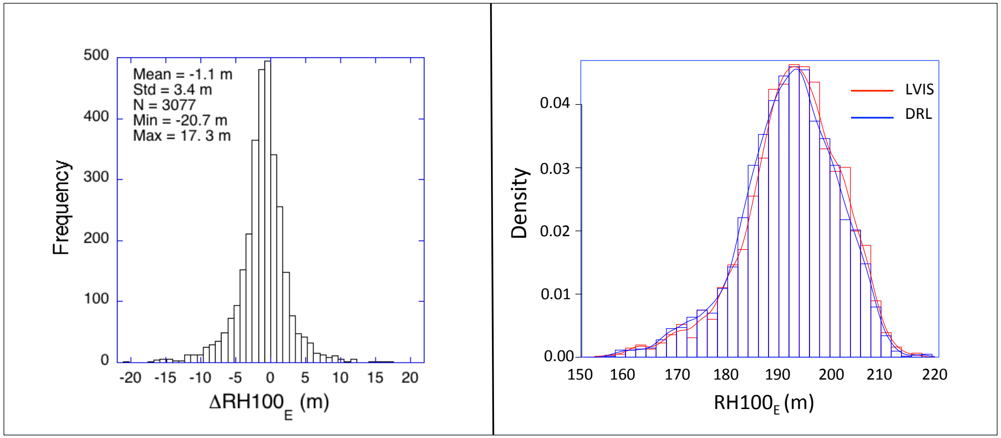

Fig. 4. Distribution of RH100E change between 1998 (LVIS) and 2009 (DRL) (a), and distribution of RH100E for each date (b).

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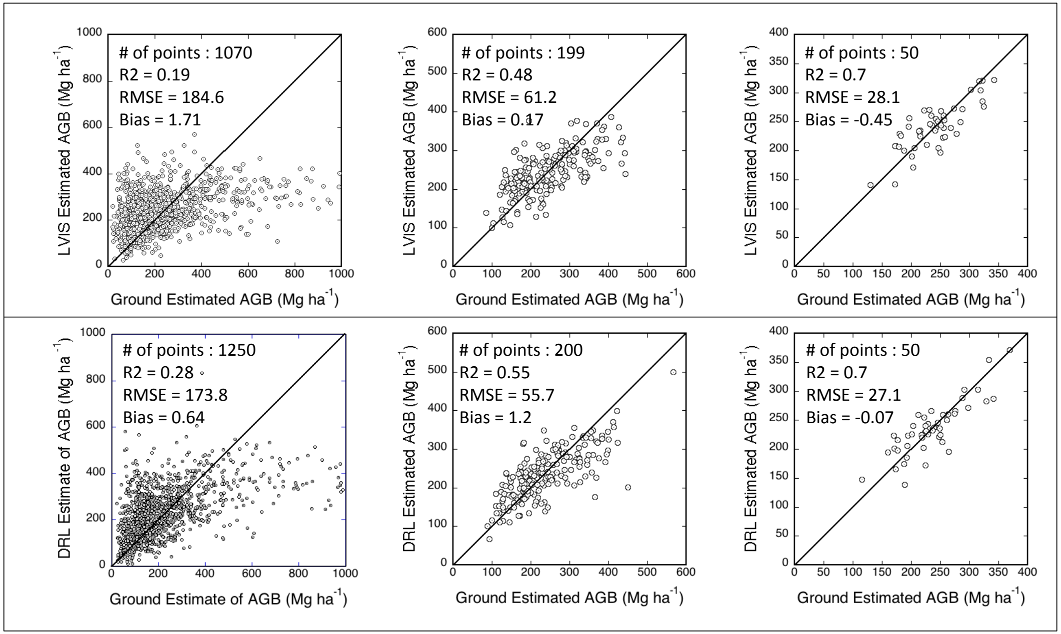

Fig. 5. Relationship between Ground estimated AGB and Lidar estimated AGB (top : LVIS, bottom : DRL), using five height metrics in the regression model.

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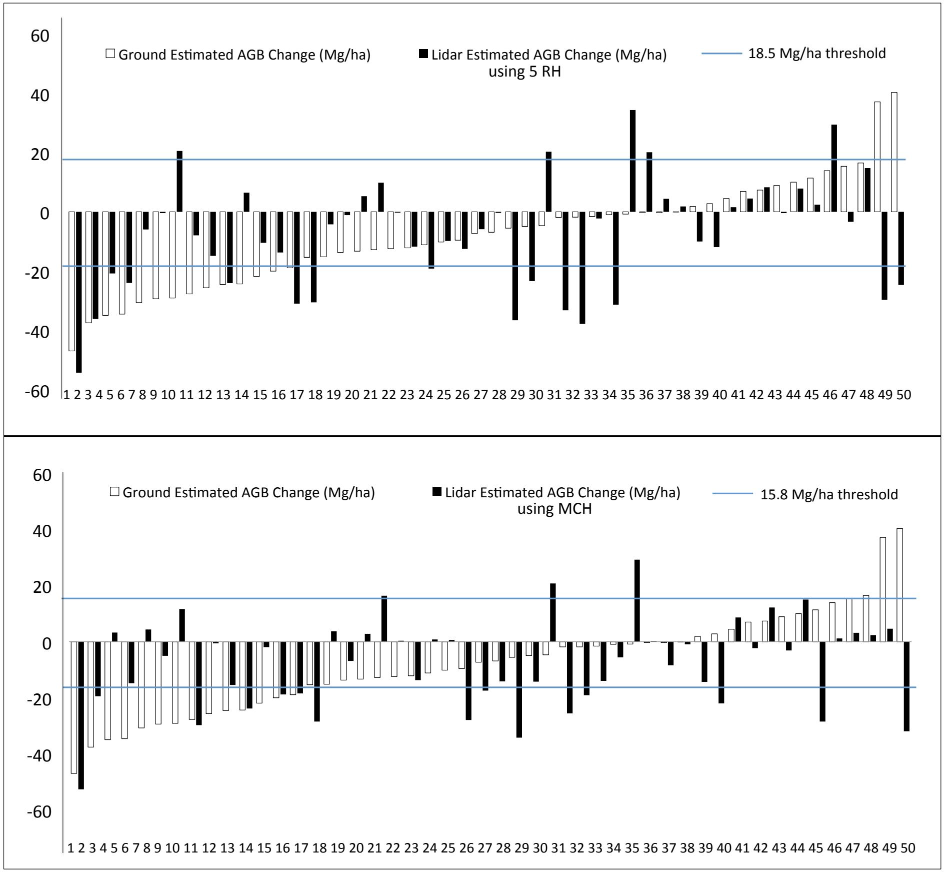

Fig. 6. Comparison of AGB change (Ground estimation vs. Lidar estimation) for every 1ha subplot using the 5RH approach (top) and the MCH approach (bottom).

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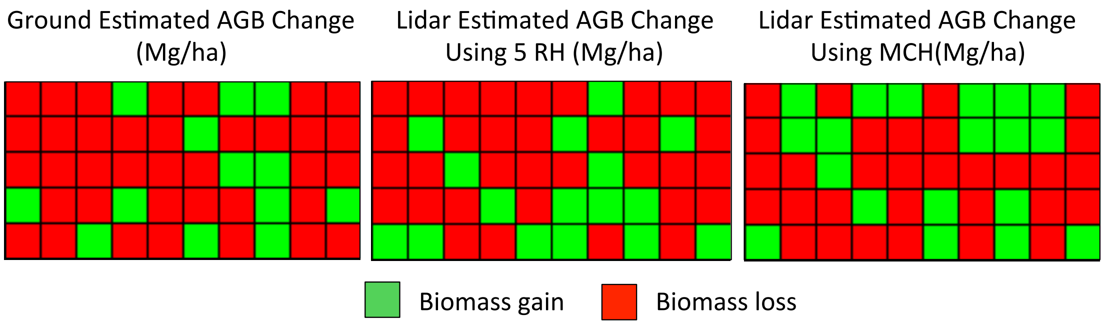

Fig. 7. AGB change (in Mg/ha) from Ground estimations (a) and from Lidar estimations (b and c) in the 50ha plot at 1ha spatial scale.

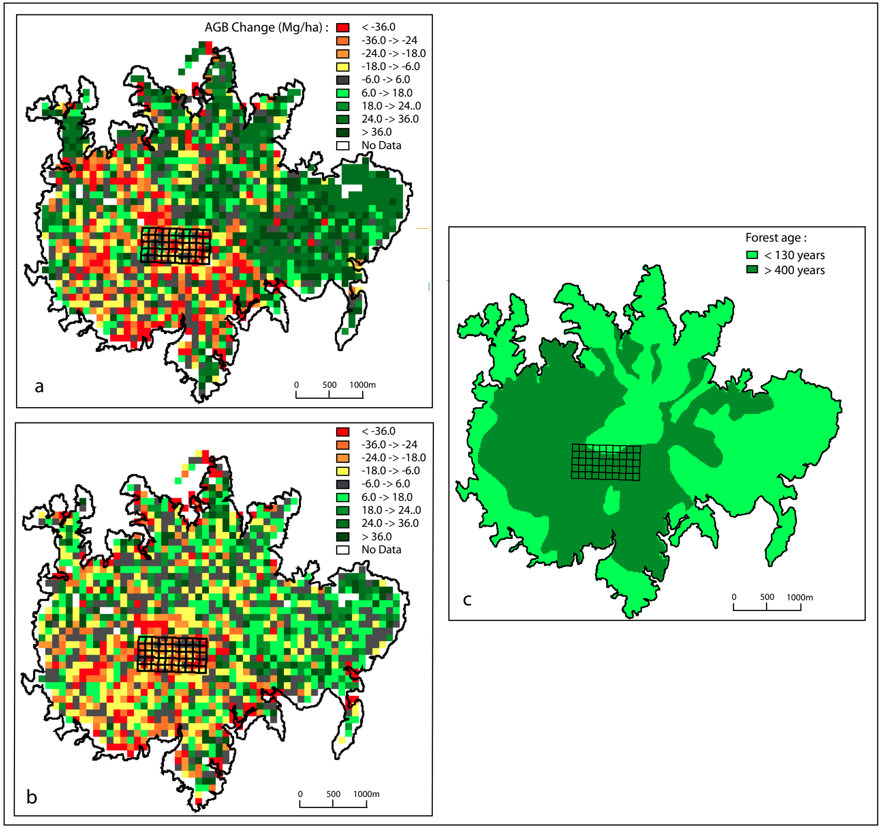

Fig. 8. AGB Change maps between 2000 and 2010 (a and b) and Forest Age map (c).

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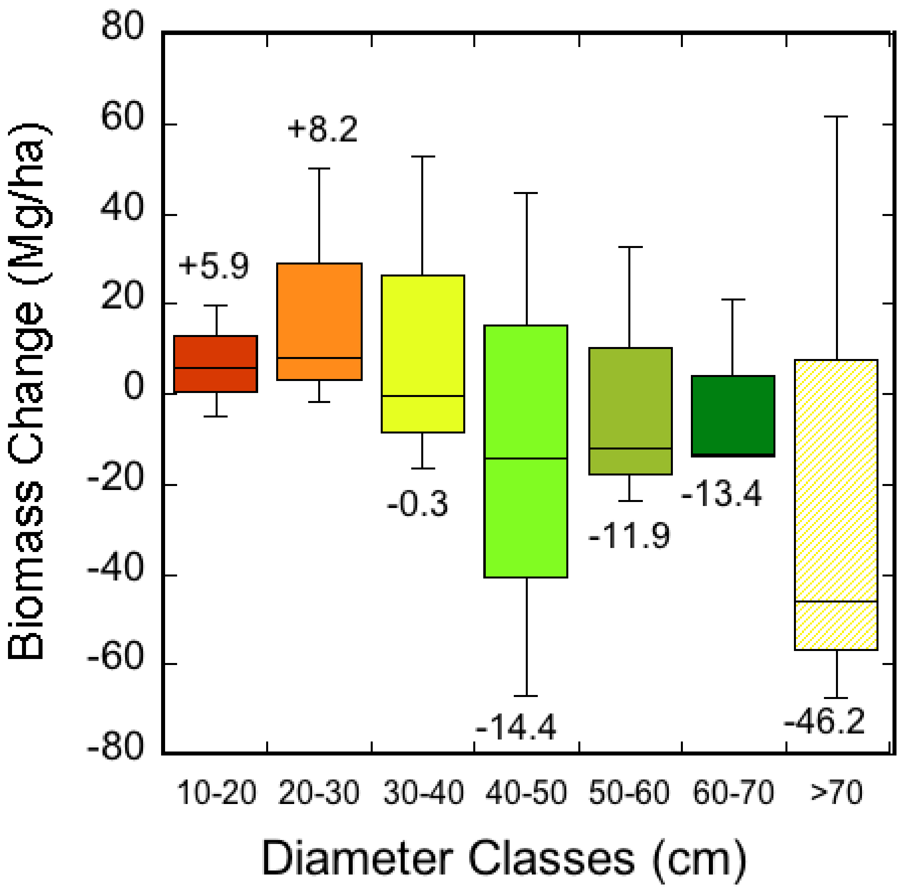

Fig. 9. DBH classes and AGB Change (20m spatial scale).

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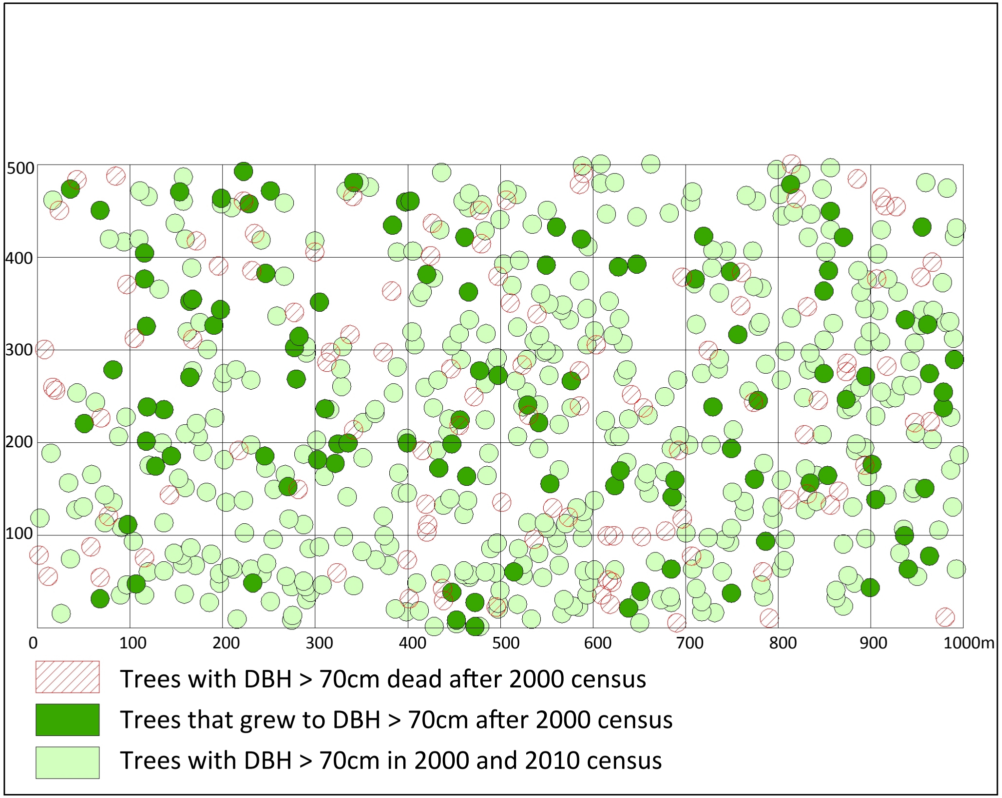

Fig. 10. Dynamics of big trees (DBH > 70cm) in the 50 Ha plot between 2000 and 2010.

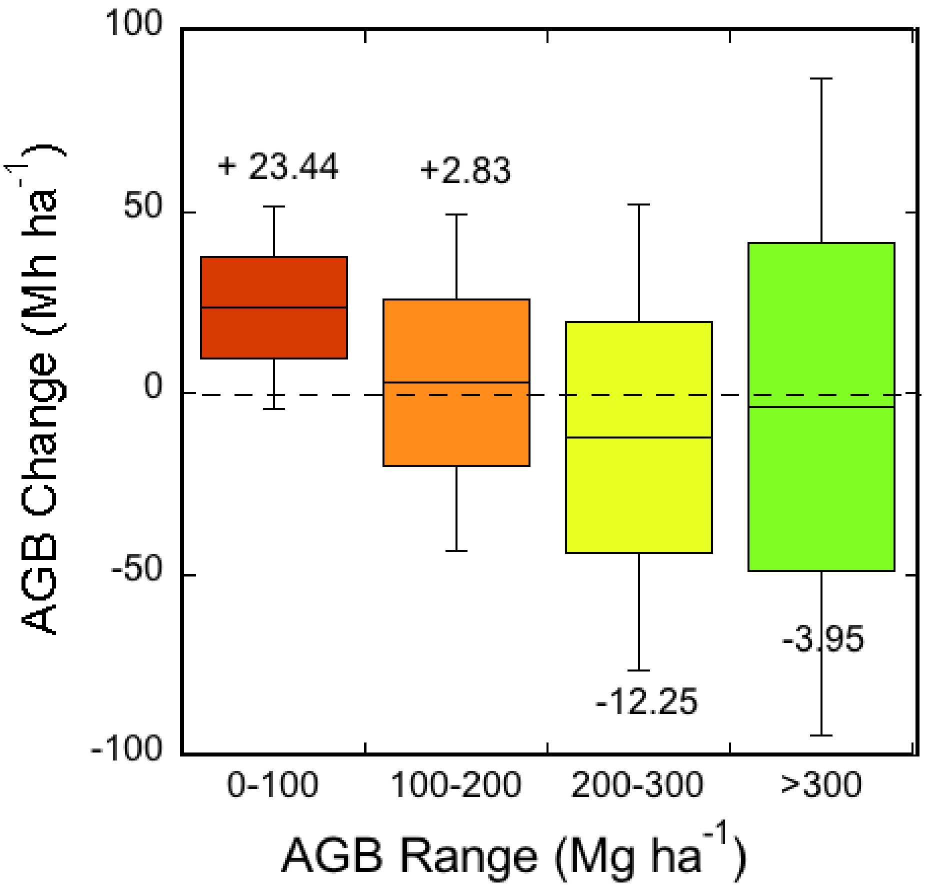

Fig. 11. Figure 11 : Lidar-derived AGB range and AGB Change (20m spatial scale).