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Interactive comment on "Robust processing of airborne laser scans to plant area density profiles" *by* Johan Arnqvist et al.

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We thank Referee #1 for a constructive review. While we prefer to wait for more Referee comments before adjusting the manuscript and properly addressing all issues raised, we here take the opportunity to give an initial response on the criticism raised mainly regarding the comparison with ground-based observations.

"No accuracy assessments/ statistical analysis to validate the improvement of the new proposed results."

Our paper is based on the small discovery that it is possible to trace nearly all (more than 99%) canopy reflections to the emitted laser pulse from which they originate. To illustrate this aspect, we have added the grey lines in Fig. 5. To be able to trace the

pulse throughout the canopy could lead to future improvements concerning comparison with ground-based techniques, since it provides more knowledge on how the pulse is affected by the complex canopy geometry. Hence, the new method more closely resembles the very early works for estimating leaf area by sampling canopy elements using long poles (Wilson, 1959), than other airborne lidar methods. Rather than poles, we here use the geometric lines defined by the lidar pulse. Based on this discovery, our main scope in the study is to introduce a new method for a physically sound plant-area-density estimation and evaluate the resulting magnitudes to other airborne lidar methods. To our knowledge, such a comparison using several ALS-> PAD methods is the first of its kind. A thorough comparison with ground-based observations would need to address the well-known weaknesses in current ground-based techniques (in example, the unknown footprint of the PCA-2000 by LiCor as well as the assumption of homogeneity) and the issue of canopy elements shading each other using fish-eye lense photography (Yan 2019), and this is beyond the scope of the current paper. In our study, we have instead chosen to focus on the demonstration of resolution dependence and add insight using the well-known framework of Jensen's inequality. It would be easy to add a more careful comparison with the ground-based reference method, such as a paired t-test or an r2 estimate, but given the referee's second comment concerning readability, we suggest to rather tone down this comparison and move it to an Appendix. The positions where we have access to reference data (seen in Fig. 2 and 3) all lie within relatively low PAI regions, and there is not much variation in PAI magnitude. This is particularly evident in Fig. 3. As Referee #1 pointed out, there does not seem to be much difference between SR and AR methods based on comparison with ground-based methods, and this is true. However, by studying Fig. 2 and Fig. 3 it is evident that there are areas with very large differences between SR and AR. The reason for this is highlighted in Fig. 5 and accompanying discussion, and we will work to clarify this point in the next version of the paper. In summary, we share the referee's view that a quantitative comparison would be desirable, but argue that given current uncertainties in the referred ground-based techniques, such a detailed comparison adds

too little value to represent a main part of the paper.

"And there is no explanation why the scaled intensity is able to fix the issue of ground PAD reflections in IR"

Hopefully the revision will clarify our explanation, but in the meantime we would like to direct attention to Fig. 5 a, b, f and g, discussion along that figure and in Sec. 2.3, line 15. Since the IR values are scaled for each individual pulse the value of any individual pulse has an upper limit of 1. For the case when all the pulses have returns that come from both canopy and ground, the improvement of SR relative to IR will be minor, but in case of heterogeneities, there will be pulses that only have ground reflections despite that the there is a canopy above since the beam is tilted. . In this case, there will be a larger difference between the two methods. The value of first-order ground returns will always be 1 in SR, but in IR the value will be that of the backscattered intensity (compare blue points at the ground in Fig. 5). As pointed out previously (Wagner et al. 2008), this can lead to a bias in the PAI/PAD estimates if the albedo of vegetation and ground is different. In summary, if there is a considerable amount of 1st order ground returns, and the ground has a different albedo to the laser beam, the SR method should limit that bias and be superior to the IR method.

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