Reply to the interactive comment on "Species-specific temporal variation in photosynthesis as a moderator of peatland carbon sequestration" by Aino Korrensalo et al.

Anonymous Referee #1

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Korrensalo et al. presents one season of field measurements (eddy covariance), controlled laboratory experiments and modeled results of net and gross photosynthesis rates and/or gross primary production from a boreal bog in southern Finland and emphasizes the species specific contributions and the integration of plot to ecosystem scales. In particular, Korrensalo et al. differentiate between the vascular and bryophyte (moss) contributions, where the latter is oftentimes given a shadow-role in the literature of carbon and energy fluxes. Here, mosses are emphasized to play an important role in the overall wetland ecosystem-level flux. The two approaches in reaching the total system fluxes (eddy covariance and species-specific laboratory experiments) arrive at similar total seasonal fluxes. However, the figures suggest rather large seasonal differences (if I interpret them correctly). I would therefore appreciate increased attention to why that is. In fact, I think this difference is an interesting story (the story?) that emerged. Below are some thoughts that came to me as I reviewed.

We thank the reviewer for the time and effort used to our manuscript and for the thoughtful comments, which have been addressed one by one below. We agree with the reviewer that the difference between the two methods should be discussed more clearly than it has been done before. We hope the suggested clarifications below sufficiently bring up the reason behind these differences.

However, we would be more than glad to hear through the discussion forum of the journal if the reviewer thinks we have not fully understood her/his ideas or do not answer the questions with sufficient accuracy.

Please define gross primary production (GPP), net (PN) and gross (PG) photosynthesis so reader who are not regularly working with these terms can follow your manuscript.

Thank you for the comment. We will add the definitions of these terms (below) in the next version of the manuscript.

"In the scale of individual plant leaves, net photosynthesis (P_N) is the CO_2 gain of the leaves, which is the leaf respiration (R) subtracted from gross photosynthesis (P_G). In the ecosystem scale, net ecosystem exchange (NEE) of CO_2 between the ecosystem and the atmosphere consists of ecosystem respiration (R_{eco}) subtracted from gross primary productivity (GPP). GPP is the rate by which CO_2 enters the ecosystem through P_G of all the individual leaves together (Chapin et al. 2011)."

Chapin, F.S., Matson, P.A., Vitousek, P.M., and Chapin, M.C. 2011. Principles of terrestrial ecosystem ecology. 2nd ed. Springer, New York, N.Y.

All figures: The graphs are presented with units, but there are no labels on the y-axes. Please include labels.

Thank you for pointing out the mistake. We will add the labels to the y-axis of all graphs in the next version of the manuscript.

Figure 1a: Why the discrepancy between the "total" and "eddy covariance" in Figure 1? It is unclear from the figure caption, but I think the two curves represent the laboratory derived estimate (total) and the eddy covariance estimate (eddy covariance) of the same variable? So why is the Total > EC in early season and EC > Total in later season?

After reading the comment we realized that our discussion on page 7, L30-38 about this matter is not clear enough. In the updated version of the manuscript we will clarify the discussion to better explain the deviations between the two methods. In the lab we measured potential photosynthesis of plants in their current condition (i.e., under various light levels in 20 °C temperature and optimal moisture, but in the physiological state impacted by moisture conditions in the field) and in the field gas exchange was measured under ambient conditions. The difference in spring between the two methods is likely due to the fact that both vascular plants and Sphagna had high photosynthetic potential (assessed as parameters k and Pmax that we measured in the lab), but were in the field limited by the low temperature. In the constant laboratory temperature of 20 °C this spring time potential was shown as high gross photosynthesis. In the end of the summer, a similar difference in temperature occurred between laboratory and field conditions. At this time, however, photosynthetic potential (again measured as k and Pmax) was low, and therefore the estimates of the two methods were similar. The higher mid-summer eddy covariance-derived GPP in comparison with laboratory measurements likely results from high above 20 °C temperatures concurrently with high PAR levels in the field. We should and will point out more clearly that our study did not take into account temperature dependence of photosynthesis.

Optimally we would have varied temperature as well as PAR while measuring photosynthesis of 19 species in our study site to capture the photosynthesis response to T and PAR over the growing season but unfortunately that was not achievable. Varying two or more factors concurrently has been done in studies focusing on one or few species but in here our main focus was in differences between the species, therefore we were only able to cover potential in one temperature level.

We thank you for the idea to point out in the manuscript that our results indicate ecosystem-level photosynthetic potential may be the highest at different time than ecosystem-level GPP (i.e. photosynthesis "in reality").

Figure 1d: What does "daily lawn surface water table" represent? I am confused by the word "lawn" (makes me think of a golf course). I suggest removing the smoothing curve and not include any line between dots unless the dots represents continuous daily measurements of water levels (there seems to be a larger data gap around Julian day 210).

Thank you for the comment! The term "lawn" is commonly used among peatland ecologists for a surface in peatland having an intermediate water table (in between hummocks and hollows). We did not realize that this term could of course be quite confusing for someone not familiar with such use of that word, especially when it is only defined in the study site description. We will add intermediate peatland surface to the figure legend.

We will gap fill the larger data gap around Julian day 210 using available manual measurements of water table depth.

Figure 1b: I suggest plotting mean daily air temperature and then present the min and max daily air temperature as a shaded fill behind the mean daily air temperature line.

This is a good idea. Will be done.

Figure 1 (figure caption): Why keeping the laboratory temperature at 20 C during the entire growing season if the mean daily air temperature only reached 20 C during a few days? What is the implication of this approach on the analyses? Can this partly explain the offsets in Fig 1a? We see a large drop in water tables in the field site following Julian day 120. The laboratory measurements tried to keep the temperature and moisture contents constant throughout the season, while the field measurements of air temperature and water table (ie moisture) present rather large variations. How does the limited moisture variability of the laboratory approach affect the overall conclusions stated by the authors? I am worried the authors may have over-stated their findings due to the complex relationships between water, air temperature and photosynthesis found in the field setting, especially considering the deviations in Figure 1a. In combination with Figure 2 (which I assume is based upon laboratory analyses, please clarify in figure text), it looks to me like the vascular plants may have been water-limited (too much water) in their photosynthesis in early season in the field (??)

It is a bit complicated that results and discussion are in separate chapters. Now in the results we show the different timing between the two estimates (laboratory and eddy covariance measurements) but we felt that we were fully allowed to discuss this only later, much later than the readers mind. We tried to work towards the discussion by adding daily temperature values as a sub-figure 1b below the comparison in Fig. 1a and by pointing out in Figure legend that lab measurements were conducted under constant 20 °C temperature.

We should and will open up the reasoning behind this choice in the section 2.2. The core of our manuscript is to show the significance of seasonal and interspecific variations in potential photosynthetic light response for the ecosystem level processes. For this we needed to make the measured photosynthetic parameters comparable over the growing season. We could either choose constant temperature and moisture for all samples or measure temperature and moisture response of photosynthesis and the latter was not possible due to the limitations of time. Temperature of 20 °C was selected simply because that is close to the room temperature and also realistic for the field conditions. Photosynthesis measurement devices have a limited capability of regulating the temperature and this temperature was possible to maintain in the laboratory. In our opinion the offsets in Fig. 1a are definitely a result of the constant temperature during the measurements. See also our plan to clarify the discussion section under your question related to Figure 1a.

Although we do agree that the effect of moisture on Sphagnum photosynthesis should be discussed in this paper, we think the constant moisture of the samples during the measurements is not as severe problem as it may seem. The physiological state of mosses is responding to prevailing moisture conditions in the field as shown by Hájek at al. (2009). In the case of Hájek et al. (2009) Sphagnum samples showed physiological differences related to site conditions over two weeks after sampling. Also in this earlier study, samples collected from the field were wetted before measurements. We think the low vascular plant photosynthesis in spring (Fig. 2) is mainly due to low vascular leaf area during that period. However, suffering from excess moisture is an interesting further explanation for this.

Finally, we will clarify all of the figure captions to make it clear, which data is based on laboratory or field analyses.

Figure 3b. Why the decreasing response of the Sphagnum species throughout the study period? The total seasonal gross photosynthesis is similar between the two methods, but the distribution of those fluxes over the season is rather different between the two methods (laboratory versus eddy covariance). This observation is currently not discussed in the manuscript and I think this is the most interesting piece of the results. I would like to see the text in the results section to address the seasonal variability that we see in the figures. The results section is currently focusing on the total seasonal values, while the figures show some rather interesting seasonal variations (in time and between methods).

We think the decreasing photosynthetic potential of Sphagna reflects the decreasing trend of water table over the growing season. Please see below the suggested additional sentences for the discussion to point this out.

"The seasonally decreasing Sphagnum P_G is likely to reflect the change in the moisture conditions. Water table depth, which together with precipitation is known to be the most important moderator of Sphagnum photosynthesis (Hayward and Clymo 1983; Backéus 1988; Lindholm 1990; Nijp et al. 2014), decreased at the study site over the growing season (Fig. 1d)."

We agree with the reviewer that our discussion regarding the differences between the two methods on page 7, L30-38 should be clarified. In the discussion we will explain more clearly, how the changes in photosynthetic parameters measured at the constant temperature results in different timing of maximum P_G (laboratory measurements) and GPP (eddy covariance measurements). Behind this were most importantly the seasonal changes in light response parameters Pmax (maximum light-saturated photosynthesis) and k (the ability of the plant to use low light levels). See also above our answer to your comment considering Figure 1a.

The results regarding seasonal variations of photosynthesis are presented shortly on Page 6, L18-26. We will consider presenting those results more in depth.

Please refer to specific figures in the discussion.

We will go through the discussion section and add appropriate references to figures there.

Page 7, Line 33: The sentence is odd. Remove "when" perhaps?

You are quite right, removing the word "when" will clarify the sentence.

The discussion refers to time by naming the month. I suggest all graphs use months instead of Julian day.

We will add the months as well.

The discussion or literature does not address the impact on hydrology to the photosynthesis, which, especially for mosses, can have a major impact.

Thank you for the good point, we should definitely address hydrology discussion. We add the following sentences on page 8, L16: "The seasonally decreasing Sphagnum P_G is likely to reflect the change in the moisture conditions. Water table depth, which together with precipitation is known to be the most important moderator of Sphagnum photosynthesis (Hayward and Clymo 1983; Backéus 1988; Lindholm 1990; Nijp et al. 2014), decreased at the study site over the growing season (Fig. 1d)."