Interactive comment on “Greenhouse gas and energy fluxes in a boreal peatland forest after clearcutting” by Mika Korkiakoski et al.

Response to Reviewer #1

General Comments: The study investigated all three main GHG gases (CO2, CH4 and N2O) and heat fluxes after a clear cut on a moderately drained boreal organic soil. The authors used a combination of eddy-covariance and chamber method for flux determination. Studies determining the effect on GHG after clear cut exits for mineral soil, but not for organic soil. Details are nicely discussed.

My main concern is the experimental design of the study. The paper is based on two years of CO2 measurement after the clear cut. Reference data (fluxes before the clear cut) are missing, although it is stated in the paper, that one year measurement of CO2 fluxes before the clear cut exits. These data are not published (p.11 ll.24-25). However the main conclusion (clearcutting turned boreal forest from neutral to C source) is based on these unavailable data. In view of the generally large interannual variability of carbon balances on organic soil, the main conclusion is weakly supported. Interannual variability is not even discussed within the paper, although the first year after clear cutting is drier and warmer than the following. Without a control site including GHG measurements it is difficult to figure out the influence of the clear cut and “normal” annual variability. It exits a control plot of a reference site, but only data of water table and soil temperature is included. There is a second EC tower, measuring above the canopy (p.4 l.27). It is not clear whether GHG flux data exits and could be used as reference. There are data from chamber measurement from the year before the clear cut (starting during mid-summer 2015). Without a reference-control site and only a very short time series before the clear cut (even not a full year) for CH4 and N2O, data interpretation is very difficult and weak. The weather conditions in 2015 are not discussed.
I would suggest including these data (CO2 balances before clear cut and GHG of reference/control site after clear cut) in order to get a complete dataset instead of publishing a partial data set with weakly supported main conclusion. In addition I would suggest to include basic information about soil properties and to check the paper for consistent data sets. See comments below.

1. We understand the concern of the referee about the unpublished data. We have measured CO_2 exchange with the EC method at the Lettosuo site for six years before harvesting the site, and these data are fully processed and analyzed. Based on this, we can conclude with confidence that the site is on average CO_2 neutral. The neutrality is caused by the fact that the emission from the soil (peat decomposition) is approximately as large as the CO_2 uptake used for tree growth. The manuscript concerning the pre-harvest data is currently in preparation, but the expected submission/publishing date is not known yet. The original EC tower (not the one used for the submitted paper) has been measuring CO_2 exchange from a partially harvested area of the site since 2016, so we cannot use the 2016-2018 data as a control here. Unfortunately, we have had no EC measurements running within the actual control area either.

Because the manuscript presenting the pre-harvest data is already in preparation and including these data would make the present paper too extensive and potentially confusing, we decided to remove the references to the unpublished data from the discussion and conclusions. We will only discuss the post-harvest balances and change the wording so that the change in CO_2 fluxes due to the clearcutting will not appear as a main conclusion of the paper. However, we can still draw some conclusions on the change in the CO_2 balance, and even in Reco and GPP, on the basis of previous studies concerning nutrient-rich peatland forests (Meyer et al., 2013; Ojanen et al., 2013; Uri et al., 2017).

2. In addition to the chamber measurements made within the clear-cut, already included in the manuscript, we have made similar measurements within the control area. We originally left the control area data out as the changes in fluxes at the clear-cut were so clear that we thought that the clear-cut data alone would have been sufficient. However, we see now why the control area measurements should be included in the paper, especially as few measurements were made before the harvest. We will include these chamber measurements from the control area into the revised manuscript.

I miss a discussion about the system boundaries regarding source/sink function of forests. Is the assumed sink or neutral function of the forest due to accumulation of wood?

3. We also think that the system boundaries are important when considering the overall carbon balance of the site. In this manuscript, however, we concentrated on reporting greenhouse gas fluxes between the ecosystem and the atmosphere. The measurements included in this manuscript constitute a part of a larger project, and there will also be a paper on soil hydrology and carbon export from the clear-cut area. All the results from the project will be combined into a review paper or a thesis that will provide a more complete view.

4. The pre-harvest CO_2 neutral state of Lettosuo is due to the significant tree growth at the site (unpublished data). Uri et al. (2017) have shown that in those well-drained peatland forests where the trees are relatively young, the trees can accumulate more carbon than is released from soil. We will add discussion on this to the revised manuscript.

Is the source function after the clear cut due to enhanced mineralisation of logging residues (which caused the former c sink/neutral)?

5. Even though the logging residues act as a source of CO_2 emissions and are a significant part of Reco (see our replies #3 and #4 to referee #2), they are not the main reason why the clear-cut acted as a source in this study. The main reason is the removal of photosynthesizing biomass (trees) and the destruction of ground vegetation. As there were no trees growing (see reply #4) and not much photosynthesizing vegetation, the GPP was low during the post-harvest summer.

What's about the peat mineralisation before and after clear cutting? GHG warming potential depending on the system boundary and source/sink function may change including C export from harvest. See also (Biogeosciences, 15, 3603–3624, 2018). Hommeltenberg et al. (2014, Biogeosciences, 11, 3477–3493, 2014) stated that a forested bog was a strong carbon sink based on EC measurement – however estimation of long term carbon loss rate since drainage indicated a carbon source of the site. I would extend the discussion on clear cuts effects on GHG balances with the focus on soil type (mineral vs organic) p 13 L21 ff. How is the carbon balance in boreal forest on mineral soils?

Perhaps it is possible to get an estimation of peat carbon mineralisation after clear cutting?

6. Based on the EC and tree growth measurements (unpublished data), we have estimated that the peat mineralisation rate at Lettosuo was about 1000 g C m-2 yr-1 before clearcutting. It is hard to estimate this rate reliably over a year after clearcutting due to mineralisation of logging residues, as they are both included in Reco. The chamber measurements, from which the peat mineralisation could be estimated, concentrated mostly around the summer, which makes the estimation of annual rates highly uncertain. As peat mineralisation should decrease with increasing water table level, we would expect decreased peat mineralisation after clearcutting. We will extend the discussion with the focus on soil type.

Information about soil properties are missing. The only information included is the peat type (nutrient-rich peatland). Information about soil organic carbon content, storage, C/N ratio and bulk density before and after the clear cut (or of the control site) would be valuable in order to compare these results with other organic soils sites. The use of heavy machinery (p4 L2-3) could lead to soil compaction, which could lead to a higher water table (depending on the reference point of water table measurement). Please include basic soil properties and an estimation peat thickness (reference and clear cut or before and after clearcutting).

7. Thank you for pointing this out. We will add data on soil organic carbon and nitrogen content with CN ratio and bulk density values in five different soil layers (humus, 0-10 cm, 10-20 cm, 20-30 cm, 30-40 cm). We will also add soil organic carbon and nitrogen stocks, and an estimation of peat thickness into the revised manuscript.

Soil T data is not consistent in Figures. Compare Figure 2. Soil T at 5 cm depth is warmer in winter time than in summer time compared to other soil depth temperature and has the lowest annual variation (perhaps data of 30 cm depth?). In Figure S3 clear cut temperature in winter 2017 is 0◦C without any variation. In Figure 2 all T soil depth are below 0◦C in winter 2017. In addition there seems different sensibility of temperature sensors during the year, especially at the end of 2017 there seems temperature drops of 0.5 ◦C. Please clarify.

8. There is a mistake in the legend of Fig. 2b, as the color scheme in the legend was shifted downwards due to a technical error. The blue color should refer to 5 cm, orange to 10 cm, green to 20 cm and red to the 30 cm temperature. We apologize for the confusion caused by this and will fix the legend.

9. The reason for the difference between Figs 2 and S3 is that they are measured with different sensors and at different places, though within 15 m from each other. The data in Fig. 2 are from the soil temperature profile measurements located at the orange dot in Fig. 1, while the temperature plotted in Fig. S3 is from the sensors located along the orange transect in Fig. 1 at 8 and 22 m from the ditch. We forgot to report the soil temperature sensors used in the transect in the methods and will add this information into the revised manuscript. Also, the resolution (0.5 °C) of the sensors located along the transect (Fig. S3) is lower than that in the profile measurement, which causes the step-like pattern in the plot.

Please use same axis label to be able to compare the same time periods. I would like to have the time mark of clear cut in all Figures (similar to Figure 2).

10. We will fix the axis labels and add the time mark of the clear-cut to all relevant figures (Figs. 8, S3 and S4) in the revised manuscript.

Figure 5 shows all accepted night-time vs T air. Below 10◦C there are very few points, below 7◦C no points. However, T air seemed to be below 5◦C for several months (Figure 2). The soil temperature (5cm) is below 5◦C (Figure 9). How does this fit together? Does this mean that the data in Figure S2 during winter 2016/ 2017 are daytime data?

11. We apologize for this, but the temperature in Fig. 5a is actually the 5 cm soil temperature (please see also reply #15) and it only includes the accepted night-time summertime data, in which the soil temperature was rarely below 10 °C. We will correct the figure label and the associated text in the revised manuscript.
    Fig. 9 includes all the chamber measurement made during the respective years, so it also includes the data outside the summer period. This is why there are sub-zero temperatures in Fig. 9.
    Fig. S2 includes all the accepted (both night- and daytime) half-hourly measurements made during the measurement period.

In the paper is stated that data coverage is 30% after selection (p.5 l.21). Could you please add the night-time and daytime coverage (per month) of EC data?

12. We will add the monthly night-time and daytime coverages to the supplement of the revised manuscript.

Is the uncertainty of NEE due to uneven distribution of day-time and night-time coverage during gap-filling considered? How does Figure 9 fit to Figure 5a?

13. We did not consider the uneven distribution of the data coverage in gap filling. However, this is a valid point, as the data coverage is usually much lower during the night than day and this may affect the uncertainty estimates. However, we did not consider this difference in the present study.
14. The idea of the Figs. 9 and 5a were to compare the respiration response between the years for the chamber and EC measurements, respectively. However, the time periods differ between the figures as Fig. 5a contains only the summertime EC data while Fig. 9 has all the chamber measurements made within a whole year. Therefore, one cannot directly compare the responses between these two measurement methods by using these figures.

Additional comments. I wonder why CO2 fluxes from chamber measurements are related to T soil, while EC CO2 night-time fluxes are related to T air and why T air is used in gap filling procedure. Please Comment.

15. We originally used air temperature for gap filling because air temperature data are better available from the surrounding weather stations. During the data analysis, however, we noticed that the time series of the soil temperature at the clear-cut was almost perfect (Fig. 2), so we decided to use that for gap filling the EC data instead. Unfortunately, we forgot to update this into the text, but this will be corrected in the revised manuscript.

The addition of annual cumulative footprint contributions in Figure 1 would help to evaluate the chosen suitable wind direction. Please add the used wind direction.

16. We will add into Fig. 1 windroses that show the annual footprint contributions to the accepted flux data.
17. Thank you for pointing out the missing wind directions. They will be added into the methods section in the revised manuscript.

I would appreciate a table including warming potential of all GHG gasses.

18. We will add the GWPs of the GHGs into the discussion text.

Figure 3: Please include water table of control site.

19. The time series of the water table level at the control site will be added into Fig. 3 in the revised manuscript.