

Author response to Reviewer 2 comment on “Carbon balance of a restored and cutover raised bog: Comparison to global trends” by Michael M. Swenson et al.

R2 General comments: The manuscript reports the results from a two year study at two peatlands in Ireland: an abandoned (but not rewetted) and a rewetted peatland. In both sites, a full carbon balance (CO₂, CH₄, DOC and DIC) was measured and calculated. The authors indicate that the abandoned site was a strong annual carbon source and that the rewetted site was a small carbon sink. The authors also compare their results with literature values (a very nice literature review is included in the Supplementary material). The manuscript is well written (although it would benefit from a spell-check and does feel a little long), tightly focused (except Discussion) and the results are clear. However, the Discussion section is disjointed and requires some surgery, and I also have some concerns in regard to the models used but this may just need clarification by the authors rather than any major reconstruction.

Response:

The Reviewer comments that the paper is “well written” but “little long” and the Discussion section is “disjointed and requires some surgery.” I agree with this comment in general. After a fresh read-through, I think that the discussion section gets a little off topic from the study results by including lengthy discussions of data from literature. The comparison to literature data is valuable, which includes Figures 11 and 12 and the extensive tables of literature data in the Supplemental Section 3. However, the discussion text surrounding these figures can be greatly shortened.

The Reviewer comments, “I also have some concerns in regard to the models used but this may just need clarification by the authors rather than any major reconstruction.” The only “concern” raised explicitly is the number of fitting parameters (an in comment below on Tables S1 and S2). The Reviewer raises a valid point for the ecosystem respiration model, in particular, which arguably had too many empirical fitting parameters. This model has been replaced by a simpler model with fewer fitting parameters, as described in more detail in the response to the comment on Table S1 and S2. This change had a minor effect on the results and conclusions of the paper. For “clarification,” the Reviewer requests that the SE of model fitting parameters be included. Additional statistical information on the modelling has been included in the Tables S1 and S2.

Manuscript changes:

The discussion section has been shortened and streamlined by cutting out much of the text describing the comparison to literature. The Figures 11 and 12 will be left in the body of the text, but moved to the results (as in comment on Section 4.2, below).

The modelling of ecosystem respiration has been redone using a simpler model, which was taken directly from Wilson et al., 2016b.

R2 COMMENT: Specific comments:

R2 COMMENT: L2 “Add C after carbon and use thereafter in abstract” “Add methane before (CH4)” “Not necessary to add “losses””

Response: These are good suggestions.

Manuscript changes: The recommended changes will be made in the manuscript abstract.

R2 COMMENT: L4 Harvested suggests a renewable fuel source. Peat removal for fuel is anything but sustainable. Please replace harvesting here (and throughout the manuscript) with either “extraction” or “mining”.

Response: OK, yes, this is a good suggestion.

Manuscript changes: The term “harvested” has been changed to “mined” in the manuscript when in reference to peatlands impacted by peat extraction.

R2 COMMENT: L5 Please define what you mean by “historically abandoned”

Response: OK, this is potentially confusing.

Manuscript changes: “historically” has been changed to “*abandoned x years ago*”

R2 COMMENT: L6/7 What do you mean by “high quality”?

Response: That is a good question; high quality is referring to the site most similar to the ecology and hydrology of undisturbed open raised bog habitat in Ireland.

Manuscript changes: As per Reviewer 1’s comments, the site description has been clarified in the abstract.

R2 COMMENT: L7 *Calluna vulgaris*

Response: The *Calluna vulgaris* refers to a species of plant. In the manuscript the *Calluna* Cutover refers to specific ecotype.

Manuscript changes: The named of specific ecotypes have been removed from the abstract to reduce confusion, as per Comment 1 from Reviewer 1.

R2 COMMENT: L14 Why upper cases for Temperate and Boreal?

Response: Indeed.

Manuscript changes: Temperate and boreal will be changed to lower case throughout the manuscript where appropriate.

R2 COMMENT: L15 “: :in this study and was: :”

Response: Ah, there is an extra word in this line.

Manuscript changes: The word “was” has been removed from this line.

R2 COMMENT: L18 Add C after carbon and use thereafter in the manuscript

Response: Agreed.

Manuscript changes: The suggested change has been applied to the manuscript.

R2 COMMENT: L26 95% is very high – 80 to 85% is generally cited

Response: OK, 95% is referring to the percent of raised bogs that have been degraded. 80-85% refers to the overall peatlands in Ireland. The way that the sentence currently reads is thus incorrect.

Manuscript changes: This line has been clarified to refer more specifically to raised bogs.

R2 COMMENT: L31 Throughout the manuscript, you use intact, natural, near-natural and pristine interchangeably - please select one and keep to it.

Response: This is a good suggestion.

Manuscript changes: The term “intact” will be used in reference to peatlands which have not been mined or drained. The term “natural” will be used in reference to those peatlands which are not actively being used for agriculture, intensive grazing, mining, forestry, etc.

R2 COMMENT: L54 Consider Fritz et al. (2011) *New Phytologist*. 190, 398-408.

Response: I was not aware of this publication. The findings from this publication are somewhat contradictory with this line of the introduction.

Manuscript changes: This line has been changed to include the findings from Fitz et al., 2011.

R2 COMMENT: L75 Please use primary source as reference; Myhre et al (2013) *Climate Change 2013: The Physical Science Basis Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*

Response: Yes, good point.

Manuscript changes: The suggested primary reference is used

R2 COMMENT: L77 I would not be inclined to use specific data here; why Helfter et al. and not McVeigh et al. for instance?

Response: Including specific data here is helpful for putting the present work in context. Helftler et al. is used as a source because they include a table of reported literature values.

Manuscript changes: The use of this source is clarified by adding “literature compilation from Helftler...”

R2 COMMENT: L78 The CH₄ values derived by Wilson et al (2016) include rewetted sites, so are not suitable here, however there are lots of CH₄ studies you could cite instead, e.g. Laine et al. (2007) *Plant and Soil*. 299, 181-193; Green and Baird (2017) *Mires and Peat*. 19, Article 09.

Response: That is a good point.

Manuscript changes: The suggested citations have been used here.

R2 COMMENT: L82 Change methane to CH₄; L90 Change methane to CH₄

Response: OK

Manuscript changes: The use of “methane” has been replaced by the chemical symbol throughout the manuscript after initially defining it.

R2 COMMENT: L89 Bain et al (2011) is not in reference list

Response: OK

Manuscript changes: This citation has been added to the reference list.

R2 COMMENT: L101 Consider Barry et al. (2016) Aquatic Sciences. 78, 541-560

Response: OK

Manuscript changes: This article has added as a reference here.

R2 COMMENT: L109 “recovering” is a new term to me. Do you mean rehabilitated?

Response: Recovering means bogs which have had no definite action taken to rehabilitate them. They have just stopped being mined and left. So, the term “rehabilitated” is not correct.

Manuscript changes: In this line “abandoned” will be used in place of “recovering”. In the manuscript, this term has now been defined as the “spontaneous revegetation of mined peatlands’ (From Poulin et al., 2005), which have had no definite action taken to rehabilitate them.”

R2 COMMENT: L129 What do you mean by “natural peatland area”? The site is obviously not natural and the surrounding landscape is mainly grassland and some forestry. Delete.

Response: OK, The site is a natural area with a variety of plant communities some of which is peatland in various degrees of degradation.

Manuscript changes: The wording has been changed from “natural peatland area” to “peatland and natural area”.

R2 COMMENT: L130 See earlier comment regarding harvesting.

Response: As in above comment.

Manuscript changes: As in above comment.

R2 COMMENT: L132 Met station location? 1980-2010?

Response: The unusual dates are due to the available data from the met station.

Manuscript changes: The met station location has been added to the manuscript.

R2 COMMENT: L134 1980s; L140 1970s and 1960s

Response: OK

Manuscript changes: The apostrophe has been removed from all decade numbers.

R2 COMMENT: Fig. 1 The quality of Fig. 1 is poor, although this might be due to the pdf. The legend on the elevation map is hard to determine.

Response: Noted.

Manuscript changes: A higher resolution figure will be used for the final submission.

R2 COMMENT: Table 1. Check font sizes and spelling of Sphagnum and Eriophorum

Response: OK, good catch.

Manuscript changes: These typo mistakes have been corrected.

R2 COMMENT: L188 Where was the sensor located?

Response: Sensor was located inside of the chamber.

Manuscript changes: This detail is added to the manuscript.

R2 COMMENT: L196 Stainless steel collars – as written it appears as if you only had one

Response: Agreed.

Manuscript changes: “collars” instead of “collar”

R2 COMMENT: L197 Where was the water trough located?

Response: Along the top edge.

Manuscript changes: Added “along the top edge” to this sentence

R2 COMMENT: L198 What does “constructed in house: : :” mean?

Response: This phrase means that the chambers were built by the authors and department technicians.

Manuscript changes: The phrase “in house” was changed to “in-house” as it should be.

R2 COMMENT: L207 and area, volume of collar/chamber?

Response: The dimensions of the chamber are given above in line 198, but the area and volume can be stated more explicitly.

Manuscript changes: This information has been added to the manuscript.

R2 COMMENT: L208 A constant temperature or a temperature similar to ambient temperature? The former could be 50C for example and fit your criteria but would be meaningless for gas

flux calculations and subsequent modelling.

Response: Reviewer 2 seems to have mis-understood the meaning of this sentence. The temperature was kept constant over the chamber closure equal to the initial ambient temperature.

Manuscript changes: The phrase “over the chamber closure time” was added to the sentence as a clarifier.

R2 COMMENT: L213 State flux sign convention used in this study.

Response: Yes, that needs to be included.

Manuscript changes: The following sentence was added after line 213 “For this study, a positive sign convention is indicates a net loss of carbon to the peatland.”

R2 COMMENT: L214 describe criteria used for quality checking.

Response: This data was quality checked to ensure that the change in CO₂ concentration over the chamber closure was monotonic, and physical parameters such as temperature and PPFD did not change substantially over the closure.

Manuscript changes: The following sentence describing quality checkin criteria was added to the manuscript: “...quality checked to ensure that the change in CO₂ concentration over the chamber closure was monotonic and that the PPFD did not change by more than 50 μmol m⁻² s⁻¹ over the chamber closure.”

R2 COMMENT: L212 How many samples?

Response: “...generally under full ambient light, 1-2 light other partial shading light levels, and a completely shaded measurement.”

Manuscript changes: The sentence in the response was added to the manuscript.

R2 COMMENT: L259-260 CH₄ fluxes have a strong diurnal variability in some plant types.

Response: The data from Pypker et al., 2013 supports the claim of a low diurnal variability in CH₄ flux compared to CO₂ flux for bog species. This line (259-260) was removed because it does not seem necessary here. The point is that CH₄ measurements taken during the daytime only were used to represent the overall CH₄ fluxes. By contrast, the CO₂ flux is strongly controlled by light level and thus had to be modelled on a shorter (hourly) time step because light level is obviously changing throughout the day.

Manuscript changes: The first sentence of section 2.6 (Line 259-260) was removed because it is not really necessary for the method description.

R2 COMMENT: L337 Unusual long-term dates; 1980-2010 more usual.

Response: This is the data range available at the nearby weather station.

Manuscript changes: No changes.

R2 COMMENT: Fig. 2b Degree symbol missing on y axis.

Response: Good catch.

Manuscript changes: The suggested changes are made to the figure.

R2 COMMENT: Fig 5b The use of a 1:1 line would provide better information as to the performance of the model

Response: That is a good idea.

Manuscript changes: The suggested changes are made to the figure.

R2 COMMENT: Figs. 4,6, 9 and 10 Check spelling of plant names.

Response: OK

Manuscript changes: Plant name spelling mistakes are corrected in the figures.

R2 COMMENT: Section 3.4 Only use “significant” when related to statistical comparisons.

Response: Yes, that is already the case. Every instance of the word “significant” in the manuscript refers to statistical comparisons.

Manuscript changes: None in response to this comment, but more statistical information is included in the text in line with Reviewer 1’s comments. This makes the use of the term significant is clearer.

R2 COMMENT: L407 GWP

Response: Yes, Good catch.

Manuscript changes: One instance of “GPW” changed to “GWP.”

R2 COMMENT: L407 tonnes (and thereafter)

Response: Yes, Good catch.

Manuscript changes: Two instances of “tons” changed to “tonnes” in the manuscript.

R2 COMMENT: Fig. 10 Given that MAWT is used as a predictor variable in the models, these observations are not independent (especially as the collars were lumped together for modelling) and I am far from convinced as to their value in this manuscript.

Response: Hourly water table (as opposed to MAWT) data was used as a parameter in modelling NEE, but not CH₄ flux. The NEE was modelled using collar specific empirical models fit to field data, and water table had a minor impact on the over modelled results. Thus, the changes in hourly water table help explain the variability in NEE but do not strongly control the modelled annual NEE. I

argue that these are independent variables and the trends in these plots are useful results for comparing with other studies. These plots are valuable because they show the interaction between ecotype, genus percent coverage, MAWT and NEE, CH₄ flux, GWP.

Manuscript changes: The plots in figure 10 were changed to include different symbols for the five ecotypes (as per comment by Reviewer 1), which improves the value of this figure in the manuscript.

R2 COMMENT: L436 Consider Nugent et al (2018) Global Change Biology, <https://doi.org/10.1111/gcb.14449>

Response: This study was not published at the time of initial submission, but is very relevant.

Manuscript changes: This suggested publication has been included and cited in section 4.1.

R2 COMMENT: L477 1960s

Response: OK

Manuscript changes: “1960’s” changes to “1960s” as per previous comment

R2 COMMENT: L484/485 join the sentences

Response: Yes, this should be one sentence.

Manuscript changes: Lines 484/485 have been joined as one sentence.

R2 COMMENT: L490 five decades

Response: OK

Manuscript changes: “5 decades” changed to “five decades”

R2 COMMENT: Section 4.2 I am not sure of the value of this section. The manuscript is already quite long and this seems superfluous (especially given the extensive data set in the Supplementary). If it really must be kept, then it should be moved to the Results section and then discussed here.

Response: After re-reading the manuscript, I agree that much of this discussion is unnecessary and a little off topic for the main findings of the paper. However, the literature comparisons in fig 11 and 12 are valuable as are the extensive data sets behind them included in the supplementary tables. This information puts the study in a broader context.

Manuscript changes: Figure 11 and Figure 12 have been moved to the results section, and the discussion in section 4.2 has been substantially shortened.

R2 COMMENT: L515 Natural or semi-natural = intact?

Response: See response to comment on Line 31, above.

Manuscript changes: As per above comment.

R2 COMMENT: L539 What does “Restoration of high quality peatland ecology” mean?

Response: I can see how this is a bit confusing.

Manuscript changes: This “high quality” has been changed to “Sphagnum dominated.” Though, much of this section has been re-written.

R2 COMMENT: L576 Not so: In Saarnio (2007) *Boreal Environment Research*. 12, 101-113, 15% of growing season flux is emitted in the non-growing season. This approach was also used by IPCC Wetlands Supplement (2014)

Response: That is a good point.

Manuscript changes: The results reported in figure 11 and 12 will remain the same, but more caution has been given to the comparison between growing season and year round data, including reference to Saarnio (2007).

R2 COMMENT: L577 What is “inter flux”?

Response: A typo: winter flux

Manuscript changes: This has been changed in the manuscript.

R2 COMMENT: L608/609 “The impact of these things..” is very vague.

Response: Yes, this line is “vague” and may not be necessary to include. It does not add anything to the manuscript.

Manuscript changes: This line has been removed from the manuscript.

R2 COMMENT: L628 and also due the pulse effect.

Response: ??? This comment does not seem match the text in this line.

Manuscript changes: No changes.

R2 COMMENT: L630 Why not quote Frolking directly?

Response: Yes, that is a good point.

Manuscript changes: The quote from Evans et al. 2016 is removed, and the primary reference is cited directly to make a similar point.

R2 COMMENT: Conclusion This reads as a summary not as a conclusion; what does your study mean for land managers, policy makers etc?

Response: That is good advice.

Manuscript changes: The conclusion has been re-written to focus less on summary and more on important findings from this work.

R2 COMMENT: L668 “best models” = the ones you used?

Response: Yes.

Manuscript changes: The wording “best models” has been changed in this line to “the models used.”

R2 COMMENT: Supplementary: Check spellings throughout

Response: OK

Manuscript changes: Section S1 has been re-worked and edited in response to both Reviewers' comments as there seems to be some confusion from both Reviewers. The supplemental section previously read as a prosaic exposition of the various models tested in the development of this work. It has been changed to simply give detailed information on the models used.

R2 COMMENT: Tables S1 and S2 Please provide the standard error (SE) associated with each parameter estimate. Given the large number of parameters in the models, I would suspect that the SE will be very high and would invalidate your approach.

Response: Including the SE of the model parameters was also suggested by Reviewer 1. That will be included in these tables.

Yes, there are a large number of fitting parameters. The same GPP and ER models were used for all 29 collars, but the model fit parameters were determined empirically for each of the collars individually. For the GPP modeling, there was sufficient field data to justify a model with 5 empirical fitting parameters. For the majority of the collars, all of the GPP model fit parameters are significant to 95% confidence. This model was designed in such a way that the effect of modelled parameters reduces to zero as the explanatory value of the additional variables decreases such that insignificant model parameters have a minor impact on the modelled results. For the ER modeling, the sample size is smaller and the point that Reviewer 2 is making is quite valid. Previously, there had been some debate among the authors as to which of two models to use for ER, so much so, that information was included on both of these models in the supplemental section in the original manuscript draft. Thus, the simpler ER model (with 3 fitting parameters compared to 5 fitting parameters) has been used to calculate ER in the updated manuscript. This model was taken directly from Wilson et al., 2016b and developed from the same type of data, collected in Ireland.

Manuscript changes: Additional statistical information has been included in the table S1 and S2 of the model fit parameters. The ER has been calculated by a different and simpler model in the revised manuscript, which had been previously described in the supplemental section but not used in the manuscript and was taken directly from Wilson et al., 2016b. The change in ER model had a minor effect on the overall conclusions of the paper. Also, the text of this supplemental section has been substantially revised to clarify confusion expressed by both Reviewers.