

Referee 1

This study helps answer an important, highly policy-relevant question concerning use of peatlands in temperate regions for plantation forestry. Very limited research on the implications for climate change of this land use on this soil type has been published. This work provides empirical data to support modelling of the balance between CO₂ emission due to peat decomposition and atmospheric CO₂ removal into tree biomass. It clarifies the reliability of assumptions used about the relative rates of heterotrophic and autotrophic restoration to estimate the rate of peat decomposition from total soil CO₂ efflux and will inform similar assumptions in future. It highlights the important role of rhizosphere priming effects in decomposition of afforested peat. This study is excellent - well conceived, carefully undertaken and concisely reported. Its limitations are recognised and discussed.

Thank you for this positive appraisal of our study.

Specific comments

1. Your finding that the soil of these 30-year-old forests is a net C sink is arguably as important as the findings about the relative magnitudes of the autotrophic and heterotrophic CO₂ effluxes. The title of the preprint indicates a focus on the latter. Consider expanding discussion of the net soil C balance and altering the title to reflect a dual focus.

We agree that the net C sink in afforested peatlands is an important finding, and have expanded and in part re-written the discussion around this (also in response to another referee; see below). We also agree that the net C balance of soils should be reflected in the title, and have changed it to: "Separating autotrophic and heterotrophic soil CO₂ effluxes and net soil carbon balance in afforested peatlands"

2. The likelihood that killing roots by trenching will also have stopped rhizosphere priming of peat decomposition is acknowledged as a limitation of the study. The priming of litter decomposition in the same way is demonstrated to make a substantial difference to litter-derived CO₂ efflux by the litter decomposition measurements in the trenched and control plots but no evidence is provided on the likely size of this effect on peat decomposition. Any further evidence that can be obtained from the literature would help in assessing the degree of underestimation of peat decomposition by the trenching treatment.

This is a good point, and we have extended the discussion on this point, adding new insights from a recent study where tree planting on heathlands was demonstrate to result in loss of organic surface soil (Lines 384-387).

3. Generally, you have been consistent about the boundaries of the system under study (line 74: 'the C budget of a drained and afforested peat soil'). Mentions of root growth in line 324 and belowground productivity in line 327 are slightly confusing because assimilation of C in tree biomass was not included in your study. If by 'root growth and turnover' and 'belowground productivity' you are referring to root litter and/or exudate deposition, make this clearer. It is important that readers do not confuse soil C stocks with below-ground C stocks.

We removed the term “root growth” to now only mention “root turnover” in line 328 to avoid confusion between living plant C stocks and belowground litter production. However, we think that “belowground productivity” is meaningful in this context, as greater productivity results in more turnover and hence organic matter (i.e. litter) input to the soil.

4. The limitations of not measuring are briefly mentioned but could be discussed more fully in the context of their implications for afforested peatland soil C balance. These limitations and any conclusion about their likely implications for the main findings should be mentioned briefly in the abstract.

We have extended the discussion around flux estimates and absence of direct belowground litter input, and also added the following sentence to the abstract (lines 24-26): “This study doesn’t account for fluvial C fluxes, which represents a small flux compared to the CO₂ soil efflux; further, root litter and exudate deposition could be a significant C source that is only partially sampled by our approach, adding to these plantations being a potential carbon sink.”

5. The final discussion point about the importance of knowing the net C balance over the lifespan of a plantation is important and welcome but, for balance, should be expanded. The fact that this lifespan normally ends with timber harvesting and deposition of large quantities of felling residues above ground and whole root systems below ground means that we need to go beyond a single forestry rotation to assess the soil C balance of the land use. The separate litter and dead root decomposition fluxes reported here may help inform assessment of post-felling CO₂ fluxes but need to recognise the different water table level and soil moisture conditions created by the soil rewetting associated with clear-felling.

“In the UK forest plantations on deep peat usually end in clear felling of the site and restoration of the peat. The results of this study could also help inform what the CO₂ fluxes will be when timber is harvested and large quantities of felling residues are left above ground as well as whole root systems below ground. However, we note that changes in water table and soil moisture conditions created by the soil rewetting associated with clear-felling will have significant and separate impacts beyond the conditions of active drainage under which we took our measurements.”

Technical corrections

18. Consider adding a sentence saying that you measured and corrected for decomposition of the excised roots.

Added: “Decomposition of cut roots was measured and CO₂ fluxes were corrected for this.”

31. ‘treed’ perhaps better than forested as these can be quite sparse.

Changed to “treed”.

35. ‘very little’ better than ‘a very little’.

We deleted “a”.

51. Consider adding ‘or outstrip’ after ‘could partly or wholly offset’.

Added “or outstrip”.

52. ‘original’ could be omitted.

We deleted “original”

55. ‘of poorer quality’ could be replaced by ‘less readily decomposed’.

Replaced with “are less readily decomposed”.

58. Consider omitting ‘chemical’, the recalcitrance is also biological and due partly to the microbial environment of the peat.

Deleted: “chemical”.

61. Consider adding ‘rhizodeposition’ after ‘litterfall’. Although you didn’t measure it, it’s important not to hide the fact that it occurs and needs to be considered as a C input to soil.

Added: “and rhizodeposition”

78. ‘forestry plantations’ is probably a better description of the land use/ecosystem than ‘forest plantations’.

Changed to “forestry plantations”

79-80. Something missing in Hypothesis 3. ‘Interactions between C supply to the rhizosphere by trees’ and what?

We have added “and surface litter decomposition”

85. Insert a comma after ‘drained’.

Done

89. Is there a simpler way of saying ‘with an average ratio per area of Sitka spruce : Lodgepole pine of 0.6’? Perhaps omit this and insert ‘3:5 (on average)’ before ‘mixture’ in line 85.

We added in 3:5 (on average) and deleted ‘with an average ratio per area of Sitka spruce : Lodgepole pine of 0.6’

92. 11.4 °C is the 30-year average maximum temperature. It would be better to give the average mean temperature or if not available, also give the average minimum, which is 3.3 °C for Kinbrace.

Changed to “an average maximum air temperature of 11.4°C and average minimum air temperature of 3.3°C”

97-99. Excellent approach.

Thank you!

100. ‘double ploughing’ is ambiguous. Either say ‘double-mouldboard ploughing’, which is technically correct or ‘twin-throw, spaced-furrow ploughing’ which is perhaps more universally understood.

Changed to “double-mouldboard ploughing”

100-105. In section 2.2, could you reduce the text description to a single sentence by including the dimensions in Figure 1?

We considered adding dimensions to Figure 1, but think that this won't help clarity, and would prefer to retain the text as it is.

114-115. Consider replacing 'with closest trees located about 30 cm from trenches' by 'but did not represent ground within 30 cm of trees'. But if 30 cm was the distance from trees to the outer edge of the trench, the unrepresented ground would be that within 60 cm of trees.

Changed to “but did not represent ground within 60 cm of trees”.

133-134. Say how you distinguished the litter that had fallen since the previous measurement.

We didn't make this distinction, as litter turnover that includes fresh litter was part of our experimental approach. By weighing actual litter amounts in collars, we were able to calculate the CO₂ flux coming from the litter.

138-139. Say that the roots extracted from the soil cores and weighed included both live and dead roots.

Added “Both dead and living roots”.

142. Say if you assumed that root density in the 20-25 cm soil layer was the same as in the 0-20 cm layer.

Added in “and root density for 0-20 cm was assumed to be representative for 0-25 cm”.

144. Replace 'in' with 'into'.

Done

213. remove 'at least' or 'over'.

Deleted “at least”.

227. Change 'higher soil temperatures' to 'soil temperature'.

Done

229-230. If possible, state the soil temperature above which CO₂ efflux decreases with soil moisture.

We now indicate in the text that the relationship has an inflection temperature between 6 and 7 °C

241-243. Having already read the abstract, this was slightly confusing. It is clearly explained in the discussion (372-373) but can you add a few words here to emphasise that the model prediction of heterotrophic respiration includes that for decomposition of excised roots?

Added: “The model prediction of heterotrophic respiration includes that for decomposition of cut roots.”

257-258. The increased litterfall into collars in the trenched treatment compared with the control is potentially interesting but is not supported by the litter trap catches. Say if the difference is significant but omit from the text if not.

Deleted: "Further, the average amount of litter in the collars (per m²) of the trenched plots is higher than in the collars of the control plots"

263-264. Could be worth mentioning possible bias from not sampling ground close to trees.

We're unsure why there should be a bias from proximity of trees, as root sampling included locations close to trees, representing root densities of the stand appropriately.

267. Replace 'was' with 'were'.

Done

283. Table 4. It is unclear what the figures in bold in the 'Decay constant' column are. If they are 2-year excised root-derived C emissions, consider moving them to a new column added on the right of the table or omit them altogether.

We apologise for this. The bold numbers in the first column were left from a previous version of the table and we forgot to take them out. This is corrected, bold numbers in the other column are the totals (and labelled as such).

303. Replace 'weighed' with 'weighted'.

Done

308. Table 6. Area-weighted fluxes and the breakdown into autotrophic and heterotrophic fluxes are quite sensitive to the area fractions of the different microforms. I checked these against some measurements I had for double-mouldboard ploughing at another northern Scotland site and found them to be quite different. Please double check that these are correct.

Here the furrows were c. 1.5 m wide, plough throws c. 0.75 m wide on either side of the original surface, which was c. 0.5 m wide. This gives the area fractions used in table 6.

310. Omit comma after 'matter'.

Done

313. Nice diagram. Would it be possible to add a net C balance figure for each microform and the area-weighted total?

Thank you. We have added the net C balance for the area weighted flux only, since we think it would become too difficult to read diagram otherwise.

316. Omit comma after '(grey)'.

Done

324. As mentioned in Specific comment 3 above, consider replacing 'root growth and turnover' with

‘root litter deposition’ or ‘rhizodeposition’ (the latter would include root exudates).

As indicated above, we have adjusted the text as suggested to make a clearer distinction between root stocks and turnover.

327. As mentioned in Specific comment 3 above, consider replacing ‘belowground productivity’ with ‘belowground litter and exudate deposition’.

We also made this amendment as suggested.

341. Replace ‘Southern Ireland’ with ‘the south of Ireland or just ‘Ireland’.

Replaced with “the south of Ireland”.

361. Replace ‘and’ with ‘the’.

Done

370-371. The first half of the sentence is an important ‘Methods’ detail so I’ve suggested adding it around lines 138-139. If you do that, you might need to reword this sentence slightly.

Changed to: “so our results might overestimate the living root biomass”

376-377. This is an interesting finding that could inform the assessment of soil CO₂ fluxes after timber harvesting on afforested peatland. Consider adding it to the abstract.

Added in abstract: “Decomposition of cut roots was measured and CO₂ fluxes were corrected for this, this resulted in a big change in the fraction heterotrophic : autotrophic flux, suggesting that even two years after trenching decaying root biomass make significant contributions to the CO₂ flux.”

384-386. A single citation of a tropical peatland study is not very helpful here. Consider either omitting this last sentence or citing a wider range of evidence, preferably as relevant as possible to temperate afforested peatlands.

We have added further recent papers focussing on peatland drainage.