Reply to: Heinemeyer, A. and Ashby, M.A.: "Constructive criticism of "*Misinterpreting carbon accumulation rates in records from near-surface peat"* by Young et al.: Further evidence on charcoal impacts in relation to long-term carbon storage on blanket bog under rotational burn management."

Dylan M. Young*[1], Andy J. Baird[1], Dan J. Charman[2], Chris D. Evans[3], Angela V. Gallego-Sala[2], Peter J. Gill[1], Paul D. M. Hughes[4], Paul J. Morris[1], Graeme T. Swindles[5,6].

[1]School of Geography, University of Leeds, Leeds, UK

[2]Geography Department, University of Exeter, Exeter, UK

[3]Centre for Ecology and Hydrology, Bangor, UK

[4]Geography and Environmental Science, University of Southampton, Southampton, UK

[5]Geography, School of Natural and Built Environment, Queen's University Belfast, UK

[6]Ottawa-Carleton Geoscience Centre and Department of Earth Sciences, Carleton University, Canada

*d.m.young@leeds.ac.uk

We thank Heinemeyer and Ashby for their interest in our paper[1]. In our reply below we use 'aCAR', an abbreviation of 'apparent Carbon Accumulation Rate'[2]. aCAR is calculated for layers within a peat core. It is the mass of carbon (C) within a peat layer divided by the difference in age (in years) between the bottom and top of the layer. aCAR is not the same as the net C accumulation rate[2]. It is aCAR that Heinemeyer et al.[3] calculated for contiguous layers in the cores taken from their study sites.

Below, we list and respond to each of the criticisms of Young et al.[1] made by Heinemeyer and Ashby.

1. *Young et al.[1] wrongly suggest that Heinemeyer et al.[3] believe that measurements of near-surface accumulation of C in peatland represent the overall, or net, C budget of the whole peatland or peat profile.*

We agree that we made this suggestion in our paper[1]. We did so because that is what Heinemeyer et al.[3] say at the beginning of their paper. Specifically, they say [bold emphasis added]:

> "We assessed **peat carbon accumulation** over the last few hundred years in peat cores from three UK blanket bog sites under rotational grouse moor burn management. High resolution (0.5 cm) peat core analysis included dating based on spheroidal carbonaceous particles, determining fire frequency based on macro-charcoal counts and assessing peat properties such as carbon content and bulk density. All sites showed considerable **net carbon accumulation** during active grouse moor management periods."

Here Heinemeyer et al.[3] conflate 'net carbon accumulation' with 'peat carbon accumulation', the latter term being used throughout the rest of their paper[3]. We are happy to accept Heinemeyer and Ashby's clarification that this was not the intention of Heinemeyer et al.[3]. We are reassured that Heinemeyer and Ashby agree that it is not possible to estimate the overall or net carbon balance of a peatland using shallow core data. This means, therefore, that the last sentence of the extract above from Heinemeyer et al.[3] is incorrect. In this context we stand by our criticism.

2. *The drainage model simulations in Young et al.[1] were used to "discredit" Heinemeyer et al.[3] and don't apply to the situations studied by Heinemeyer et al.[3].*

In our paper[1] we used the DigiBog peatland model to simulate an undrained and a drained peatland to illustrate the problems of using near-surface measurements of aCAR to infer rates of net peatland C accumulation. Nowhere in our paper[1] do we say the drained version of the model applies specifically to the sites studied by Heinemeyer et al.[3] and we are happy to make that clear here. However, we do note in our paper[1] that the problems in using aCAR, as illustrated by *all* our simulations (drained and undrained), also apply to studies carried out in other management settings, including the burn-managed peatlands considered by Heinemeyer et al.[3] and Marrs et al.[4]; that remains our position.

3. *Young et al.[1] wrongly suggest that it is not reasonable to compare rates of apparent C accumulation in near-surface peat and to use these to assess the effect of management over time.*

Heinemeyer et al.[3] and Heinemeyer and Ashby suggest that down-core changes in aCAR can be meaningfully interpreted and related to management (see, e.g., Figure 6 of Heinemeyer et al.[3]). We disagree (see also[2,5] in support of our argument). As we show in our paper[1], the increase in aCAR towards the surface of a peat core is an *artefact*. This artefact – called the acrotelm effect – does not represent any change in the rates at which new C was added to a peatland over time. How the acrotelm effect arises is explained in in our paper[1] but is also illustrated and explained in Fig. 1. The only exception to this is where upper peat has a lower aCAR than deeper layers; i.e., the opposite of what would be expected in steady state. This reversal in the pattern of aCAR suggests that either productivity has declined or decay rates have increased in more recent time periods[6].

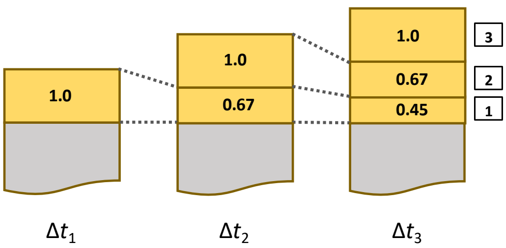

Figure 1: Schematic of a column of peat over three time periods showing the acrotelm effect. Carbon (in plant litter) is added to the peatland at a constant rate of 1 mass unit per unit area per time period (Δt). All litter added since Δt_1 is assumed to be part of the

acrotelm and decays at a constant proportionate rate of 0.33. Thus, litter added in Δt_1 undergoes decay so that only 0.67 C units remain in Δt_2, and 0.45 C units by the end of Δt_3. By the end of Δt_3 there are three 'new' layers of peat, each with different masses. If aCAR is calculated for each layer at the end of Δt_3 it will suggest that the rate of carbon 'accumulation' has increased to the present, when in fact rates of C addition have remained constant. It would obviously be wrong to interpret this apparent increase as real – it is simply an artefact related to the length of time each layer has had to decay. Pre-existing peat is shown in grey. For simplicity, this older peat is shown as having a constant mass in the figure. However, it is possible for more mass to be lost from this older peat than is being added at the peatland surface so that the peatland as a whole loses peat. aCAR is unable to reveal mass losses from peat that is not part of the dated layer being considered.

4. *The data from Heinemeyer et al.[3], when overlaid on the results from the DigiBog undrained run from Young et al.[1], show that it is unlikely that there were losses of C associated with drainage at the sites studied by* Heinemeyer et al.[3].

As we note above, we did not apply the DigiBog model to the sites from Heinemeyer et al.[3]. Given that Heinemeyer and Ashby suggest that the model scenario that we used (a raised bog) does not apply to the sites studied by Heinemeyer et al.[3], we are surprised that they compare core data from their site with our model output. We believe it is not appropriate to simply overlay core data from Heinemeyer et al.[3] onto outputs from simulations that were not set up to represent their site. We additionally note that data from the sites studied by Heinemeyer et al.[3] (see here[7]) show that water tables regularly fall below the base of the cores taken by Heinemeyer et al.[3], and that it is possible that oxic decay of this deeper peat occurs.

5. *Young et al.[1] wrongfully criticise Heinemeyer et al.[3] for using spheroidal carbonaceous particle (SCP) distributions to derive a peat age/depth profile.*

Young et al.[1] do not comment on the use of SCPs by Heinemeyer et al.[3], so we don't know why Heinemeyer and Ashby make this criticism.

6. *Young et al.[1] criticise attempts to compare C flux with C stock budgets, but their criticism overlooks (i) the fact that methane C fluxes are often not included and (ii) the long time scales needed to capture management (disturbance) and recovery (plant regrowth) in C flux assessments.*

We thank Heinemeyer and Ashby for raising this point and agree that methane fluxes are important. We note that long-term flux-measurement studies such as those at Mer Bleue in Canada[8] do measure this important component of the C budget and have run for more than 20 years. We agree, however, that more studies would be useful. We note that many contemporary flux tower studies include measurement of methane fluxes.

7. *Young et al.[1] are subjective in their criticism. Why, for example, don't they criticise Garnett et al.[9] in the same way they criticise Heinemeyer et al.[3] and Marrs et al.[4].*

We criticise several studies in our paper, including some that consider the impact of drainage-based plantation forestry on the peatland carbon balance. We agree with Heinemeyer and Ashby that Garnett et al.[9] make the same mistake as Heinemeyer et al.[3], although their primary focus is on spatial comparisons of aCAR over the same time scales in a replicated plot design, which is less problematic. We[1] make this point in our conclusion: 'Spatial comparisons of recent C addition can be made using short cores but cannot be used to infer the total peatland C budget.' Our conclusions[1] are general and do not just apply specifically to Heinemeyer et al.[3] and Marrs et al.[4]; they concern any study using near-surface measurements of aCAR and we are happy to make that clear here.

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Author contributions

D.M.Y wrote the paper, undertook the DigiBog simulations and processed the simulation outputs. A.J.B proposed the paper, helped write it, and helped design the DigiBog simulations. D.J.C., A.V.G-S. and G.T.S. supplied the peat core data used in Figure 1[1]. D.J.C., P.D.M.H., P.J.M., A.V.G-S., and G.T.S. helped with the peatland palaeoecological context. C.D.E. helped with the peatland land use context. P.J.G wrote and implemented the algorithm to speed up model run times. All authors contributed to the preparation of the final paper[1].

Competing interests

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