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

Andreas Heinemeyer[1]* | Mark A. Ashby[2]

[1]Department of Environment and Geography, Stockholm Environment Institute, University of York, York, YO10 5NG, UK

[2]Whitebeam Ecology, Stone, Staffordshire, UK

* Corresponding author: andreas.heinemeyer@york.ac.uk

Disclaimer: Whilst we submitted this article to *Scientific Reports* on 12th August 2020, it had only been peer-reviewed by June 2021 and, unfortunately, it was declined to be published. However, we have questioned this decision and are awaiting the outcome of an appeal to this decision. Therefore, we deemed it appropriate to publish this manuscript as a pre-print to prevent the debate around prescribed burning impacts and discussions of key studies from moving forward without our contribution.

Abstract

It is with great interest that we read the recent paper by Young et al. entitled "*Misinterpreting carbon accumulation rates in records from near-surface peat*". However, we have some concerns about: (i) the use of an unvalidated deep **drainage** model to criticise studies investigating the impact of **heather burning**; (ii) the model scenarios and underlying model assumptions used; and (iii) misleading claims made about net C budgets and deep C losses. We feel that these issues require clarification and, in some cases, correction, especially as Young et al. has been used by a leading peatland policy and conservation body (IUCN UK Peatland Programme) to incorrectly characterise two recent studies by Heinemeyer et al. and Marrs et al. as having "presented misleading conclusions". We strongly believe that one of

the main ways to increase our scientific understanding is through vigorous and factual debate. Whilst we are open to and welcome criticism, such criticism needs to be accurate, balanced and evidence-based. Criticism must avoid unfounded or speculative accusations, especially when based on unrelated and unvalidated model scenarios. Indeed, studies aims, hypotheses and discussion sections need to be considered to ensure any criticism is applicable. We accept that deep C losses can be caused by peatland drainage and that this can lead to the misinterpretation of peat surface C accumulation rates or peatland C budgets. But these issues do not apply to the Heinemeyer et al. study, which investigated two specific and clearly stated burn-related hypotheses (charcoal impacts on peat properties and thus peat C accumulation), which only required comparing C accumulation rates within recent peat layers. Moreover, using peat core data collected by Heinemeyer et al., we provide strong evidence that the accusations of deep C losses by Young et al. are unfounded. However, the peat core data from Heinemeyer et al. does highlight the value of the Young et al. model scenarios for predicting short-term C loss caused by recent drainage. Finally, we also highlight the value of a detailed peat layer organic C content (%Corg) assessments to detect potential management (i.e. drainage) induced deep peat C loss.

Comments on Young et al. (2019)

Whilst the modelling study by Young et al.[1] provides valuable insights into how deep drainage can impact C accumulation rate assessments, it is context limited, and the findings should not have been specifically generalised to unrelated studies, especially those that focus on the prescribed burning of heather-dominated vegetation. Our concerns about Young et al. relate to: i) the use of an unvalidated deep drainage model to criticise studies on heather burning by Heinemeyer et al.[2] and Marrs et al.[3]; ii) the model scenarios and underlying model assumptions used by Young et al.[1]; and, iii) misleading claims regarding net C budgets and deep C losses that are not supported by peat core data presented by Heinemeyer et al.[2]. However, we also agree with Young et al.[1] about several aspects and present data collected by Heinemeyer et al.[2] that support some of their findings.

Our first criticism of Young et al.[1] is that their model cannot be directly applied to the findings of Heinemeyer et al.[2] and Marrs et al.[3] because it does not test the impact of heather burning on C accumulation rates. Indeed, Young et al.'s model does not include any of the fire-mediated C cycle processes that the findings of Heinemeyer et al. suggest are important, such as charcoal, organic C content and bulk density[2].

Heinemeyer et al. report C accumulation over a measured depth and not total peat depth net C accumulation[2]. In fact, they explicitly acknowledge the potential issues of C loss from deeper peat layers and C fluxes vs C budgets (see quotes in the *supplementary information*). Yet Young et al.[1] state that: (i) "*both Heinemeyer et al. (p.7) and Marrs et al. (p.109) make inferences about changes in C accumulation rates over time, comparing very recently-formed peat to older material that accumulated decades to centuries earlier. However, palaeoecologists have known for some time that estimates of C accumulation rates in recently added peat cannot be assumed to be directly comparable to those derived from deeper peat.*"; (ii) "*Apparent increases in the rate of C accumulation are often evident in near-surface peat, but are an artefact*"; and, (iii) "*both modelling approaches show clearly why it is a mistake to use recent rates of C addition to the upper part of a peat profile as an indication of overall peatland C accumulation rates, or of net peat C balance*." Such criticism is unfounded because Heinemeyer et al.[2] do not infer overall C accumulation rates or a net peat C balance, the issue of any potential deep C loss limits rather than invalidates comparison across specific peat layers, and Heinemeyer et al.[2] clearly acknowledge and discuss these issues (see quotes in the *supplementary information*).

Rainfall, water table depth (WTD) and drainage effects are not reported by Young et al.[1], which makes it difficult to assess model scenario applicability and C loss predictions due to decomposition. Furthermore, to show only net rainfall is unusual and obscures how this was derived and limits comparisons to other sites. To omit WTD data in a study on drainage is also unhelpful because readers cannot assess the validity of the drainage scenario being used. We certainly acknowledge the negative impacts of deep drainage on peat C storage. To this end, the model of Young et al. provides a significant contribution. However, the effect of blanket bog drainage on WTD usually only extends a couple of metres on either side of the ditch; beyond this point, the impacts on WTD are generally small (only a few centimetres of drawdown)[4,5,6] owing to low hydraulic conductivity, particularly on shallowly sloping or flat areas as on our sites. Young et al. do not state at what distance from ditches their model applies to, nor is it clear what the WTD was. Was it a generic 50 cm WTD reduction? This would be possible, but only right next to the drainage ditch. Still, it would be meaningless in relation to Heinemeyer et al.[2] or in general because, as previously stated, WTD impacts only extend outwards by a few metres and decrease rapidly with distance. Only by including all this information can a general assessment of model processes, performance and validity be made.

Another issue is that the 'artefact' of higher C accumulation is context-dependent. While near-surface C accumulation rates are never an indication of total peat accumulation rates, carbon losses from deeper peat layers are dependent on the edaphic conditions in those layers. For example, if the deeper peat is at least predominantly waterlogged (i.e. limiting decomposition), and there is no other significant C loss from the deeper layers (e.g. via methane, dissolved organic carbon or erosion from via peat pipes – although all are near impossible to assess in any peat core assessment), then it is quite 'safe' to derive and compare such C accumulation rates. The peat core sites used by Heinemeyer et al.[2] are all located at a ‘safe’ distance (~15 m) from any old ditches or gullies, which means the basal layers are likely to be waterlogged (and thus storing, rather than losing, carbon). In any case, the C accumulation rates measured by Heinemeyer et al.[2] were only derived to be compared to other studies over similar periods, and highlight that previously assumed high C losses from burning is not necessarily true (note: the only significant reduction in C accumulation rates in Marrs et al.[3] was measured in the 10-year rotation at Moor House, which is an unrealistic scenario due to the very slow vegetation growth at the site). The main aims of the Heinemeyer et al., study were the charcoal specific impacts on peat properties affecting C accumulation rates (i.e. bulk density and organic C content, %Corg).

Unfortunately, Young et al. ignored the previously published, validated and more applicable MILLENNIA model[7], which considered the impacts of both burning and drainage on blanket bog C storage. Some of the processes considered by the MILLENNIA model included the natural infilling of ditches and burn rotation cycles (*ibid*). The MILLENNIA model was validated using WTD depth measurements from Moor House and *testate amoebae* WTD reconstructions (*ibid*). However, like Young et al.[1], the MILLENNIA model did not include any burn-related processes, such as charcoal impacts on bulk density and %Corg[7].

The precursor to the Young et al. model clearly showed that "*when the infilling ditch was simulated, the downslope area and both ditchside columns maintained near or at surface water tables*"[8]. The cores used by Heinemeyer et al.[2] were extracted from areas on shallow slopes (i.e. ~flat) with infilling ditches/gullies at about a distance of ~15 m. Crucially, the drainage scenario across the sites of Heinemeyer et al.[2] is in stark contrast to the continuous deep drainage over 250 years modelled by Young et al.[1]. In fact, only two of the three sites used by Heinemeyer et al.[2] were drained, with ditches knowingly being dug only in the 1970s. Thus, the impacts of drainage on the sites used by Heinemeyer are likely to be minimal, which is supported by the drainage impact simulations in the MILLENNIA model study[7] and another peat core study from a similar peatland near one of the sites[9].

Moreover, if there were any drainage induced C losses at the sites used by Heinemeyer et al.[2], then this should be evident within the peat core data (as per model output in Fig. 2c in Young et al.[1]). However, the recent C accumulation rates (Figure 1) presented in Heinemeyer et al. ([2]; cf. Fig. 4) show very similar ranges (~60 - 140 gC m^{-2} yr^{-1}), increasing rates over the past 100 years (note: we already pointed out how to explain the artefact of increasing C accumulation rates[2]) compared to the temperate bogs shown in Young et al. (cf. Fig. 1[1]), and a noisy recent period (note: most likely this reflects variable leaf and root litter inputs due to climate, herbivory and, in our case, also management, the latter also including charcoal layer C inputs affecting bulk density, %Corg and thus C accumulation rates). However, important to note is the overall positive relationship of these factors with charcoal counts (as per the Heinemyer et al.'s [2] hypotheses). Likewise, the older C accumulation rates within the sites used by Heinemeyer et al.[2] (Figure 2) are even slightly higher than the Young et al. 'natural' (undrained) scenario and certainly do not indicate C losses due to deep drainage (cf. Young et al.'s Fig. 2c[1] showing a reduction from about 30 to about 10 gC m^{-2} yr^{-1} by drainage).

Young et al. highlight the issues with using shallow peat cores to determine peatland C accumulation rates[1]. However, it remains unclear how full-length peat core analysis could overcome these issues because both climatic and management impacts could exert an influence on C accumulation rates throughout time, but how can individual influences be detected or related to 'intact' cores? We propose that one way is to use %Corg data as an assessment tool. For example, if drainage is causing C losses, %Corg should decline due to drainage induced decomposition. Peat core data from the sites used by Heinemeyer et al.[2] (see Figure 3) show that there is a slight drop in C accumulation rates at around 9-12 cm depth (1900-1870) at the two sites with drainage (Nidderdale and Mossdale) implemented in the 1970s (this assumes a 5-10 cm drop in water tables that affected the peat ~60-100 years earlier in relation to peat depth/age) (Figure 1). Crucially, the drop displayed in Figure 1 agrees with reduced C accumulation rates predicted by the model of Young et al. (cf. Fig 2[1]). This highlights the value of detailed %Corg assessments to detect potential management (drainage) induced peat C loss and the value of model scenarios by Young et al.[1].

We have one further comment, Young et al. criticise attempts to compare C flux with C stock budgets, but their criticism overlooks the fact that methane C fluxes are often not included (in addition to challenges in how to atrribute overall catchment-scale fluvial C losses to specific plot-level flux measurement locations) and the long time scales needed to capture management (disturbance) and recovery (plant regrowth) in C flux assessments. Hardly any such long-term C flux studies exist, which is a point recently acknowledged in the literature[10, 11]. We suggest that C flux studies investigating the impacts of heather burning on peatlands should be conducted for about 25 years (i.e. covering a complete burning rotation), but possibly longer. Importantly, our latest but as yet unpublished C flux data suggest fast C uptake due to vegetation recovery on burnt plots will soon offset combustion losses (i.e. Nidderdale)[12].

Finally, after outlining our main concerns, we would like to highlight the subjective criticism of Young et al. For example, Young et al. used their results to criticise the burning studies of Heinemeyer et al. and Marrs et al. [2,3], but not the related burning study of Garnett et al. [13], which used the same Hard Hill plots as Marrs et al.[3,13] to investigate the impact of burning on carbon accumulation (note: Garnett et al.[13] only used two of the experimental treatments). Thus, for the purposes of objectivity, Garnett et al. [13] should have been included by Young et al. in their criticism of Heinemeyer et al. and Marrs et al. [2,3].

Concluding remarks

While Young et al. is a welcome addition to the issue of drainage impacts on peatland C stocks, it cannot be used to directly criticise prescribed vegetation burning studies on peatland [2,3]. Indeed, Young et al.'s criticism of two recent burning studies[2,3] is based on non-validated and unexplained model scenarios that omit crucial fire-mediated C cycle processes; we urge peatland researchers to include such burn-related C-cycle processes within future model scenarios[2,7]. For example, (i) net C fluxes at the three Heinemeyer et al. sites[2] (see the Peatland-ES-UK website[12]) indicate a potentially high net C uptake on regrowing burnt plots (possibly higher than that of unburnt plots with aging/degenerating heather and soon to offset combustion losses, but this requires a complete burn rotation to allow comparing cumulative C flux budgets versus C stocks estimates); (ii) recent work[14] adds to the prescribed heather burning work[2,3] in highlighting the positive role that charcoal (produced during cool burns or low-severity fires) can have on peatland C storage (e.g. it has the potential to increase peat C stocks by adding recalcitrant Corg in the form of charcoal and further reducing C losses via decomposition of soil organic matter); finally, (iii) a recent study suggests that low-severity fires may reduce methane emissions relative to no burning or high-severity fires in cooler climates[15].

Our greatest concern is that Young et al.'s unjustified criticisms of specific studies[2,3] have been reproduced within publications of important peatland conservation bodies, such as in the IUCN UK Peatland Programme[16], which explicitly refer to the two heather burning studies[2,3] as having "*presented misleading conclusions*" (n.b. the IUCN UK PP confirmed the link to the Young et al. study to us). Such statements and related policy advice should be based on validated facts. Therefore, Young et al's unjustified (and probably unintended) criticisms of two recent and unrelated burning studies[2,3] should be corrected in their paper[1] and removed from the IUCN UK PP documents - there is a fine line between questioning other people's work and unfairly discrediting it. We also suggest that the title of Young et al. is changed to "***Potential for*** *misinterpreting carbon accumulation rates in records from near-surface peat*" since they provide no general and robust evidence to support their generic claims.

Competing Interests

A. Heinemeyer has written this response (in collaboration with Mark Ashby) independently (with internal publication funding from the Stockholm Environment Institute) during the time of a second funding phase of the Peatland-ES-UK project. In order to maintain full transparency regarding any perceivable conflicts of interest, the author would like to acknowledge that phase two of the Peatland-ES-UK project and associated PhD projects have received funding from several groups: University of York (UoY); Natural Environmental Research Council (NERC); Natural England (NE); The Moorland Association (MA); United Utilities (UU); Yorkshire Water Services (YWS); The Yorkshire Wildlife Trust (YWT); Law Family Charitable Foundation; The British Association for Shooting and Conservation (BASC). M. Ashby has provided independent ecological advice and evidence synthesis services to the Moorland Association since April 2019 and the Game & Wildlife Conservation Trust since October 2019.

Author Contributions

A.H. and M.A. conceived the paper; A.H. collected and analysed the data and wrote the first draft of the manuscript. Both A.H. and M.A. interpreted the results, revised the manuscript and gave final approval for submission.

References

[1] Young, D. M., Baird, A. J., Charman, D. J. Evans C. D., Gallego-Sala A. V., Gill P. J., Hughes P. D. M., Morris P. J. & Swindles G. T. Misinterpreting carbon accumulation rates in records from near-surface peat. *Sci. Rep.* 9, 17939; https://doi.org/10.1038/s41598-019-53879-8 (2019).

[2] Heinemeyer A., Asena Q., Burn W. L. & Jones A. L. Peatland carbon stocks and burn history: blanket bog peat core evidence highlights charcoal impacts on peat physical properties and long-term carbon storage. *GEO: Geography and Environment* 5(2), e00063; https://doi.org/10.1002/geo2.63 (2018).

[3] Marrs, R. H., Marsland E.-L., Lingard R., Appleby P. G., Piliposyan G. T., Rose R. J., O'Reilly J., Milligan G., Allen K. A., Alday J. G., Santana V., Lee H., Halsall K. & Chiverrell R. C. Experimental evidence for sustained carbon sequestration in fire-managed, peat moorlands. *Nat. Geosci.* 12, 108 (2019).

[4] Luscombe D. J., Anderson K., Grand-Clement E., Gatis N., Ashe J., Benaud P., Smith D. & Brazier R. E. How does drainage alter the hydrology of shallow degraded peatlands across multiple spatial scales? *Journal of Hydrology*, 541, 1329-1339 (2016).

[5] Wilson, L., Wilson, J., Holden, J., Johnstone, I., Armstrong, A. & Morris, M. Recovery of water tables in Welsh blanket bog after drain blocking: discharge rates, time scales and the influence of local conditions. *Journal of Hydrology*, 391, 377–386 (2010).

[6] Holden, J., Chapman, P. J. & Labadz, J. C. Artificial drainage of peatlands: hydrological and hydrochemical process and wetland restoration. *Progress in Physical Geography*, 28, 95-123 (2004).

[7] Heinemeyer A. & Swindles G. T. Unraveling past impacts of climate change and land management on historic peatland development using proxy-based reconstruction, monitoring data and process modeling. *Global Change Biology*, 24(9), 4131-4142 (2018).

[8] Young, D. M., Baird, A. J., Morris P. J. & Hodlen J. Simulating the long-term impacts of drainage and restoration on the ecohydrology of peatlands. *Water Resources Res*. 53(8), 6510-6522 (2017).

[9] McCarroll, J., Chambers, F. M., Webb, J. C. & Thom, T. Application of palaeoecology for peatland conservation at Mossdale Moor, UK, *Quaternary International*, 432 (A), 39-47 (2017).

[10] Heinemeyer A., Asena Q., Burn W. L. & Jones A. L. & Ashby M. A. Response to: Comment on "Peatland carbon stocks and burn history: Blanket bog peat core evidence highlights charcoal impacts on peat physical properties and long-term carbon storage by Evans et al. *GEO: Geography and Environment*; https://doi.org/10.1002/geo2.78 (2019).

[11] Evans, C. D., Bonn, A., Holden, J., Reed, M. S., Evans, M. G., Worrall, F., Couwenberg, J., & Parnell, M. Relationships between anthropogenic pressures and ecosystem functions in UK blanket bogs: Linking process understanding to ecosystem service valuation. *Ecosystem Services*, 9, 5–19 (2014).

[12] Heinemeyer, Peatland-ES-UK Peatland (upland & heather-dominated Blanket Bog) - Management and Ecosystem Services in the UK. http://peatland-es-uk.york.ac.uk/field-measurements/C-fluxes (2020).

[13] Garnett, M. H., Ineson. P. & Stevenson, A. C. Effects of burning and grazing on carbon sequestration in a Pennine blanket bog, UK. *The Holocene*, 10, 729–736 (2000).

[14] Flanagan, N. E., Wang, H., Winton, S., Richardson, C. J. Low-severity fire as a mechanism of organic matter protection in global peatlands: Thermal alteration slows decomposition. *Glob Change Biol*. 26(7), 3930-3946 (2020).

[15] Davidson, S. J., Van Beest, C., Petrone, R. & Strack, M. Wildfire overrides hydrological controls on boreal peatland methane emissions. *Biogeosciences*, 16, 2651–2660 (2019).

[16] IUCN UK Peatland Programme POSITION STATEMENT: Burning and peatlands. V.2 March 2020. https://www.iucn-uk-peatlandprogramme.org/sites/default/files/header-images/Resources/IUCN%20UK%20PP%20Burning%20and%20Peatlands%20Position%20Paper%202020%20Update.pdf (2020).

[17] Heinemeyer A., Vallack H.W., Morton P.A., Pateman R., Dytham C., Ineson P., McClean C., Bristow C. and Pearce-Higgins J.W. with an Appendix by Richard A. Lindsay. Restoration of heather-dominated blanket bog vegetation on grouse moors for biodiversity, carbon storage, greenhouse gas emissions and water regulation: comparing burning to alternative mowing and uncut management. Final Report to Defra on Project BD5104, Stockholm Environment Institute at the University of York, York, UK. http://sciencesearch.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=17733 (2019).

Figures

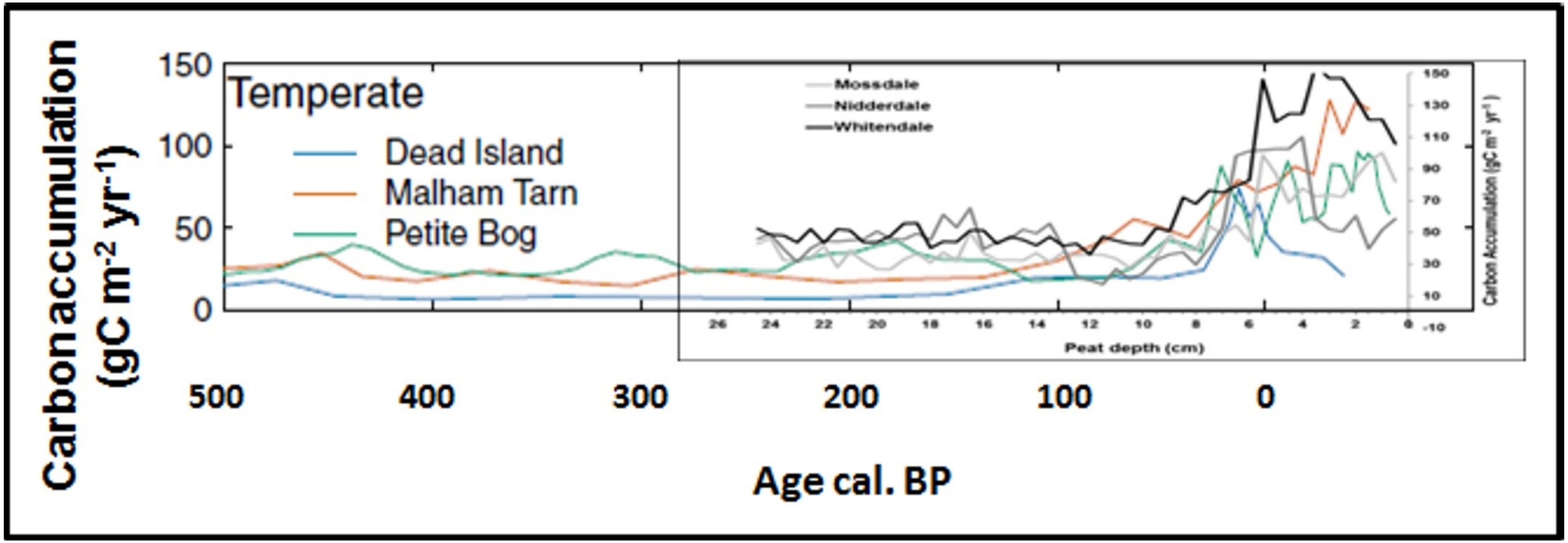

Figure 1 Carbon accumulation rates from Heinemeyer et al.[2] overlaid (based on peat depth/age estimates for the three sites, Nidderdale, Mossdale and Whitendale) onto those for temperate bog examples given within Young et al.'s[1] Figure 1.

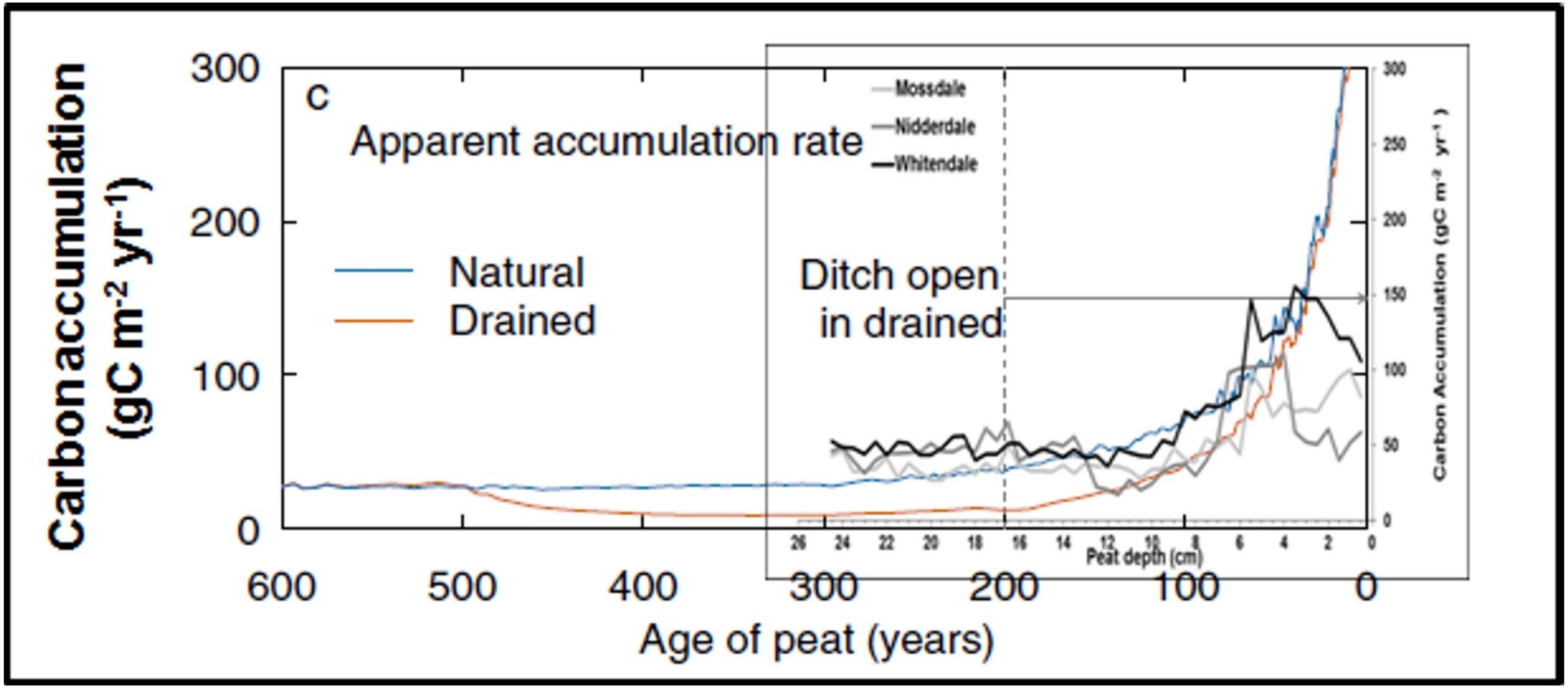

Figure 2 Carbon accumulation rates from Heinemeyer et al.[2] overlaid (based on peat depth/age estimates for the three sites, Nidderdale, Mossdale and Whitendale) onto simulated rates for natural and drained peatlands shown in Young et al.'s[1] Figure 2c.

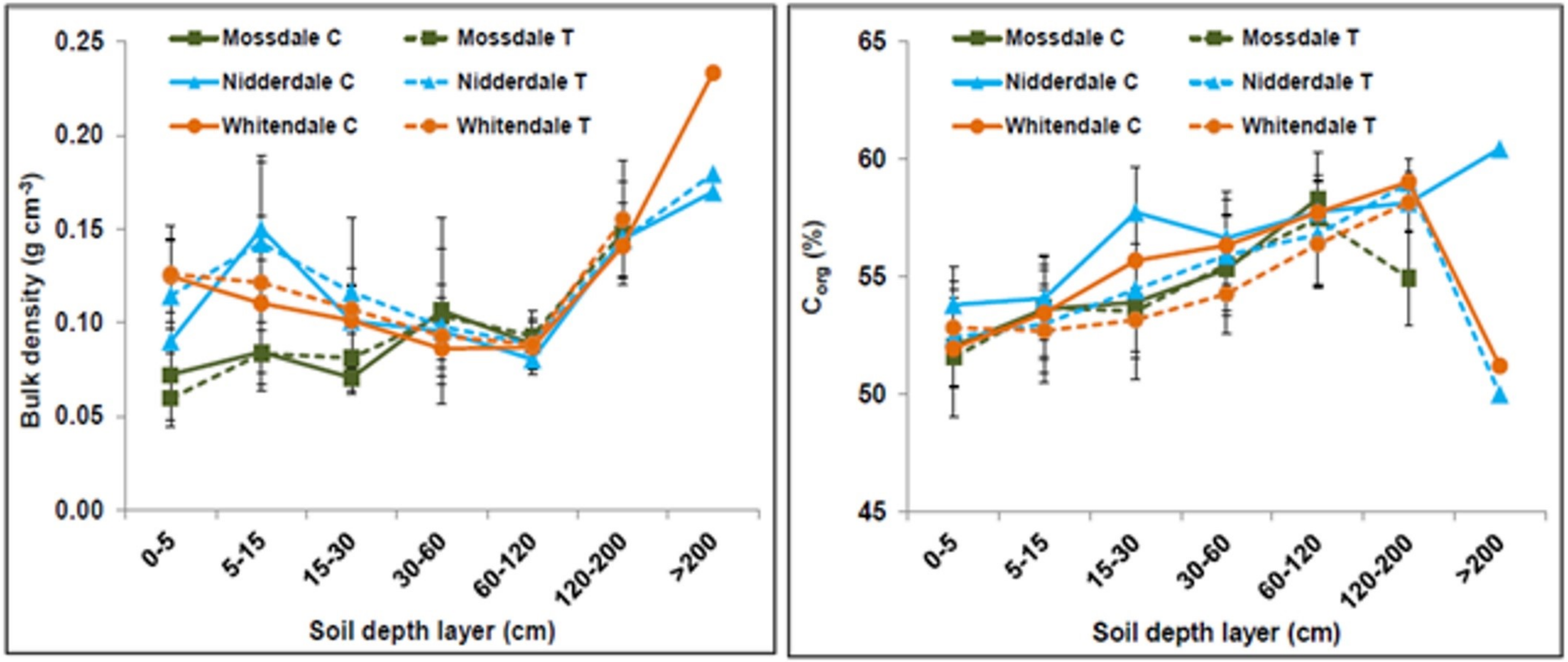

Figure 3 Average (± standard deviation) bulk density (left) and organic carbon content (%Corg; right) based on manual peat core sampling (30/08/12) for up to (depending on total peat depth) six peat core sections (i.e. 5 cm^3 sample of the mid soil depth range) for the three sites (Nidderdale, Mossdale and Whitendale) and their two sub-catchments (C & T) of the Peatland-ES-UK project (Figure taken from Heinemeyer et al.[17] where more information on methods is provided).