Carbon dioxide and methane fluxes on a degraded lowland bog undergoing restoration with micro-propagated *Sphagnum*

Manchester Metropolitan University

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BeadaMoss® Sustainably Produced Sphagnum

The Wildlife Trust Lancashire Manchester N. Merseyside

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INTRODUCTION

Intact, functioning peatlands are believed to sequester more atmospheric carbon per hectare than other habitats, so play a vital role in combating anthropogenic climate change[1]. However, peatlands have been damaged by human activities with consequences for their carbon balance. Peatlands drained for peat extraction emit large amounts of carbon dioxide (CO_2) from the newly-exposed aerobic peat[2]. When these same peatlands are restored and re-wetted other researchers found reduced CO_2 emission from aerobic microbial respiration, but increased methane (CH_4) production through methanogenic microbial respiration[3]. The rationale for this study is that peatland restoration is part of UK climate change mitigation obligations and there is currently a lack of data on carbon fluxes from degraded lowland raised bogs[4] so this trial will add to the body of knowledge on this area in the UK.

Re-establishment of peat-forming *Sphagnum* mosses may be vital for returning normal function and carbon sequestration to a damaged peatland[5]. *Eriophorum* (cottongrass) species are early colonisers, and also perhaps the species of choice to nurse *Sphagnum* moss re-colonisation[6] as they provide environmental protection and help stabilize the peat surface. But aerenchyma in *Eriophorum* species, act as 'chimneys' for CH_4 from the anaerobic peat to the atmosphere[7] and raise CH_4 emissions from restored peatlands. Rapid colonisation by *Sphagnum* mosses is needed to reduce vascular plant cover[1].

Micro-propagated *Sphagnum* moss products, developed by our industrial partner MicroPropagation Services Ltd, are being used as source material is scarce: there are very few natural bog systems left in England and those are under conservation measures and cannot be harvested. One of these products, known as BeadaGel™ contains 11 species of *Sphagnum* in a nutrient gel which is sprayed onto the peat surface. This study is being undertaken on Cadishead Moss, a degraded lowland raised bog near Manchester under restoration management by the Lancashire Wildlife Trust. We aim to discover how newly propagated *Sphagnum* moss affects the CO_2 and CH_4 fluxes on re-wetted peatlands by taking regular gas measurements using field chambers and a portable greenhouse gas (GHG) analyser (Los Gatos Research, California).

METHODS

Study site: Cadishead Moss. Study period: September 2016 - 2018

Rainfall: 800 mm yr^{-1}

Temperature Mean:
Jan: 4.9 °C
July: 17.3 °C
Annual: 10.4 °C

Elevation: 23 m asl

Study site: Cadishead Moss SBI (red outline) owned by Lancashire Wildlife Trust. 9 miles west of Manchester, UK; trial area (green outline)

Field Trial set-up:

Mature cottongrass with established *Sphagnum*

Immature cottongrass with new BeadaGel™ application

Bare peat – any new vascular plants removed throughout the trial

- Permanent sampling collars for GHG flux measurements
- Dipwells for monitoring water-table depth for group of 3 collars in each plot
- Mature *Sphagnum* and cottongrass; control plots of mature cottongrass only
- New application of BeadaGel™ in open sward of immature cottongrass; control plots of immature cottongrass only and bare peat
- Los Gatos GHG Analyser using a closed system of Perspex chamber with extension for taller vegetation
- Fortnightly measurements in growing season, monthly during plant senescence.
- Monthly measurement of vegetation volume

Los Gatos GHG analyser and chamber with extension

Typical plot set-up – one of 6 plots in immature vegetation

CONCLUSIONS/FURTHER RESEARCH

Conclusions:

Benefits of *Sphagnum* introduction:

- Reduces dominance of cottongrass
- 'stabilises' the system
- May act as CH_4 filter
- Moves the overall $CO_{2\,eq}$ balance towards sink rather than source

Gaseous carbon fluxes:

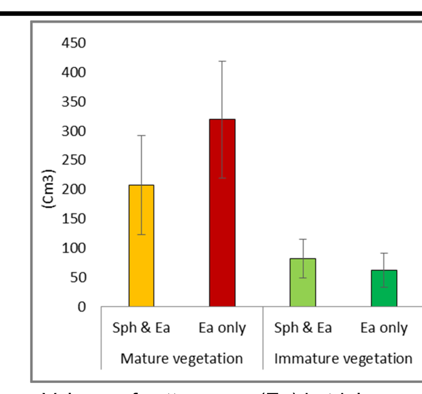
- Low on this site at this stage compared with published data from established and undamaged sites (CO_2: 97 – 239 mg CO_2 m^2 h^{-1}; CH_4: 0.14 -1.05 mg CH_4 m^2 h^{-1})[8]
- To retain/improve ecosystem carbon storage function during dry periods – consider irrigation

Further research:

- Develop a full carbon balance for this site: modelling, incorporating PAR, air and peat temperature, vegetation volume
- Micro-propagated *Sphagnum*: exploration of physiology
- Understanding *Sphagnum* role in affecting methane emissions

RESULTS AND DISCUSSION

The graphs below show trends in carbon fluxes in relation to rainfall (background blue) and water table level (purple line).



Volume of cottongrass (Ea) in trial areas – suppression over time with S. addition

Net Ecosystem Exchange (NEE):

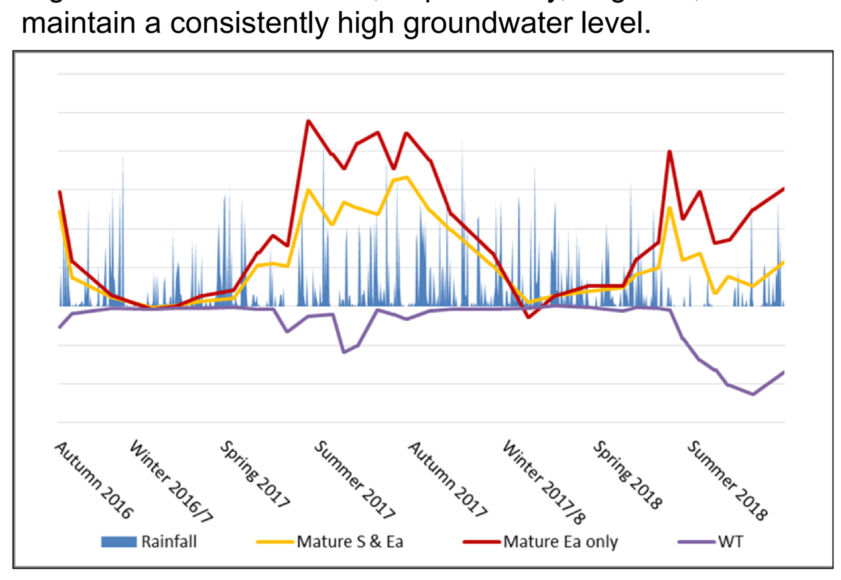
Mature vegetation:

- 1st year - expected and healthy plant response to typical warm, wet British summer
- 2nd year – reduced NEE during non-typical hot, dry summer
- Higher response in cottongrass only plots (red) compared to plots with *Sphagnum* (gold)

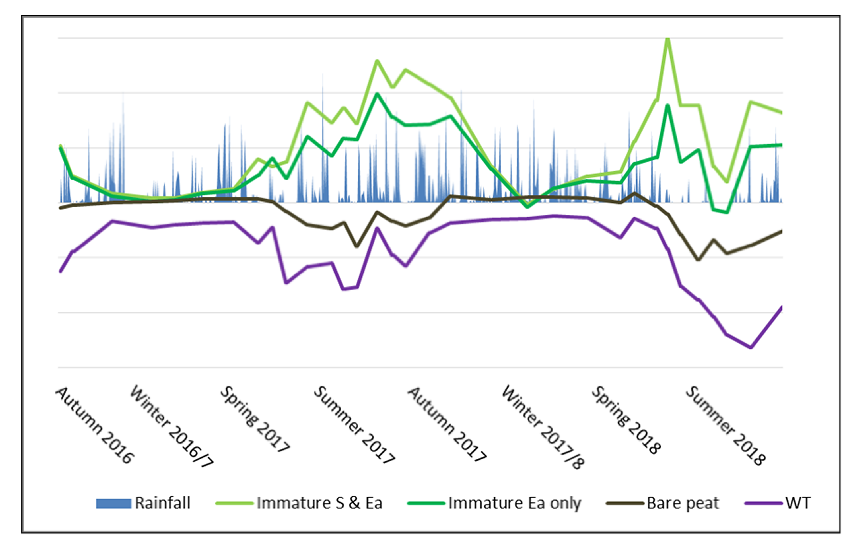
Immature vegetation:

- NEE rates are erratic as immature vegetation is more sensitive to environmental change
- Bare peat plots (black) are a carbon source throughout the warmer parts of the year

Plants respond to a return of even a small amount of regular rainfall well before the water table begins to rise suggesting that regular amounts of rainfall, or potentially, irrigation, is more important to the carbon budget in very dry periods than trying to maintain a consistently high groundwater level.



NEE - Mature vegetation*:*
Sphagnum and Cottongrass: -6 to 665 (μg CO_2 m^{-2} h^{-1})
Cottongrass only: -58 to 956 (μg CO_2 m^{-2} h^{-1})
Water Table (below surface): -4 to 452 (mm)



NEE - Immature vegetation*:*
Sphagnum and Cottongrass: -4 to 597 (μg CO_2 m^{-2} h^{-1})
Cottongrass only: -36 to 396 (μg CO_2 m^{-2} h^{-1})
Bare peat: -206 to 33 (μg CO_2 m^{-2} h^{-1})
Water Table (below surface): 47 to 526 (mm)

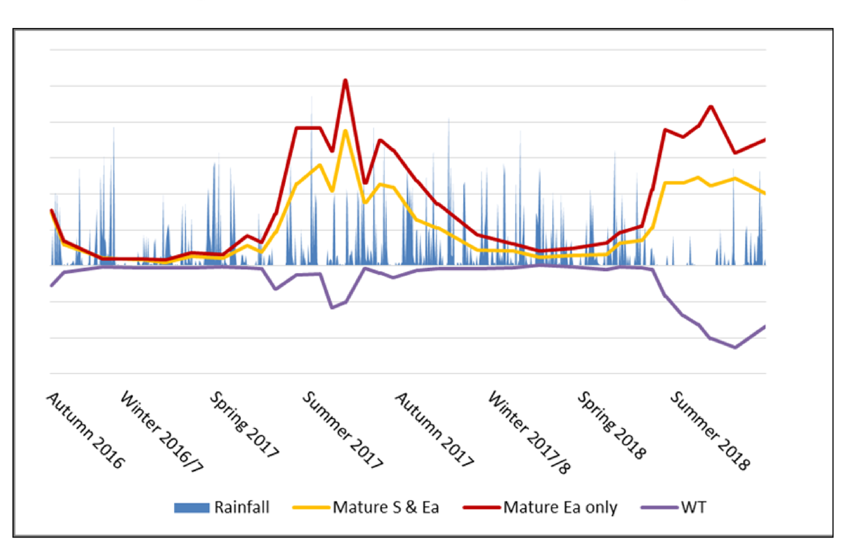
Plant Respiration:

Mature vegetation:

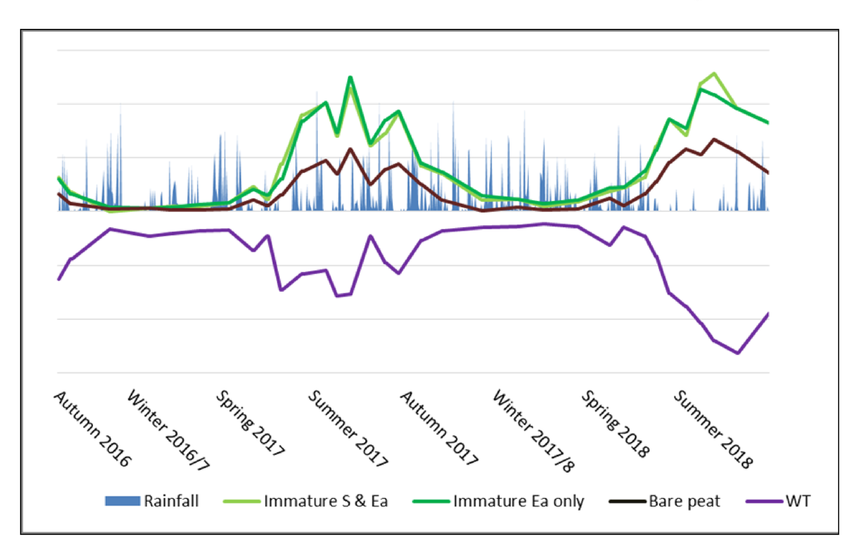
High in cottongrass only plots, even during dry periods

Lower and a little less variable in plots with *Sphagnum*, perhaps due to lower volume of cottongrass and greater local retention of moisture

Immature vegetation: little difference between vegetated plots, which have a similar pattern to bare areas, but with higher rates



Respiration - Mature vegetation*:*
Sphagnum and Cottongrass: 18 to 754 (μg CO_2 m^{-2} h^{-1})
Cottongrass only: 31 to 1031 (μg CO_2 m^{-2} h^{-1})
Water Table (below surface): -4 to 452 (mm)



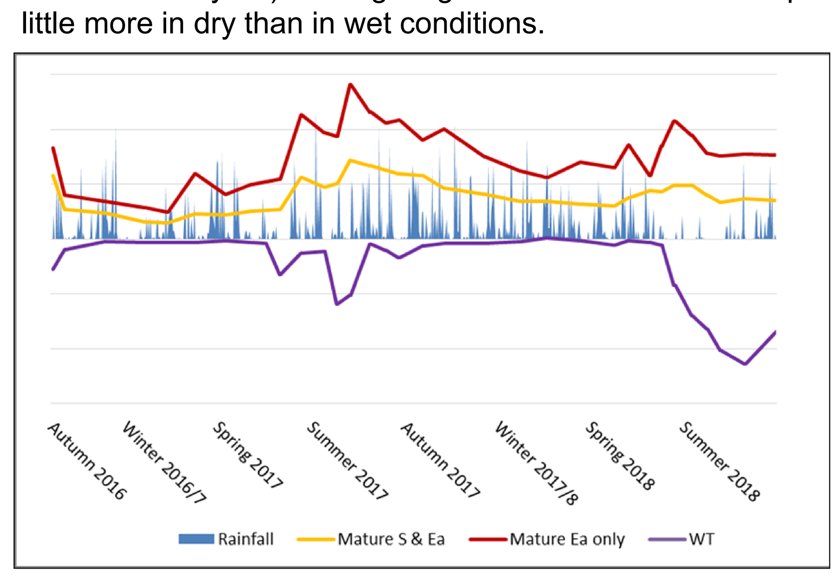
Respiration - Immature vegetation*:*
Sphagnum and Cottongrass: 1 to 515 (μg CO_2 m^{-2} h^{-1})
Cottongrass only: 14 to 500 (μg CO_2 m^{-2} h^{-1})
Bare peat: 2 to 268 (μg CO_2 m^{-2} h^{-1})
Water Table (below surface): 47 to 526 (mm)

Methane emissions:

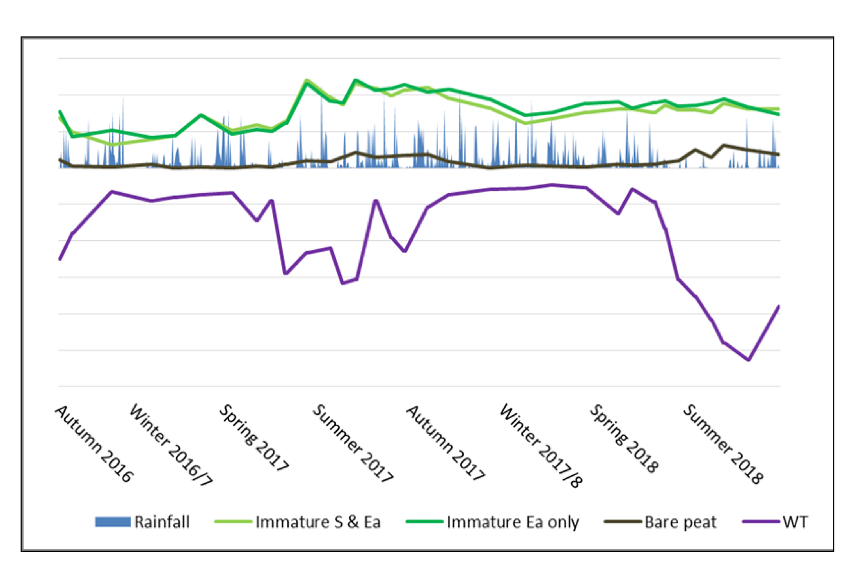
Minimal overall, perhaps rising a little over time with either increase in cottongrass growth or laying down of new carbon, but emissions add very little to the carbon budget.

Mature vegetation: plots with *Sphagnum* have lower fluxes than those with only cottongrass – either because there is less cottongrass or perhaps a methane-filter effect

Immature vegetation: little difference related to vegetation type (perhaps a *Sphagnum* methane-filter effect becoming evident in the second year) although higher emissions than bare peat alone, which emits little methane throughout but, surprisingly, a little more in dry than in wet conditions.



Methane emissions - Mature vegetation*:*
Sphagnum and Cottongrass: 0.3 to 1.4 (μg CH_4 m^{-2} h^{-1})
Cottongrass only: 0.5 to 2.8 (μg CH_4 m^{-2} h^{-1})
Water Table (below surface): -4 to 452 (mm)



Methane emissions - Immature vegetation*:*
Sphagnum and Cottongrass: 0.3 to 1.2 (μg CH_4 m^{-2} h^{-1})
Cottongrass only: 0.4 to 1.2 (μg CH_4 m^{-2} h^{-1})
Bare peat: 0 to 0.3 (μg CH_4 m^{-2} h^{-1})
Water Table (below surface): 47 to 526 (mm)

References: **[1]** Lindsay (2010) *Peatbogs and carbon: a critical synthesis to inform policy development in oceanic peat bog conservation and restoration in the context of climate change*. RSPB Scotland. **[2]** Danevčič *et al.* (2010) Emissions of CO_2, CH_4 and N_2O from Southern European peatlands. *Soil Biology & Biochemistry* 42: 1437-1446. **[3]** Haddaway *et al.* (2014) Evaluating effects of land management on greenhouse gas fluxes and carbon balances in boreo-temperate lowland peatland systems. *Environmental Evidence* 3:5 (systematic review: open access). **[4]** Evans *et al.* (2016). Lowland peatland systems in England and Wales – evaluating greenhouse gas fluxes and carbon balances. Final report to Defra on Project SP1210, Centre for Ecology and Hydrology, Bangor. **[5]** Quinty & Rochefort (2003) *Peatland Restoration Guide, second edition* [online] Canadian *Sphagnum* Peat Moss Association and New Brunswick Department of Natural Resources and Energy, Québec. **[6]** Pouliot *et al.* (2011) Initiation of *Sphagnum* moss hummocks in bogs and the presence of vascular plants: Is there a link? *ActaOecologica*37: 346-354. **[7]** Schimel (1995) Plant transport and methane production as controls on methane flux from arctic wet meadow tundra. *Biogeochemistry* 28: 183-200. **[8]** Carter *et al.* (2012) Synthesizing greenhouse gas fluxes across nine European peatlands and shrublands – responses to climatic and environmental changes, *Biogeosciences Discussions* 9:3693–3738.

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