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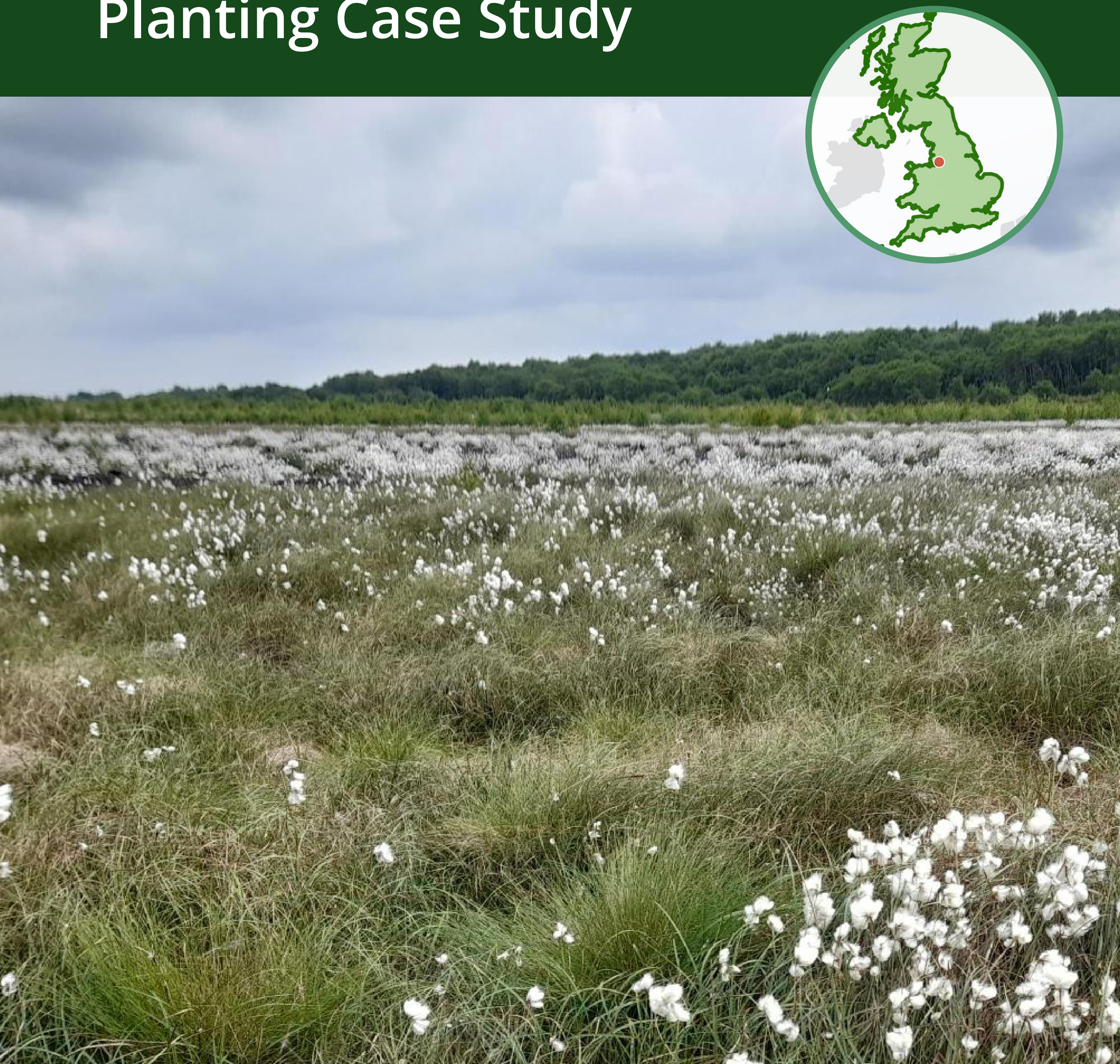
# INTERREG CARE-PEAT

# Little Woolden Moss Companion Planting Case Study



# REPORT

Little Woolden Moss Companion Planting Case Study

**Author(s)**

Jo Kennedy, Lancashire Wildlife Trust
Sarah Johnson, Lancashire Wildlife Trust
Mike Longden, Lancashire Wildlife Trust
Anna Keightley, Manchester Metropolitan University
Chris Field, Manchester Metropolitan University
Simon Caporn, Manchester Metropolitan University
Neal Wright, Micropropagation Services (EM) Ltd

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**Contact information**

Katrien Wijns | Project coordinator Interreg Care-Peat
Natuurpunt Beheer | Coxiestraat 11, 2800 Mechelen, Belgium
katrien.wijns@natuurpunt.be | +32 (0)497/05.29.21
www.nweurope.eu/care-peat

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# Introduction

## 1. Introduction

The aim of this Care-Peat pilot was to showcase a method of restoring the carbon storage function of a formerly commercially extracted bare peat site being restored to lowland bog by rapidly covering the pilot site with *Eriophorum* and *Sphagnum* species, which should reduce carbon losses and support the hydrological integrity and biodiversity of the main nature reserve.

The pilot has been specifically designed to promote rapid colonisation of bare peat with vegetation in order to minimise the time taken to return the site to a $CO_2$ sink. This work applies previous research findings on the carbon benefits of specific plant mixes.

### 1.1 The importance of peatlands

Peatlands are not only habitats with a highly specialised flora and fauna, they also play an important role in global climate regulation. Peatlands are the most efficient carbon sink on the planet - in the northern hemisphere they account for three to five per cent of total land area but contain approximately 33 per cent of global soil carbon.

Yet many peatlands are in poor condition due to a myriad of reasons including burning, drainage for agricultural use, peat extraction and historic pollution which is causing carbon that has been stored over thousands of years to be released to the atmosphere, contributing to large-scale greenhouse gas (GHG) emissions and particularly increased atmospheric carbon dioxide ($CO_2$). These carbon stores are further threatened by extreme weather conditions due to climate change (notably longer periods of drought) which will further increase the rate of decomposition. Global GHG emissions from drained organic soils are equivalent to 1,600 MT $CO_2$ (twice the $CO_2$ emissions from aviation) and for the EU in total these emissions are 506 MT/year; for the North West Europe region they are approximately 150 MT/year (more than the annual GHG emissions of Belgium).

The restoration of peatlands is therefore seen as vital in our battle against climate change and key to achieving the European Union's aim to be carbon neutral by 2050. Key to the restoration of peatlands is the rewetting and control of the water table followed by the re-establishment of suitable vegetation capable of future carbon sequestration.

## 1.2 Aims of the Little Woolden Moss Companion Planting pilot

Overall, for the wider Little Woolden Moss (LWM) site, the aim is restoration to lowland raised bog with representative plant communities and to establish the best way to achieve the restoration planting needed on bare peat that also effectively reduces carbon GHG emissions.

The pilot built on earlier research carried out by Manchester Metropolitan University (MMU) between 2016 and 2018 on the neighbouring site of Cadishead Moss, which looked at the relationship between types of vegetation cover, vegetation maturity, and GHG fluxes. Ideally the pilot would test:

1. The establishment rate of desired ground coverage of vascular plant communities found in lowland raised bog habitat.

2. Whether the chosen plant assemblage provides a supportive environment for reintroduction and establishment of hummock-forming *Sphagnum* species.

3. Whether the chosen vascular and *Sphagnum* plant assemblage could be successful in converting an area of bare peat from a presumed state of emitting gaseous carbon to sequestration.

# Site description and suitability

## 2.1 Location and former usage

The companion planting pilot area is located on Little Woolden Moss (LWM), 107 hectares (ha) of former lowland raised bog degraded through commercial peat milling, which has been owned since 2012 by the Lancashire Wildlife Trust (LWT) and is located in the Metropolitan District of Salford in Greater Manchester. The site is approximately 8 miles from Manchester city centre (Figure 1).

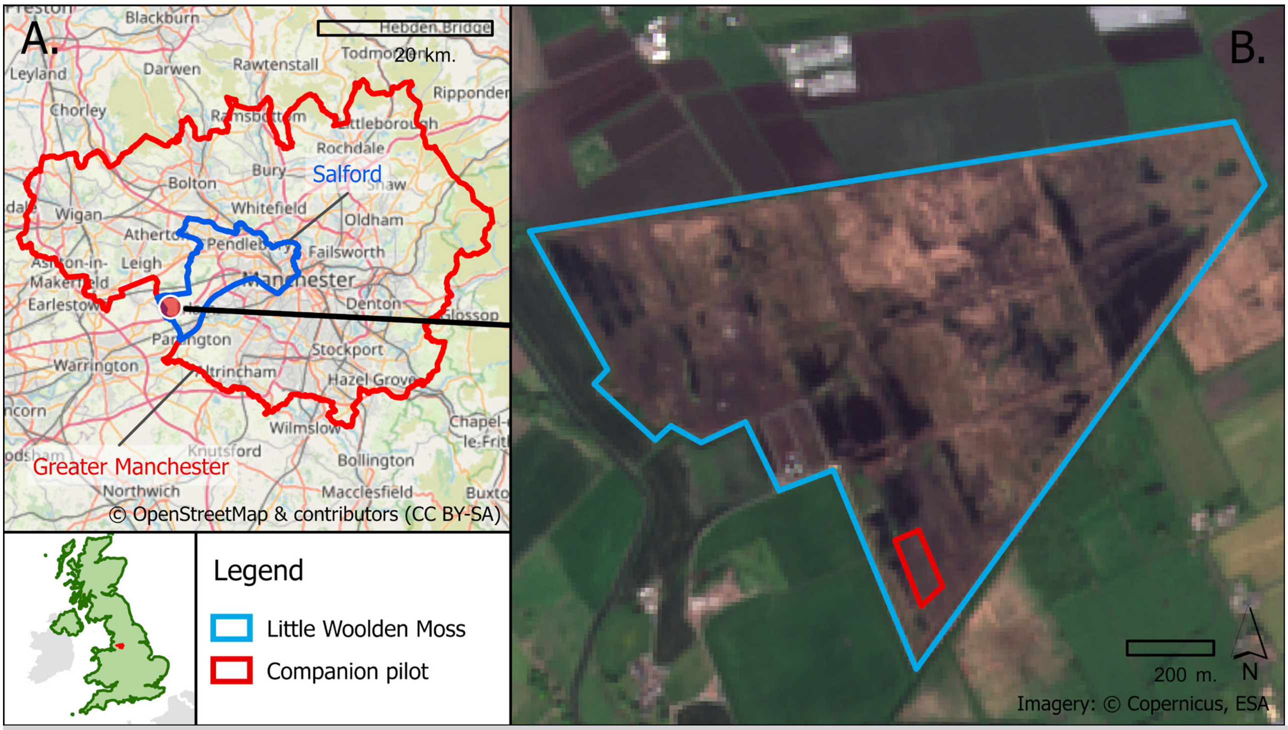


Figure 1: Map showing the location of the Companion Planting Pilot on Little Woolden Moss in Salford, north west England, UK

Until end-of-tenure on 31 December 2017, the part of LWM where the pilot site is located, was commercially extracted for peat, with internal drainage ditches spaced approximately 16 m apart. In spring 2018 work began to re-wet the area, reprofiling through filling in the ditches, and creating a network of bunding to help retain higher, more controlled, groundwater levels. Shelter belt woodland was planted to protect the area from the drying effects of wind. Subsequent subsidence of infilled ditches has created a topography of ridges and depressions (here called 'Hummocks' and 'Hollows') across Little Woolden Moss and the pilot site reflects this.

The 1 ha pilot site lies fully within the boundary of Little Woolden Moss (Figure 2) which is in various stages of restoration through rewetting by bunding and ditch-blocking and revegetation with a mixture of bog characteristic plants including *Eriophorum spp*. and *Sphagnum*. Surrounding Little Woolden Moss is agricultural land, used for livestock and winter feed crops and patchy areas of woodland. A large drainage ditch runs to the west of the pilot site.

LWM sits within the Great Manchester Wetlands Nature Improvement Area and is considered an important linking site between the nearby Manchester Mosses Special Areas of Conservation (SAC) sites.


Figure 2: Map indicating the location of the Companion Planting trial area within Little Woolden Moss

## 2.2 Meteorology

Over the two-year study period, annual rainfall and average air temperature were 1102 mm and 9.4°C in year 1, and 916 mm and 10.8°C in year 2. Minimum and maximum air temperatures for January and July were -6.0°C and 10.6°C, and 3.8°C and 31.3°C respectively in year 1 and -5.9°C and 14.1°C and 6.0°C and 37.5°C respectively in year 2. Long-term average weather data between 1991 and 2020 was derived from the nearest Met Station at Woodford 53°20’24.0”N 2°09’14.4”W 88m asl 23.8 km SE (Met office, 2022). This gives annual rainfall of 868.4 mm, and mean air temperature values: annual 9.74°C; January 4.1°C, and July 16.2°C.

## 2.3 Soil condition and vegetation

The peat quality on the pilot site at the start of the project was poor, coarse, highly degraded (humified) with much surface cracking and low permeability and the most obvious plant remains within it were grass, heather and wood. The peat depth varies from 0.5 m up to 1.5 m in places due to fluctuations in the underlying substrate. Underneath this peat is a thin layer of glacier-deposited sand overlaying clay, with wood underlaying the peat in places. Prior to planting the area was predominantly bare peat.

## 2.4 Soil chemistry

Six replicate soil cores were sampled from the top 15 cm of peat in the summer of 2019, taken from a series of Hummocks (Hk) and Hollows (Hw) and analysed. The ‘Hollows’ represented filled in former drainage ditches from when the site had been extracted; they remain wetter and are slightly lower than the original bare-peat surface (Hummocks). The mean pH across the site was 4. This fits well with typical values from raised bogs survey confirming potential for a raised bog habitat (usually pH<4.2). Peat soil is also characterised by Loss on Ignition (LOI) values of greater than 80% and C% of around 50% and the results above confirm that LWM can be clearly defined as peat (Table 1).

Table 1. Soil chemistry data companion planting pilot site, highlighting the different elevation areas

| | pH | LOI % | C % | N % | C/N | Ammonium (mg/kg) | Magnesium (mg/kg) | Calcium (mg/ kg) | Nitrate (mg/ kg) | Phosphate (mg/kg) | Sulphate (mg/kg) | Total inorganic N (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **LWM Hummock 1** | 3.93 | 97.56 | 53.94 | 1.08 | 50.04 | 59.77 | 0.00 | 234.33 | 2.19 | 0.00 | 6.21 | 46.98 |
| **LWM Hummock 2** | 4.05 | 95.28 | 51.03 | 1.29 | 39.51 | 18.51 | 0.00 | 158.40 | 3.34 | 0.00 | 0.17 | 15.15 |
| **LWM Hummock 3** | 4.06 | 97.35 | 50.57 | 1.02 | 49.63 | 24.87 | 214.50 | 128.87 | 2.57 | 0.00 | 0.15 | 19.92 |
| **LWM Hollow 1** | 4.08 | 98.47 | 54.05 | 1.03 | 52.71 | 53.10 | 105.57 | 99.26 | 1.10 | 0.00 | 0.68 | 41.55 |
| **LWM Hollow 2** | 4.12 | 95.72 | 51.96 | 1.1 | 47.15 | 20.25 | 50.65 | 77.63 | 2.36 | 0.00 | 0.92 | 16.28 |
| **LWM Hollow 3** | 3.76 | 91.76 | 49.17 | 0.96 | 51.33 | 7.29 | 2249.68 | 145.90 | 3.62 | 0.00 | 0.14 | 6.49 |

Nutrient data was very variable suggesting some localised enrichment may occur, possibly from bird or other animal faeces, enriched water or the close proximity of the underlying mineral layer. LWM is located west of Manchester and near to a major motorway and may receive elevated atmospheric nitrogen deposition currently and historically, and as formerly drained, bare peat mineralisation and oxidization of organic matter could have occurred.

## 2.5 Site drainage and land levels

The area was levelled and bunded to rewet it, prior to the pilot, ready for restoration-planting (Figure 3). The pilot site has a slightly sloping topography from south to north, and the peat depth reduces from just over 1 m at the southern end to less than 0.5 m at the northern end. The legacy of peat extraction is evident with ridges of hard peat-milled beds interspersed with sunken infilled ditches of softer peat, running north-south.

The northern end of the pilot site (with the shallowest peat layer) tends to retain surface water after heavy rain.

Figure 3: Prepared pilot site at LWM before planting

# Planting approach

## 3.1 Companion planting options

The following three companion planting options were originally proposed for study:

1. Common  cottongrass (*Eriophorum angustifolium*) plugs with *Sphagnum* plugs added after a 6-month period

2. 75% Common cotton gras and 25% Hare's-tail cottongrass (*Eriophorum vaginatum*) plugs with *Sphagnum* plugs added after a 6-month period.

3. Common cottongrass plugs and 'bog in a box' (these are an approach being trialled by LWT consisting of small containers planted with bog species and cultivated off-site to enable planting of well-established plants in order to speed up plant coverage in restoration work).

Following discussions with project knowledge partners, it became clear that due to the monitoring resource requirements of the project, it would only be possible to measure one of these approaches and a control area. It was decided that option 2 together with a control area of bare peat would be piloted. It is recognised that research into the other planting approaches would still be useful for comparison and establishing long-term best practice.

The pilot would allow for investigation of this form of companion planting against the option of re-wetting the bare peat site and allowing it to re-vegetate through natural re-colonisation, which is sometimes the approach taken on former extraction sites. It was hoped that the pilot might also provide information about the hummock/hollow effect on re-vegetating and GHG fluxes; again, useful, applicable data for this particular type of peat restoration site.

## 3.2 *Sphagnum* choice

The pilot used a five-species mix of *Sphagnum*, recommended by sub-partner Micropropagation Services Ltd (MPS, trading as Beadamoss®), who provided the *Sphagnum*.
The Beadamoss®SBHYP mix (BeadaHumok™) was used, comprising of:

- *S. capillifolium* (30%)
- *S. palustre* (30%)
- *S. papillosum* (30%)
- *S. medium/divinum* (5%)
- *S. subnitens* (5%)

This mix has a variety of species, including hummock-forming species which have greater resistance to decomposition and adaptions to drier conditions than other species. *S. palustre* and *S. subnitens* are included due to elevated nutrients in parts of the site. Once fully covering the peat surface, they anticipated these species could maximise carbon storage.

## 3.3 Planting

The planting regime was based on clumps of 75% Common cottongrass and 25% Hare's-tail cottongrass plugs, in the arrangement shown in Figure 4, with *Sphagnum* plugs added into the centre of the Cotton grass mix after a 6-month initial growth period, when they could provide some environmental protection for *Sphagnum* establishment. There is also a control plot of bare peat for monitoring purposes.

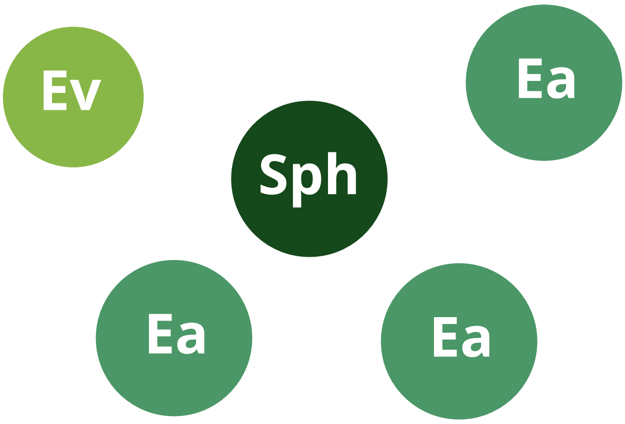


Figure 4. Proposed planting diagram: Ev = *E. vaginatum*; Ea = *E. angustifolium*; Sph = *Sphagnum* BeadaHumok™ plugs.

18,000 plugs of *E. angustifolium* and 6,000 plugs of *E. vaginatum* were planted out by LWT staff in March 2020 in groups (as per Figure 6.) spaced approximately 1 m apart. Then, after a period of growth over the summer to allow the cottongrasses to get established, 10,000 *Sphagnum* plugs were planted by LWT volunteers in September 2020 (Figures 5-7).

Figure 5. Volunteers planting the *Sphagnum*, September 2020

Figure 6. On completion of planting October 2020

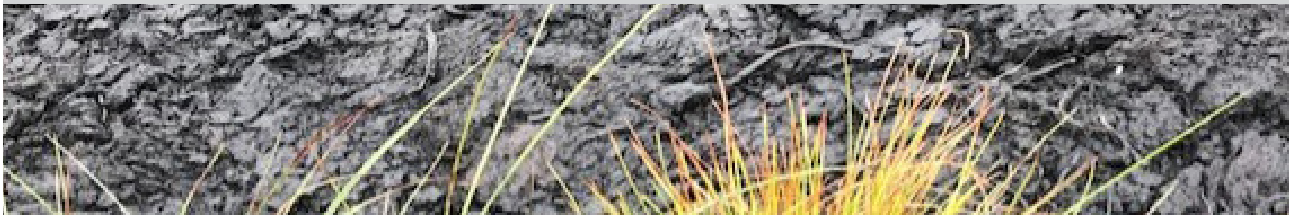

Figure 7. Arrangement of the cottongrasses and the *Sphagnum*

# Management and Monitoring

## 4.1 Changes, challenges and responses

Immediately after planting the *Sphagnum* plugs were pulled up by crows. They were re-planted where possible, and bird-deterrent devices employed to reduce further damage, but many plugs were lost entirely and the disturbance contributed to the majority of *Sphagnum* failing to thrive.

The pilot site was subject to water pooling deeply at the base of the slope, in the north-west corner particularly (not near the monitoring plots), despite flood-control overflow pipes, during the winter/spring months of 2020/21, and much of the above-ground plant material was lost in that area due to wave action. E. vaginatum plants were a little more resilient, having a tighter growth habit, and *E. angustifolium* plants showed subsequent signs of regenerating from rhizomes in some areas. An overflow pipe was re-sited to reduce flood water more effectively.

One area of the site, at the first vegetation survey in 2021, appeared to consist solely of *E. vaginatum*, although it is unclear if it lost *E. angustifolium* due to flooding or whether it was planted that way. This area was supplemented during 2022 with *E. angustifolium* turfs translocated from elsewhere in the pilot site, as was the area of the site prone to flooding.

While the control area was left bare, natural colonisation from surrounding planted areas has been observed (Figure 8).

Figure 8. Control area November 2022

## 4.2 Monitoring

Monthly monitoring of methane and carbon dioxide fluxes, along with environmental variables of water table depth (WTD), soil temperature and photosynthetically active radiation (PAR) was carried out by project partner Manchester Metropolitan University. Also, a continuous WTD logger was installed in one of the pilot site dipwells. A micro 'weather station' was already in place in another area of the site, 100m to the NW, which monitored peat temperature, air temperature, relative humidity, PAR and rainfall every 15 seconds.

Carbon Greenhouse Gas (CGHG) monitoring collars were inserted with accompanying dipwells in areas with a likely range of moisture levels and peat quality (i.e., in both hummock and hollow areas): six in the 'companion planting' area and six in the adjacent bare peat (Control) area (Figure 9). Collars were monitored for 12 months until vegetation became too dense (due to *E. vaginatum* expansion) to be representative of the pilot. Collars were then relocated to adjacent mature natural stands of *E. angustifolium* that had colonised from plug rhizomes and monitoring resumed after a 6-month gap. This gave an 'establishment' year from June 2020 and a 'post-establishment/mature' year from December 2021.

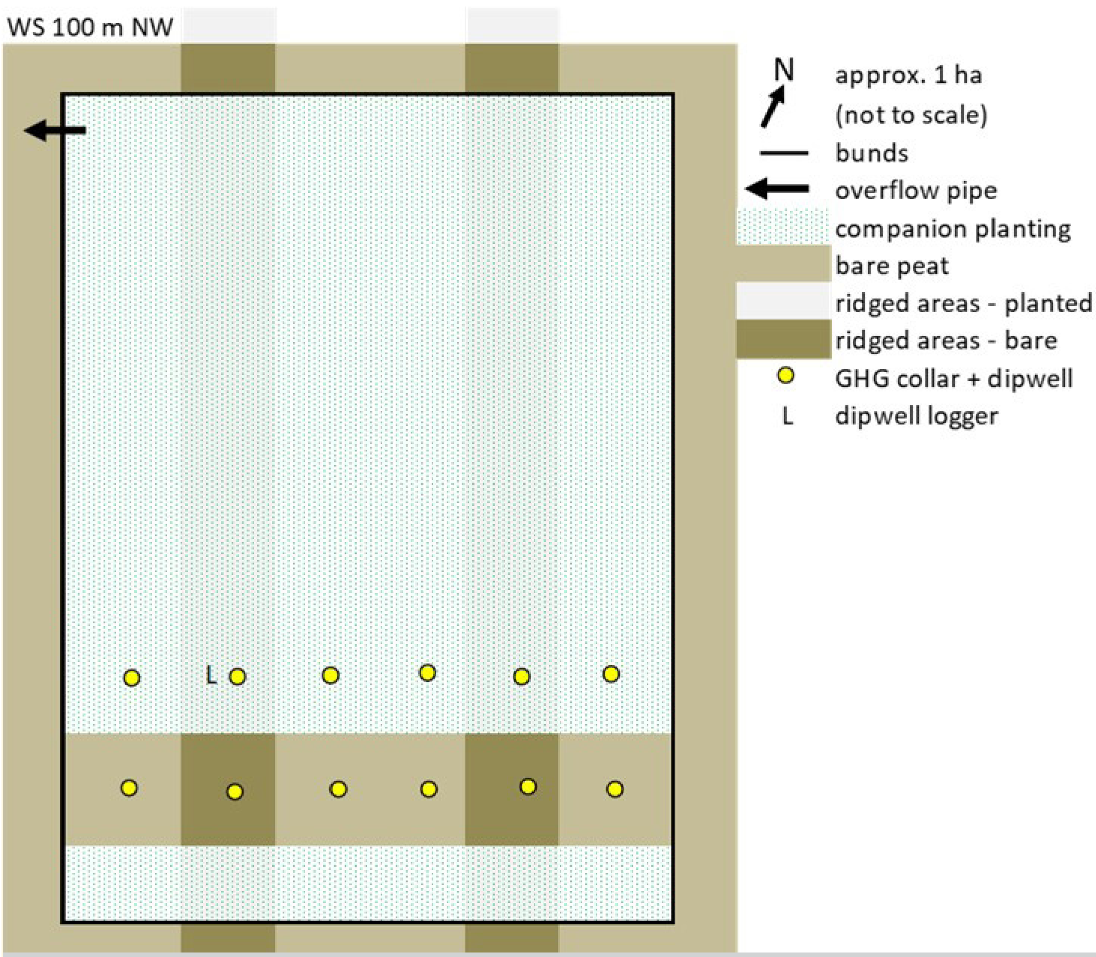


Figure 9: Layout of Little Woolden Moss Companion Planting pilot

### 4.2.1 Measurements of GHG flux and environmental variables

CGHG fluxes were measured monthly using a Los Gatos Ultraportable Analyser (LGR) (Figure 10), using readings in the dark, semi-light (mesh cover) and full light to obtain Ecosystem Respiration (RECO), methane flux ($FCH_4$) and Net Ecosystem Exchange (NEE) in a range of light conditions, from which Gross Primary Productivity (GPP) could be calculated (NEE = RECO + GPP). $FCH_4$ was converted to $CO_2$e using GWP100 = 28 (Myhre et al., 2013). Peat temperature, photosynthetically active radiation (PAR), water table depth (WTD) via dipwells and CGHGs were measured concurrently at each monitoring collar. WTD was also logged every 15 minutes in one dipwell at LWM in each restoration and control area. The WTD loggers proved unreliable at times and infilled data for each dipwell had to be used for calculations in the first year at LWM. Hourly WTD for each dipwell was modelled from measured and logged data where possible.

The meteorological station measured air and peat temperatures, rainfall, and PAR on a 15-minute basis. Thereby, measured CGHG fluxes and environmental variables were modelled and the annual CGHG budget calculated.

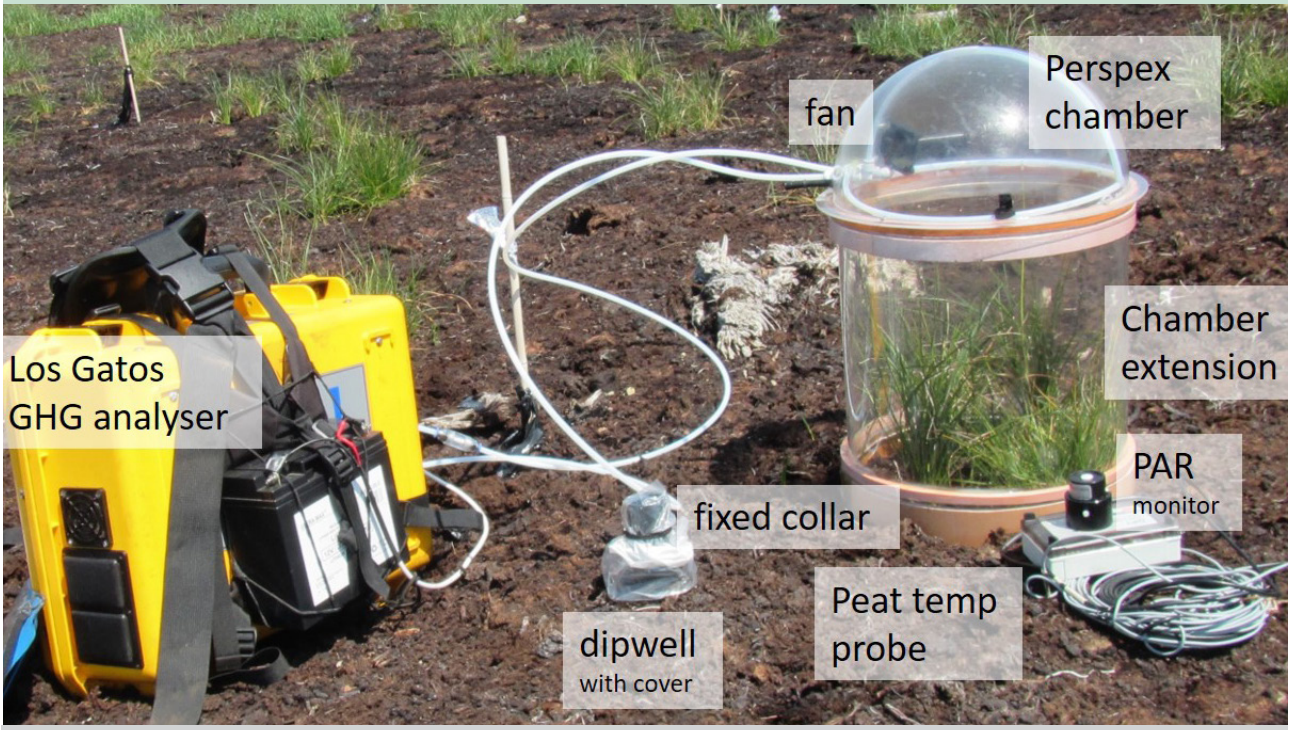


Figure 10. The Greenhouse Gas Monitoring equipment.

Vegetation density was also measured. The pilot site was separated into distinct areas for recording purposes, GPS measured and mapped. Targeted monitoring using 2 x 2 m quadrats, placed randomly in areas of dense vegetation, measured the cover percentage of each *Eriophorum* species. *Sphagnum* cover was not sufficient to provide any meaningful measurements.

# Outcomes

## 5.1 Vegetation

Despite the flooding in the first year and the high temperatures during the pilot, *Eriophorum* species (particularly *E. angustifolium*) rapidly covered the bare peat and did particularly well where conditions were optimal i.e., not flooded nor too dry.

Vascular plant volume (both *E. angustifolium* and *E. vaginatum*) in the CGHG collars was significantly higher in the establishment year, when plants were vigorously growing (and *E. vaginatum* grows more densely than *E. angustifolium*), than during the second year of measurements, after the collars had been moved to mature stands of *E. angustifolium*, in order to measure the mature phase, when there was also no expected increase in plant volume during the growing period, partly due to senesence of material after flowering the previous year (Figure 11).

Across the main pilot, in areas not subject to flooding, the *Eriophorum* species colonised rapidly (Figure 12), with 49.1% and 69.0% cover at 17 months and 31 months after planting respectively, with a ratio of E. angustifolium to *E. vaginatum* 7.2:1 and 8.2:1 at the same time points. A prolonged drought in summer 2022 caused some early senescence of *E. angustifolium*, but new shoots developed rapidly in the following autumn and the remaining plant litter would help to protect future *Sphagnum* establishment (re-planting is planned).

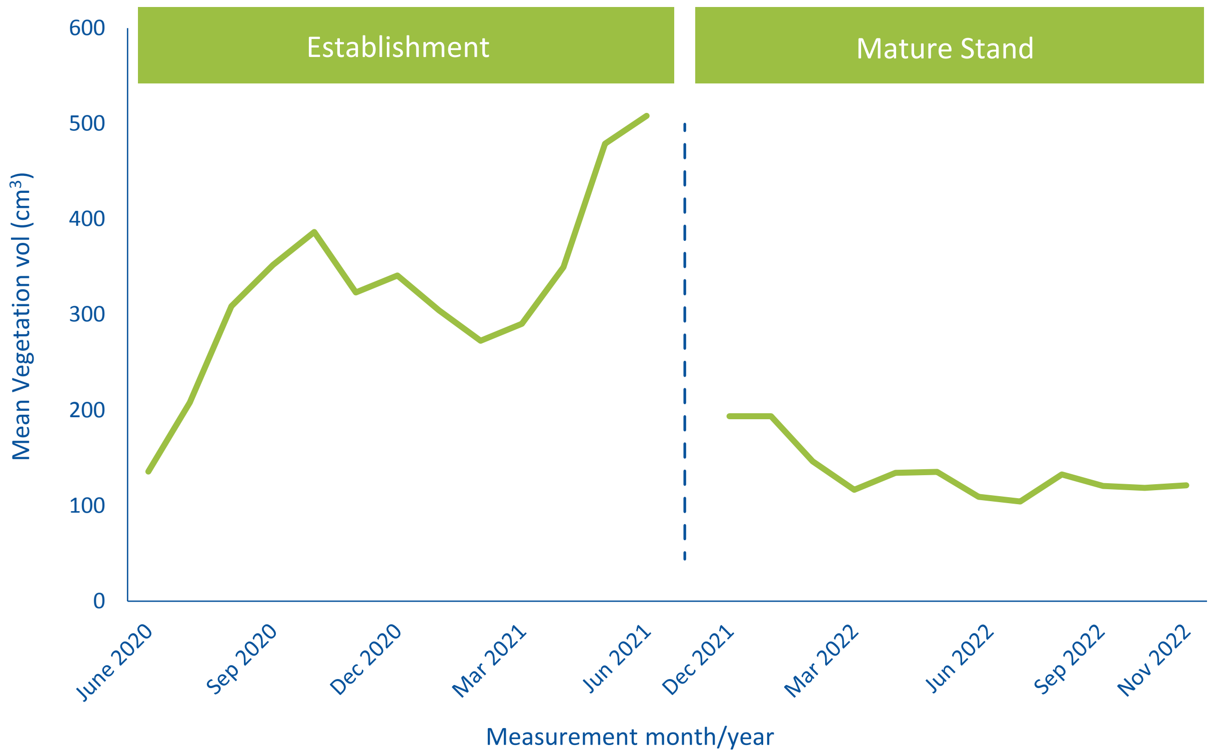


Figure 11. Vascular plant cover in the CGHG collars, separated into the establishment phase (*E. angustifolium* and *E. vaginatum* growing from plug plants) and mature phase after the collars were moved into mature stands of *E. angustifolium*

Figure 12. LWM companion planting site, May 2020 (top), July 2021 (middle), and May 2022 (bottom); representing 2, 16 and 26 months after planting respectively.

In the flooding area vegetation had begun to colonise by November 2022 (Figure 13) on drier areas alongside bunds and edges, partly due to translocation of *E. angustifolium* turfs from within the pilot into the area. This area continued to flood (albeit to a reduced extent) in wetter seasons, and vegetation fails to survive wave action in large, deeper substrate depressions, with this area being the lowest in vegetation cover across the pilot.

Figure 13. Area of pilot where flooding is experienced, November 2022. The lower level of vegetation cover can be clearly seen.

In the area found to only contain *E. vaginatum*, subsequently planted *E. angustifolium* turfs expanded to fill the gaps between *E. vaginatum* tussocks, but this area still had a low vegetation cover (19.1%) compared to the other planted areas (those not subject to flooding) (70.8% to 79.5%).

The ratio of *E. angustifolium* to *E. vaginatum* cover by November 2022 was 8:2. This is obviously greater than the initial planting ratio of 3:1, and makes *E. angustifolium* the primary choice for revegetating bare peat areas, due to the advantage of rhizomatous over tussock-forming growth for rapid ground cover. However, for a lowland raised bog to be considered in good condition it does need a variety of representative plant species to allow for the invertebrates and associated high species whose life cycles are interlinked with particular plants.

*Sphagnum* moss plugs were only seen occasionally across the site during vegetation surveys, and most were in a central area (Figures 14 and 15), particularly in a gully near the eastern edge of the site, which generally stays damp throughout the year. This area also had the least amount of bare peat.

Figure 14. Area of site where *Sphagnum* survived best November 2022

Figure 15. *Sphagnum* plugs growing in damp peat, protected by surrounding vegetation, September 2021

Although terrestrial *Sphagnum* is known to benefit from environmental protection provided by vascular plants, it was perhaps introduced too early in this environment, when the ground water level was still unstable, the peat surface still generally hostile and dry, and the vascular plant cover was not yet complete. However, some *Sphagnum* survival is encouraging, and suggests that re-introduction when the area has full plant cover and greater hydrological stability is likely to be more successful.

While there has been some birch establishment, other weeds, such as *Juncus*, have not posed an issue on this site.

## 5.2 Water table depth

Water table depth (WTD) (Figure 16) followed expected seasonal fluctuations with measurements in the bare (Control) area being slightly higher than the vegetated (Restoration) area; peat depth reduces from south to north on the pilot and deeper peat (where the control plot is located) is likely to retain higher moisture levels for longer.  The April 2021 dry period and a prolonged drought over summer 2022 were clearly seen.  Water levels in the establishment year of CGHG monitoring (June 2020 to June 2021) were markedly higher overall, and water levels are variable throughout due to positioning of dipwells in both Hummocks and Hollows.

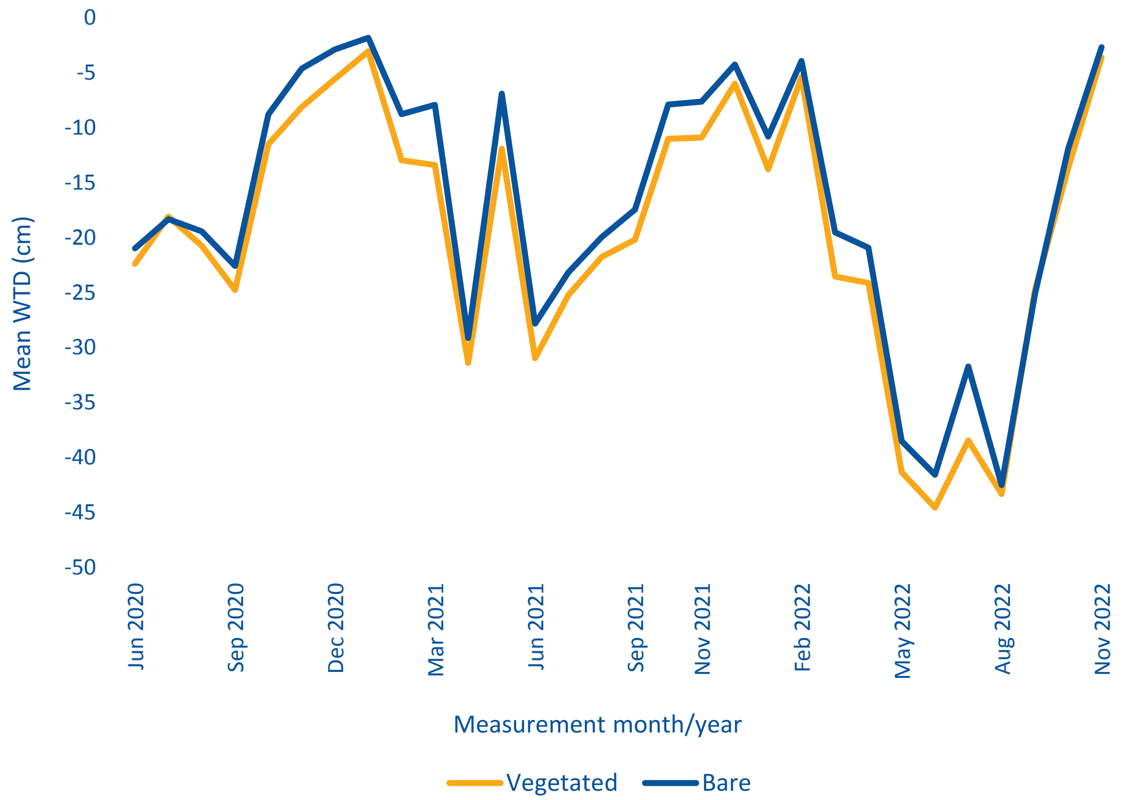


Figure 16. Water table depth (WTD) measurements on the LWM companion planting pilot, showing seasonal variation between monitoring points.

## 5.3 GHG fluxes

Rapid vascular plant growth resulted in an overall uptake of carbon in the 'establishment' phase. During the post-establishment phase, however, this was much less noticeable, with actual net $CO_2$ emission from some collars during warmer, drier months, due to high levels of plant and soil respiration, and accumulation of plant litter after early senesence. $CO_2$ emissions were low but continuous from bare peat throughout the monitoring period, rising with warmer drier conditions, becoming larger and more variable overall in the post-establishment year compared to the establishment year. Methane emissions were small overall in the establishment year in the vegetated plots and negligible in the post-establishment phase in all areas.

Data was highly variable between collars and between monitoring years due to a combination of differences in water table levels and peat quality, and prolonged drought in the second year. Flux data was modelled for each collar and a mean $CO_2$equivalent (eq) budget obtained for both restoration and control areas. There was a mean $CO_2$ uptake on vegetated plots in year 1 of -22.41 (± 32.88) $tCO_2eq\ ha^{-1}\ yr^{-1}$ and an emission of 26.09 (± 26.44) $tCO_2eq\ ha^{-1}\ yr^{-1}$ in year 2. On bare plots there was a continual emission of 4.30 ± 1.40 $tCO_2eq\ ha^{-1}\ yr^{-1}$ in year 1 and 7.47 ± 3.13 $tCO_2eq\ ha^{-1}\ yr^{-1}$ in year 2.

On the restoration area, one collar with some existing *Sphagnum*, situated in a hollow area, showed a small uptake of $CO_2$eq in the second year, whereas collars in drier, hummock areas showed the highest emissions, particularly where plant volume was lowest. These differences will be explored in a further year of monitoring, where *Sphagnum* has been added to three collars with a range of moisture levels to identify whether *Sphagnum* addition has a positive influence on $CO_2$ uptake, whether it survives at all, and if recovery of vascular material (after the drought year) is sufficient to restore a measure of equilibrium to $CO_2$eq fluxes.

# 5.4 Earth Observation

Earth observation analysis was undertaken for the Little Woolden Moss companion pilot site, to investigate the benefits of remotely sensed optical satellite imagery to monitor environmental change from peatland restoration. Initial observations were generated from time series (April 2018 – June 2023) Sentinel-2 image data (European Space Agency, Copernicus programme) for sample points located across bare peat, and vegetated areas within proximity of the on-site GHG collars and dip-wells. To provide a consistent time lag for further analysis, index values for bare peat and vegetated areas respectively, along with overall on-site measurements, were aggregated to quarterly averages. WTD was monitored on-site between June 2020 and November 2022, and exhibited a strong positive correlation between the Normalised Soil Moisture Index (NSMI), for uncorrected, and trend corrected values (Figure A).

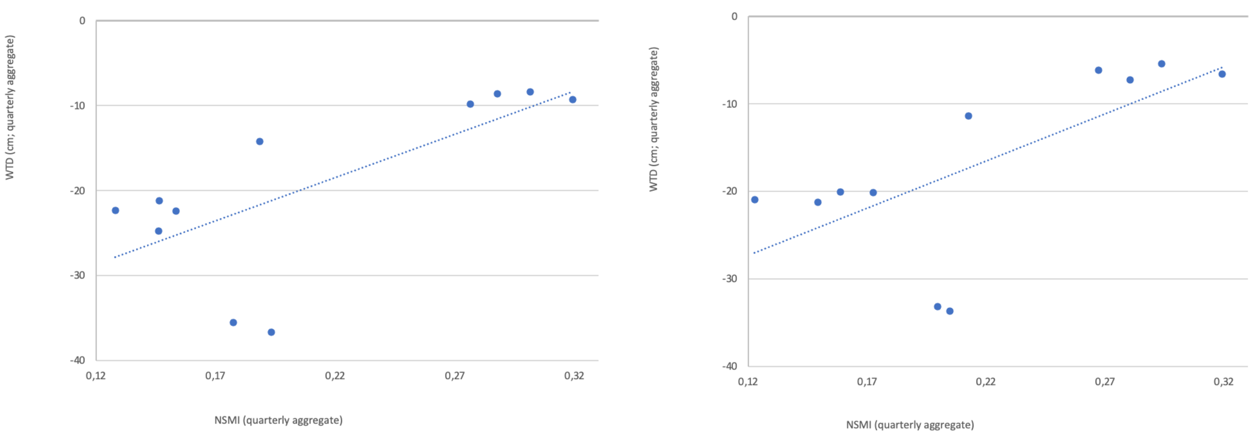


Figure A. Patterns and indicative correlation values between quarterly aggregates for NSMI and WTD for Bare peat (left) and Vegetated (right) areas.

This contrasts to patterns exhibited in vegetation indices, the enhanced vegetation index (EVI) and normalised difference vegetation index (NDVI) which exhibit a general upward trend post-restoration (Figure B). These patterns relate well to upwards growth in vegetation volume for establishment areas. This relationship is not apparent for mature vegetation stands however, which indicates the dominance of establishment vegetation in the current spectral signal. While relationships between remotely sensed indices and on-site observations may change due to vegetation development in the future, current analysis indicate potential benefits of earth observation for monitoring conditions in peatland restoration.

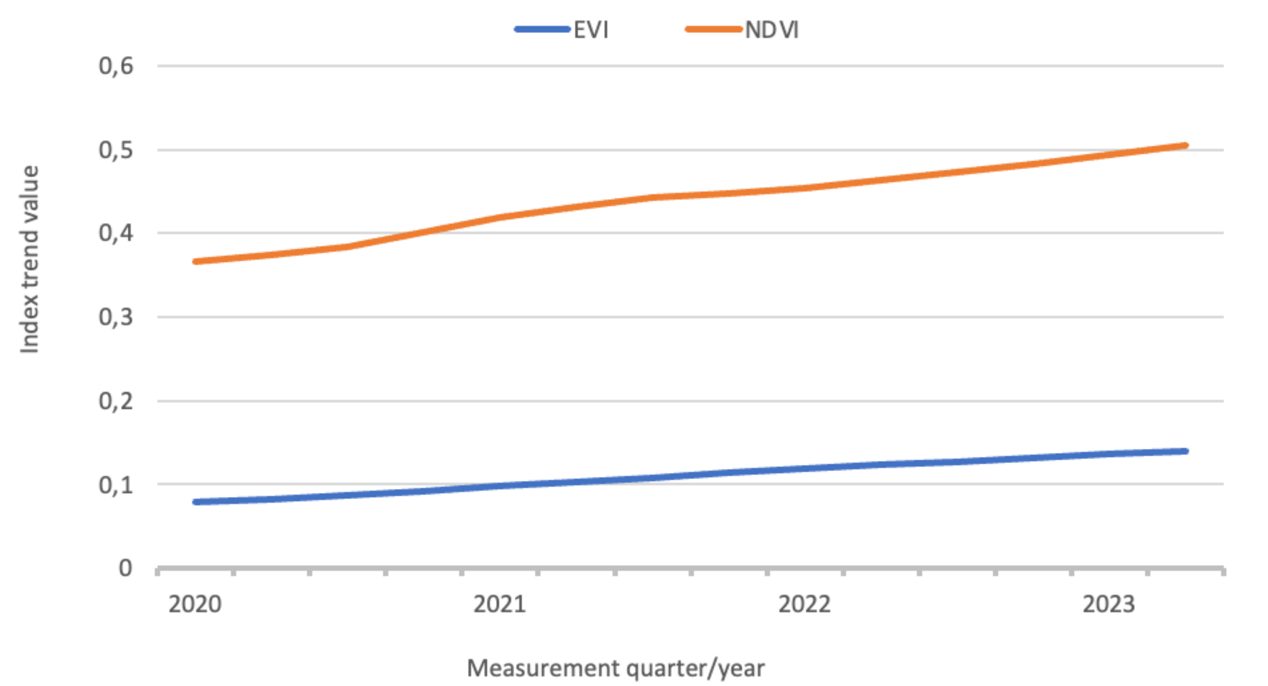


Figure B. Decomposed trend in quarterly EVI and NDVI index values aggregated for vegetation points between January 2020 (start of monitoring period) and June 2023.

## 5.4 Biodiversity and other ecosystem services

The focus of Care-Peat has been the reduction of carbon emissions but co-benefits to biodiversity and other ecosystem services are also sought. Specific monitoring programmes have not been established with Care-Peat. As the west end of Little Woolden Moss continues its journey from bare peat to rewet and revegetated state, it will increase the area of suitable habitat available to the existing wildlife on the already restored part of the site. These include internationally endangered Curlew (*Numenius arquata*), Skylark (*Alauda arvensis*), Short-eared Owl (*Asio flammeus*), Hobby (*Falco subbuteo*) and Merlin (*Falco columbarius*). Black darter dragonflies (*Sympetrum danae*), Common Lizards (*Zootoca vivipara*), Brown Hare (*Lepus europaeus*) and the rare Bog Bush Cricket (*Metrioptera brachyptera*) should also be able to expand. Already there have been signs of improvement, for example Lapwings (*Vanellus vanellus*) were observed breeding successfully in the pilot area during the 2022 season.

# Engagement

Restoring peat and establishing best practices in doing so is most sustainable when stakeholders are involved to increase understanding, appreciation and disseminate information. For this pilot, stakeholders include local neighbouring landholders on the wider moss, policy makers (at a national, regional and local level) who can help shape the peatland restoration agenda, environmental organisations who could play a part in adopting and promoting new carbon-friendly restoration approaches and research and knowledge institutions who can help advise, assess and promote. Natural England, one of the UK governments statutory conservation advisory bodies, is a key stakeholder due to the position of the site near to the Manchester Mosses SAC. Local communities who use the site are also interested and their understanding of the purpose of the work is informed by the project sign installed by the footpath (Figure 17).


Figure 17. Care-Peat signage at Little Woolden Moss

There are over 6000 ha of lowland peatland across Greater Manchester, which vary from recently extracted peatland, such as LWM, to various forms of agriculture on peat and there are a handful of degraded bogs under active restoration so influencing knowledge on peat restoration is key to the regional environmental agenda. The Care-Peat project is one of LWT's peat programme projects in Greater Manchester and is also considered to be making a contribution to the Great Manchester Wetlands Nature Improvement Area Partnership's aim of nature recovery at a landscape scale. An event was held in September 2021 to introduce local stakeholders to the restoration work and the wider Care-Peat project. Representatives from Great Manchester Wetlands, other Wildlife Trusts, local authorities, community organisations, regional universities, local landowners and farmers and countryside charities attended a site visit (Figure 18) followed by presentations and discussion sessions about the work and peat restoration more widely (Figure 19). Stakeholders were interested in aspects of the restoration approach, carbon balance aspects, opportunities for community engagement and funding for peatlands.

Figure 18. Site tour of the Companion Planting pilot September 2021

Figure 19. Presentations to stakeholders at Companion Planting pilot event September 2021

# Discussion, conclusions and next steps

Restoring peatland carbon storage capacity has proved challenging and is not yet achieved at the pilot site.  Growing-season drought conditions over the project period hampered progress and highlighted the urgent need for improving resilience to climate change in peatland restoration projects, particularly regarding water retention.  The pilot has demonstrated that re-vegetation of a post-extraction site, even on shallow, poor-quality peat, can be achieved quickly, despite some challenges.

However the specific premise of this pilot, of using the Cotton grass to "protect" the *Sphagnum* and assist its establishment could not be fully tested as the *Sphagnum* mainly failed early on in the pilot establishment, so its influence on GHG fluxes could not be assessed. Consistent CGHG benefits are not likely to be observed until *Sphagnum* re-establishes, but biodiversity gain will be rapid.

It was thought that perhaps allowing at least 1 full year's growth of the *Eriophorum* species before introducing the *Sphagnum* would have provided better environmental shelter and protection from disturbance, and the planned next step is to replant the site with *Sphagnum* as the vascular plant cover is now sufficient to protect it.

The failure of the *Sphagnum* very early on was more of a fundamental problem for the restoration of the site and its ability to impact CGHG emissions than initially realised. Without the presence of the *Sphagnum*, the site will struggle to reach its proper functionality. However, care needs to be taken with its addition, that it is not among stands of *Eriophorum* that block light to the *sphagnum* due to their density.

The west side of Little Woolden Moss, where the pilot site is located, is particularly challenging in terms of poor peat quality, being very damaged from the previous extraction activity. The pilot area has also struggled with water level balance – too much in any one area damages plants through the adverse effect of wave action, but equally, retention of water on site is needed to support high ground water levels, particularly for elevated parts of the site and also to prevent extensive summer drawdown during increasingly regular drought periods.

Overflow pipes allowing release of flood water have now been relocated to better effect, and changes to the hydrological management of the surrounding area (undertaken and planned) should both allow greater retention of water in the upper slope of the site and reduce flooding elsewhere. Increased vascular plant cover on the lower areas should also reduce any future wave action.

The pilot did not complete some of the original aims within the timescale of the Care-Peat project - *Sphagnum* growth rates, whether the planting combination could rapidly achieve emissions reductions and switch the site to carbon sequestration, specific differences between hummocks and hollows, and comparison with other vegetation reintroduction regimes. However, it has highlighted some interesting points, e.g., the dominance of *E. angustifolium* compared to *E. vaginatum* in colonisation rate, the length of time needed to establish protective vascular plants, the difficulty in establishing *Sphagnum* on bare peat sites, and unforeseen threats such as flooding and damage by corvids.

The two years of monitoring were too different to draw any firm conclusions with changes in plant growth along with different environmental conditions. Continuing the pilot operation, monitoring and data analysis would provide further information and may allow the original objectives to be achieved. LWT has secured a small further amount of funding after Care-Peat (up to end 2025) for continuing to operate, improve and monitor the companion planting pilot, but longer term funding is essential to continue to gather the field data to assess the long term effects and to document best-practice approaches to restoration.

## 7.1 Recommendations

The following recommendations can be made following the experiences with the pilot:

- Replant the site with more *Sphagnum* now that the Cotton grass is well established.
- Continue monitoring of GHG fluxes, water table depth, *Eriophorum* and *Sphagnum* coverage.
- Document findings so other projects can benefit from the successes and failures encountered during projects.
- Pursue investigation of the other original proposals (see 3.1) for revegetating bare peat sites.
- Update stakeholders on the conclusions/outcomes from the pilot.
- Promote the role and place of Companion Planting in the wider peat agenda – how to identify when it is the right approach to adopt and best practice management.

# Acknowledgements

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