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THEMATIC PRIORITY



LOW CARBON



MONITORING REPORT

IRISH CARBON CONNECTS PILOT SITE

MONITORING PERIOD: MAY 2020 - DECEMBER 2021

AUTHORS:

Dr. Amey S. Tilak¹, Mr. Seamus Hoyne¹ and Mr. Mark O' Conner²

1: Technological University of Shannon : Midlands and Midwest, Ireland

2: Independent Environmental Consultation, Westport, Mayo, Ireland



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Table of content

3	Introduction
3	Goals and objectives
5	Sampling protocol and monitoring schedule
8	CO ₂ monitoring from bare peat areas
8	Drain blocking conducted at the pilot site
9	Cost of the monitoring
10	Monitoring Results
10	Rainfall
11	Groundwater table depths (WTDs)
15	Peat physical properties and % organic carbon in peat
16	Water quality (surface and groundwater)
17	pH and redox results
18	GHG quantification using Site Emissions Tool (SET)
19	Vegetation and Bettles
20	CO ₂ emissions from bare-peat surfaces
21	Conclusion
21	Results
22	Future work
22	Challenges
22	Major Conclusions
22	Acknowledgements
23	References
25	Annexes

7 Introduction

The Irish pilot site for the Carbon Connects project is located near the town of Oughterard Co. Galway in Republic of Ireland. The Oughterard lies 11m above sea level, the climate is generally warm and temperate. The average rainfall is 1227 mm per year, having an average temperature of 9.9 °C. The pilot site of 9 hectares is shown in Figure 1.

The private landowner owns the peatland site located in Oughterard, Galway for the past 24 years. The total peatland site is about 344 ha of which 100 ha planted with conifer forest in late 1980s and about 220 ha is blanket peatland devoid of conifer plantation. The landowner also grows blueberries and apples on less than 5 ha of land, but not for commercial purposes. The blanket peatland site was drained and utilised for turf production i.e. selling turf to local domestic market for domestic heating purposes.

The private landowner is currently working with the Freshwater Pearl Mussel project, an European Innovation project (EIP), providing financial incentives to farmers and landowners for rewetting their drained peatlands, thus improving carbon sequestration, water quality, biodiversity and enhancing habitats for pearl mussel located in freshwater lakes and streams adjacent to rewetted peatlands.

The Irish carbon connects project started monitoring the drained blanket peatland of 9 ha from May 2020 until November 10, 2020. On November 10-11, 2020, the 8 hectares drained peatland was rewetted with help of local contractor, private landowner, PMP project and Cconnects team. The monitoring continued post rewetting from November 11, 2020 until December 23, 2021. The monitoring of pH and redox stopped on December 23, 2021, however, rainfall and peat temperature will be monitored until July 2022, for quantifying CO₂ emissions from bare-peat surfaces. Even though the total pilot site was larger and accounted to 8 hectares, based on available financial and human resources and other site logistics, the effective monitoring was conducted over an area of 2.68 hectares, computed based on groundwater data, location of dipwells and google map (source: aerial photograph : Google Maps, Airbus Imagery 2022).

2 Goals and objectives

The purpose of monitoring the pilot site is quantifying the GHG emissions (CO₂, CH₄ and N₂O) in pre-rewetting and post-rewetting phases. We hypothesized that rewetted blanket peatland will reduce 50% GHG emissions compared to drained peatland.

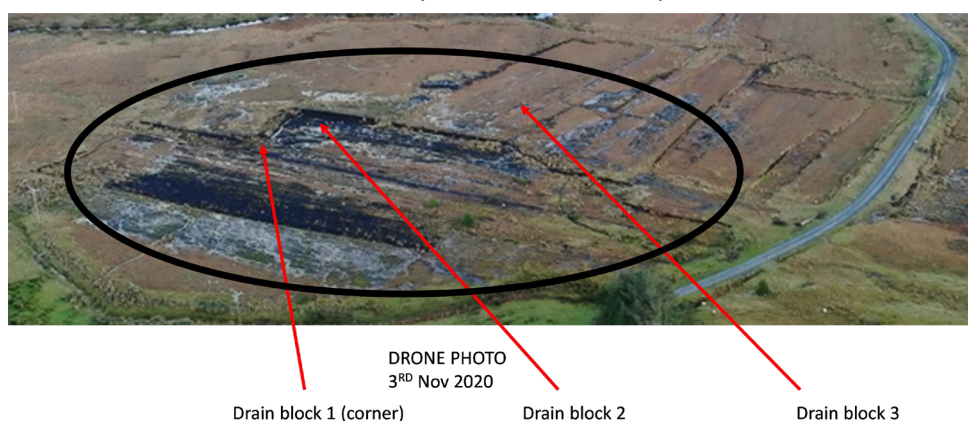


Figure 1. Drone photo of the Irish Carbon Connects Pilot Site (courtesy : private landowner).

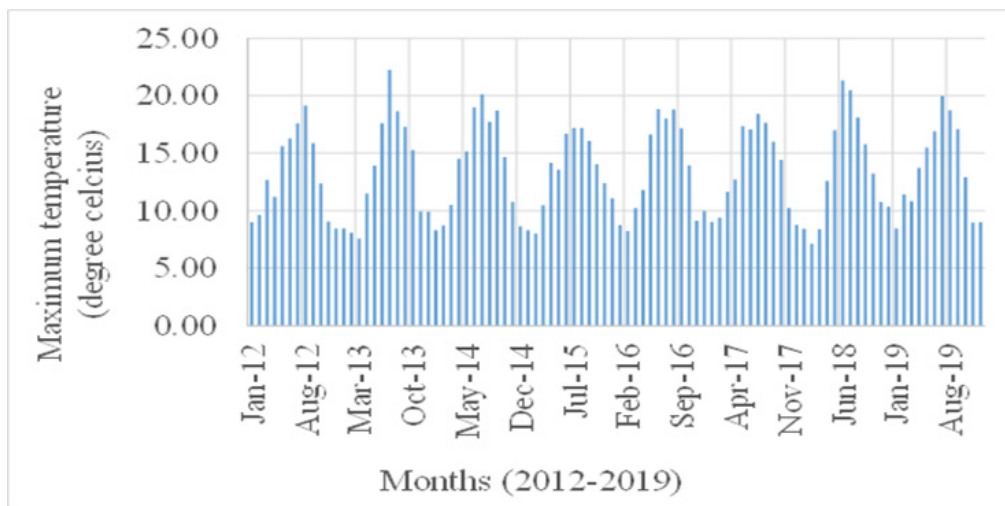


Figure 2. Maximum air temperatures recorded at Irish meteorological monitoring station in Oughterard., Galway

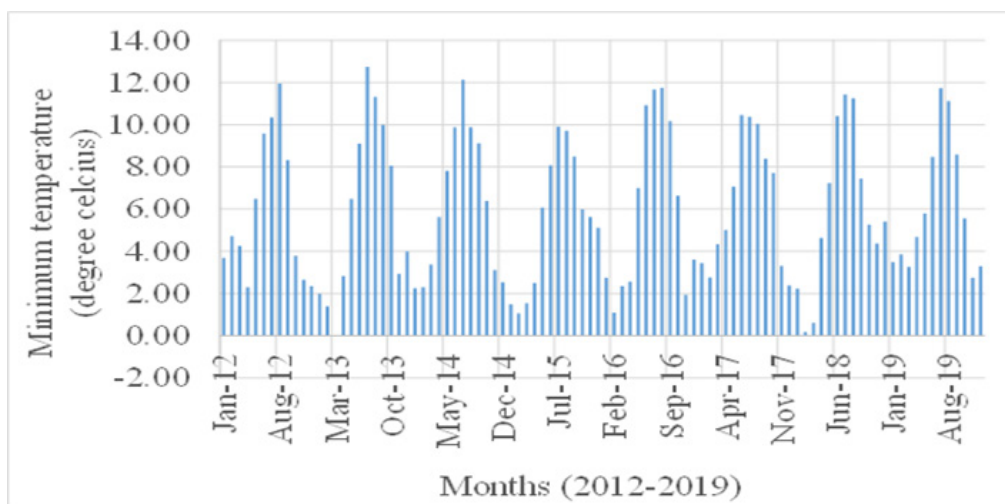


Figure 3. Minimum air temperatures recorded at Irish meteorological monitoring station in Oughterard, Galway

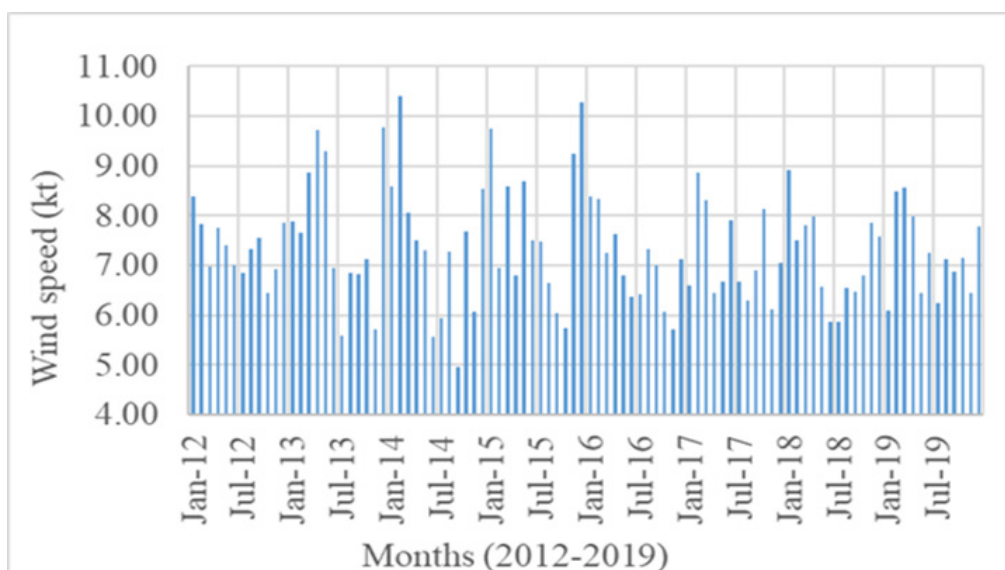


Figure 4. Wind speed recorded at Irish meteorological monitoring station in Oughterard, Galway

3 Sampling protocol and monitoring schedule

The Irish Cconnects pilot site monitoring began on May 14, 2020, consisting of environmental variables such as rainfall, groundwater table depths (WTDs), pH, redox and quantifying carbon in peat and water, bulk density, moisture content etc. The environmental monitoring conducted in two phases : pre-rewetting i.e. drained condition from May 14, 2020 to November 10, 2020 and post-rewetting i.e. after drain blocking from November 11, 2020 to December 23, 2021. The peat depth at the pilot site was measured at several places and varied from 0.5-1.5 m but less than 2 m. The peatland site showing location of four groundwater table wells, pH, redox and rain gauge shown in Figure 5. The Figure 6 shows rain gage, groundwater, pH and redox sondes for one of the four wells. The monitoring protocol for pilot site shown in Table 1.

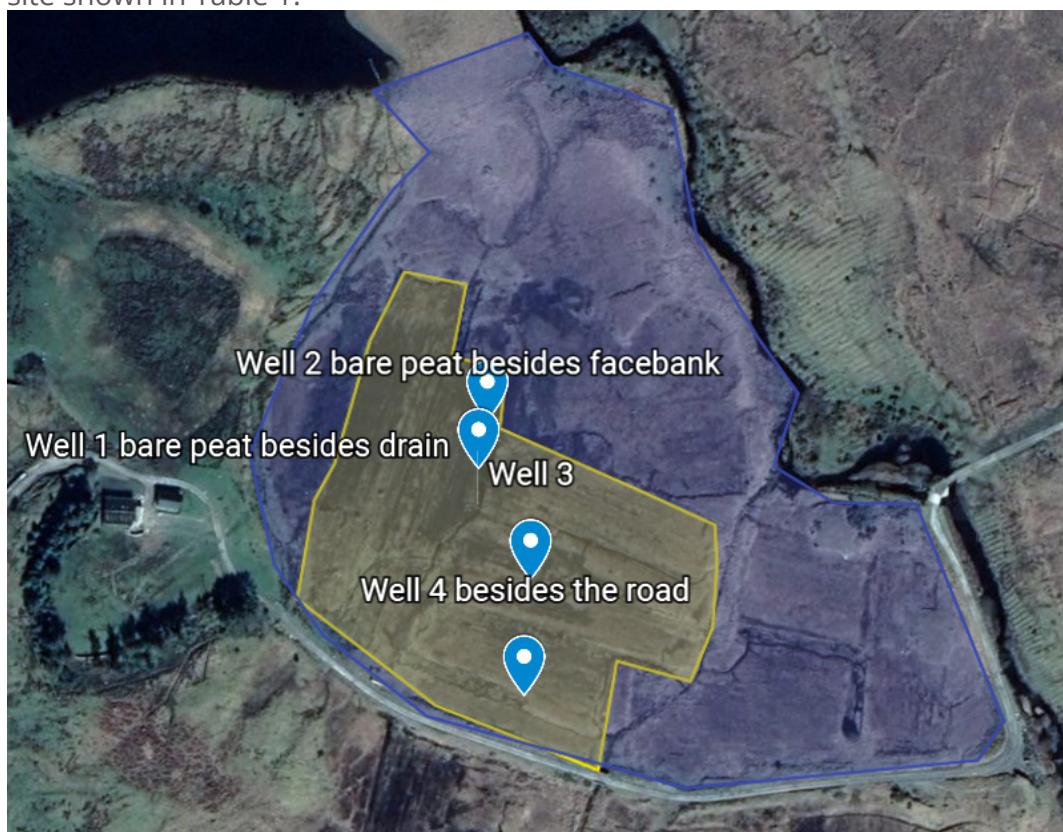


Figure 5. Irish Cconnects peatland site, blue pins are 4 sets of groundwater wells, each set having two wells and independent rain gauge. In yellow, the rewetted area and in blue the total area of the pilot site.



Figure 6. Rain gauge recording daily rainfall and set of groundwater wells (one well hosting water table recorder and second well hosting pH and redox combined sonde/probe).

Table 1. Irish Cconnects site monitoring protocol (May 14, 2020 to December 23, 2021).

Parameter	Data Frequency	Data Utility
Rainfall (Tipping bucket)	Will record all rain events as and when they occur and store in storage device	Spatial and temporal variability
Groundwater (TD-Baro)	Every 30 minutes	Wetness; type of vegetation; GHG emissions
(pH and Oxidation reduction potential sensors)	Every 30 minutes	Water Chemistry; vegetation growth;
Water chemistry (manual water sampling)	Once in pre-rewetting and once in post rewetting	Indicative of carbon and nutrients present;
Peat Carbon	Once in pre-rewetting and once in post rewetting	Amount of carbon present
Bulk density and Porosity	Once in pre-rewetting and once in post rewetting	Peat physical properties
Vegetation and beetles (IT, Sligo)	Monthly site visits	Type of vegetation linked: groundwater; GHG emissions
Site Emissions Tool (SET)	Long term predictions	GHG (CO ₂ , CH ₄ and N ₂ O)
CO ₂ emissions from bare-peat surface	Peat temperature and groundwater data collected every 30 minutes	CO ₂ emissions from bare peat surfaces devoid of vegetation

Table 2. Latitude and longitude of four sets of groundwater wells and peat sampled for bulk density, total organic carbon in pre-rewetting and post-rewetting periods.

Location of monitoring equipment's and sampling	Latitude	Longitude
Well 1: bare peat besides drain	53.41662	-9.40653
Well 2: bare peat besides face bank	53.41641	-9.40659
Well 3: vegetated high area	53.41593	-9.40621
Well 4: vegetated besides road	53.41542	-9.40626
Rain gauge	53.41656	-9.40725
Peat sampling for bulk density and total organic carbon location 1 (pre-wetting)	53.4168262	-9.406503
Peat sampling for bulk density and total organic carbon location 2 (pre-wetting)	53.4160736	-9.4061596
Peat sampling for bulk density and total organic carbon location 3 (pre-wetting)	53.415423	-9.4062612
Peat sampling for bulk density and total organic carbon location 1 (post-wetting)	53.4167696	-9.4064452
Peat sampling for bulk density and total organic carbon location 2 (post-wetting)	53.4166397	-9.4064922
Peat sampling for bulk density and total organic carbon location 3 (post-wetting)	53.4164889	-9.4065787

The peat was sampled for bulk density, total organic carbon and moisture content measurements. The peat samples were collected from the field in pre-rewetting period in August 2020, transported into the LIT environmental laboratory for bulk density and moisture content analysis, while total organic carbon (TOC) was measured by the BHP laboratory in Limerick, Ireland. The peat samples collected from the field in the post-rewetting phase in October 2021 transported to BHP laboratory in Limerick, Ireland and analysed for bulk density, moisture contents and total organic carbon. The Figure 7 shows peat sample collected using Russian peat corer in pre-rewetting and post-rewetting phases.



Figure 7. The peat profiles shown in a and b sampled in the pre-rewetting phase and peat profiles shown in c and d sampled in post-rewetting phase.

Table 3. Environmental data collected from peatland site for quantifying hydrology, water quality and water chemistry

Environmental data	Data utility
Hydrology data	Rainfall and measured groundwater depths (every 30 min)
Peat physical properties	Bulk density, porosity and moisture content
Peat chemical properties	Total organic carbon
Peat water quality	Dissolved organic carbon, total nitrogen, total phosphorus, NO_3^- -N and NH_4^+ -N.



Figure 8. Water quality sampling conducted by Dr. Amey S. Tilak using a plastic bailer for drawing groundwater from a well (left photo) and peat sampling using Russian peat corer (right photo).

For the CO₂ monitoring, two areas were identified at the pilot site. These two areas have bare peat surfaces devoid of any vegetation. The first (well 1) area is not much affected by drain blocking (i.e. acting as a control) and second area (well 2), is highly affected by drain blocking acting as a treatment respectively. For computing the CO₂ emissions from bare peat surfaces, daily measured WTDs and peat temperatures are utilised as a proxy using the methodology given in Renou-Wilson et al. (2014). In this paper, daily WTDs and soil temperatures at 5 cm depth are utilised for computing CO₂ emissions using the following equation given below:

$$R_{eco} (CO_2) = (a + (b \times WTD)) \times \exp\left(c \times \left(\frac{1}{T_{ref} - T_o}\right) - \left(\frac{1}{T_{5cm} - T_o}\right)\right) \dots (1)$$

Where $R_{eco} (CO_2)$; amount of CO₂ evolved/emitted; T_{ref} ; reference temperature set at 283.15 K; T_o is minimum temperature at which respiration reaches zero and set at 227.13 K; T_{5cm} ; temperature monitored by the probe/sensor at 5 cm below the top peat surface and WTD : the daily groundwater levels; a and b are coefficients. The CO₂ vs. temperature calibration curve will be completed by measuring lowest and highest peat temperatures and coefficients a and b will be computed. After the coefficients a and b are obtained, the daily groundwater levels and peat temperatures will be utilised from field collected data and CO₂ emissions from bare peat surfaces will be computed.

Drain blocking conducted at the pilot site

The drain blocking (i.e. rewetting) was conducted at the pilot site in consultation with private landowner, Freshwater Pearl Mussel project team (Derek McLoughlin and Patrick Crushell), local contractor and Carbon Connects team (Amey Tilak and Seamus Hoyne). The drain blocking was conducted on November 10 and 11, 2020 (see photos in Figure 9).



Figure 9. Drain blocking photos (top left and top right) taken on November 10, 2020. The pools of water on November 11, 2020 (below left) and in October 2021 (below right) because of the drain blocking.

6 Cost of the monitoring

Table 4. *Monitoring costs of Irish pilot site from May 2020 to December 23, 2021.*

Monitoring equipments	Euro costs
Rainfall HOBO logger	621
Groundwater data loggers	2880
pH and Redox probes	5835
Environmental consultant Mr. Mark O' Conner hired for installing, maintaining equipments, materials for wells outer casing and sending environmental data each month to Dr. Amey S. Tilak	5000
Additional costs by Mark O' Conner (site meetings, drain blocking meeting, equipment maintaince and travel to sites for data maintainece	815
Exploratory respiration study for estimating annual CO ₂ respiration from wet and dry bare peat and providing final results	4200
Costs paid to landowner and contractor for rewet-ting pilot site	4000
Bulk density and total organic carbon analysis	1467
Water quality analysis (total N, P, NO ₃ -N, NH ₄ -N, DOC)	1097
Field equipments (soil rings, russian peat corer, bail-ers for water sampling etc.	3361
Approximate total costs (more accurate costs is included in the financial reports submitted to INTER-REG)	29,276

7 Difficulties and challenges in rewetting the pilot site

The pilot site was approximately 8 ha and since the site was privately owned, there was no previous elevation data available. The site was extremely uneven, peat cutting was randomly conducted resulting in uneven slopes, ditches and depressions. It was extremely difficult to identify the drains, ditches, that could result in uniformly rewetting the entire pilot site of 8 hectares. With the given available financial and human resources, it was not possible to rewet the entire site. For rewetting the entire site, more detailed survey measurements (i.e. topographic details) are required, which can be expensive. Based on the available financial and human resources, location of dipwells, and Google earth maps, we estimated the effective monitoring area that can be potentially rewetted was approximately 2.68 ha. So for estimating GHG emissions, we have only considered effective area of 2.68 ha. With the given resources, we were not able to have more groundwater wells covering the entire 8 ha site.

Rainfall

The total rainfall at the pilot site from May 28, 2020 to December 23, 2021 was 2842 mm. The Table 1 provides monthly rainfall from May 2020 to December 23, 2021. The Figure 10 shows daily rainfall (mm) that occurred at the pilot site. About 63% of the rainfall at the pilot site ranged from 0-3.8 mm and 11.4%, 9.5%, 6.3%, 2.08%, 1.89%, 1.71%, 1.51% and 2.46% rainfall ranged from 3.8-7.6 mm, 7.6-11.4 mm, 11.4-15.2 mm, 15.2-19 mm, 19-22.8 mm, 22.8-26.6 mm, 26-34 mm and 34-60 mm respectively.

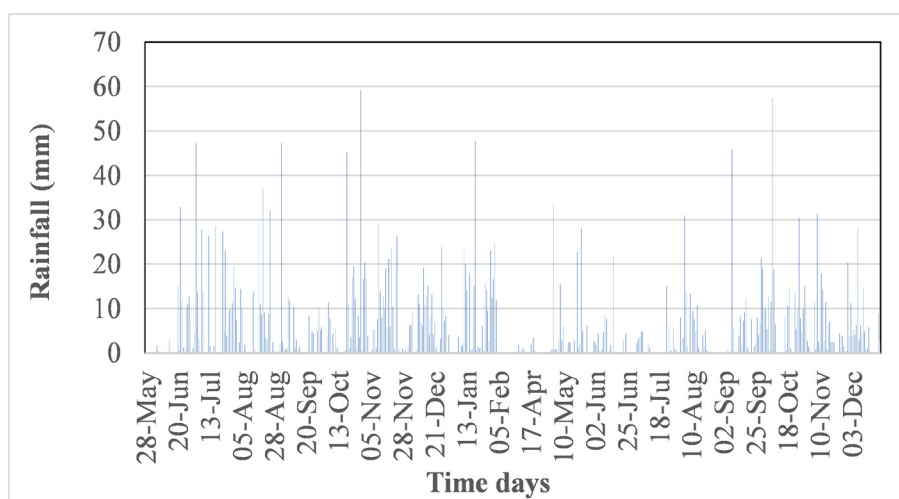


Figure 10. Daily rainfall (mm) that occurred at the pilot site

Table 5. Monthly rainfall (mm) that occurred at the Irish Connects pilot site

Months	Rainfall (mm)
May, 2020	0 (started from May 28, 2020)
Jun 2020	108.6
Jul 2020	292.4
Aug 2020	197.4
Sep 2020	134
Oct 2020	240.4
Nov 2020	274.2
Dec 2020	213.6
Jan 2021	235.4
Feb 2021	53.2
Mar 2021	0 (data logger malfunctioned)
Apr 2021	13.6
May 2021	137.8
Jun 2021	65.4
Jul 2021	51.2
Aug 2021	116.4
Sep 2021	166.4
Oct 2021	275.2
Nov 2021	152.6
Dec 2021	114
Grand Total	2842 mm

Groundwater table depths (WTDs)

Table 6. Average and range of measured WTDs at the Cconnects pilot site

Time	Measured water table depths (cm)			
May 14 2020-December 23, 2021	Well 1 cm	Well 2 cm	Well 3 cm	Well 4 cm
(mean) cm	+17.3	-22.7	-3	+0.7
(range) cm	+2.8 to +44	-39.8 to +28.1	-11 to +5	-4.4 to +5.3

The mean and the range of groundwater data from four wells is shown in the Table 6. The well 1 averaged +17.3 cm below the top peat surface and ranged from +2.8 to +44 cm below the top peat surface. The WTDs in well 2 were significantly affected by drain blocking and averaged -22.7 cm above the top peat surface and ranged from +28.1 cm below the top peat surface to -39.8 cm above the top peat surface. The well 3 averaged -3 cm above the top peat surface and ranged from +5 cm below the top peat surface to -11 cm above the top peat surface. The last well 4, averaged +0.7 cm below the top peat surface and ranged from +5.3 cm below top peat surface to -4.4 cm above the top peat surface. The daily WTDs for all 4 wells are shown in Figure 11. The red arrow shows the conducted drain blocking affecting WTDs in all 4 wells.

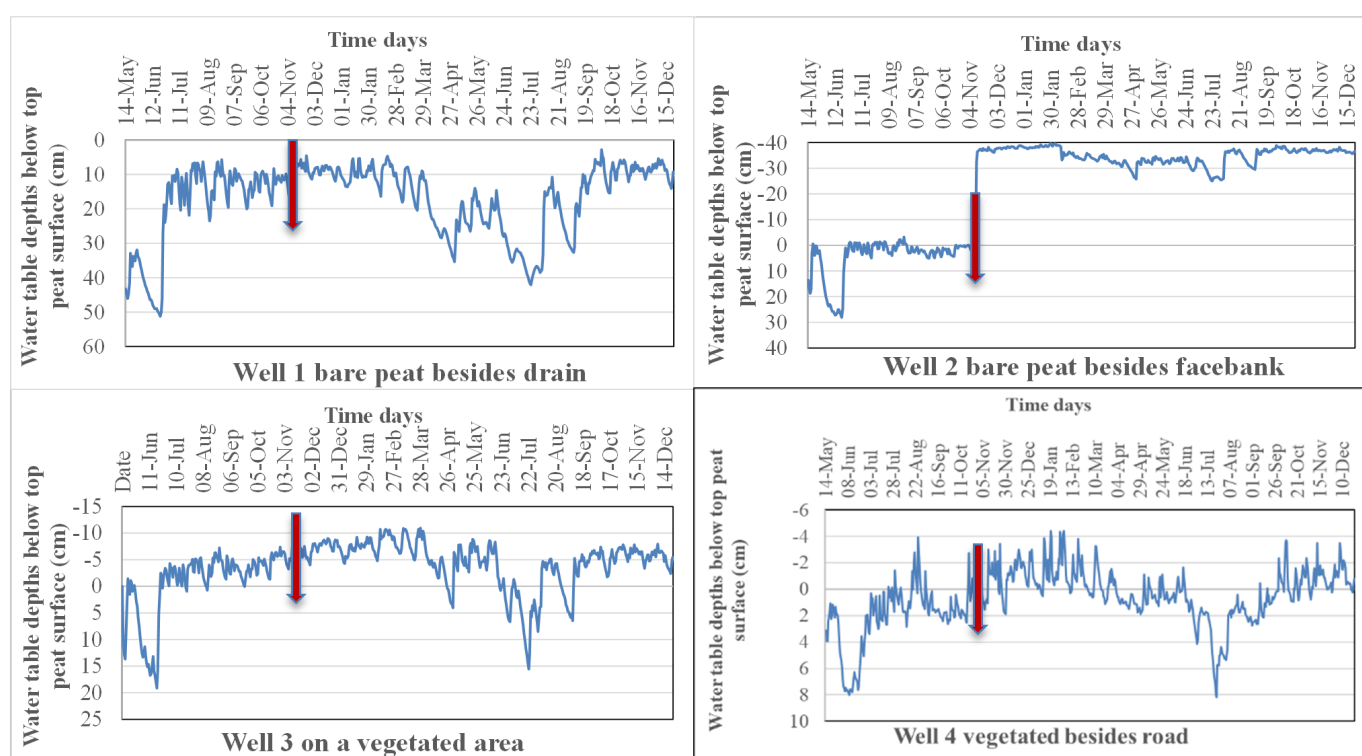


Figure 11. Daily WTDs in 4 wells from May 14, 2020 to December 23, 2021.

Table 7. Average WTDs in the pre-rewetting and post-rewetting periods (Note : + value below the top peat surface and -ve above the top peat surface).

WTDs in wells and their locations	Average WTD (cm) before drain blocking (May 14-Nov 10, 2020)	Average WTD (cm) after drain blocking (Nov 12 2020-December 23, 2021)
Well 1 (bare peat besides drain)	+20	+16.3
Well 2 (bare peat besides face bank)	+5	-34.9
Well 3 (vegetated area)	-1	-5
Well 4 (vegetated besides road)	+2	+0.11
Average	+6.5	-6

The table 7 results shows average WTDs in pre-rewetting as +6.5 cm below top peat surface, while post-rewetting WTDs as -6 cm above the top peat surface. Tables 8 and 9 show monthly average water temperatures and WTDs from May 2020 to December 23, 2021.

Table 8. Monthly average water temperatures recorded using sondes hosted in 4 wells.

Months	Water temp° C in well 1	Water temp° C in well 2	Water temp °C in well 3	Water temp °C in well 4
May 2020	9.67	9.76	9.82	10.17
June 2020	10.54	10.44	10.53	11.08
July 2020	11.48	11.26	11.41	11.99
August 2020	12.24	11.96	12.21	12.78
September 2020	12.67	12.49	12.79	13.19
October 2020	11.47	11.32	11.71	11.71
November 2020	10.14	9.13	10.22	10.27
December 2020	8.49	6.48	8.56	8.56
January 2021	7.08	5.9	7.56	7.01
February 2021	7.03	6.396	7.66	7.07
March 2021	7.62	7.504	8.05	7.73
April 2021	8.432	8.87	8.70	8.54
May 2021	9.23	9.72	9.38	9.47
June 2021	10.17	10.766	10.189	10.54
July 2021	11.24	11.850	11.162	11.77
August 2021	12.60	13.094	12.406	13.16
September 2021	13.02	13.528	13.023	13.63
October 2021	12.66	12.23	12.95	13.02
November 2021	10.91	9.40	11.12	11.04
December 2021	9.14	7.40	9.72	9.21
Average	10.33	10.02	10.49	10.63

The water temperatures in the 4 wells varied from a low of 5.9° C in the peak winter month of January to a high of 13.6° C in summer (June, July, August) or early autumn (September) in 2020 and 2021 (Table 8). As shown in Table 9, average WTDs in well 1 varied from +8.607 cm below the top peat surface in October 2021 to +39 cm below the top peat surface in June 2020. The well 1 was least impacted by drain blocking as average WTDs before drain blocking were +20 cm below the top peat surface and after drain blocking were +16.3 cm below the top peat surface. The drain blocking resulted in elevating WTD by 3.7 cm towards the top peat surface i.e. change of 18.5% after drain blocking (Table 7). The average WTD in well 2 varied from -38 cm above the top peat surface in December 2020 to +17.25 cm below the top peat surface in June 2020. The well 2 was most impacted by drain blocking, as the area around the well 2 was flooded/ponded with water most of the time. The average WTD in well 2 before drain blocking was +5 cm below the top peat surface, while the average WTD after drain blocking was -34.9 cm above the top peat surface i.e. change of 86% after drain blocking (Table 7). The average WTD in well 3 varied from -8.64 cm above the top peat surface in February 2021 to +9.39 cm below the top peat surface in June 2020. The average WTD in well 3 before drain blocking was -1 cm above the top peat surface, while the average WTD after drain blocking was -5 cm above the top peat surface i.e. 80% change after drain blocking (Table 7). The average WTD in well 4 varied from -1.55 cm above the top peat surface in December 2020 to +6.09 cm below the top peat surface in June 2020. The average WTD in well 4 before drain blocking was +2 cm below the top peat surface, while the average WTD after drain blocking was +0.11 cm below the top peat surface i.e. 94% change after drain blocking (Table 7). Overall the average WTDs of 4 wells before the drain blocking and after the drain blocking were +6.5 cm below the top peat surface and -6 cm above the top peat surface i.e. overall change of 192% (Table 7).

Table 9. Monthly WTDs averaged from hourly data recorded using sondes in 4 wells (Note : + below the top peat surface ; -above the top peat surface).

Months	Average WTDs well 1	Average WTDs well 2	Average WTDs well 3	Average WTDs well 4
May 2020	+37.16	+7.27	+3.69	+2.59
June 2020	+39.04	+17.25	+9.39	+6.09
July 2020	+12.55	+0.83	-2.59	+1.28
August 2020	+12.50	+0.52	-3.57	+0.35
September 2020	+13.21	+2.60	-3.01	+1.59
October 2020	+12.09	+1.79	-4.62	0.74
November 2020	+10.31	-24.23	-5.79	-0.46
December 2020	+8.92	-38.01	-7.82	-1.55
January 2021	+10.05	-38.3	-7.04	-1.38
February 2021	+9.07	-36.40	-8.64	-1.38
March 2021	+13.27	-34.04	-8.23	-0.39
April 2021	+25.13	-31.3	-3.19	+0.97
May 2021	+22.27	-32.4	-5.15	+0.37
June 2021	+23.89	-32.713	-3.090	+0.75
July 2021	+36.18	-29.083	5.408	+3.88
August 2021	+21.76	-34.168	-1.377	+2.13
September 2021	+18.98	-34.96	-2.013	+1.25
October 2021	+8.607	-37.22	-5.52	-0.691
November 2021	+8.87	-36.67	-5.93	-0.690
December 2021	+8.70	-36.67	-5.42	-1.175
Average	+17.3	-22.74	-3.35	+0.70

The bulk density and % moisture content measurements carried out once in pre-rewetting in August 2020 and once in post-rewetting in October 2021. The bulk density measurements in pre-rewetting were carried out in area having *Sphagnum* moss or other sedge like vegetation. The lower bulk density reported for *Sphagnum* mosses and other vegetation areas shown in Table 10 are similar to those reported by Golubev et al. (2021); Bengtsson et al. (2016); McCarter and Price, (2014); Bencoster et al. (2011) and Hajek, (2009). The bulk densities reported in post-rewetting areas were collected from drained bare peat areas devoid of any vegetation. The higher bulk density numbers shown in Table 11 are similar to bulk density numbers reported by Loisel et al. (2014) from drained bare peat areas.

Peat physical properties and % organic carbon in peat

Table 10. Bulk density (BD) and % moisture contents (MC) in the pre-rewetting phase i.e. before drain blocking.

Sampling depth (cm)	Location 1		Location 2		Location 3	
	(BD) g/cm ³	MC content (%)	(BD) g/cm ³	MC content (%)	(BD) g/cm ³	MC content (%)
4-8	0.041	89.3	0.038	87.4	0.034	88.2
10-14	0.040	87	0.045	89.2	0.055	89.8
20-24	0.038	89.4	0.044	90.2	0.052	90.5
30-34	0.051	90.7	0.043	90.1	0.027	91.5
40-44	0.043	91	0.039	90.9	0.028	92.4

Table 11. Bulk density and moisture contents in post-rewetting phase i.e. after drain blocking.

Sampling depth (cm)	Location 1		Location 2	
	(BD) g/cm ³	MC content (%)	(BD) g/cm ³	MC content (%)
0-10	0.318	48	0.308	41
10-20	0.338	41	0.371	50
20-30	0.375	48	0.451	44
30-40	0.346	49	0.427	45
40-50	NA	NA	0.452	39

The total organic carbon measured once in the pre-rewetting period in August 2020 and once in post-rewetting period in October 2021. The total organic carbon measurements in pre-rewetting and post-rewetting are shown in Table 12. There is 1.5 fold increase in total organic carbon measured in the pre-rewetting and post-rewetting period. But more frequent measurements i.e. each month are required to confirm these findings.

Table 12. Percent total organic carbon measurements (%) in pre-rewetting and post-rewetting (note 1% TOC : 1000 mg/kg).

Sampling depth (cm)	Sample locations (pre-rewetting)			Sample locations (post-rewetting)	
	1	2	3	1	2
0-10	50	49	65	82	81
10-20	52	42	55	81	90
20-30	29	46	29	86	82
30-40	41	47	35	87	84
40-50	52	52	31	NA	82

Water quality (surface and groundwater)

The water quality samples were taken from 4 wells for quantifying total nitrogen (N), total phosphorus (P), $\text{NO}_3\text{-N}$, $\text{NH}_4\text{-N}$ and total organic carbon (TOC) in the pre-rewetting (August 2020) and in post-rewetting (October 2021).

Table 13. Groundwater quality parameters in pre-rewetting measured in August 2020.

Parameters	Sampling well 1	Sampling well 2	Sampling well 3	Sampling well 4
Total N	1.10	1.58	0.664	2.54
Total P	0.05	0.05	0.05	0.05
$\text{NH}_4\text{-N}$	0.309	0.807	0.052	1.52
$\text{NO}_3\text{-N}$	<0.1	<0.1	<0.1	<0.1
DOC	24.3	21.1	9.13	20.1

Table 14. Groundwater quality parameters in post-rewetting measured in October 2021.

Parameters	Sampling well 1	Sampling well 2	Sampling well 3	Sampling well 4
Total N	0.793	0.759	17 (looks outlier)	0.708
Total P	0.019	0.020	0.037	0.033
$\text{NH}_4\text{-N}$	0.025	0.014	0.042	0.026
$\text{NO}_3\text{-N}$	<0.1	<0.1	<0.1	<0.1
DOC	17.9	20.9	26.5	18.9

Table 15. Surface water quality parameters in post-rewetting measured in October 2021.

Parameters	Sampling well 1	Sampling well 2	Sampling well 3	Sampling well 4
Total N	1.45	0.871	1.19	0.648
Total P	0.121	0.041	0.033	0.017
$\text{NH}_4\text{-N}$	0.625	0.056	0.074	0.013
$\text{NO}_3\text{-N}$	<0.1	<0.1	<0.1	<0.1
DOC	21	28.9	24.7	17.9

pH and redox results

Table 16. Average pH and redox measurements in pre-rewetting and post-rewetting periods using daily collected data from sonde 1 and sonde 2.

Time	Sonde 1 (well 1)		Sonde 2 (well 4)	
	pH	Redox (mV)	pH	Redox (mV)
May 14-November 10, 2020 (pre-rewetting)	+4.67 (4.34-4.94)	+189 (+36 to +376)	+4.81 (4.53-5.18)	+176 (-135 to +400)
November 11, 2020 to December 23, 2021 (post-rewetting)	+4.66 (4.49-4.94)	+311 (+180 to +414)	+4.84 (4.63-5.15)	+310 (+227 to +400)

Table 17. Monthly average water temperatures, pH and Redox data at sonde 1 (located in well 1) and sonde 2 (located in well 4). The S1 and S2 are sondes 1 and 2 respectively.

Months	Water temp° C		pH		Redox (mV)	
	S1	S2	S1	S2	S1	S2
May 2020	10.80	12.76	4.66	4.65	249	258
June 2020	11.43	13.85	4.92	4.72	-41	302
July 2020	13.70	14.58	4.48	4.74	334	280
August 2020	14.95	15.80	4.61	4.82	205	208
September 2020	13.79	14.18	4.69	4.87	220	98
October 2020	12.13	11.59	4.72	4.96	190	-12
November 2020	NA	10.18	NA	5.01	NA	7.05
December 2020	NA	8.40	NA	4.82	NA	337
January 2021	NA	6.83	NA	4.83	NA	375
February 2021	8.99	7.14	4.65	4.82	249	367
March 2021	8.959	9.73	4.72	4.78	221	271
April 2021	8.508	8.82	4.71	4.75	323	368
May 2021	9.639	10.29	4.64	4.73	353	375
June 2021	12.21	13.23	4.65	4.79	290	343
July 2021	15.01	16.71	4.98	4.84	252	358
August 2021	15.27	15.98	4.68	4.78	324	288
September 2021	15.12	15.64	4.63	4.82	309	193
October 2021	12.66	12.97	4.56	4.93	264	260
November 2021	10.88	11.00	4.57	4.96	342	352
December 2021	9.04	9.15	4.52	4.99	345	363
Average	11.94	11.94	4.67	4.83	+261	+269

The monthly data of water temperatures, pH and redox derived from hourly values collected by sondes located in well 1 (sonde 1) and well 4 (sonde 2) respectively. The water temperatures in both sondes varied from 8.5° C to 16.71° C over the period of May 2020 to December 2021. The pH in both sondes varied from 4.52 to 5.01, indicating acidic pH. The redox in both sondes varied from +98 mV to +375 mV. The pH and redox data were not affected by drain blocking as seen from Table 17. The values of -41 and -12 were outliers caused due to logger malfunctioning.

Table 18. Redox classification having different ranges Kaurichev and Shiskova, (1967).

Redox parameters	Redox class
Well aerated soils	Greater than +400 mV
Moderately reduced soils	+100 to 400 mV
Reduced soils (anaerobic or anoxic)	-100 to +100 mV
Highly reduced soils	-100 to -300 mV

Based on pH and redox data from Tables 16 and 17 and comparing them to redox standards in Table 18, the peatland site is acidic, nutrient poor (no elevated N and P concentrations in surface and groundwater as seen from Tables 13,14 and 15) and moderately reduced redox state (+100 to +400 mV) respectively.

GHG quantification using Site Emissions Tool (SET)

The average WTDs from Tables 3, 4 and 5, local vegetation data as per measurements from Institute of Sligo, working with Freshwater Pearl Mussel project, the green-house gas emissions (GHGs) computed using « Site Emissions Tool » developed by VHL, Netherlands, lead partners of the Carbon Connects project. More information on Site Emission Tool (SET) on <https://www.nweurope.eu/projects/project-search/cconnects-carbon-connects/>. This SET tool quantifies GHG emissions i.e. CO₂, CH₄ and N₂O using field measured WTDs and dominant vegetation type in pre-rewetting and post-rewetting periods. The SET tool was applied at the pilot site using field measured WTDs and vegetation data. The associated GHG emissions in pre-rewetting (May-November, 11, 2020) and post-rewetting (November 12, 2020-December 23, 2021) shown in Table 19.

Table 19. GHG quantification of Irish Cconnects pilot site (Note : + below top peat surface and – above top peat surface ; GWP : global warming potential).

Parameters	Pre-rewetting (May 14, 2020-Nov 10, 2020)	Post re-wetting (Nov 11, 2020-December 23, 2021)
Average WTD below/above peat surface	+6.5 cm	-6 cm
Dominant vegetation pre-rewetting and targeted post rewetting vegetation	Wet bog heath	Wet to very wet sphagnum hollows
CO ₂ (t/CO ₂ equ/year)	0	-12.3
N ₂ O (t/CO ₂ equ/year)	+5.7	+5.7
CH ₄ (tCO ₂ equ/year)	+47.7	+31.7
Total GWP (t CO ₂ equ/year)	+53.4	+25.1

The results from Table 19, showed that Irish pilot site was a GWP source of +53.4 tonnes CO₂ equivalent per year for total of 2.68 ha i.e. 19.9 tonnes of CO₂ equivalent per hectare per year in pre-rewetting period. Upon drain blocking, the site was a GWP source of +25.1 tonnes of CO₂ equivalent for total of 2.68 ha i.e. 9.36 tonnes of CO₂ equivalent per hectare per year after rewetting.

Importantly, rewetting the pilot site reduced GHG emissions by 53% compared to the drained condition. Importantly, SET tool predicted that if the peatland site were not rewetted, the peat would oxidize in 1316 years i.e. no peatland would be existing after 1316 years. But if the peatland site were rewetted, then peat would not oxidize forever i.e. peatland site will exist for infinite years, as long as it is not drained.

Vegetation and Bettles

The Institute of Technology, IT, Sligo monitored the vegetation and Carabid beetles communities in drained and later rewetted (Irish pilot site). They found that the vegetation cover in the pre-rewetted and post rewetted pilot site was low and so were the species diversity of Carabid beetles. The Figure 12 shows the low score category for the Cconnects pilot site (O15).

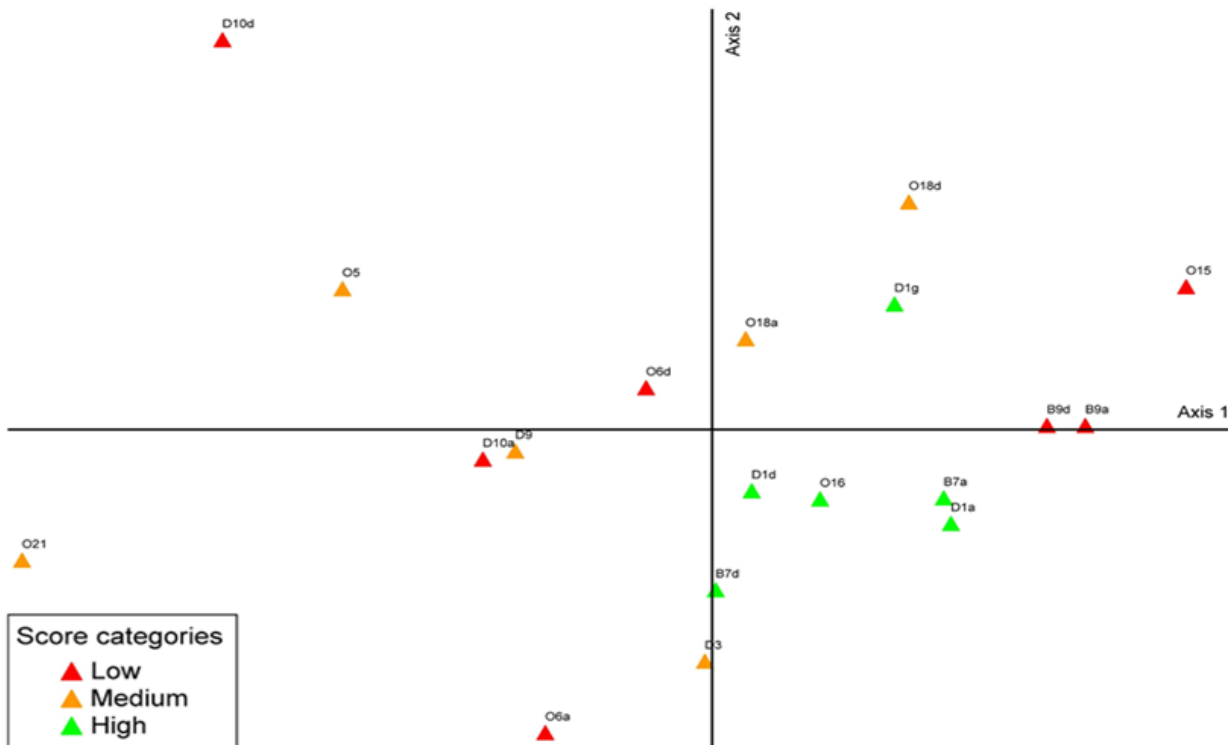


Figure 12. NMS ordination displaying associations of carabid beetles and peatland plots, Carbon Connects site highlighted on the right (O15).

Carbon Connects - low scoring peatland



Figure 13. The pilot site has fewer vegetation species such as sedges, Ling heather; bare peat surfaces and lower cover of individual species especially Sphagnum mosses).

CO₂ emissions from bare-peat surfaces

Based on the peat temperatures and WTDs in wells 1 and 2, the CO₂ emissions will be quantified using empirical relationships (see page 8) developed by Wilson et al. (2014). The peat temperature data collection went smoothly from May 2020 to January 2021 and since then, loggers malfunctioned and wires were damaged by sheep from January 01, 2021 until June 2021 and then loggers were re-deployed in July 2021. Due to this data loss, peat temperature and WTD monitoring will continue at the pilot site until August 2022 for having meaningful CO₂ emissions from bare-peat areas located near wells 1 and 2. However, Figure 14, shows the peat temperature data collected by loggers 1 and 2 located near wells 1 and 2 respectively. The loggers 1 and 2 had mean peat temperatures of 13.4 °C and 9.7 °C respectively. The range of peat temperatures of loggers 1 and 2 were -0.5-26.31 °C and 2.6-17.3 °C respectively. The logger 2 near well 2, severely impacted by drain blocking had lower peat temperatures compared to logger 1 near well 1, not severely impacted by drain blocking. We will report meaningful CO₂ results in the next reporting period of the capitalisation call in July 2022.

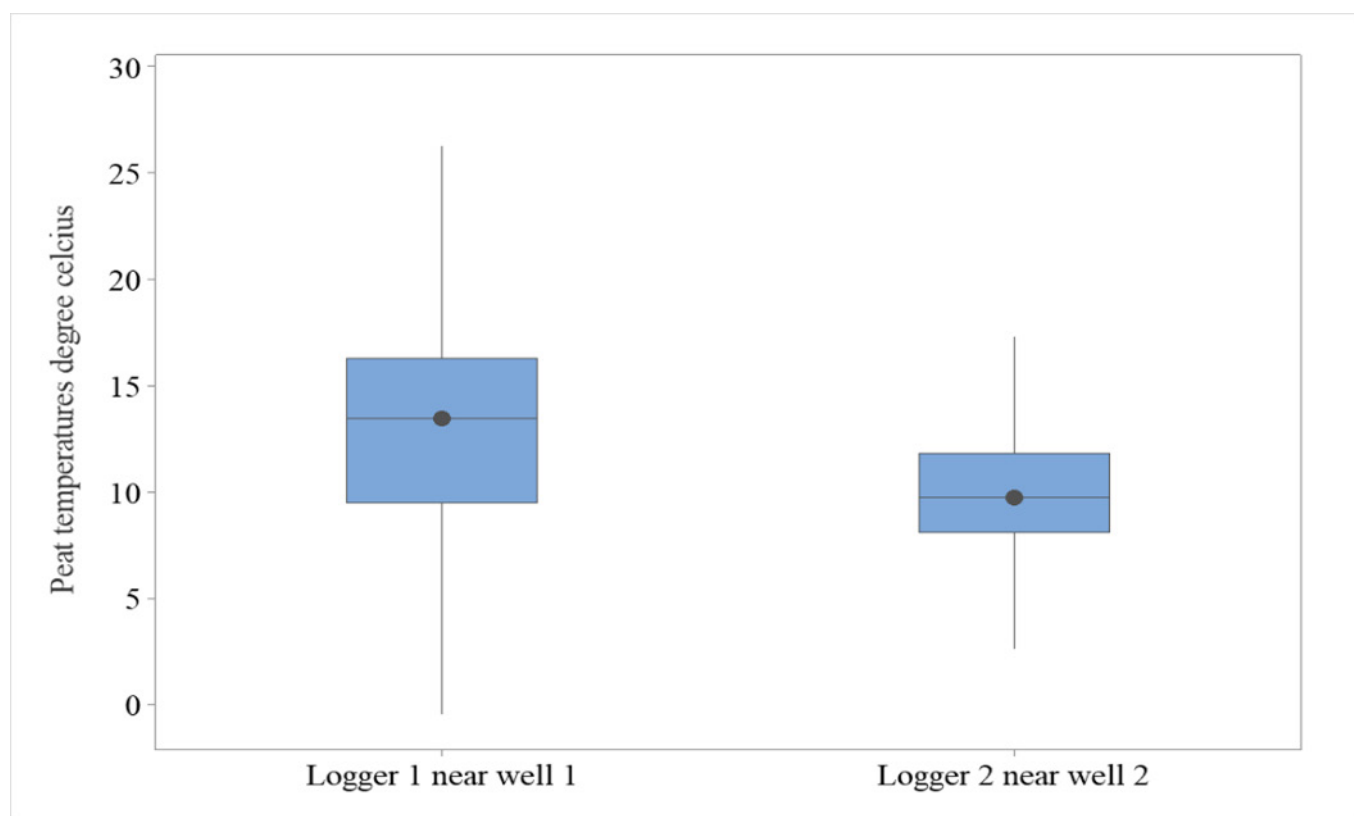


Figure 14. Peat temperatures of loggers 1 and 2 located adjacent to wells 1 and 2 respectively.

Results

1. The field measured WTDs and vegetation were utilised for quantifying GHG emissions in the pre-rewetting and post-rewetting periods. The pilot site was a GWP source of +53.4 tons of CO₂ equivalent for total of 2.68 ha in pre-rewetting period. In the post-rewetting period, the site was a GWP source of +25.1 tons of CO₂ equivalent for total of 2.68 ha. Importantly, rewetting the pilot site resulted in 53% GHG reduction compared to the pre-rewetting (drained condition).
2. Based on water quality, pH and redox data, pilot site was acidic, nutrient poor and moderately reduced. The total N, P and NH₄-N concentrations were very low and NO₃-N concentrations were found below detectable limit, indicating that no external nutrient inputs were added onto the peatland site i.e. no fertilizer applications conducted on the pilot site. The site has waterlogged, nutrient poor and acidic conditions conducive for *Sphagnum* moss regrowth, but for this to happen, the site must remain in the waterlogged condition and should not be drained.
3. The dissolved organic carbon (DOC) concentrations at the pilot site varied from 9-29 mg/L, comparable to studies conducted by Koehler et al. (2009) who measured DOC in Irish blanket peatland in Glencar and these varied from 2.7-11.5 mg/L. Four studies on blanket peatlands of Scotland and UK measured DOC concentrations and found them to vary from 3.9-18.3 mg/L and 5-35 mg/L respectively (Hope et al., 1997; Clark et al., 2005; Dawson et al., 2002; Dawson et al., 2004).
4. The total organic carbon (TOC) was measured upto 50 cm depth and varied from 29-65% and 81-90% in pre-rewetting and post-rewetting periods respectively, indicating carbon build-up due to rewetting. However, TOC sampling was only conducted once in the pre-rewetting and post-rewetting periods. There is greater need for conducting monthly sampling for making more definite conclusions. The TOC measurements at this site were comparable to TOC measurements made by Wellock et al. (2011) in raised bogs, high level blanket bogs and low level blanket bogs in Ireland and found TOC varying from 23.9-56.7% respectively.
5. Bulk density at the pilot site varied from 0.0367-0.074 g/cm³ at locations having *Sphagnum* moss growth. The bulk density in the post-rewetting on compacted bare peat surfaces varied from 0.308-0.452 g/cm³. The high bulk density of bare peat surface was caused due to many years of drainage, compaction and turf cutting. The bulk density of worldwide peatland soils vary from 0.06-0.79 g/cm³ (Kiely et al., 2014). Wellock et al. (2011) measured bulk density (g/cm³) of raised bogs, high level blanket bogs and low level blanket bogs in Ireland and found bulk densities varying from 0.065-0.208 g/cm³. The reported bulk densities in the Irish pilot site are within the ranges reported in the literature.

Future work

The rainfall and WTD monitoring will continue until August 2022 at the pilot site for estimating CO₂ emissions from the bare-peat surfaces at two locations (one location not impacted by drain blocking (rewetting) and second location severely impacted by drain blocking (rewetting)).

Challenges

The site is very remotely located and it is very challenging to install monitoring equipments and also challenging for rewetting the entire site of 8 ha i.e. blocking the drains/ditches etc. since the site has a hilly terrain, uneven slopes due to drainage, turf cutting and compaction etc.

Major Conclusions

1. In the pre-rewetting period (drained condition), the WTDs in four wells averaged +6.5 cm below the top peat surface from May 28, 2020 to November, 10 2020 and ranged from -4.6 cm above the top peat surface to +39 cm below top peat surface respectively.
2. In the post-rewetting period (after rewetting), the WTDs in four wells averaged -6 cm above the top peat surface from November 11, 2020 to December 23, 2021 and ranged from -37 cm above the top peat surface to +36 cm below the top peat surface.
3. The rewetting i.e. drain blocking resulted in reduction of 53% GHG emissions compared to pre-rewetting period (drained condition) as predicted by Site Emissions Tool (SET).
4. The Site Emissions Tool (SET) is an effective computer tool for quantifying GHG emissions from rewetted and drained peatlands, based on WTDs and vegetation and can be easily utilised by land managers, farmers and landowners.

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The Peat bulk density measurements method was obtained from published paper by Chamber et al. (2011) (<http://mires-and-peat.net/pages/volumes/map07/map0707.php>).

The protocol for Protocol for measuring Bulk Density is as follows below :

1. Measure empty weight of sampling ring on weighing balance; note it in the table below;
2. Measure the sample+ring weight on weighing balance and note it in the table below;
3. **Actual wet weight of the sample is sample + ring minus the ring weight only; do not remove the sample from the ring and disturb the sample;**
4. After steps 1, 2 and 3, place all the peat samples on a single tray; remove plastic lids from both sides of the sampling rings. Ensure that samples are not disturbed or they do not break by falling on to the floor.
5. Then place all peat samples on a single tray and load them into oven for drying at 105 degrees Celsius for at least 24 hours.
6. After 24 hours, visually inspect if samples are still wet, if wet then load the tray back into oven at 105 degrees for another 6 hours, upon fully drying, remove the tray and allow it cool at room temperature for a while.
7. After the samples are cooled at room temperature, record the dry weight on a weighing balance without disturbing the sample; write down the dry weight in a table below.
8. Bulk density is the wet sample weight minus dry sample weight divided by total wet volume of the sample. **The wet volume of peat samples from 13 to 22 contained in the intact rings is 113 cm³. The wet volume of samples 23 contained in the plastic bag is 672 cm³ and wet weight of sample 24 contained in the plastic bag is 686 cm³.**

Table 19. Bulk density measurements of the peat soils

Peat samples	Empty ring weight (g) same for all samples	Wet sample weight+ring weight (g)	Actual wet weight of each sample:	Dry weight of sample g: this should not include ring weight g	Bulk density of peat sample
	a	b	c=b-a	d	(d-c)/113 cm ³
No 11					
No 12					
No 13					
No 14					
No 15					
No 16					
No 17					
No 18					
No 19					
No 20					