8. Peatland Resources

highly significant in Ireland's efforts to combat climate change

Table 11: The original area of peatland habitat per county and the current area remaining with intact carbon stores and biodiversity. Source: IPCC sites database and Hammond 1979[1]. * The Blackstairs Mountains Blanket bog which occurs in Wexford and Carlow was not included in Hammond's figures.

	Original Area (ha) Source: Hammond 1979[1]				Intact Area (ha) Source: IPCC database of peatland sites								
County	Fen Area (ha)	Raised Bog Area (ha)	Blanket Bog Area (ha)	Total Area (ha)	Fen Area (ha)	# Sites	Raised Bog Area (ha)	# Sites	Blanket Bog Area (ha)	# Sites	Total Area (ha)	Total # Sites	% Original Area
Clare	7883	6,766	46,831	61,489	687	22	1,326	6	4,540	13	6,552	41	11
Cavan	81	7,689	3,185	10,995	304	10	444	6	5,603	3	6,351	19	58
Carlow	0	197	850	1,047	75	4	29	2	2,658*	1	2,762	7	264*
Cork	0	0	74,198	74,198	952	16	0	0	8,872	18	9,823	34	13
Donegal	0	0	149,125	149,125	639	15	0	0	41,291	43	41,930	58	28
Dublin	0	0	469	469	93	3	0	0	0	0	96	3	20
Galway	10,012	50,314	99,413	159,739	2,650	32	11,419	56	33,089	16	47,158	104	30
Kildare	5,844	18,473	0	24,317	339	13	2,642	16	0	0	2,981	29	12
Kilkenny	316	1,016	405	1,737	563	13	208	2	35	1	806	16	46
Kerry	4,654	10,999	81,211	96,864	299	10	474	7	14,384	21	15,157	38	16
Longford	1,232	20,527	0	21,759	698	11	3,919	20	0	0	4,617	31	21
Louth	81	1,012	0	1,093	164	10	300	1	300	1	764	12	70
Leitrim	16,030	5,876	35,513	57,419	399	14	254	3	12,542	10	13,194	27	23
Laois	5,140	10,478	5,241	20,859	606	6	1,003	9	1,115	1	2,724	16	13
Limerick	352	1,853	18,827	21,032	722	21	72	3	919	5	1,714	29	8
Meath	3,901	6,388	0	10,289	254	12	540	7	0	0	794	19	8
Monaghan		1,437	1,416	2,853	288	36	259	5	592	1	1,138	42	40
Mayo	469	28,906	182,569	211,944	2,585	36	574	3	66,554	34	69,713	73	33
Offaly	13,901	47,712	2,533	64,146	959	18	5,981	30	1,115	1	8,055	49	13
Roscommon	4,828	39,764	1,190	45,782	1,734	23	7,698	37	1,397	4	10,829	64	24
Sligo	1,279	6,662	29,562	37,503	573	30	664	2	14,103	10	15,340	42	41
Tipperary	4,298	15,000	14,691	33,989	1,306	15	3,339	17	3,875	9	8,520	41	25
Westmeath	11,026	26,702	0	37,728	1,295	21	4,945	24	0	0	6,240	45	17
Wicklow	0	971	15,633	16,604	558	12	105	2	14,773	8	15,436	22	93
Wexford	566	0	162	728	418	8	0	0	2,658*	1	3,076	9	423
Waterford	615	0	11,343	11,958	433	21	0	0	2,989	4	3,422	25	29
Total	**92,508**	**308,742**	**774,367**	**1,175,617**	**19,592**	**432**	**46,196**	**258**	**233,403**	**205**	**299,192**	**895**	**25**

1 Hammond, R. F. (1979) The Peatlands of Ireland. Soil Survey Bulletin No. 35, Teagasc, Dublin.

9. Managing and Protecting Carbon

through peatland restoration

The role of managing Ireland's peatlands is really important for carbon accounting at national level. Because of the climate crisis land managers need to work together from all sectors not only to restore carbon sequestration function in peatlands but more crucially to protect the carbon stocks in those peatlands and prevent their continued degradation and loss from accelerating climate change. It must be borne in mind that the majority of Irish peatlands have been converted to other uses such as agricultural land, forested land, industrial peat land and cutover peatland from domestic turf cutting and are emitting greenhouse gases which are contributing to climate change. Alongside such peatlands are the sites designated for conservation which also have been degraded by on-going drainage, turf extraction and other uses (see Table 12).

In their current state, all Irish peatlands are also vulnerable to the changes presently occurring and predicted to occur to our climate. Without restoration climate change itself will accelerate further loss of sites, loss of carbon stores and loss of carbon sequestration function. Decisions must be made about what needs to be done to manage the carbon stocks remaining in our "drained only intact" and man-modified peatlands.

When peat is wet the carbon stocks are safe and carbon sequestration may be occurring. When peat is drying, the carbon stock is being lost as well as the capacity of the peatland to sequester carbon.

The multiple advantages of peatland rewetting (in restoration and rehabilitation) projects have been assessed by Renou-Wilson et al 2018[1] and they have ranked the peatlands in rewetting priority order based on maximizing biodiversity provision, climate mitigation and taking into account the area of land area available in each land use category (see Table 13). Drained only/domestic cutover and grassland sites are ranked in first and second position in terms of restoration priority based on maximizing synergies between biodiversity and greenhouse gas emission reduction.

In Ireland the Irish Peatland Conservation Council have been monitoring on-going peatland restoration on over 65 sites and on-going peatland rehabilitation on 40 former industrial extraction sites. These projects have provided valuable practical experience on the feasibility and techniques of peatland restoration and rehabilitation (Mackin et al 2017[2] and Bord na Móna 2016[3]).

Peatland restoration/rehabilitation and rewetting projects have proven to be cost-effective compared to other available

Table 12: The greenhouse gas emission levels from various peatland uses in the Republic of Ireland before and after rewetting from Turraun Bog (Wilson et al 2015[4]) and the NEROS network of sites (Renou-Wilson et al 2018[1]). N_2O was not detected in either the drained or rewetted sites studied (see Figures 14 and 15).

Peatland Type LUC land use category	Site Example	Drained CO_2 Emissions t C ha^{-1} yr^{-1} (+ source - sink)	Drained CH_4 Emissions t C ha^{-1} yr^{-1} (+ source - sink)	Rewetted CO_2 Emissions t C ha^{-1} yr^{-1} (+ source & - sink)	Rewetted CH_4 Emissions t C ha^{-1} yr^{-1} (+ source & - sink)
Nutrient-rich Industrial Cutaway	Blackwater Turraun	+1.51 +2.86	+0-0.015 range for all Land Use Categories (LUC's)	+0.32	+0.173
Drained Only & Domestic Cutover	Cuckoo Hill, Moyarwood, Sharavogue, Killyconny, Croaghonagh	+1.37		-0.49	+0.197
Nutrient-poor Industrial Cutaway	Bellacorrick	+0.91		-1.04	+0.092
Grassland	Glenvar	+0.81		-0.40	+0.044
Forestry	Cloonshanville, Scohaboy (Sopwell), Carrickbar, Poolagoona	not measured		+1.02-5.6	+0.020-0.026

1 Renou-Wilson, F., Wilson, D., Rigney, C., Byrne, K., Farrell, C. & Müller., C. (2018) Research 236: Network Monitoring Rewetted and Restored Peatlands/Organic Soils for Climate and Biodiversity Benefits (NEROS). EPA Wexford.

2 Mackin, F., Barr, A., Rath, P., Eakin, M., Ryan, J., Jeffrey, R. & Fernandez Valverde, F. (2017) Best practice in raised bog restoration in Ireland. Irish Wildlife Manuals, No. 99. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

3 Bord na Mona Biodiversity Action Plan 2016-2021, Bord na Móna, Newbridge, Co. Kildare

4 Wilson, D., Dixon, S.D., Artz, R.R.E., Smith, T.E.L., Evans, C.D., Owen, H.J.F., Archer, E. and Renou- Wilson, F., (2015) Derivation of greenhouse gas emission factors for peatlands managed for extraction in the Republic of Ireland and the United Kingdom. Biogeosciences 12 (18): 5291–5308.

Table 13: Rewetting priority order of different peatland types in the Republic of Ireland. This is extracted from the Environmental Protection Agency NEROS Report 2018[1]. The ranking order is based on maximizing biodiversity provision, climate mitigation and taking into account the area of land available in each category.

Peatland Type LUC land use category/ Rewetting Priority	Biodiversity Provision	CO_2 Emissions	Land Area Coverage in Ireland (ha)	Paludiculture Options	CH_4 Emissions	Potential Costs of Rewetting High	Difficulty maintaining high water level in some sites	Priming Effects from Brash Decomposition	Potential N_2O Emissions
1. Rewetting drained-only & domestic cutover	High	High CO_2 emissions avoided	High (c. 260,000-600,000ha)		Moderately High	Yes	Yes		
2. Rewetting grassland areas	Modest	High CO_2 emissions avoided	Medium (c. 300,000-374,690)	Yes	Moderate	Yes	Yes		
3. Rewetting industrial cutaway	Low (but potentially new ecosystem diversity)	High CO_2 emissions avoided	Medium (c. 67,715-100,000)	Yes	Moderate		Yes		
4. Rewetting afforested areas	Modest	High CO_2 emissions	Medium (c. 321,927)		Moderate		Yes	Yes	Yes

carbon reducing technologies. They also have the added bonus of re-establishing the multiple benefits arising from peat-forming ecosystems including biodiversity, water regulation and recreation. For example Wilson et al 2012[2] examined the greenhouse gas emissions from different revegetated communities colonising the rewetted cutaway bog at Bellacorrick in Co. Mayo The work assessed the potential economic value of restoration in terms of avoided losses and gains of C (€/tonne CO_2-eq ha^{-1}) through the use of a number of timeline scenarios. These followed the peatland from the cessation of peat extraction (Tzero), through rewetting (T1) and on to the present day (Tpresent). The results showed that in the period T1 to Tpresent, an estimated 75 tonnes CO_2-eq ha^{-1} was mitigated by the restoration actions at Bellacorrick – resulting in an estimated value of €1506 ha^{-1} in avoided losses. In addition, net C sequestration at the peatland during the 12-month period of this study (Tpresent) was worth an estimated €118 ha^{-1} yr^{-1}. The rewetting of industrial cutaway and cutover bogs corresponded to an average cost-effectiveness value of just under €4 per tonne of carbon dioxide equivalent (CO_2-e), a value that would support climate mitigation efforts involving rewetting of peatlands. While these results are exciting they come with warnings from the researchers. The cutaway bog studied occurs in the blanket bog region which is very different in terms of rainfall and peat substrate and may not be representative of potential savings that rewetting of the industrial cutaway raised bogs of the midlands of Ireland might provide. Also the results are based on 1 year of measurement of greenhouse gases and do not take into account inter-annual variations nor the rapidly changing plant succession that occurs during rewilding of rewetted cutaway bogs. Nevertheless studies such as this are vitally important to stimulate rewetting action and to form a basis for carbon accounting and trading of carbon credits.

Emissions from damaged peatlands and carbon savings from peatland restoration are eligible for national accounting under the UN Framework Convention on Climate Change. There is therefore an opportunity for Ireland to look at including peatland restoration and re-wetting in our national climate action plans (IUCN 2017[3]).

Figure 14: "Dark" chamber on Moyarwood Bog, Co. Galway used for measuring methane (CH_4) and nitrous oxide (N_2O) fluxes. Photo: © D. Wilson

Figure 15: "Clear" chamber on Clara Bog, Co. Offaly used to measure net exchange of CO_2 between an ecosystem and the atmosphere (NEE). Photo: © D. Wilson

1 Renou-Wilson, F., Wilson, D., Rigney, C., Byrne, K., Farrell, C. & Müller., C. (2018) Research 236: Network Monitoring Rewetted and Restored Peatlands/Organic Soils for Climate and Biodiversity Benefits (NEROS). EPA Wexford.

2 Wilson, D., Renou-Wilson, F., Farrell, C., Bullock, C. & Muller, C. (2012) Carbon Restore – The Potential of Restored Irish Peatlands for Carbon Uptake and Storage. Climate Change Research Programme (CCRP) 2007-2013 Report Series No. 15, EPA, Wexford.

3 IUCN (2017) Peatlands and Climate Change. IUCN Issues Brief. www.iucn.org.

10. Peatland Restoration in Practice

an expensive, time-consuming collaborative effort

A continuum of peatland condition occurs, ranging from relatively intact and degraded sites with a full or partial peat-forming function and carbon store through to bare peat and grassland with no peat-forming function and with an eroding carbon store. The position of a particular peatland along that continuum determines its potential for recovery, through natural processes or management intervention so that it returns to good condition. Where management is required, the cost-effectiveness of that intervention needs to be considered.

In very simple terms, the more degraded a site, the longer it will take to restore, the more it will cost and the lower the likelihood of success. In some cases, that cost may not appear to represent good value in the short term, but on the basis of greenhouse gas emissions savings alone it is likely that in most cases it will be cost-effective in the medium to longer term. This does, however, highlight the merits of intervening at an early stage and ensuring that peatlands already in good condition are managed sustainably. The development of site management plans in line with national habitat and species conservation objectives and climate mitigation strategies is crucial to inform actions on sites.

Some types of damage/ degradation are relatively easily reversed. If a site is over-grazed, reduce the level of grazing. If invasive species are present, remove them. If a site is under-grazed, increase the grazing. If a site is trampled by visitors, provide and maintain boardwalks. If a site has been planted with conifers, remove the trees, block the drains and control regeneration. If a site is drained, block the drains. If the site was formerly an industrial production area, reprofile the remaining peat and block drains to achieve maximum rewetting which stabilises the surface peat and protects the carbon stocks remaining in the peat.

In reality restoration of Irish peatlands is not an easy task because damage has caused years of deterioration on sites. This includes subsidence, puncturing of the natural hydrological seal within the peatland basin or removal of the peat substrate through turf cutting and industrial harvesting.

Restoration Targets

The National Parks and Wildlife Service[1] have set a target to protect 3,600ha of active raised bog and its supporting habitat of 30,867ha. To this end they have proposed a restoration programme in three phases of 6 years ending in 2036 for all of the raised bogs in Ireland designated in SACs or NHAs which amounts to 129 sites (see Table 8).

In relation to blanket bogs and fens, no conservation target has been set to date. Due to the severe losses of pristine examples of these peatland types, IPCC would expect that Government will set a conservation target to protect all of the active peat-forming habitat that remains and the supporting habitat in the sites in which the active peatland area occurs. Based on IPCC's tracking of peatlands of conservation importance in our sites database, for blanket bogs this would be in the range of 233,500ha (see Table 11) and for fens the figure at present would be 19,592ha (see Table 11). The estimate for fens is likely to be low as this habitat has not been formally surveyed by NPWS researchers to date.

Restoration Achieved and In Progress

Prior to the development of the National Raised Bog Special Areas of Conservation Management Plan 2017-2022 restoration works were carried out on over 65 sites in Ireland[2]. Significant projects were undertaken by Coillte to remove conifers from peatlands of conservation importance between 2002 and 2015 through 3 projects funded from the EU LIFE programme, Coillte and NPWS. The work involved restoration works on 1,207ha of raised bog across 29 sites and 2,000ha of blanket bog across 17 sites[3]. In 2009 Bord na Móna launched its Raised Bog Conservation Programme targeting sites that were drained but never advanced into peat production. To date restoration has been carried out on 39 sites and 3,964ha of raised bog[4]. Some sites are of sufficiently high quality to be designated as SACs (Clonboley Complex (including Ballydangan Bog) Roscommon and Killeglan Bog Cluster Roscommon) or NHAs (including Glenlough Bog Longford/Westmeath, Clonwhelan Bog Longford/Westmeath, Knockahaw Bog Tipperary/Kilkenny and Ballysorrell Bog Tipperary).

NGO's play a key role in restoring peatlands in their ownership

1 National Raised Bog Special Areas of Conservation Management Plan 2017-2022, National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Dublin

2 Malone, S. & O'Connell, C. A. (2009) Ireland's Peatland Conservation Action Plan 2020. Irish Peatland Conservation Council, Kildare

3 Coillte Life Projects Reference Numbers: LIFE02 NAT/IRL/008490; LIFE04 NAT/IE/000121 & LIFE09 NAT/IE/000222

4 Bord na Móna Biodiversity Plan 2016-2021, Bord na Móna, Newbridge, Co. Kildare

including BirdWatch Ireland, Irish Wildlife Trust and the Irish Peatland Conservation Council.

The National Parks and Wildlife Service have also been active in this area and have carried out a variety of restoration works on raised bogs in liaison with Dutch peatland conservationists. In the period from 2004-5 to 2011-13 they undertook restoration works on 12 raised bog sites with an active peat forming target of 39.3ha (NPWS[1]). These works were funded through EU Cohesion and EU LIFE funding with matched funding from the NPWS. They also undertook significant work on the restoration of blanket bogs through the control of grazing using the Commonage Framework Plans from 2002 onwards[2].

Other privately-funded groups engage in restoration. A positive step in the protection and management of peatlands was the establishment of Community Wetlands Forum in 2013. This group with a membership of 21 communities (www.community-wetlandsforum.ie accessed 19.10.2020)[3] works to help communities appreciate their local peatland and seeks to ensure that community engagement is valued in the management of peatlands by all those working on restoration.

Restoration projects in progress include the Interreg VA project CANN Collaborative Action for the Natura Network (2017-2021). This project will develop Conservation Action Plans for SACs on the border with Northern Ireland and conduct direct conservation actions on a portion of these. A second project is also working cross-border – the CABB project Co-operation Across Borders for Biodiversity (2017-2021). Conservation actions from these projects will include drain blocking, fencing, adopting suitable grazing regimes and writing conservation action plans. CARE-Peat (2019-2022) is another Interreg project which aims to develop techniques to monitor and restore the carbon storage capacity of peatlands. This project will involve two demonstration sites in Ireland - Cloncrow Bog NHA, Co. Westmeath and Cavemount Cutaway Bog in Co. Offaly.

The SAC raised bog restoration programme described in the National SAC Management Plan has been underway since 2016. The Living Bog Raised Bog Restoration Programme (LIFE14 NAT/IE/000032) is a high profile restoration project which aims to restore 12 raised bog sites over a 5-6 year period delivering 752.7ha of active peat-forming raised bog habitat at a cost of €5.4 million (NPWS[1]). To accelerate the raised bog restoration programme another 9 raised bogs are to be restored in 2020 using €5 million funding collected from the Carbon tax. In relation to blanket bogs the LIFE-IP PAF Wild Atlantic Nature project 2020-2028 will protect and restore 24 blanket bogs at a cost of €12 million. It will involve the removal of encroaching trees and shrubs, blocking drains and improvement of fire management measures.

Eco-hydrological Models of Peat-forming raised bog habitat

Much research work has been commissioned by the National Parks and Wildlife Service to develop an understanding of the eco-hydrological functioning of raised bogs so that they can predict based on physical measurements of site topography such as slope, rainfall and hydrological attenuation/drainage patterns available from LiDAR data for each raised bog site where the supporting conditions for peat forming vegetation occur on a raised bog site (Mackin et al 2017)[4]. Active peat-forming

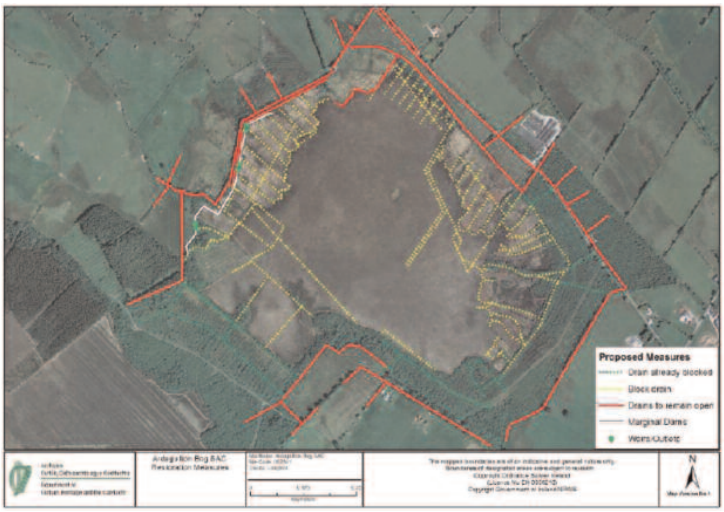


Figure 16: Ardagullion Bog, Co. Longford SAC 2341 showing the complexity of restoration. A conifer plantation on 25ha of this site was removed as part of a Coillte LIFE-funded project in 2008 (LIFE04 NAT/IE/000121) and the extensive drain network on the bog surface has been blocked in 2019 with up to 800 peat dams as part of the LIFE-funded Living Bog project (LIFE14 NAT/IE/000032). In addition a barrier dam has been constructed in the cutover bog containing two wiers. These actions will protect the existing active bog of 14ha in the site and extend it by 9ha. Photo: © NPWS[1].

1 National Raised Bog Special Areas of Conservation Management Plan 2017-2022, National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Dublin

2 Malone, S. & O'Connell, C. A. (2009) Ireland's Peatland Conservation Action Plan 2020. Irish Peatland Conservation Council, Kildare

3 Flood, K. (2017) Community Wetlands Forum Strategic Plan 2017-2020

4 Mackin, F., Flynn, R., Barr, A. & Fernandez-Valverde, F. (2017) Use of geographical information system-based hydrological modelling for development of a raised bog conservation and restoration programme. Ecological Engineering 106: 242–252.

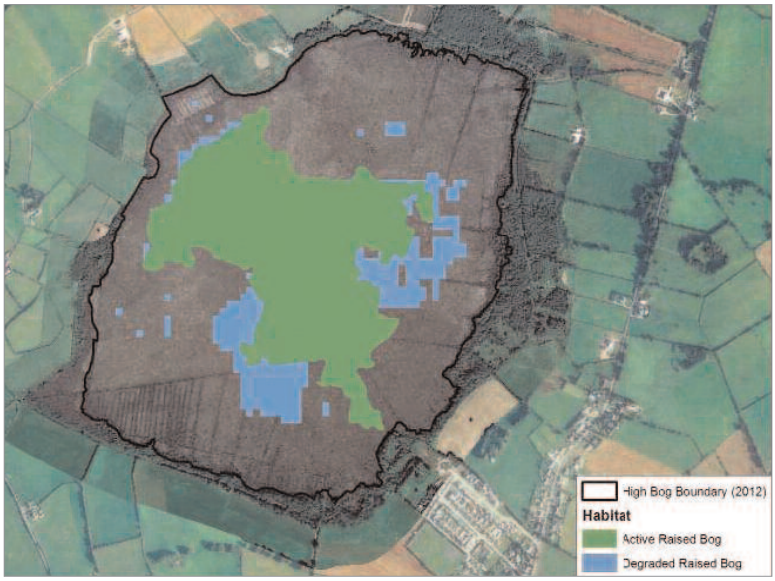
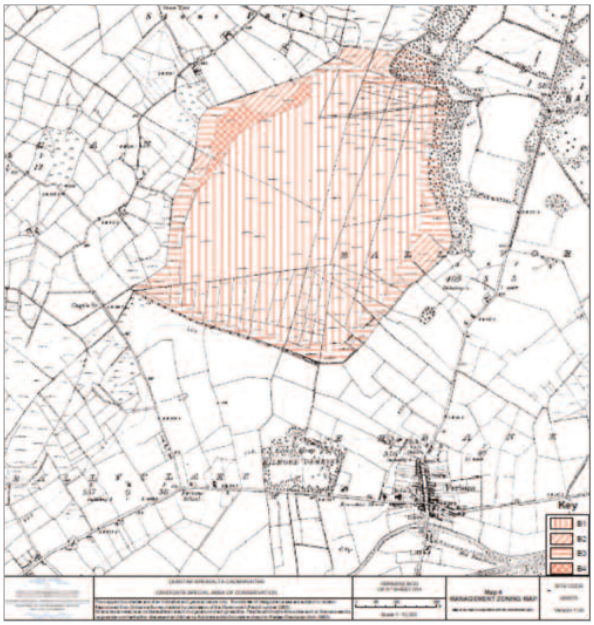


Figure 17: Turf-cutting ceased on Ferbane in 2011 and private turf cutters have been compensated through the turf compensation scheme. The map above shows the area of active peat forming habitat on the site in green. The degraded raised bog area that can be restored to peat formation with management works principally blocking almost 16,000 metres of drains on the high bog on the southern and eastern margins of the site is shown in blue. Photo: © NPWS[1]. The map below shows the management zones on the Ferbane Bog labelled B1 to B4. Different management strategies have been devised for each zone with the highest priority being given to B1 and B4 on the high bog Photo: © NPWS[2].



raised bog typically develops on uncut peatlands with slopes of between 0.2% and 0.6%, depending on effective rainfall which varies between 200 and 900mm per year. It may also occur in more localised focused-flow flushes on slopes exceeding 1%. On the ground peat forming conditions can be verified by the presence of specific vegetation ecotopes. The information gained has been used to develop hydrological management plans and site specific restoration plans for each raised bog. These plans contain a series of maps of necessary restoration action measures. Tasks are zoned prioritizing those actions that are cost effective and achieve the greatest impact first. Priority is given to the creation of conditions in suitable locations where active peat formation can be achieved. This includes high uncut bog locations as well as cutover bog locations. The restoration plans resulting are complex and depend on the co-operation of all stakeholders and landowners in a particular site and in the landscape surrounding a site that may be affected by the hydrological changes within the peatland. As a result drainage management plans have been prepared for each raised bog and the landscape within which it sits. A key element in this regard is the need for the National Parks and Wildlife Service to communicate with local communities in a conversation about restoration and to provide incentives to ensure good will and co-operation with the necessary restoration process.

Restoration in practice is very complex as shown in Figures 16 and 17 of Ardagullion Bog in Longford and Ferbane Bog in Offaly, two sites included in the Living Bog EU LIFE Raised Bog Restoration Project 2016-2020 (LIFE14 NAT/IE/000032). Achieving a site-specific conservation objective may take 10 or more years after restoration works are finally completed. Besides restoration works within the designated site, drainage management, beyond the raised bog boundary, is integrated into the restoration plan for each bog. Drainage management plans are developed for each site in consultation with local communities and these help to allay fears of farmland being subject to flooding as a result of site restoration.

1 National Raised Bog Special Areas of Conservation Management Plan 2017-2022, National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Dublin

2 National Parks and Wildlife Service Conservation Plan for 2005-2010 Ferbane Bog cSAC Site Code 575 Co. Offaly

Peatland Rehabilitation

Peatland rehabilitation generally refers to rewetting and other actions concentrated in peatland sites that cannot be returned to their former state. It applies to cutaway bogs, peatlands managed for grassland and peat soils under forest plantations.

With the closure of milled peat production across the Bord na Móna industrial cutaway bogs, much attention has been focused on the future of such sites and on their rehabilitation. Creating hydrological regimes that support the development of peatland habitats such as fens and wet woodlands is essential on cutaway bogs but equally, management actions that reduce greenhouse gas leakage from these sites and protect the remaining carbon stores are vital. Drain blocking, control of water outflow and profiling are important actions in such rehabilitation. These must be followed by on-going monitoring to ensure their effectiveness.

Because of the climate crisis, land managers need to work collectively from all sectors not only to restore carbon sequestration function in peatlands if they can but more crucially to protect the carbon stocks in those peatlands and prevent their decomposition from accelerating climate change.

Rehabilitation Targets

In light of the serious impact of greenhouse gas emissions from peat soils, rehabilitation, rewetting and restoration programmes need to be designed for all peat soils. In this regard rehabilitation of industrial cutaway bogs has begun through the work of Bord na Móna. Under the IPC License, this company must stabilise the peat in sites commercially exhausted which automatically

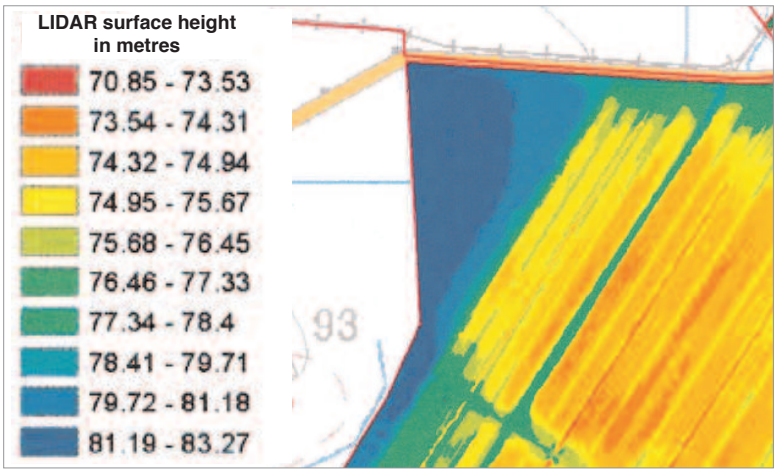


Figure 18: The first stage of site assessment involves a consideration of surface levels across the industrial cutaway site. This site is Lodge Wetlands North near Lullymore in Co. Kildare. It's rehabilitation began in 2016. Photo: © Bord na Móna

Figure 19: Typical starting point site condition for rehabilitation at Cavemount, Co. Offaly in 2019. Photo: © C. O'Connell

sets a rehabilitation target of 88,000ha of peatland. The Government approved funding of €108m to Bord na Móna from the Climate Action Fund for the rehabilitation of 33,000ha of industrial cutaway bogs that were formally peat energy sites from 2021-2025[1]. Objectives must be set for this Enhanced Peatland Rehabilitation Scheme (EPRS) before large scale rehabilitation and repurposing of cutaway bogs is undertaken.

Besides stimulating the creation of jobs, a national management plan for the cutaway bogs is needed that is climate proof. Drained cutaway bogs are significant CO_2 emission hot spots. These must be targeted for rewetting as a climate mitigation strategy. Renou-Wilson & Wilson 2018[2] have shown that rewetting industrial cutaway peatlands corresponds to an average cost-effectiveness value of just under €4 per tonne of CO_2-e avoided which clearly supports such mitigation methods. As rewetted cutaway bogs are highly sensitive to annual weather conditions, monitoring (to include greenhouse gas dynamics, vegetation composition and water table levels) is essential to ensure that the rewetting rehabilitation measures employed are sustainable and climate proof.

1 Cabinet approves €108 million funding for ground-breaking Bord na Móna rehabilitation plan. Department of the Environment, Climate and Communications 24 November 2020

2 Renou-Wilson, F. & Wilson, D. (2018) Vulnerability Assessment of Peatlands: Exploration of Impacts and Adaptation Options in Relation to Climate Change and Extreme Events (VAPOR). Report No. 250, EPA Wexford.

Figure 20: Hydrological images for Lodge Wetlands South, Co. Kildare from 2015 (left) before rehabilitation began and in 2020 (right) showing rewetting of the residual peat through the creation of berms and blocking the outflow from the site. In managing for climate change it is necessary to rewet a greater proportion of such sites through reprofiling of the peat surface remaining in the post-industrial site. Photos: © Bord na Móna

Figure 21: Vegetation maps for Lodge Bog Wetlands North, Co. Kildare from 2016 (left) when rehabilitation began and in 2017 (right). The spread of wetland habitat described as open water and pioneer poor fen mosaic can be seen across the low lying areas of the site. Photos: © Bord na Móna

A decision pathway for successful rewetting and climate proofing of cutaway bogs may have the following steps[1]:

1. Site assessment (see Figures 18 and 19)

2. Site preparation works for maximum rewetting bringing the water table close to the surface including reprofiling and levelling the peat surface, cambering the edges of peat fields, compartmentalising sections by constructing berms and managing outflow

3. Monitoring of effectiveness including water table (see Figure 20), vegetation change (see Figure 21) and greenhouse gases

4. Intervention works to correct undesired successional and hydrological outcomes.

A decision tool is urgently needed to consider the future of peatlands under forestry and privately owned sites under agriculture and turbary. There are very strong arguments for rewetting in terms of its effectiveness in reducing CO_2 emissions as shown in Tables 12 and 13 from the Environmental Protection Agency[2].

1 Renou-Wilson, F., Wilson, D., Rigney, C., Byrne, K., Farrell, C. & Müller., C. (2018) Research 236: Network Monitoring Rewetted and Restored Peatlands/Organic Soils for Climate and Biodiversity Benefits (NEROS). Report No. 236, EPA Wexford.

2 Renou-Wilson, F., Wilson, D., Rigney, C., Byrne, K., Farrell, C. & Müller., C. (2018) Research 236: Network Monitoring Rewetted and Restored Peatlands/Organic Soils for Climate and Biodiversity Benefits (NEROS). Report No. 236, EPA Wexford.

11. Peatland Restoration Methods

nature-based solutions to reduce net emissions of greenhouse gases

The techniques used for restoring peat-forming conditions on bogs are summarised in Table 14. Prior to drain blocking it is necessary to remove invasive birch and pine trees from around the drains to provide access for wide track machines that are used for building peat dams. In the Living Bog LIFE Raised Bogs Restoration Project (LIFE14 NAT/IE/000032) teams of three workers with chain saws removed trees obscuring drains. The chain saw team were followed by a 3 tonne excavator with a thumb grab attachment to remove the cut trees away from the restoration zone.

Machines used to block drains using peat dams are specially adapted for the wet bog environment (see Figure 22). A seven tonne machine was used with wide tracks to 13 feet and with a load bearing of <2 pounds per square inch (psi). When blocking drains using peat, the peat used must stick together. The sides of the drain where the dam is to be constructed are cleaned. This means the peat keys in firmly and prevents the dam from failing. The dam is built in layers using peat with a paste-like consistency taken from a borrow pit on the bog surface. The bucket on the digger is used to apply pressure to the peat dam and crush the peat down into the drain. The surface scraw from the borrow pit is placed over the top of the peat dam. The position of dams is determined using GPS which allows a contractor to upload a map of the dam positions to his vehicle.

Current best practice in raised bog restoration recommends that dams are constructed at every 10cm fall in elevation to bring the water table within 10cm of the surface. A minimum of three dams per 100m is recommended and where peat dams are used a maximum of ten dams per 100m is best practice to ensure the bog surface is not significantly disrupted by an excessive number of borrow pits. Peat dams are the most common material used for drain blocking in raised bogs; however, alternative methods include the use of plastic sheet piling which is inserted into the drain and driven down to an appropriate depth. In some cases, a combination of peat

Figure 22: Specially adapted machine developed by Bord na Móna to construct peat dams on bogs of conservation importance. Photo: © Bord na Móna

Case Study: Effectiveness of Drain Blocking

On Lodge Bog in Co. Kildare, the Irish Peatland Conservation Council blocked 4km of drains with 198 dams constructed from plastic drain piling (see Figure 23)[2]. Within days the water level on either side of the dams rises. Vegetation changes take longer and this requires monitoring. In 2010 and 2016 IPCC monitored the effectiveness of the dams in terms of *Sphagnum* moss recolonisation by recording % cover in a quadrat placed on either side of a dam. The results showed an increase in the number of dams with between 75 and 100% cover of *Sphagnum* moss from 25% in 2010 to 51% in 2016. They also showed a decrease in the number of dams with 0% *Sphagnum* cover from 65% in 2010 to 23% in 2016. The increase in *Sphagnum* cover over the 6 year period proves that drain blocking works and that it facilitates the spread of *Sphagnum* moss and the reduction in the loss of carbon from the site as a result.

Figure 23: Drain with high water table after blocking with plastic sheet piling on Lodge Bog, Co. Kildare in 2010. Photo: © M. Kenny

1 Mackin, F., Barr, A., Rath, P., Eakin, M., Ryan, J., Jeffrey, R. & Fernandez Valverde, F. (2017) Best practice in raised bog restoration in Ireland. Irish Wildlife Manuals, No. 99. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.

2 McCluskey, A. & Geraghty, G. (2016) *Sphagnum* moss returns after drain blocking on Lodge Bog. Peatland News 62: 16, Irish Peatland Conservation Council

Table 14: Peatland restoration measures practiced in Ireland (Source Mackin et al 2017[1] and Jack McGauley The Living Bog pers comm 31.7.2020 and 19.10.2020). Cell bunding and other bunding methods being trialled at present and are not included. Significant costs are incurred in compensating land owners for loss of turf cutting or for undertaking necessary management works on their land, for the development of restoration and drainage management plans, land purchase and essential on-going monitoring of the effectiveness of restoration.
*** High Density Polyethylene.**

Restoration Technique	Method	Estimated Cost € (includes materials & labour)	Dimensions	Materials
Peat Dams	Wide track machine 12 feet wide with load bearing pressure <2psi or no more than 1.6 lb inch^{-2}	€30 per dam installed	1m deep, 50cm above bog surface and 50cm wider than drain width of 1-2m	Machine and peat
Plastic Dams (See Figure 23)	By Hand	€90 per dam installed	1m deep, <1m wide	Corrugated sheets of 5mm HDPE* interlocking piling 25cm wide
Partial infilling of drain	By Hand	€15 per linear metre using local peat infill	Variable length, 1m deep, 1m wide	Humified Peat
Site preparation for drain blocking - tree clearance	Chainsaw crew of 3 and thumb and grab machine to remove cut trees	€1,200 per day	Clear material away from drains and access routes	Machine
Removal of conifer plantation	Clear felling using specialist harvester machine or chain saw	Harvester: €1200-€1500 per ha. Chainsaw €900-€1200 per ha.	Hectare cleared of conifers	Machinery
Barrier Dam (See Figure 24)	Machine	€25-€30 per linear metre	Trench 1.5m deep and 0.5m wide, filled with peat. Finished height 1m above bog surface and covered with living bog vegetation or scraw	Humified peat and machine
Weir	Constructed from 8x4' steel sheet, 6mm thick, seams welded. Finished structure coated in galvanised	€3,500	Specific to barrier dam	8x4' steel sheet, 6mm thick
***Sphagnum* transfer inoculation (See Figure 25)**	Hand	€1,325 per ha	Hectare of bare peat inoculated	Live *Sphagnum* moss from donor site, straw

Figure 24: Barrier dam constructed on Ardagullion Bog in 2019 as part of the Living Bog Restoration Project to provide peat-forming conditions in the cutover bog. Photo: © J. McGawley

dams with plastic sheet piling can be effective where significant flow is experienced, as the plastic can prevent erosion of the peat in the dam while the peat forms a more effective seal in the drain than plastic alone.

Barrier dams are suited to flat areas of cutover bog where there is sufficient water supply run off from the high bog. They are less than 1m in height and constructed from low permeability peat to prevent water flowing under the dam. Weirs or outlets are necessary to ensure that water levels do not rise too high behind the barrier dam. Weirs are a bespoke construction to match site requirements. Barrier dams have been constructed at Killyconny Bog, Co. Cavan and Ardagullion Bog in Co. Longford (see Figure 24).

Figure 25: *Sphagnum* inoculation trial in 2020 three years after inoculation on Girley Bog, Co. Meath by the Irish Peatland Conservation Council in 2018. Photo: © C. O'Connell.

1 Mackin, F., Barr, A., Rath, P., Eakin, M., Ryan, J., Jeffrey, R. & Fernandez Valverde, F. (2017) Best practice in raised bog restoration in Ireland. Irish Wildlife Manuals, No. 99. National Parks and Wildlife Service, Department of Culture, Heritage and the Gaeltacht, Ireland.