Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

ERAMMP Technical Annex-105TA1S8: Wales National Trends and Glastir Evaluation Supplement-8: Peatland Emissions

Williamson, J.

UK Centre for Ecology & Hydrology

Client Ref: Welsh Government / Contract C208/2021/2022
Version 1.0
Date: 04-April-2025

Funded by:

Llywodraeth Cymru
Welsh Government

Canolfan Ecoleg a Hydroleg y DU
UK Centre for Ecology & Hydrology

Version History

Version	Updated By	Date	Changes
1.0	PMO	04/04/2025	Publication

This report is available electronically at: www.erammp.wales/105TA1S8

Or by scanning the QR code shown.

Series Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)

Title ERAMMP Technical Annex-105TA1S8:
Wales National Trends and Glastir Evaluation
Supplement-8: Peatland Emissions

Client Welsh Government

Client reference C208/2021/2022

UKCEH contact details Bronwen Williams
UK Centre for Ecology & Hydrology (UKCEH)
Environment Centre Wales, Deiniol Road, Bangor, Gwynedd, LL57 2UW
01248 374500
erammp@ceh.ac.uk

Corresponding author Jennifer Williamson, UKCEH
jwl@ceh.ac.uk

Authors Williamson, J.

Contributing authors & reviewers

How to cite (long) Williamson, J. (2025). *Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP)*. ERAMMP Technical Annex-105TA1S8: Wales National Trends and Glastir Evaluation Supplement-8: Peatland Emissions. Report to Welsh Government (Contract C208/2021/2022) (UK Centre for Ecology & Hydrology Project 08435)

How to cite (short) Williamson, J. (2025). ERAMMP Technical Annex-105TA1S8: Wales National Trends and Glastir Evaluation Supplement-8: Peatland Emissions. Report to Welsh Government (Contract C208/2021/2022) (UKCEH Project 08435)

Approved by Bridget Emmett (UKCEH)
James Skates (Welsh Government)

Abbreviations Used in this Report

DOC	Dissolved organic carbon
GHG	Greenhouse Gas
IPCC	Inter-Governmental Panel on Climate Change
LULUCF	Land Use, Land Use Change and Farming
NE	Natural England
NPAP	National Peatland Action Programme
NRW	Natural Resources Wales
POC	Particulate organic carbon
WG	Welsh Government

Contents

1 BACKGROUND

Within the land use and management sector, progress has slowed towards meeting the net zero target. From 2010 to 2021 there has been an increase in emissions from Agriculture reported in the Agriculture GHG Inventory for Wales of 0.33 Mt CO_2eq yr^{-1} to 5.7Mt CO_2eq yr^{-1} in 2021 and a reduction in the sink within the Land Use, Land Use Change and Forestry sector of 0.02Mt CO_2eq/yr^{1} to -0.7Mt CO_2eq yr^{-1}. There therefore remains a significant gap between the two inventories of 5Mt CO_2eq yr^{-1} to achieve if the land-based sector is to achieve Net Zero as a whole (Figure 1-1).

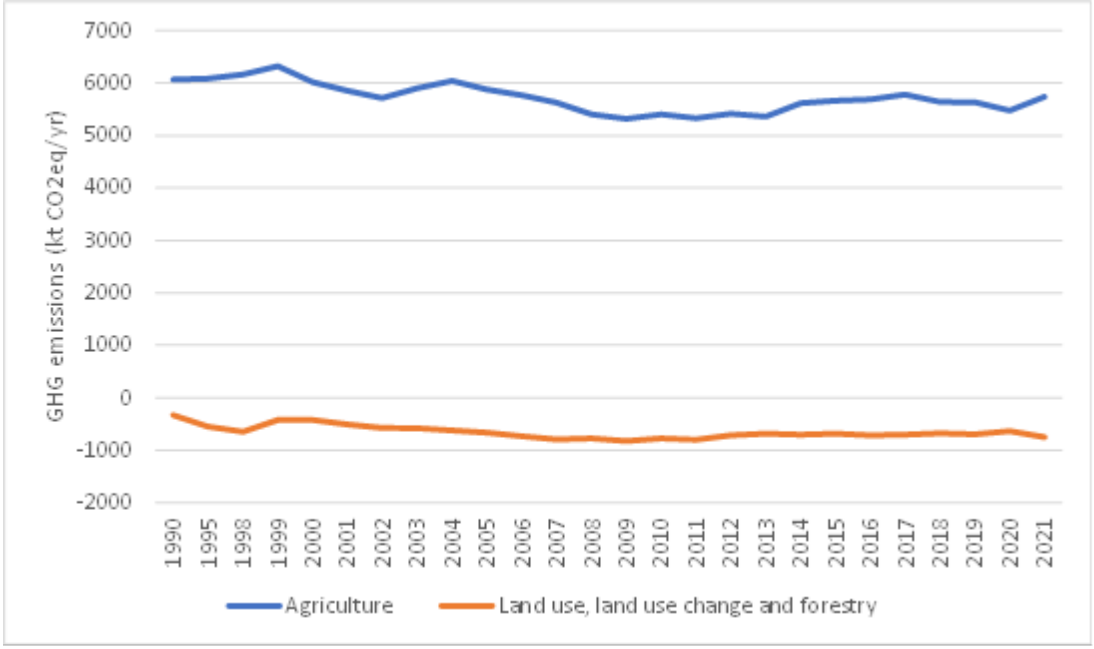

Figure 1-1 Trends in GHG emissions from Agriculture and the Land Use and Land Use Change and Forestry (LULUCF) as captured in the 2021 GHG Inventory for Wales.

Forest planting and peatland restoration were the main likely potential contributors to increasing the LULUCF sink in the 2020 to the Climate Change Commission (Thomson et al. 2020). These two issues are explored in the following sections.

Peatlands in Wales have been subject to historical degradation through anthropogenic activity including drainage, peat cutting, forestry, over-grazing and burning. Since approximately 2010 there has been an increasing focus on restoration of these peatlands primarily via measures designed to increase water levels and remove invasive vegetation. In 2020, to provide a mechanism for upscaling peatland restoration across Wales the National Peatland Action Programme (NPAP) was commissioned, with the aim of ensuring restoration management of all semi-natural peatlands in Wales. This aim is led by the two headline Government policies covering net zero and biodiversity.

Peatlands in a near natural condition are characterised by continuously high water levels, which enable a negative net ecosystem carbon balance (i.e. more carbon dioxide is taken

[1] www.naei.beis.gov.uk/reports/reports

up via photosynthesis than is released via respiration or carbon lost as dissolved organic carbon (DOC) or methane (CH_4), which is released following incomplete anaerobic breakdown of organic matter. When peatlands are drained the water table drops, which allows the aerobic decomposition of previously waterlogged organic matter. This releases carbon dioxide to the atmosphere and once the mean annual water table drops below approximately 20 cm below the surface the carbon balance switches from a sink to a source (Evans et al., 2021).

The contribution of peatlands to Net Zero is, however, complicated by the emission of methane from peatlands as they become increasingly waterlogged, and potentially inundated in areas following restoration. As methane has a global warming potential of 28 times that of carbon dioxide on a 100-year timeframe, increasing methane emissions can, in the short term, switch sites from a sink to a source when reporting emissions as carbon dioxide equivalents. Despite this, global radiative forcing models show that the total warming effect from peatlands is minimised by earlier rewetting, despite the increased methane emissions (Gunther et al., 2020).

At present carbon dioxide and methane fluxes from peatlands are determined using a Tier 2 (UK specific) emission factor methodology, following the guidance issued in the IPCC Wetlands Supplement (IPCC 2014). Peatland areas are assigned a condition category depending on land cover and management and emissions are calculated as emission per unit area * area.

2 METHODS

Spatial data covering peatland area and peatland restoration was compiled up until February 2023 from available data sources (Table 2-1). There may be additional peatland restoration in Wales that was not covered by this dataset, for example additional restoration on the Vyrnwy Estate.

Following the methodology of Evans et al. (2015) the Welsh peat area from the 2021 Welsh peatland map was categorised into baseline peat condition categories using the Phase 1 habitat mapping survey of Wales from 1990. These condition categories have UK specific Tier 2 emission factors as updated in Evans et al. (2023) (Table 2-2). Using drainage information from the unified peat map (Evans et al., 2015) any locations within a 10 m buffer of a mapped drain in the uplands and 50 m of a mapped drain in the lowlands were recategorized as drained as part of the baseline emissions categorisation.

All areas covered by the vegetation and tree management categories were classified as modified bog – drained, while all areas with a rewetting category were classified as rewetted bog or fen, depending on their location. Where areas had both vegetation management and rewetting the vegetation management change was applied prior to the rewetting management change so that the final condition of such locations was rewetted fen or bog. Where restoration areas did not completely align with the peat map these were clipped to the outline of the peat map for reporting.

Table 2-1 Spatial data sources for peatland mapping.

Data	Source	Information
Peatlands_of_Wales_scg8	Welsh data portal	Welsh Peatland Map procured in 2021
Peatlands_of_Wales_emissions	Welsh data portal	Not used. Based on old emission factors and unsure as to how land was categorised per area.
Wg_unified_peat_2019	Welsh data portal	Updated version of unified peat map developed in GMEP to include restoration up until 2017 and newly surveyed lowland peats
NPAP funded restoration activity	NRW. Split by restoration type	6 shapefiles, erosion control, grazing management, hydrology management, tree management and vegetation management. Also, total area
SNPA restoration activity	SNPA	Overlaps with NPAP data but not all SNPA restoration work NPAP funded
Blocked ditches as of 2017	NRW	Ditches blocked by any restoration funding source up until early 2017
GA Poly and GA point	NRW	This is rewetting work funded under Glastir advanced up until 2018. Not used in this work.
All LIFE raised bog restoration data	NRW	Restoration activity funded under LIFE for Welsh Raised Bogs Life project
NNR polygon area for Fenns and Whixall	NE	NE did not have all restoration data immediately accessible but communicated that restoration had covered the whole NNR area under multiple funding sources
Glastir rewetting	WG	Polygon data of all Glastir advanced areas with rewetting.

Table 2-2 Combined emission factors for all GHG source/sink pathways for each peat condition category, expressed in t CO_2 ha^{-1} yr^{-1} based on IPCC AR5 100-year Global Warming Potentials (28 for CH_4 and 265 for N_2O). Emission factors based on IPCC Tier 1 defaults are shown in italics.

Peat Condition	Drainage status	Direct CO_2	CO_2 from DOC	CO_2 from POC	Direct CH_4*	CH_4 from Ditches	Direct N_2O	Total
Near-natural Bog	Undrained	-3.54	*0.69*	0.00	3.17	*0.00*	*0.00*	**0.32**
Near-natural Fen	Undrained	-5.06	*0.69*	0.00	4.01	*0.00*	*0.00*	**-0.36**
Rewetted Bog	Rewetted	-3.54	*0.69*	0.00	3.17	*0.00*	0.00	**0.32**
Rewetted Fen	Rewetted	-0.69	*0.88*	0.00	3.12	*0.00*	*0.00*	**3.31**
Modified Bog-grass/heather	Drained	0.03	*1.14*	0.26	1.69	*0.15*	0.05	**3.32**
	Undrained	0.03	*0.69*	0.00	1.73	*0.00*	0.05	**2.51**
Modified Bog – eroding	Drained	5.44	*1.14*	10.27	1.14	*0.76*	*0.12*	**18.86**
	Undrained	5.44	*0.69*	10.27	1.20	*0.00*	*0.12*	**17.72**
Extracted – Domestic	Drained	10.27	*1.14*	1.76	1.14	*0.76*	*0.12*	**15.18**
Extracted – Industrial	Drained	5.44	*1.14*	10.27	1.14	*0.76*	*0.12*	**18.86**
Grassland – Extensive	Drained	11.78	*1.14*	0.51	0.96	*0.74*	*0.76*	**15.88**
Grassland – Intensive	Drained	14.86	*1.14*	0.51	0.77	*1.63*	3.03	**22.00**
Cropland (peat > 40 cm)	Drained	27.04	*1.14*	0.51	0.05	*1.63*	*6.78*	**37.17**
Cropland –wasted (peat < 40 cm)	Drained	16.00	*1.14*	0.51	0.05	*1.63*	*6.78*	**26.10**

2.1 A comparison of method used for LULUCF inventory and ERAMMP

The UK Greenhouse Gas Inventory (UKGHGI) provides annual spatially resolved emissions estimates at a 1* 1 km resolution for each sector (Tsagatakis, et al., 2023). GHG emissions from peatlands are reported within the section covering agriculture, land-use and forestry and a methodology applicable across all areas of the UK is used to ensure the consistency of approach. Estimates of land use change over time are tracked using a Bayesian data assimilation approach (Brown, et al., 2023), while specific changes in land use as a result of peatland restoration are assumed to occur in proportion to the extensive grassland and modified peatland areas on peat (Brown, et al., 2023).

At a Wales -wide scale, spatially explicit maps of peatland restoration resulting from rewetting, vegetation management and grazing management on peatlands are now available from NRW as part of the NPAP. This allows us to map the location of restoration against baseline (1990) land use data from the Phase 1 habitat survey of Wales.

Specific methodological differences between the approach outlined here for reporting the impacts of restoration on GHG emissions from Welsh peatlands and the UK GHG Inventory are shown in Table 2-3.

Table 2-3 Comparison of GHG mapping approaches for peatlands between the UK GHG Inventory and ERAMMP reporting

	LULUCF	ERAMMP	Comments
Peat map source	GMEP	WG 2021 peat map	Overall reduction of peats = 10,000ha WG map is at a 50*50 m resolution and excludes some smaller peat areas.
Emission Factors (EF)	Carbine used for forest on peats	2017 GMEP report	All other EF apart from forest land are the same
Drainage assumptions	Assume fixed %	Use of mapped drainage from a range of data sources	Mapped drainage doesn't provide 100% coverage of Wales
Restoration extent and land use	Assumes 427ha yr^{-1} proportionally split across habitat present in 1990	Use a range of data sources from actual restoration projects	LULUCF assumed most restoration is on extensive grassland. ERAMMP identified most is on modified bog.
GHG emissions 2021	285,612 t CO_2-e ha^{-1} yr^{-1}	490,986 t CO_2-e ha^{-1} yr^{-1}	Driven by higher emissions from forest and continued presence of extensive grassland in ERAMMP database.

Overall, ERAMMP has used best data sources to provide the most up to date information to WG with respect to restoration extent and land use, and GHG emissions. The use of the gridded Welsh peat map limited the mapping of small peat fragments and provided much of the spatial disconnect between the ERAMMP reporting and the UK GHG Inventory reporting. A decision needs to be made as to how WG wish to align peatland reporting against the UK GHG Inventory.

2.1.1 Emission factor approach

At present carbon dioxide and methane fluxes from peatlands are determined using a Tier 2 (UK specific) emission factor methodology, following the guidance issued in the IPCC Wetlands Supplement (IPCC, 2014). Peatland areas are assigned a condition category depending on land cover and management and emissions are calculated as emission per unit area * area (Table 2-3).

To capture national trends in peatland restoration, the potential impacts for GHG emissions and the contribution from Glastir, spatial data covering peatland area and peatland restoration was compiled up until February 2023 from available data sources (Table 2-1). There may be additional peatland restoration in Wales that was not covered by this dataset, for example additional restoration on the Vyrnwy Estate.

3 RESULTS

These results are supplementary to those reported in ERAMMP Technical Annex-105TA1: Wales National Trends and Glastir Evaluation (Emmett et al., 2025)

The location of peat soils in Wales is shown in Figure 3-1, with peat soils covering just over 80,000 ha (Table 3-2). The majority of peat soils are found in the uplands, with three main areas in mid and north Wales; Migneint Arenig Dduallt SAC, Berwyn Mountains SAC and Pumlumon, and Elenydd SAC. There are also nationally significant areas of lowland raised bog including Cors Fochno, Cors Caron, and Fenns and Whixall Moss. While there are fewer near natural fens in Wales pockets of this habitat remain, for example Cors Erddreiniog and Cors Goch on Anglesey.

The data from the Phase 1 habitat survey of Wales showed that much of the peatland area in Wales had undergone some degree of modification (Figure 3-2, Table 3-2), with semi-natural blanket bog locations becoming heather or *Molinia* dominated, particularly in mid Wales. Large areas of peatland were also classified as woodland habitat, and much of this is non-native conifer plantation, planted on drained peat. Only comparatively small areas of peat have been modified to improved grassland or arable land in Wales, probably because of the dominance of upland peats in the Welsh peatland resource.

Table 3-1 shows the area of restored peatlands in Wales by 2023, as reported by various sources. Work is underway by the NPAP to standardise the methods for reporting the area impacted by restoration, which is particularly relevant where some data providers may provide the whole area where activity has taken place, while others may only report the area directly impacted by (for example) the blocking of an individual drainage ditch. Of the restoration work funded just over half of the area overlapped with the 2021 Welsh peat map. This is likely to be due to a combination of factors, including inaccuracies in the peat base map, restoration taking place over areas with shallow peaty soil not mapped as peat, or restoration occurring at a habitat scale necessary for restoration success but included some areas of non-peat soil within the wider peatland landscape. At a national scale much of this restoration occurred in modified bog and fen areas, resulting in the remapping of these as rewetted bog and fen respectively. Some apparently inconsistencies occur, for example a reduction in near natural bog habitat between 1990 and 2023 (Table 3-2). This is likely to be either due to degradation since 1990 (for example conifer encroachment), or a misclassification of the habitat by the 1990 baseline data.

Figures 3-4 and 3-5 show the proportion of Welsh peat mapped under each habitat in 1990 and 2023, showing that despite the work carried out the overall proportions have changed comparatively little.

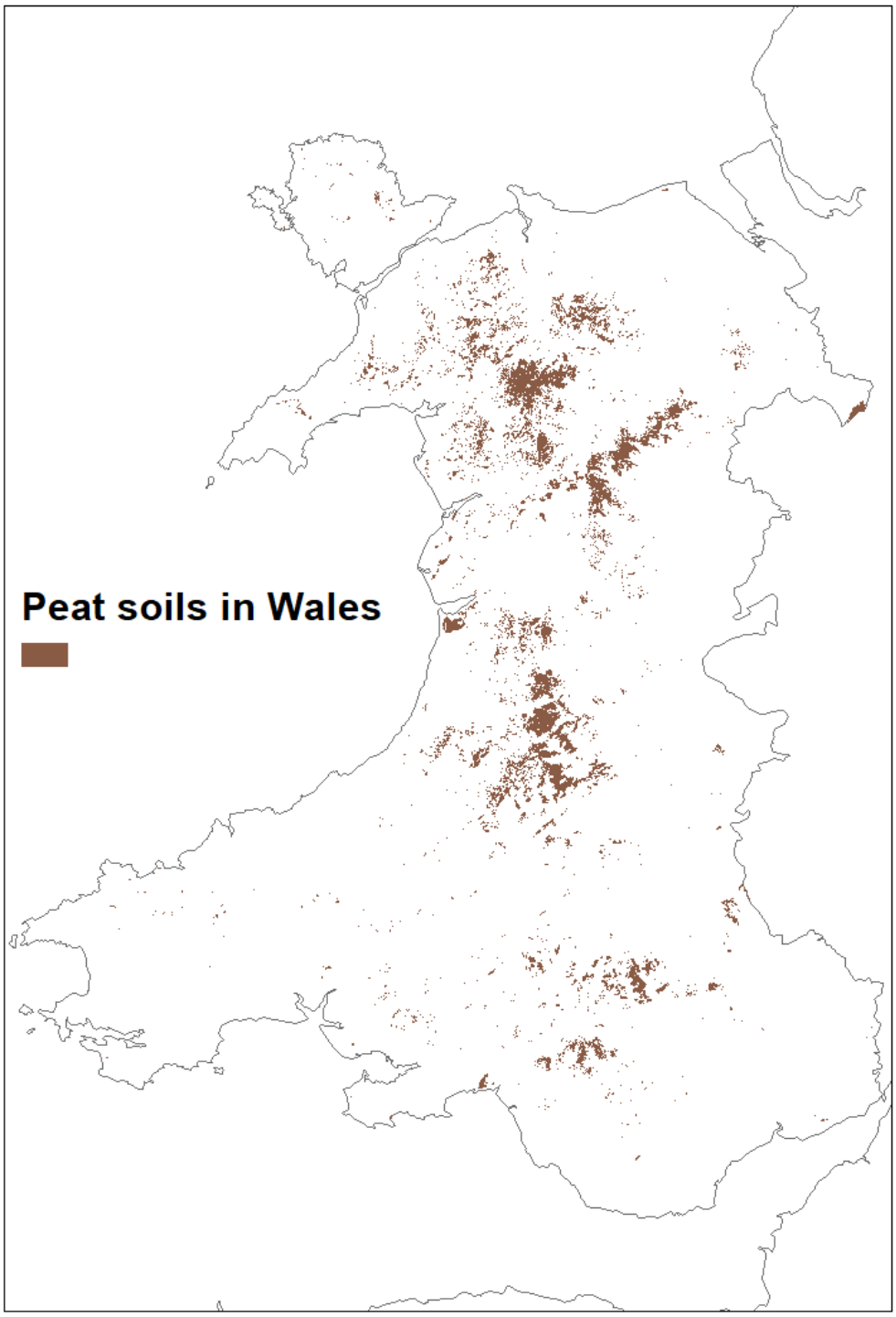

Figure 3-1 Peat soils in Wales

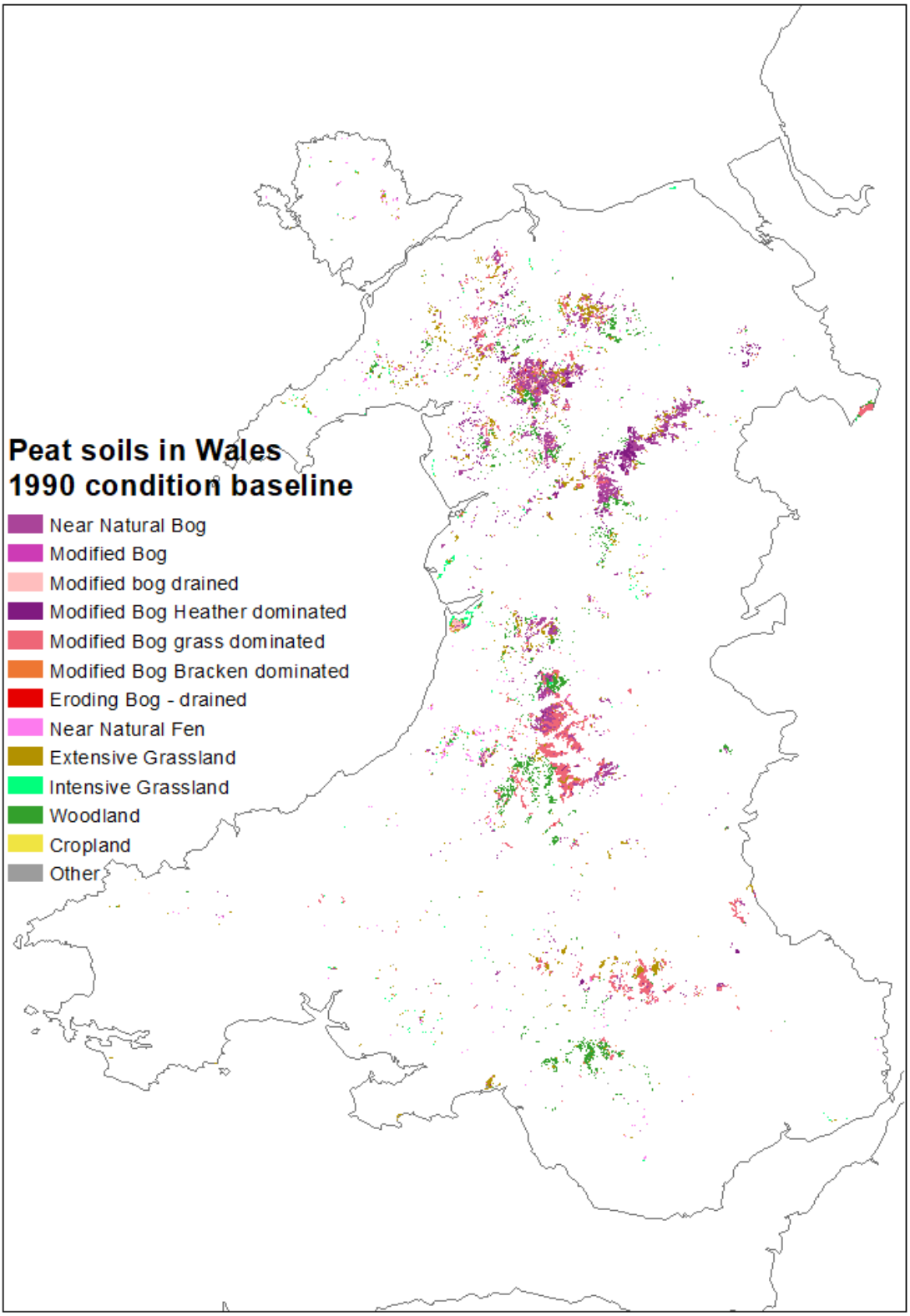

Figure 3-2 Baseline 1990 land cover on peat in Wales. Based on Phase 1 habitat survey data.

Table 3-1 Areas of restoration datasets and the area of each dataset overlapping the Welsh Peat Map

Funding stream	Area Restored (ha)	Area overlapping peat map (ha)
Glastir	992	507
NPAP – vegetation management	4951	1955
NPAP - rewetting	393	229
LIFE Raised Bogs	482	437
SMS Peatlands	139	116
Fenns and Whixall	583	519
Other (pre 2016)	1582	1305
Total	**9122**	**5068**

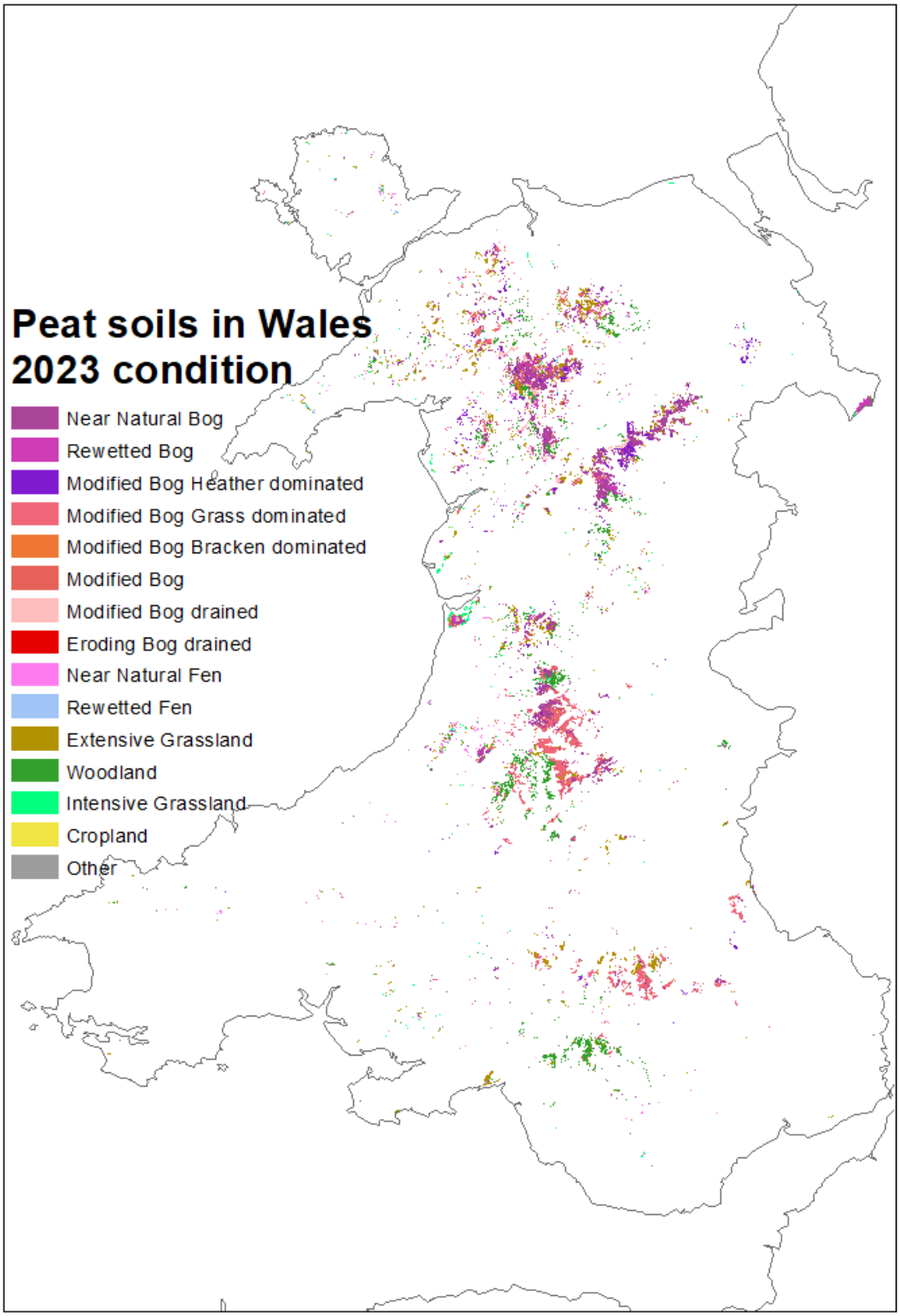

Figure 3-3 2023 peat condition in Wales. Based on Phase 1 habitat survey data and available peatland restoration data.

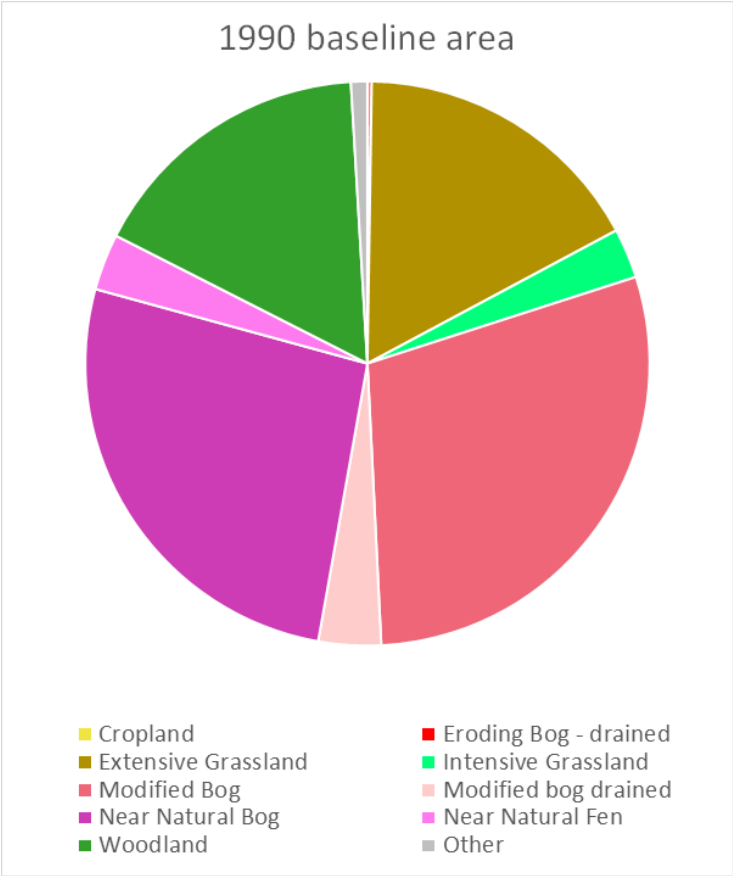

Figure 3-4 1990 peatland land cover

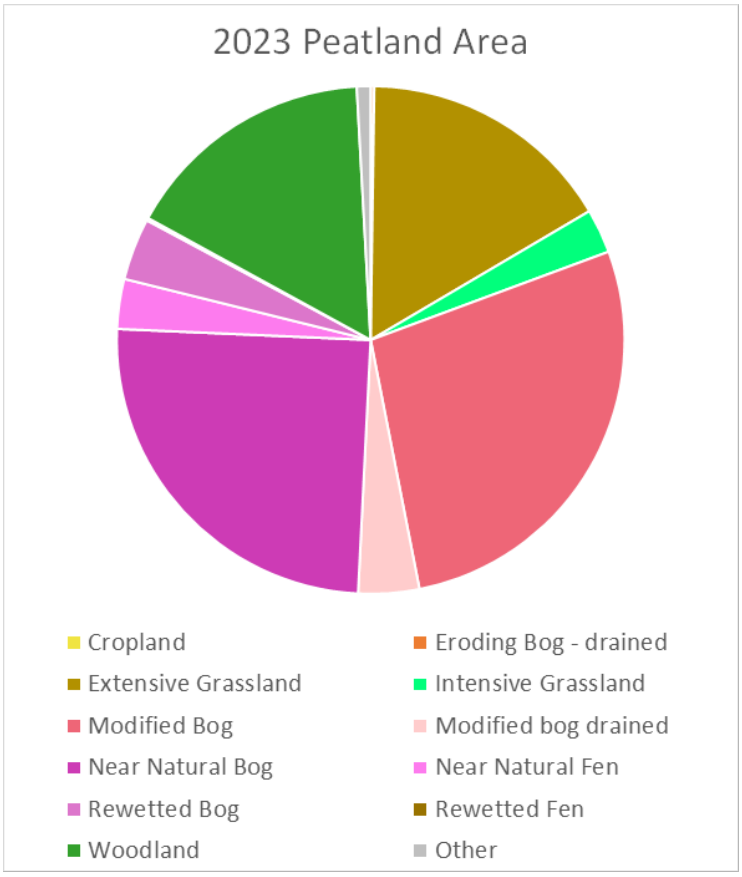

Figure 3-5 2023 peatland land cover

Table 3-2 Comparison of peatland land cover between 1990 and 2023.

Land use	1990 Area (ha)	2023 Area (ha)
Cropland	33	31
Eroding Bog - drained	168	155
Extensive Grassland	13845	13320
Intensive Grassland	2330	2306
Modified Bog	23853	22534
Modified bog drained	2928	3167
Near Natural Bog	21617	20354
Near Natural Fen	2637	2590
Rewetted Bog	0	3226
Rewetted Fen	0	131
Woodland	13554	13203
Other	766	713
Total	**81730**	**81730**

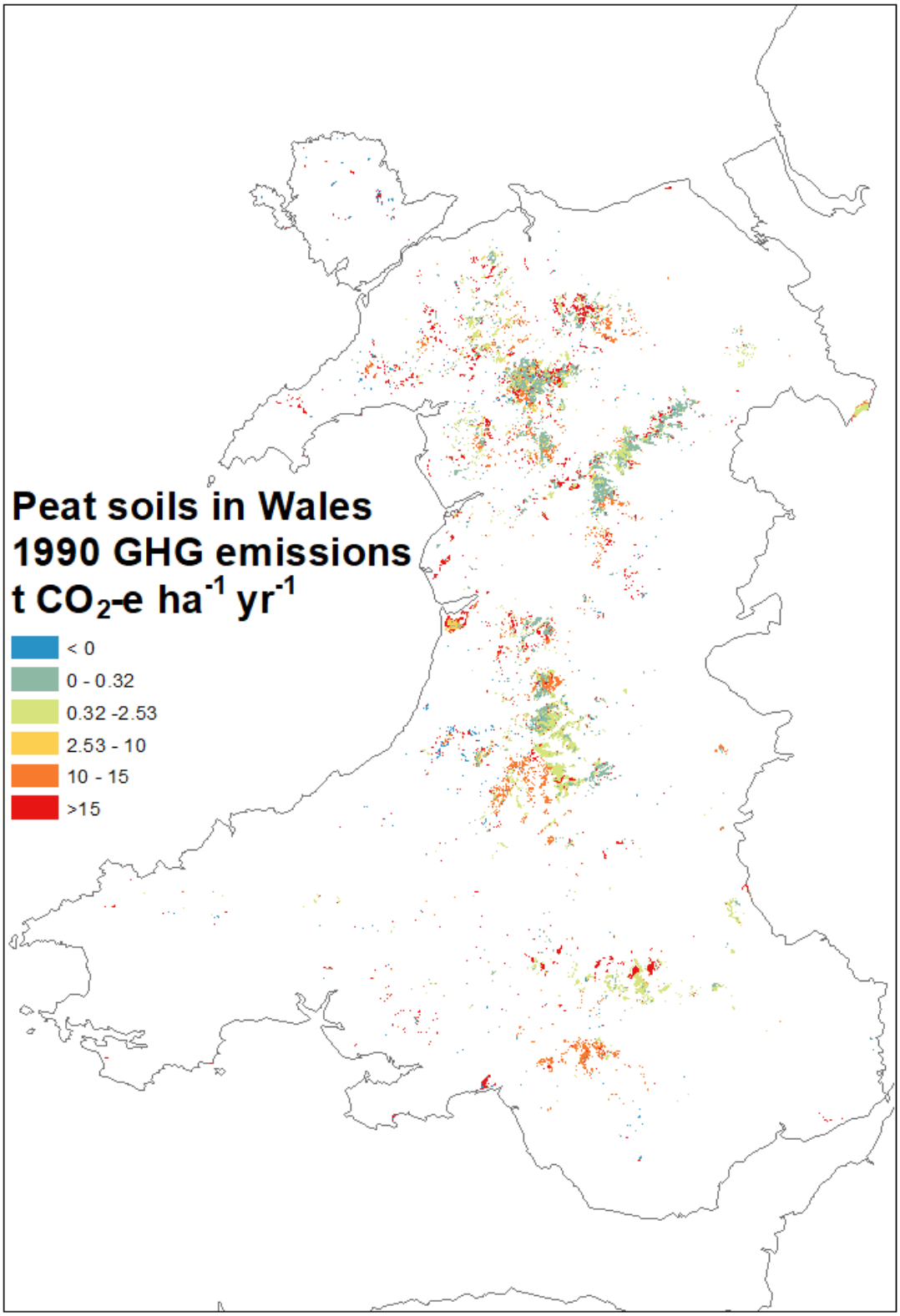

Figure 3-6 Baseline 1990 GHG emissions from peatlands in Wales

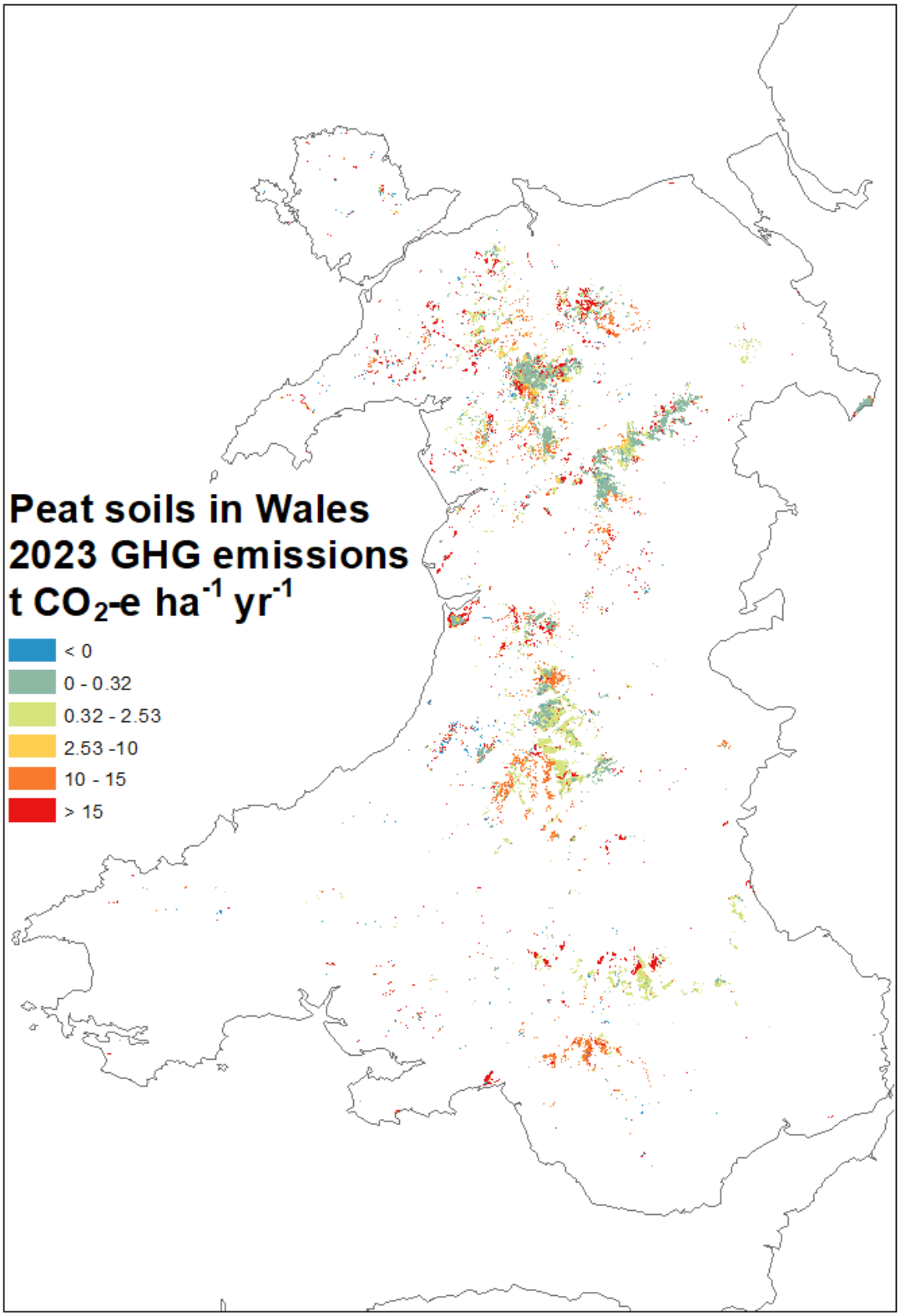

Figure 3-7 2023 GHG emissions from peatlands in Wales.

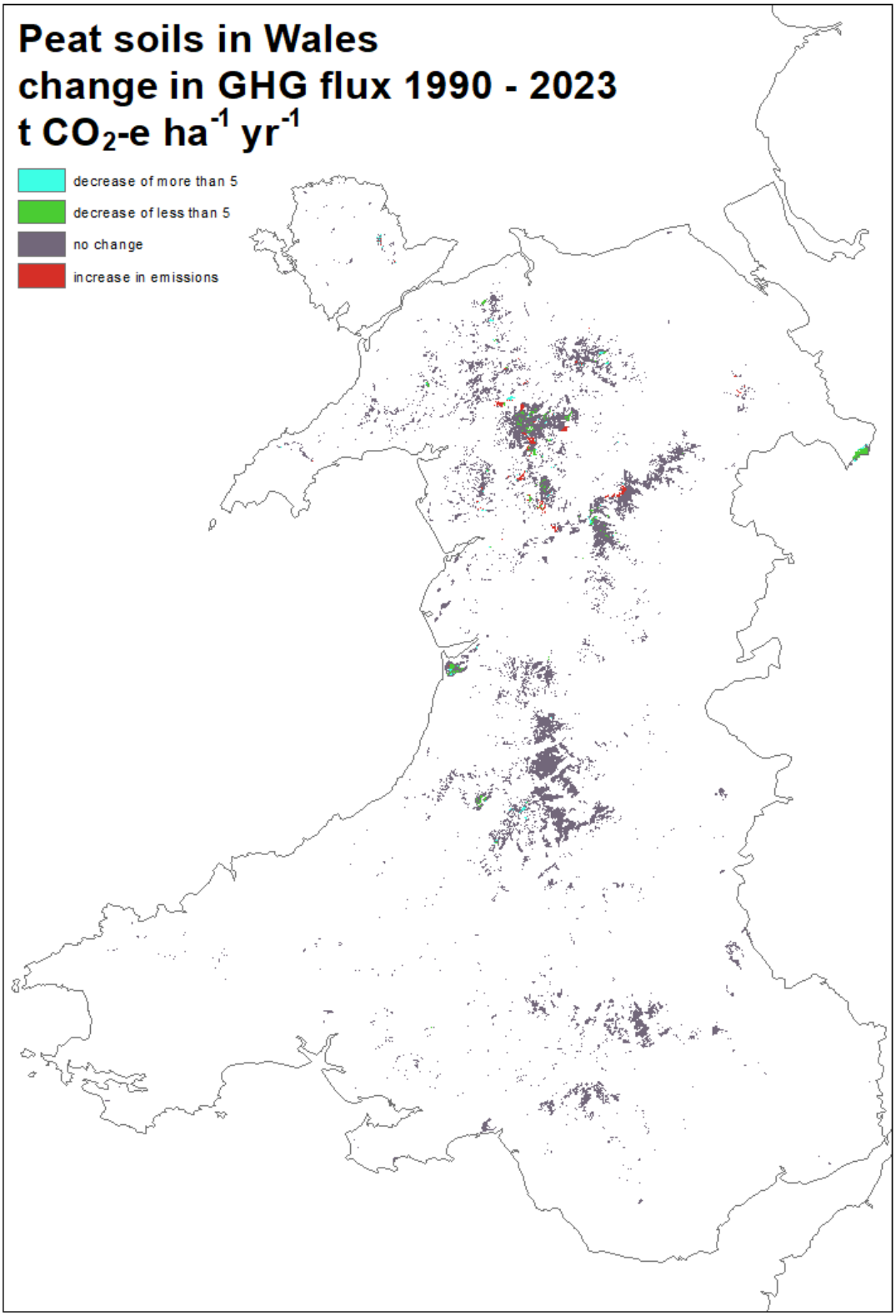

Figure 3-8 Change in GHG emissions resulting from peatland restoration between 1990 and 2023

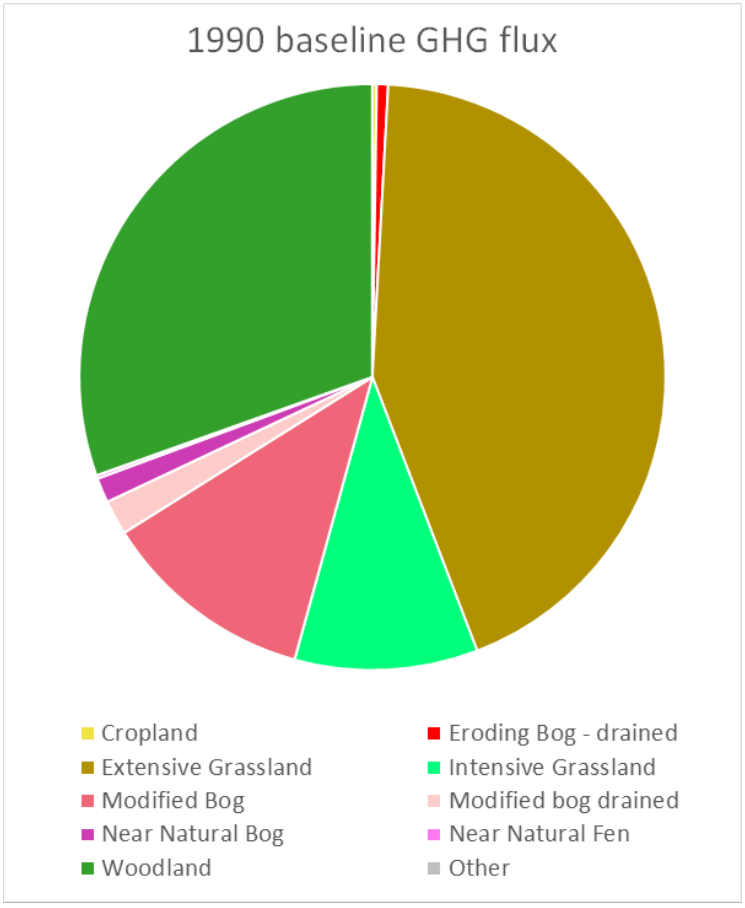

Figure 3-9 1990 baseline GHG emissions for Wales by land cover

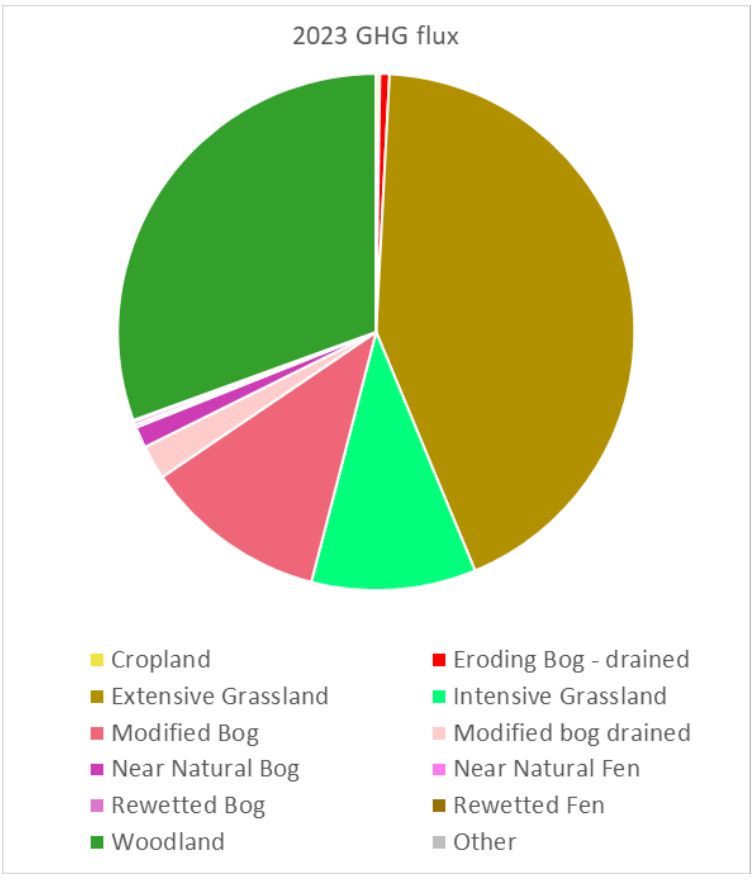

Figure 3-10 2023 peatland GHG emissions by land cover type

Table3-3 Comparison of peatland GHG fluxes between 1990 and 2023

Land use	1990 GHG emissions (t CO_2-e yr^{-1})	2023 GHG emissions (t CO_2-e yr^{-1})
Cropland	1208	1163
Eroding Bog - drained	3160	2921
Extensive Grassland	219858	211525
Intensive Grassland	51260	50739
Modified Bog	59879	56566
Modified bog drained	9720	10515
Near Natural Bog	6917	6513
Near Natural Fen	-949	-932
Rewetted Bog	0	1032
Rewetted Fen	0	433
Woodland	154516	150511
Other	0	0
Total	**505570**	**490986**

Using Tier 2 emission factors (Table 2-2) we calculated the GHG emissions from the Welsh peatland resource in 1990 and 2023 (Figures 3-7 and 3-8). Hot spots of GHG emissions can be seen in the maps for both 1990 and 2023 in the smaller peatland pockets and around the edges of the main peatland areas. Figure 3-8 shows that main picture across the majority of Wales is of little change in total GHG emissions from peat. Emissions were reduced as a result of restoration by approximately 15,00 t CO_2-eq yr^{-1}, but still represent a total GHG source of a little under half a million t CO_2-eq yr^{-1}. Much of these emissions are from the more modified peatlands, particularly the extensive grasslands and woodlands (Figures 3-9, 3-10 and Table 59) that are yet to be the focus of restoration.

For Wales to reduce GHG emissions from peatlands restoration needs to be focussed on these more modified systems. If the aim is restoration to semi-natural fen or bog then both extensive grassland and woodland provide opportunities for this restoration, and a comparatively large area to realise emissions reductions across. Although the highest GHG emissions per unit area are from arable soils and intensive grassland, these represent a comparatively small proportion of the total GHG emissions from Welsh peat due to their small total area. These are the areas where changes in land management could reduce GHG emissions, even without full restoration, for example through raising of the water levels, though at present work to be able to represent these changes in the national GHG inventory is still underway.

It should be noted that reporting peatland restoration purely in terms of the impact on GHG emissions does not account for improvements in habitat quality or connectivity, or any changes in biodiversity that may have occurred on these sites.

4 REFERENCES

Brown, P., Cardenas, L., Del Vento, S., Karagianni, E., MacCarthy, J., Mullen, P., . Willis, D. (2023). UK Greenhouse Gas Inventory, 1990 to 2021: Annual report for Submission under the Framework Convention on Climate Change. BEIS.

Emmett, B.A. et al. (2025). Environment and Rural Affairs Monitoring & Modelling Programme (ERAMMP). ERAMMP Technical Annex-105TA1: Wales National Trends and Glastir Evaluation. Report to Welsh Government (Contract C210/2016/2017)(UK Centre for Ecology & Hydrology Project 06297)

Evans, C., Rawlins, B., Grebby, S., Scholefield, P., Jones, P. (2015) Glastir Monitoring & Evaluation Programme. Mapping the extent and condition of Welsh peat. Welsh Government (Contract reference: C147/2010/11). NERC/Centre for Ecology & Hydrology (CEH Project: NEC04780).

Evans, C.D., Peacock, M., Baird, A.J. et al. Overriding water table control on managed peatland greenhouse gas emissions. Nature 593, 548–552 (2021). https://doi.org/10.1038/s41586-021-03523-1

Evans, Chris ; Artz, Rebekka; Burden, Annette ; Clilverd, Hannah ; Freeman, Ben; Heinemeyer, Andreas; Lindsay, Richard; Morrison, Ross ; Potts, Jackie; Reed, Mark; Williamson, Jennifer . 2023 Aligning the Peatland Code with the UK Peatland Inventory [Final report]. London, Department for Environment, Food & Rural Affairs

Günther, A., Barthelmes, A., Huth, V. et al. Prompt rewetting of drained peatlands reduces climate warming despite methane emissions. Nat Commun 11, 1644 (2020). https://doi.org/10.1038/s41467-020-15499-z

IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands, Hiraishi, T., Krug, T., Tanabe, K., Srivastava, N., Baasansuren, J., Fukuda, M. and Troxler, T.G. (eds). Published: IPCC, Switzerland

Thomson, A., Evans, C., Buys, G., & Cliverd, H. (2020). Updated quantification of the impact of future land use scenarios to 2050 and beyond. Final Report. Report for Climate Change Commission. 07610/Final report for CCC.

Tsagatakis, I., Richardson, J., Evangelides, C., Pizzolato, M., Ben, R., Hows, S.-M., . . . Otto, A. (2023). UK Spatial Emissions Methodology: A report of the National Atmospheric Emission Inventory 2021. BEIS.

ERAMMP Programme Office
UKCEH Bangor
Environment Centre Wales
Deiniol Road
Bangor, Gwynedd
LL57 2UW
+ 44 (0)1248 374500
erammp@ceh.ac.uk

www.erammp.cymru

www.erammp.wales