Rewetted industrial cutaway peatlands in western Ireland: a prime location for climate change mitigation?

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SUMMARY

Rewetting of drained industrial peatlands may reduce greenhouse gas (GHG) emissions and promote recolonisation by peat forming plant species. We investigated carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) dynamics over a three-year period in a rewetted industrial peatland in Ireland. Sample plots were established in bare peat, *Juncus effusus*-*Sphagnum cuspidatum*, *Sphagnum cuspidatum* and *Eriophorum angustifolium* dominated microsites. The relationships between fluxes and environmental variables were examined and regression models were used to provide an estimate of the annual GHG balance for each microsite. All the vegetated microsites were carbon sinks for the duration of the study. Highest uptake occurred in the *Eriophorum* microsite (146–583 g C m^{-2} yr^{-1}), followed by *Juncus*-*Sphagnum* (35–204 g C m^{-2} yr^{-1}) and *Sphagnum* (5–140 g C m^{-2} yr^{-1}). The bare peat microsite was a source of 37–82 g C m^{-2} yr^{-1}. No N_2O fluxes were detected. Strong inter-annual variation was observed in all microsites, driven by variation in precipitation and subsequent changes in the position of the water table. In terms of Global Warming Potential (GWP), the microsites had either a cooling effect (*Eriophorum*), a close to neutral effect (*Juncus*-*Sphagnum*, *Sphagnum*) or a warming effect (bare peat) on the climate.

KEY WORDS: carbon dioxide; global warming potential; greenhouse gas; methane; peatland restoration

INTRODUCTION

Rewetting of degraded peatland ecosystems has been suggested as one of the most cost effective ways of reducing greenhouse gas (GHG) emissions and mitigating the effects of climate change (Parish *et al.* 2008, Motherway & Walker 2009). In recent years, a wide body of research has quantified the impacts of degradation on the carbon (C) store contained within the global peatland resource (e.g. Sundh *et al.* 2000, Waddington & Price 2000, Page *et al.* 2002, Joosten 2010, Evans & Lindsay 2010, Worrall *et al.* 2011). In the Republic of Ireland, peatlands cover around 20 % of the land area (Connolly & Holden 2009) and contain an estimated 1064 –1503 Gt of C (Tomlinson 2005, Eaton *et al.* 2008). However, only a small percentage of the peatland area is in a natural or intact condition (Douglas *et al.* 2008). In over 80 % of the peatland area, the main ecosystem functions characteristic of natural peatlands (hydrology, vegetation composition, C cycling etc.) have been seriously impaired as a consequence of land use changes, for example agricultural reclamation, forestry and peat extraction (Renou-Wilson *et al.* 2011). Currently, the Irish semi-state company Bord na Móna industrially supplies over three million tonnes of peat *per annum* to three peat-fired power stations in Ireland (http://www.bordnamona.ie) with peat also extracted for horticultural use (professional and non-professional markets) and domestic fuel sale.

Industrial peat extraction has a number of fundamental impacts on peatland ecosystem functioning. In order to facilitate the use of heavy machinery on the peatland during the peat extraction process, drainage ditches are installed at 15 m intervals. The resulting lowering of the water table leads to increased oxidation of the peat substrate and a rise in soil CO_2 emissions (Holmgren *et al.* 2006). Removal of the vegetation removes the CO_2 fixing capacity (i.e. photosynthesis) of the peatland (Waddington & Price 2000) and the ecosystem is transformed from a net CO_2 sink to a net CO_2 source. While CH_4 emissions may decrease (Sundh *et al.* 2000, Wilson *et al.* 2009), fluxes from drainage ditches may still be significant (Nykänen *et al.* 1996, Sundh *et al.* 2000). N_2O emissions, considered negligible in natural peatlands, may increase significantly following drainage (Martikainen *et al.* 1995, Augustin *et al.* 1998), particularly in nutrient-rich peatlands (Kasimir-Klemedtsson *et al.* 1997, Schils *et al.* 2008).

Following the cessation of industrial peat extraction, the cutaway peatland is available for other uses. In Ireland, these uses have included agriculture and commercial forestry (now limited), and natural re-generation of wetlands (open water, fen, reedbed and acidic wetlands) and woodland (birch and willow scrub) habitats. To date, around 11,000 ha of acid and alkaline wetlands on cutaway peatlands have been created by Bord na Móna, which equates to around 14 % of their total land holdings. As the post-industrial use of the cutaway is largely determined by the residual peat type, underlying soil type and drainage conditions (Renou *et al.* 2006), a further 40,000 ha of cutaway peatland could be suitable for wetland creation over the next decades (Wilson *et al.* 2012a).

The challenge of re-establishing suitable peat forming communities on industrial cutaway peatlands has been widely documented (e.g. Schouwenaars 1993, Wind-Mulder *et al.* 1996, Price *et al.* 1998, Price & Schlotzhauer 1999, Van Seters & Price 2001, Campbell *et al.* 2002, Farrell & Doyle 2003). In general, restoration starts by raising the water table through blocking of the drainage ditches and the creation of bunds or ridges (Smolders *et al.* 2003). In the absence of vegetation characteristic of natural peatlands, in particular peat-forming plants such as *Sphagnum*, these can be re-introduced (Cooper & MacDonald 2000, Rochefort *et al*. 2002, Tuittila *et al*. 2003). Re-establishment of the desired vegetation can be enhanced with help of companion species, such as *Polytrichum commune* (Groeneveld *et al.* 2007), *Eriophorum angustifolium* (Ferland & Rochefort 1997) and *Juncus effusus* (Farrell & Doyle 2003), by peat surface topography manipulations that create a series of ridges and shallow basins that enhance conditions for *Sphagnum* establishment (Ferland & Rochefort 1997, Farrell & Doyle 2003, Campeau *et al.* 2004) and by phosphorus fertilisation (Sottocornola *et al.* 2007).

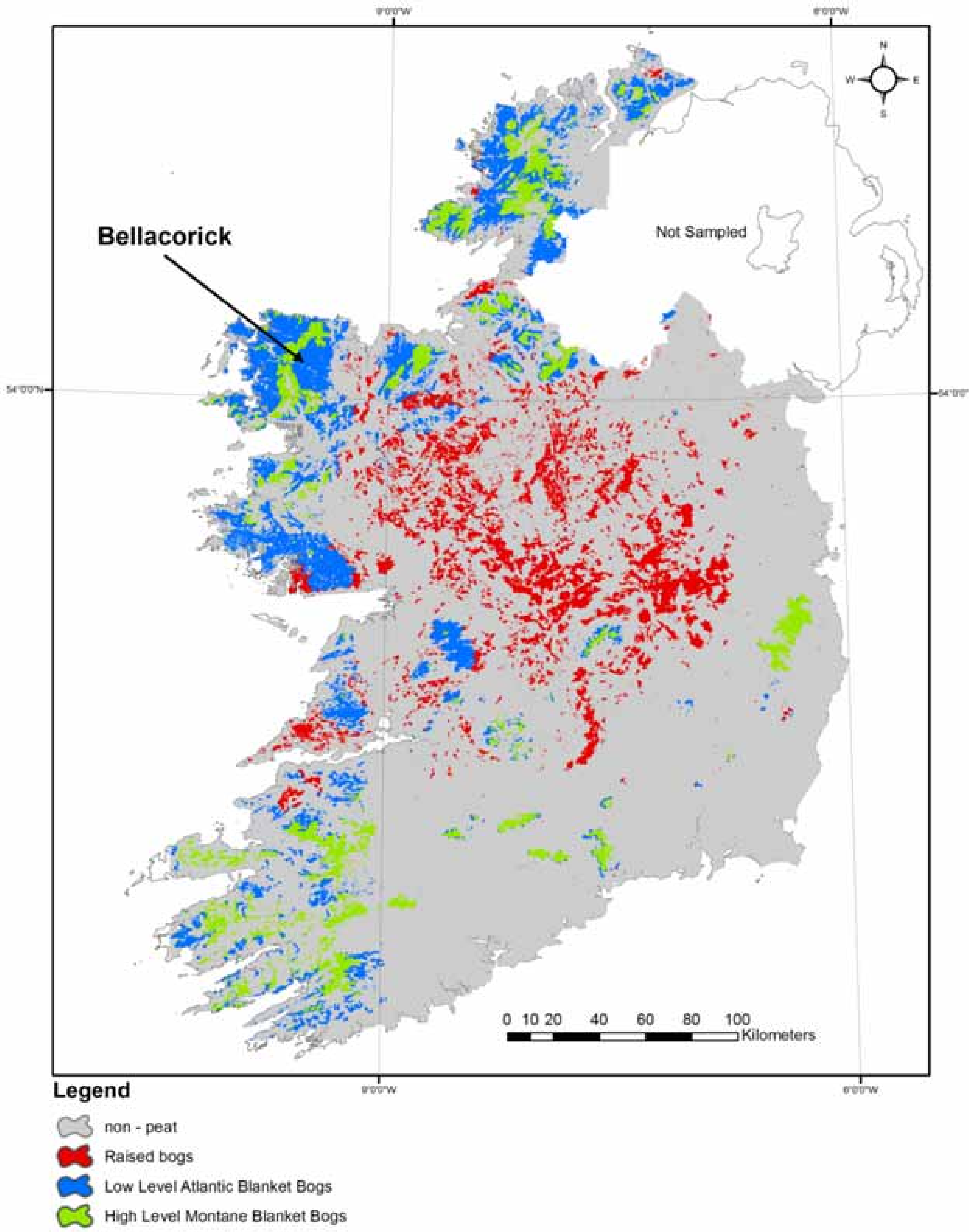
The speed at which the C sink function may be restored following rewetting of the peatland is likely to vary considerably from one peatland to the next, determined by a combination of site-specific factors (Basiliko *et al.* 2007) and the climate of the region. For example, some studies have reported a reduction in the magnitude of CO_2 emissions (i.e. avoided losses) when a peatland was rewetted and vegetation re-established (Waddington & Price 2000, Waddington & Warner 2001, Drösler 2005, Worrall *et al.* 2011, Strack & Zuback 2012) while other studies have reported C gas dynamics similar to those of natural peatlands (i.e. CO_2 sink and CH_4 source) within a short time frame (Komulainen *et al.* 1998, Komulainen *et al.* 1999, Tuittila *et al.* 1999, Soini *et al.* 2010). In the period following rewetting, peat oxidation rates are low as a consequence of the anoxic soil conditions and most of the C sequestered is contained within the peatland biomass pool (leaves, stems, roots, microbial communities). Over longer time frames a decrease in the amount of CO_2 that is sequestered annually by a peatland has been reported (cf. Tuittila *et al.* 1999, Yli-Petäys *et al.* 2007). Resumption of CH_4 emissions after rewetting has been widely reported (Tuittila *et al.* 2000, Bortoluzzi *et al.* 2006, Waddington & Day 2007, Couwenberg 2009, Wilson *et al.* 2009, Couwenberg & Fritz 2012). Following rewetting, CH_4 emissions may be very low initially due to the absence of labile organic matter (Waddington & Day 2007, Urbanová *et al.* 2011) and low methanogenic activity (Francez *et al.* 2000, Andersen *et al.* 2006). However, once vegetation has re-established, emissions increase considerably as a result of the input of fresh plant litter and exudates, and high water levels (Basiliko *et al.* 2007, Waddington & Day 2007). In general, N_2O emissions tend to decrease when a peatland is rewetted, as nitrate (NO_3^-) is fully reduced to nitrogen (N_2) or taken up by plants out-competing the denitrifying microbes for the available nitrogen (Silvan *et al.* 2005, Glatzel *et al.* 2008, Roobroeck *et al.* 2010.

The objectives of this study were to determine whether rewetting of an industrial cutaway peatland in north-west Ireland has resulted in restoration of the C sink function characteristic of natural peatlands. Over a three-year period, we quantified GHG fluxes in a range of microsites within the peatland; modelled the relationship between GHG fluxes and environmental variables (e.g. water table, vegetation *etc*.); and estimated annual CO_2-C, CH_4-C, GHG balances and the Global Warming Potential (GWP) for each microsite.

METHODS

Study site

The study site was located at Bellacorick, Co. Mayo (54° 7' N, 9° 35' W, Figures 1–3). The climate of the area is characterised by prevailing south-westerly winds and a mean annual rainfall of 1143 mm. The mean monthly temperature ranges from 5.6 °C in January to 14.1 °C in August with a mean annual temperature of 9.3 °C (Met Éireann – Belmullet Station, 1961–1990).



Connolly and Holden, 2009. Mapping peat soils in Ireland: updating the derived Irish peat map. Irish Geography, 42, 3, 343-352

Figure 1. Map of Ireland showing the location of the study site, from Connolly & Holden (2009).

The site was formerly an Atlantic blanket bog and forms part of the much larger Oweninny bog complex (6,500 ha). From 1960 to 2003, milled peat was extracted and used in the nearby Bellacorick power station for electricity generation. The average thickness of the residual peat layer within the study site is 50 cm and the peat is composed mainly of highly humified cyperaceous peat overlying glacial till (Farrell & Doyle 2003). The peat is nutrient-poor with a C:N ratio of 58 (n = 6) and average pH of 3.8 (± 0.3), which is typical of an Atlantic blanket bog bottom peat layer (Hammond 1981).

Figure 2. Photograph of Bellacorick prior to rewetting (C. Farrell).

Figure 3. Photograph of Bellacorick in 2010, taken in the same general area as Figure 2 (D. Wilson).

Small-scale rehabilitation test areas were established at the site between 1996 and 2002 and, following the cessation of peat extraction in 2002, a larger-scale rehabilitation plan was implemented in a sequential fashion across the peatland. The plan involved the use of bulldozers and excavators to block drains and create peat ridges resulting in a number of significant changes: (1) a rise in the water table level over large areas of the peatland, (2) the creation of areas of open water and (3) recolonisation of the bare peat substrate by a range of vascular-plant and moss communities. Initial re-colonisation was dominated by *Juncus effusus* (soft rush), which in turn has facilitated the establishment of moss species such as *Polytrichum commune* and *Sphagnum cuspidatum* (Farrell & Doyle 2003, Fallon *et al.* 2012). In the wetter parts of the site, *Eriophorum angustifolium* (bog cotton) is widespread either as a pure stand or growing with *Sphagnum cuspidatum*. The areas of open water and bare peat are decreasing annually as a result of rapid re-colonisation. On the drier edges of the site and along the peat ridges, *Pinus contorta* (lodgepole pine), *Calluna vulgaris* (heather) and *Rhododendron ponticum* (common rhododendron) are present.

Vegetation

Following a visual survey of the site to identify the main microsite types (Table 1), 12 permanent sample plots were established within the following vegetation types: (1) *Juncus effusus*-*Sphagnum cuspidatum* dominated communities (n=3); (2) *Sphagnum cuspidatum* dominated communities (n=3); (3) *Eriophorum angustifolium* dominated communities (n=3); and (4) bare peat (n=3). To enable examination of the effect of rewetting on GHG exchange, each plot was delineated with a 60 cm square stainless steel collar inserted into the peat to a depth of 30 cm. A wooden boardwalk was built to minimise damage to the vegetation and to avoid compression of the peat during observations. In order to incorporate the seasonal dynamics of the vegetation into C gas exchange models, a green area index (*GAI*) was estimated for each of the sample plots. This involved measuring the green photosynthetic area of all vascular plants within the sample plot at monthly intervals. Moss cover was estimated twice during each year. Species-specific model curves were applied to describe the phenological dynamics of the vegetation of each plot, and the models (vascular plants and moss) were summed to produce a plot-specific *GAI*. For a detailed description of the method see Wilson *et al.* (2007).

Environmental variables

A perforated PVC pipe (dipwell) (60 cm long, 2 cm diameter) was inserted vertically into the peat adjacent to each sample plot to measure water table level (*WT*). Data loggers (Micrologger Model 4R, Zeta-tec, Durham, UK) were established within bare peat and *Sphagnum* microsites and recorded hourly soil temperatures at 5, 10 and 20 cm depths. A weather station (WatchDog Model 2400, Spectrum Technologies Inc., Illinois, U.S.A) was established within a *Juncus*-*Sphagnum* microsite and programmed to record photosynthetic photon flux density (PPFD, µmol m^{-2} s^{-1}) every ten minutes using Spec 8 Pro software (Spectrum Technologies Inc., Illinois, USA).

Table 1. Species composition of the vegetation characterising the four main microsite types identified on rewetted and bare industrial cutaway at Bellacorick.

Microsite name	Dominant plant species	Other plant species
(1) *Juncus – Sphagnum*	*Juncus effusus* *Sphagnum cuspidatum*	*Polytrichum commune* *Hydrocotyle vulgaris* *Eriophorum angustifolium* *Juncus bulbosus* *Sphagnum capillifolium*
(2) *Sphagnum*	*Sphagnum cuspidatum*	*Eriophorum angustifolium*
(3) *Eriophorum*	*Eriophorum angustifolium*	*Polytrichum commune*
(4) Bare peat	-	-

CO_2 flux measurements

CO_2 fluxes were measured from November 2008 to December 2011 at fortnightly (summer months) to monthly (winter months) intervals using the static chamber method (Alm *et al.* 2007), generally between 8 a.m. and 6 p.m. Instantaneous net ecosystem exchange (NEE) was measured over a range of PPFD (μmol m^{-2} s^{-1}) values using a transparent polycarbonate chamber (60 × 60 × 33 cm). For each measurement, the chamber was placed in a water-filled channel at the top of the collar and CO_2 concentration (ppmv) in the chamber headspace was measured at 15-second intervals over a period of 60–180 seconds using a portable CO_2 analyser (EGM-4) (PP Systems, UK). PPFD was measured by a quantum sensor (PAR-1, PP Systems) located at the top of the chamber. At the same time, air temperature (°C) within the chamber was recorded. Concurrently with the chamber measurements, soil temperature (at 5, 10 and 20 cm depths) was recorded at each collar with a soil temperature probe (ELE International, UK) and water table level (*WT*) in the dipwell, relative to the soil surface, was measured manually with a water level probe (Eijkelkamp Agrisearch Equipment, The Netherlands). Following each NEE measurement, the chamber was vented for a short time by removing it from the collar in order to ensure equilibration of the gas concentration. The chamber was then replaced in the collar and covered with a white lightproof cover, and the CO_2 measurements were repeated in order to provide an estimate of ecosystem respiration (R_{eco}). Flux rates (mg CO_2 m^{-2} h^{-1}) were calculated from the linear change in CO_2 concentration in the chamber headspace over time with respect to the chamber volume, collar area and air temperature. A positive flux indicated a net loss of CO_2 from the peatland and a negative value indicated a net uptake of CO_2. An estimate of gross photosynthesis (P_G) was calculated as the sum of NEE and R_{eco} values (Alm *et al.* 2007).

A flux was accepted if the coefficient of determination (r^2) was at least 0.90. Exceptions were made in cases where the flux was close to zero (mainly in winter when soil/plant processes are typically slower and the r^2 is always low; Alm *et al.* 2007). In these cases (~5 % of all measurements), the flux data were examined graphically and fluxes with obvious non-linearity (due to chamber leakage, fan malfunction etc.) were discarded. The remainder were accepted provided that some of the environmental variables measured at the same time (e.g. soil temperature, PPFD, GAI) were sufficiently low to account for the low flux values.

CH_4 and N_2O flux measurements

CH_4 and N_2O fluxes were measured at monthly intervals using the static chamber method, which consisted of an opaque, polycarbonate chamber (60 × 60 × 25 cm) equipped with a battery-operated fan which mixed the air within the chamber headspace. Four 50 ml samples were withdrawn into 60 ml polypropylene syringes from the chamber headspace at 5-minute intervals over a 20-minute period. The measurement period was increased to 40 minutes during wintertime when low fluxes were expected (Laine *et al.* 2007b). During each measurement, air temperature inside the chamber, soil temperature (at 5, 10 and 20 cm depths) and *WT* were recorded at each collar. The CH_4 and N_2O concentrations of the gas samples were measured in a gas chromatograph with attached auto-sampler unit (Shimadzu GC-2014, LAL, Gottingen, Germany) within 24 hours of collection, using a flame ionisation detector (FID) and an Electron Capture Detector (ECD). Detector temperatures were 200 °C (FID) and 310 °C (ECD) and the oven temperature was 70 °C (Loftfield *et al.* 1997). Nitrogen was used as the carrier gas (22 ml min^{-1}). The CH_4 (1.8, 3.99 and 10 ppm) and N_2O (0.30, 0.80 and 9.96 ppm) standards were supplied by BOC Gases Ireland Ltd. Gas peaks were integrated using *Peak Simple* software (SRI Inc. Silicon Valley, California, USA). Fluxes (mg m^{-2} h^{-1}) were calculated from the linear change in gas concentration as a function of time, chamber volume, collar area and air temperature. A flux was accepted if the coefficient of determination (r^2) was at least 0.90. Positive values indicated losses of CH_4 and N_2O to the atmosphere, and negative flux values indicated CH_4 and N_2O uptake.

GHG flux modelling

P_G, R_{eco} and CH_4 were parameterised separately for each microsite. Model parameters were estimated using the Levenberg-Marquardt multiple non-linear regression technique (SPSS, Version 15.0 for Windows, SPSS Inc. Chicago. USA). One-third of the data was randomly removed from all datasets and used to independently test the models.

Gross photosynthesis (P_G)

In the P_G models, we used PPFD, GAI and water table level (*WT*) as explanatory variables. Only those variables that increased the explanatory power of the model were included. The residuals of each model were evenly distributed along the range of explaining variables. Model evaluation was based on the following criteria: (a) statistically significant model parameters ($p<0.05$), (b) lowest possible standard error of the model parameters and (c) highest possible coefficient of determination (adjusted r^2) (see Laine *et al.* 2009). P_G is strongly dependent on irradiation (PPFD) and is commonly described by the Michaelis-Menten function showing a hyperbolic response approaching an asymptotic maximum. The seasonal variation in the photosynthetic capacity of the vegetation, described by *GAI*, was incorporated into the model in a manner similar to that described by Wilson *et al*. (2007). A strong relationship between P_G and PPFD was observed for all the vegetated microsites. The *GAI* parameter was added to the model as either a linear term (Equations 1, 2) for *Juncus-Sphagnum* and *Sphagnum*) or as a hyperbolic term (Equation 3) for *Eriophorum*. The incorporation of *WT* (Equation 1) improved the performance of the P_G model for the *Juncus–Sphagnum* microsite only.

$$P_G = P_{\max}\left(\frac{PPFD}{PPFD + k_{PPFD}}\right) \times GAI \times \left[\exp\left(-0.5\left(\frac{WT - a}{b}\right)^2\right)\right] \quad [1]$$

$$P_G = P_{\max}\left(\frac{PPFD}{PPFD + k_{PPFD}}\right) \times GAI \quad [2]$$

$$P_G = P_{\max}\left(\frac{PPFD}{PPFD + k_{PPFD}}\right) \times \left[\frac{GAI}{(GAI + c)}\right] \quad [3]$$

In Equations 1–3: P_G is gross photosynthesis; P_{max} is maximum photosynthesis; *PPFD* is photosynthetic photon flux density; k_{PPFD} is the *PPFD* value at which P_G reaches half its maximum; *GAI* is green area index; *WT* is water table level; and *a*, *b*, c are model parameters.

Ecosystem respiration (R_{eco})
To model annual R_{eco} we used soil temperature at 5 cm depth ($T_{5\text{cm}}$) and *WT* as explanatory variables for all the vegetated microsites (adapted from Riutta *et al.* 2007) (Equation 4).

$$R_{eco} = a \times \exp\left[b\left(\frac{1}{(T_{REF} - T_0)} - \frac{1}{(T - T_0)}\right)\right] \times \left[\frac{1}{1 + \exp\left(\frac{WT - c}{d}\right)}\right] \quad [4]$$

where R_{eco} is ecosystem respiration; T_{REF} is reference temperature set at 283.15 K; parameter T_0 is the (minimum) temperature at which respiration reaches zero; *WT* is water table level; and *a*, *b*, *c*, *d* are model parameters.

For the bare peat microsite (Equation 5), *WT* was the main explaining variable and the addition of $T_{5\text{cm}}$ improved the explaining power of the model (adapted from Laine *et al.* 2007a).

$$R_{eco} = (a + (b \times WT)) \times \left[b\left(\frac{1}{(T_{REF} - T_0)} - \frac{1}{(T - T_0)}\right)\right] \quad [5]$$

Methane (CH_4)
The annual CH_4 fluxes were closely related to the soil temperature at 10 cm depth ($T_{10\text{cm}}$) for all microsites, to *WT* (Equation 6) for *Juncus-Sphagnum* and *Sphagnum*, and to *GAI* (Equation 7) for *Eriophorum*:

$$CH_4 = (\exp(a \times T_{10cm})) \times (b + (c \times WT)) \quad [6]$$

$$CH_4 = (\exp(a \times T_{10cm})) \times (b + (c \times GAI)) \quad [7]$$

where $T_{10\text{cm}}$ is temperature at 10 cm depth in the peat; *WT* is water table level; *GAI* is the green area index; and *a*, *b*, *c* are model parameters.

Reconstruction of annual CO_2 –C balance

The response functions estimated for P_G and R_{eco} were used for the seasonal reconstruction of Net Ecosystem Exchange (NEE). In combination with hourly time series of (1) *PPFD* and $T_{5\text{cm}}$ as recorded by the weather station and data loggers, (2) modelled *GAI* and (3) *WT* linearly interpolated from weekly measurements, P_G and R_{eco} fluxes were reconstructed for each sample plot. NEE was then calculated on an hourly basis as:

$$\text{NEE} = P_G - R_{eco} \quad [8]$$

(Alm *et al.* 1997). Negative NEE values indicated a net uptake of CO_2 from the atmosphere to the peatland and positive values indicated a net loss of CO_2 to the atmosphere. The annual CO_2-C balance (g C m^{-2} yr^{-1}) was calculated for each sample plot by integrating the hourly NEE values over each 12-month period (01 January to 31 December). An average value (± standard deviation) for each microsite type was calculated from the annual CO_2-C balances of the three sample plots.

Reconstruction of annual CH_4-C balance

The response functions estimated for CH_4 were used for the seasonal reconstruction of CH_4 fluxes. In combination with hourly time series of (1) $T_{10\text{cm}}$ as recorded by the data loggers, (2) modelled *GAI* and (3) *WT* linearly interpolated from weekly measurements, hourly CH_4 fluxes were reconstructed for each sample plot and integrated over each 12-month period (01 January to 31 December). An average annual value (± standard deviation) for each microsite type was calculated from the annual CH_4-C balances of the three sample plots.

Global Warming Potential (GWP)

In order to calculate the Global Warming Potential (GWP) (t CO_2-eq ha^{-1} yr^{-1}), the annual CO_2-C, CH_4-C and N_2O-N balances calculated for each microsite (Table 2) were firstly converted to CO_2, CH_4 and N_2O by multiplying them by 3.667, 1.334 and 1.571 respectively. The GWP was then calculated for each of the microsites by multiplying the converted annual balances by 1, 25 and 298 for CO_2, CH_4 and N_2O respectively (100-year horizon, IPCC 2007). Negative GWP values indicate a net cooling effect on the climate and positive GWP values indicate a net warming effect.

RESULTS

Environmental variables

Photosynthetic photon flux density (*PPFD*) values exhibited strong diurnal and seasonal variation (Figure 4a). Daily *PPFD* values were generally highest in the period from midday to 2 p.m. and lowest at night (zero). Seasonally, *PPFD* increased steadily from January, peaked in mid-June (~2000 µmol m^{-2} sec^{-1}) and declined towards December. Annual *PPFD* was similar in 2009 and 2011 and 6 % higher in 2010. During the period of the study, the mean annual air temperature was 10.5 °C, which is a deviation from the long-term average value by +9 %. Annual rainfall was 1326 mm in 2009, 1125 mm in 2010 and 1376 mm in 2011 (Met Éireann, Belmullet Station) representing deviations from the long-term average value by +16 %, -1.6 % and +20 % respectively (Figure 4b). Soil temperatures reached maxima of around 18 °C in mid-summer 2009 and 2010 and 15 °C in 2011, and a minimum of -1 °C in December 2010 (Figure 4c).

WT was relatively constant in all the microsites throughout the three years of the study (Figure 5). For the vegetated microsites, the water table was above the peat surface throughout the study with the exception of a period in mid-summer 2010 when *WT* decreased sharply. The largest decrease was observed in the bare peat microsite where *WT* dropped to -40 cm in mid-summer 2010. Highest mean annual *WT* was observed in the *Sphagnum* microsite in each year (12.5, 9.5 and 13.2 cm), followed by the *Juncus*-*Sphagnum* (5.6, 3.5 and 7.1 cm), *Eriophorum* (6.3, 6.0 and 7.4 cm) and bare peat (-0.4, -3.9 and -0.4 cm) microsites (Table 2).

Vegetation dynamics

A strong seasonal variation in *GAI* was apparent in all microsites throughout the duration of the study (Figure 6). Plant growth increased during the springtime in response to increased *PPFD* values and soil temperatures. Peak values occurred in mid-summer before decreasing during the autumn with the onset of senescence. Throughout the winter months, *GAI* values remained well above zero, indicative of the presence of evergreen plant species in all microsites. The highest variation in *GAI* occurred within the *Eriophorum* microsite with very little variation observed in the *Sphagnum* microsite.

GHG exchange models

The strength of the relationship between the GHG fluxes and the environmental variables varied between the microsites. The strong relationships between gross photosynthesis (P_G), *PPFD* and *GAI* for all the vegetated microsites explained 55–74 % of the variance in *Juncus*-*Sphagnum* and *Sphagnum* and 74 –82 % for *Eriophorum*. With incorporation of *WT* (Equation 1), the improved performance of the P_G model explained 65–79 % of the variance for the *Juncus*–*Sphagnum* microsite. No statistically significant relationship between P_G and *WT* was observed for the other microsites. A strong relationship between ecosystem respiration (R_{eco}), T_{5cm} and *WT* was observed at all microsites and explained 55–77 % of the variance. CH_4 fluxes were strongly correlated (r^2 = 0.61–0.77) with the soil temperature at 10 cm depth (T_{10cm}) and *WT* (Equation 6) or *GAI* (Equation 7). For bare peat, monthly mean CH_4 fluxes were calculated and integrated over each 12-month study period because no statistically significant correlation with any environmental variable was identified. N_2O fluxes were negligible and below the detection level of the equipment throughout the study period (data not shown).

The correspondence between observed and modelled P_G and R_{eco} was good for *Juncus*-*Sphagnum* and *Sphagnum* but there was more variation within the *Eriophorum* dataset, particularly at higher P_G values (Figure 7). In contrast, modelled CH_4 fluxes showed very good agreement with observed fluxes in *Eriophorum* microsites and displayed more variation at higher fluxes in the other two vegetated microsites.

GHG exchange

A strong seasonality in modelled P_G, R_{eco} and NEE was evident for the vegetated microsites throughout the study (Figure 8). Maximum monthly values were reached in the summer months (May to August) and the lowest monthly values were observed in the winter period (November to February). P_G values remained above zero during the winter months in all years and P_G values were relatively similar across all years. In contrast, R_{eco} displayed considerable inter-annual variation in all

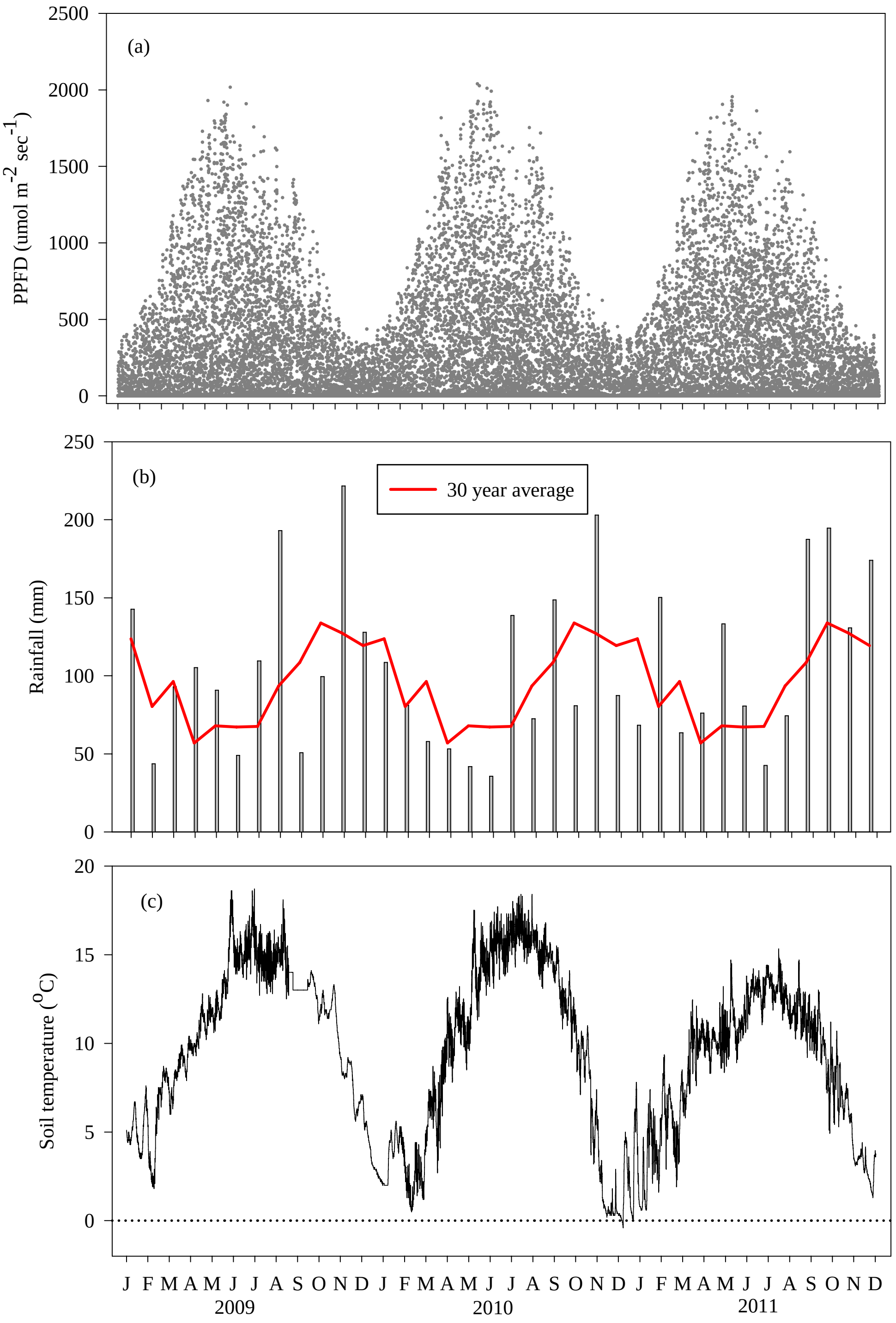


Figure 4. Climate data for Bellacorick, Co. Mayo in 2009, 2010 and 2011. (a) Photosynthetic Photon Flux Density (*PPFD*, µmol m^{-2} s^{-1}); (b) monthly rainfall (mm) (Met Éireann Belmullet Station); and (c) soil temperature (°C) at 5 cm depth.

microsites. Higher R_{eco} values were observed in summer 2010 in all microsites, driven by a combination of low water tables and sustained higher soil temperatures. All vegetated microsites were net monthly CO_2-C sinks (i.e. negative NEE) with the exception of the mid-summer period in 2010 (all microsites) and the October–December 2011 period (*Eriophorum* microsite).

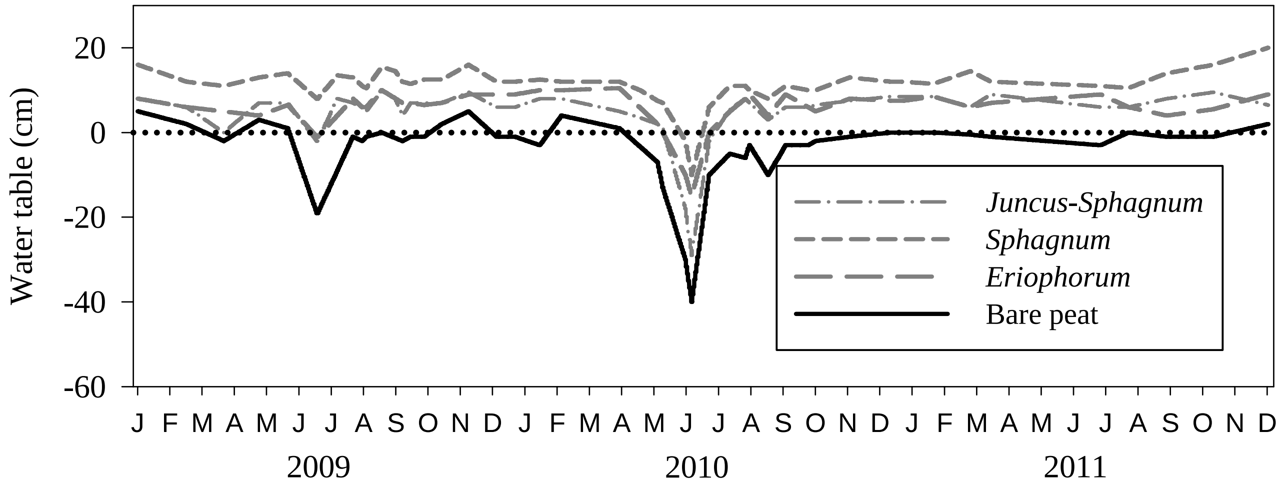


Figure 5. Water table level (*WT*, cm) in *Juncus-Sphagnum*, *Sphagnum*, *Eriophorum* and bare peat microsites. Positive values indicate water table above the peat surface (dotted line). For clarity, values for one sample plot per microsite are shown. The replicates showed similar dynamics (not significantly different).

Table 2. Mean annual water table level (*WT*, cm), minimum and maximum values shown in parentheses; annual NEE (g CO_2-C m^{-2} yr^{-1}); annual CH_4 (g CH_4-C m^{-2} yr^{-1}); N_2O; and GHG balance (g C m^{-2} yr^{-1}) for the microsites of rewetted and bare cutaway at Bellacorick for 2009, 2010 and 2011. Standard deviation of the mean (n=3) in parentheses. Positive *WT* values indicate that the water table is above the peat surface. Negative NEE values indicate net CO_2-C uptake by the peatland and positive CH_4 values indicate CH_4-C emissions to the atmosphere.

		Microsites			
Year		Bare peat	*Juncus-Sphagnum*	*Sphagnum*	*Eriophorum*
2009	*WT*	-0.4 (-19–5)	5.6 (-4–10.5)	12.5 (8–16)	6.3 (-9–14)
	NEE	38.6 (5.4)	-142.8 (8.8)	-106.8 (3.6)	-587.9 (161)
	CH_4	0.11	9.85 (0.16)	12.27 (0.30)	5.4 (1.4)
	N_2O	0	0	0	0
	GHG	38.7 (6.2)	-132.9 (8.7)	-94.5 (3.7)	-582.6 (159.3)
2010	*WT*	-3.9 (-40–5)	3.5 (-29–8.5)	9.5 (-11–20)	6 (-18–20)
	NEE	81.6 (20.7)	-43.1 (38.8)	-13.9 (49.2)	-150.9 (86.9)
	CH_4	0.11	7.8 (0.10)	9.1 (0.1)	5.3 (1.4)
	N_2O	0	0	0	0
	GHG	81.7 (20.7)	-35.3 (38.7)	-4.9 (49.3)	-145.6 (85.5)
2011	*WT*	-0.4 (-5–2)	7.1 (4.5–9.5)	13.2 (9–21)	7.4 (2–14)
	NEE	37.3 (3.6)	-211.2 (46.3)	-147.9 (69.1)	-305 (89.1)
	CH_4	0.11	6.8 (0.20)	8.2 (0.6)	5.12 (1.36)
	N_2O	0	0	0	0
	GHG	37.4 (3.59)	-204.4 (46.3)	-139.8 (68.8)	-299.9 (87.7)

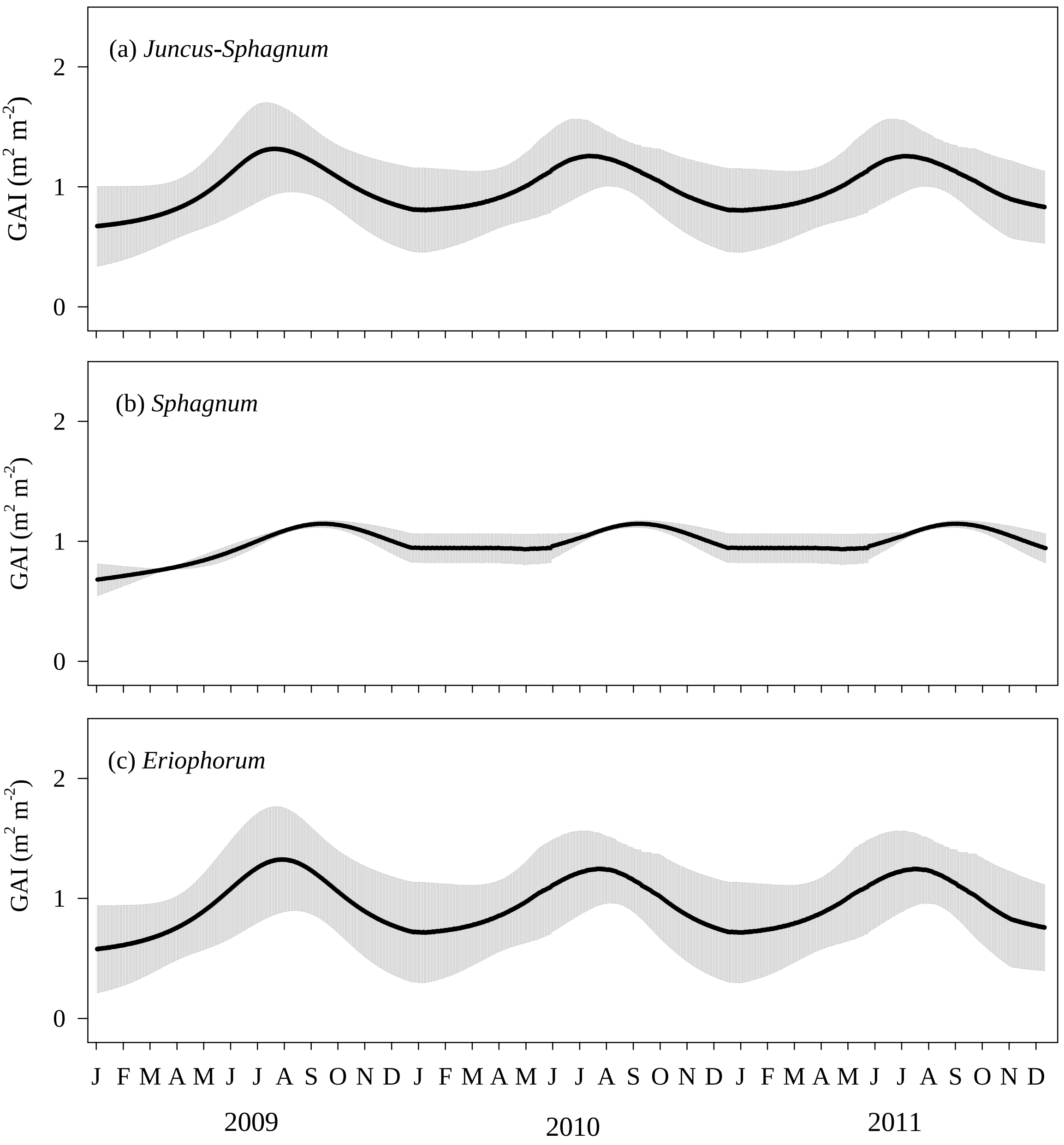


Figure 6. Modelled Green Area Index (*GAI*, m^2 m^{-2}) for (a) *Juncus-Sphagnum*, (b) *Sphagnum* and (c) *Eriophorum* microsites. The black line represents the mean (n=3) *GAI* for each microsite, and the grey shaded area represents the standard deviation of the mean.

Considerable spatial and temporal variation was observed in modelled CH_4-C fluxes (Figure 9). The highest flux values occurred in *Sphagnum*, followed by *Juncus-Sphagnum* and *Eriophorum* microsites. The modelled CH_4 fluxes were stongly seasonal with the highest values occurring each year in mid-summer and decreasing over the winter periods. A strong decrease in modelled CH_4 emissions was apparent in *Sphagnum* and *Juncus-Sphagnum* over the three-year study period. Maximum summer values were highest in 2009 and lowest in 2011. The strong relationship between CH_4 fluxes and *WT* was particularly clear in the *Juncus-Sphagnum* microsite, with a sharp reduction in the magnitude of CH_4 emissions observed in mid-2010 when the water table level dropped to -30 cm (Figure 5).

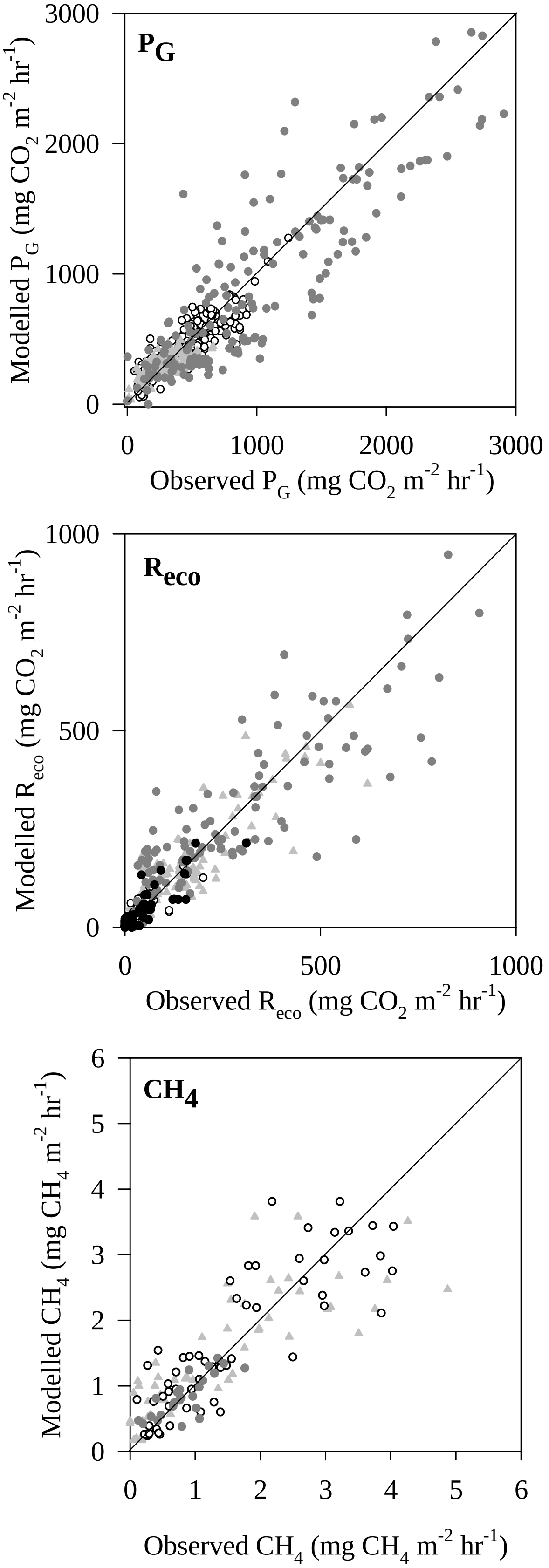


Figure 7. Relationship between observed and modelled P_G, R_{eco} and CH_4 fluxes in bare peat (black circle), *Juncus*-*Sphagnum* (white circle), *Sphagnum* (grey triangle) and *Eriophorum* (dark grey circle) microsites.

Annual CO_2-C, CH_4-C and GHG balance

The bare peat microsite was a CO_2-C and CH_4-C source in all years of the study (Table 2). Annual CO_2-C emissions ranged from 37.3 to 81.6 g m^{-2} yr^{-1} and annual CH_4-C emissions were estimated at 0.11 g m^{-2} yr^{-1}. All vegetated microsites were CO_2-C sinks over the duration of the study although strong inter-annual variation was observed in all microsites (Table 2). Highest annual CO_2-C uptake took place in the *Eriophorum*-dominated microsite and ranged from -150.9 g CO_2-C m^{-2} yr^{-1} in 2010 to -587.9 g CO_2-C m^{-2} yr^{-1} in 2009 (Table 2). Lower annual CO_2-C uptake was estimated for *Juncus*-*Sphagnum* and *Sphagnum* microsites, where values ranged from -43.1 to -211.2 and from -13.9 to -147.9 g CO_2-C m^{-2} yr^{-1}, respectively. All the vegetated microsites were annual CH_4-C sources throughout the study. The highest emissions occurred in the *Sphagnum* microsite (8.2–12.3 g CH_4-C m^{-2} yr^{-1}) followed by *Juncus*-*Sphagnum* (6.8–9.95 g CH_4-C m^{-2} yr^{-1}) and *Eriophorum* (5.1–5.4 g CH_4-C m^{-2} yr^{-1}). CH_4 emissions at all vegetated microsites were highest in 2009 and then steadily decreased in subsequent years. N_2O fluxes were negligible and below the detection level of the equipment throughout the study period (data not shown), and are assigned values of zero here.

With the exception of bare peat, all microsites were annual net carbon sinks throughout the study (Table 2), although in 2010 values were close to zero in the *Sphagnum* microsite. The carbon balance was dominated by NEE in all microsites across the three years of the study. However, in 2010, NEE uptake was lower in all vegetated microsites and the relative importance of the CH_4-C component increased despite a reduction in CH_4-C emissions in that year.

Global warming potential

In 2009, the bare peat (1.45 t CO_2-eq ha^{-1} yr^{-1}) and *Sphagnum* (0.17 t CO_2-eq ha^{-1} yr^{-1}) microsites had a net warming effect and the *Juncus*-*Sphagnum* (-1.95 t CO_2-eq ha^{-1} yr^{-1}) and *Eriophorum* (-19.76 t CO_2-eq ha^{-1} yr^{-1}) microsites had a net cooling effect on climate over a 100-year horizon (Figure 10). In particular, *Eriophorum* had a strong cooling effect, driven by large NEE and moderate CH_4 emissions. In 2010, all microsites except *Eriophorum* (-3.77 t CO_2-eq ha^{-1} yr^{-1}), had a net warming effect on the climate (1.02 to 3.03 t CO_2-eq ha^{-1} yr^{-1}) as a consequence of a much reduced NEE component in that year. In 2011, all vegetated microsites had a net cooling effect (-2.69 to -9.48 t CO_2-eq ha^{-1} yr^{-1}) driven by a high NEE component and a reduction in CH_4 emissions.

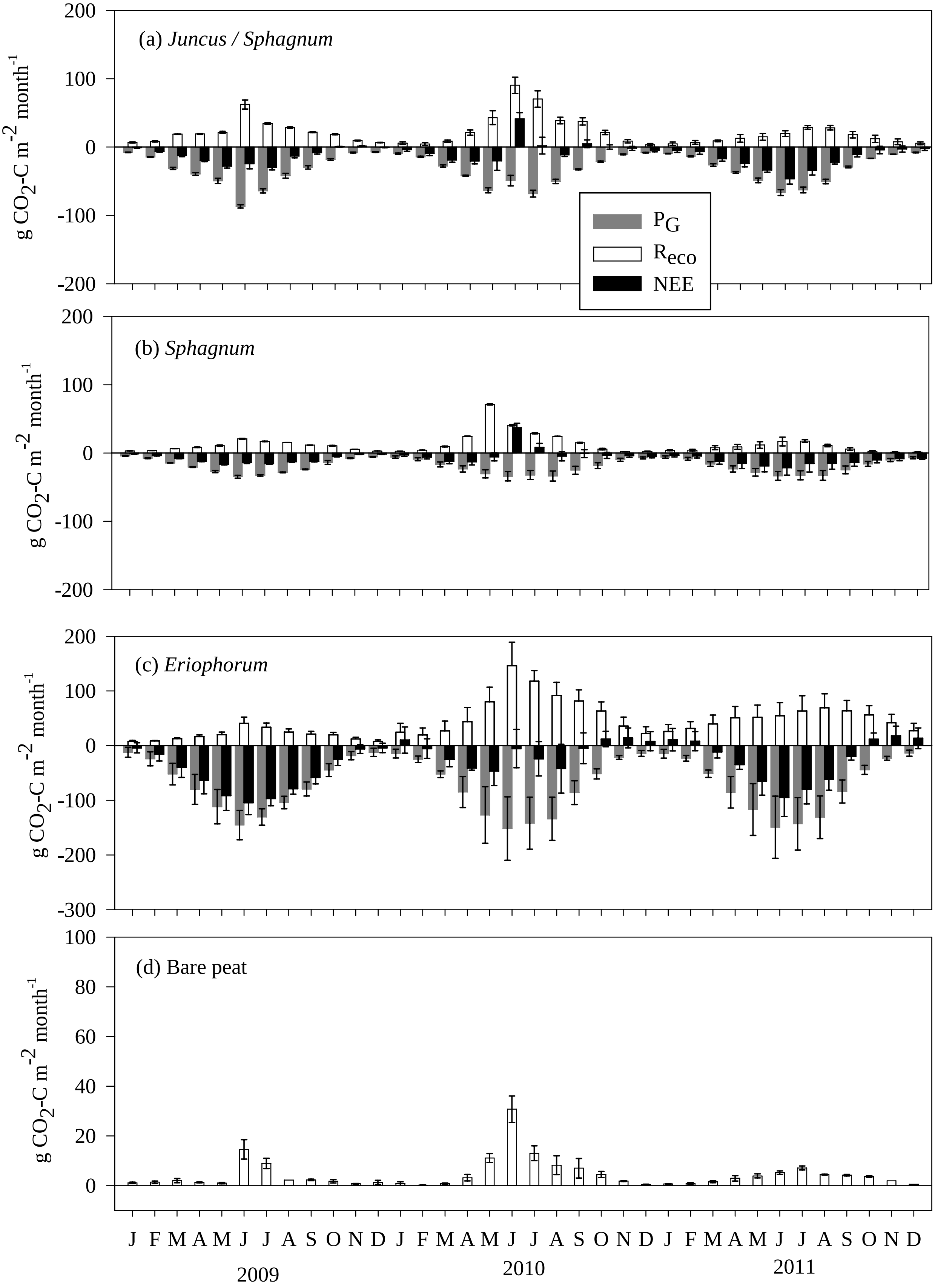


Figure 8. Average monthly modelled (± standard deviation) gross photosynthesis (P_G), ecosystem respiration (R_{eco}) and net ecosystem exchange (NEE) (g CO_2-C m^{-2} $month^{-1}$) for (a) *Juncus-Sphagnum*, (b) *Sphagnum*, (c) *Eriophorum* and (d) bare peat microsites. Positive values indicate a loss of CO_2 to the atmosphere and negative values indicate CO_2 uptake by the peatland. Note differences in scale on y-axis.

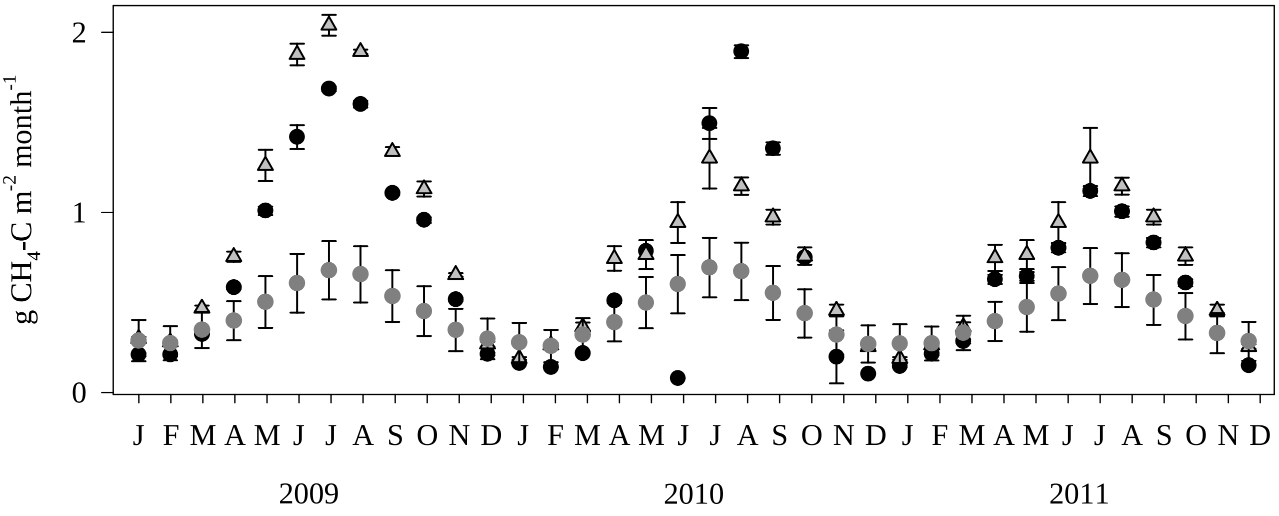


Figure 9. Average monthly modelled CH_4 (g CH_4-C m^{-2} $month^{-1}$) (± standard deviation) for *Juncus-Sphagnum* (black circle), *Sphagnum* (grey triangle) and *Eriophorum* (dark grey circle). Positive values indicate a loss of CH_4-C to the atmosphere.

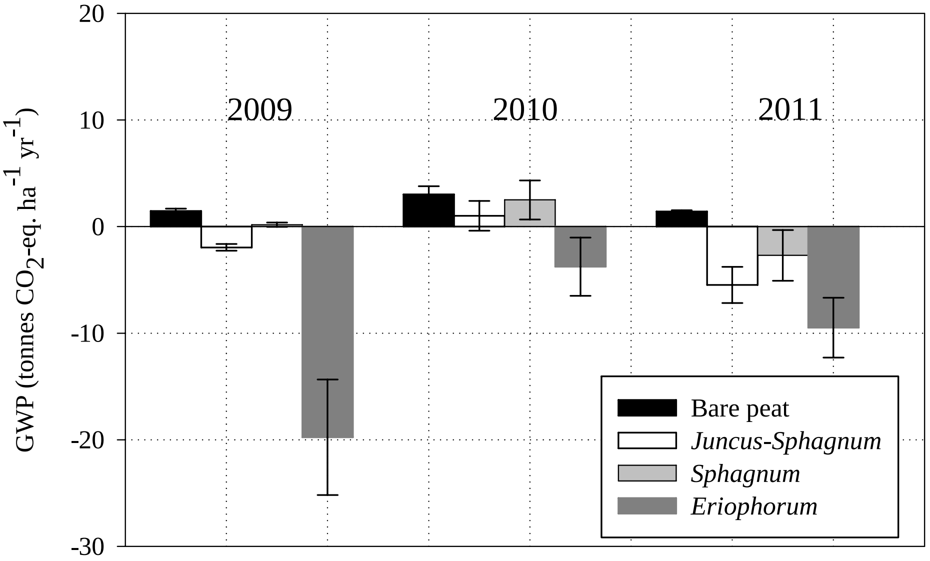


Figure 10. Mean Global Warming Potential (GWP, tonnes CO_2-eq ha^{-1} yr^{-1}, 100 year horizon) (± standard deviation) for the microsites at Bellacorick, Co. Mayo. Positive values indicate that the microsite had a net warming effect on climate for the period of the study. Negative values indicate that the microsite had a net cooling effect on climate over the duration of the study.

DISCUSSION

Long term monitoring of GHG dynamics in rewetted industrial cutaway peatlands is essential to assess more accurately (1) the capacity of the peatland to sequester C and (2) the inter-annual trends in GHG dynamics. The results presented show that, 7–9 years after rewetting of a highly degraded peatland in north-west Ireland, suitable conditions for C sequestration have been created.

The water table in all microsites remained relatively stable throughout the study. The combination of compartmentalisation of the peatland surface (Smolders *et al.* 2003) prior to rewetting and the high, seasonally persistent rainfall experienced in this region provide optimal conditions for water retention in the peatland. The water table remained above the surface in all vegetated microsites throughout the study except for a sharp drop early in the summer of 2010 (Figure 4), which followed a six-month period with lower-than-average rainfall. At that time, the water table descended farthest in the bare peat microsites, less in the microsites with vascular plants and least of all in the *Sphagnum* microsites, indicating that water table fluctuations are better regulated in vegetated areas. This may in turn reflect some degree of ‘self-regulation’ attributable to acrotelm formation. Full development of the function of the vegetation layer (acrotelm) in limiting the amplitude of water table fluctuations is vital to successful restoration of the peatland and especially, in the present context, of its C sequestration and storage functions. The water table must be relatively high and stable to retard the decomposition of dead plant matter (by waterlogging) so that some of it accumulates as new peat in the underlying catotelm layer (Smolders *et al.* 2002, Lucchese *et al*. 2012).

The CO_2-C sink values presented here are at the upper range of values reported for rewetted industrial peatlands in general (Tuittila *et al.* 1999, Bortoluzzi *et al.* 2006, Yli-Petäys *et al.* 2007, Kivimäki *et al.* 2008, Waddington *et al.* 2010) for a number of reasons.

1. In the early successional stages following rewetting there is a strong increase in the microbial (Andersen *et al.* 2006) and plant biomass pools (Lucchese *et al.* 2010) and, therefore, a considerable proportion of the CO_2-C that is sequestered annually is likely to be incorporated into these pools. Over longer time frames, the rate of CO_2 sequestration into the rewetted peatland may slow down (cf. Tuittila *et al.* 1999, Yli-Petäys *et al.* 2007) and may slow towards an equilibrium point in the future at which C uptake by the vegetation just balances C losses (decomposition, CH_4, DOC) such that the store of accumulated peat is maintained but does not increase any more.
2. The growing season is considerably longer in the mild temperate maritime climate of western Ireland than in boreal climates, so that C uptake by plants can extend through a greater portion of each year (Wilson *et al.* 2007). Moreover, the presence of evergreen species such as *Sphagnum cuspidatum* at Bellacorick means that photosynthesis (and hence C uptake) takes place even during the winter months (Figure 8).
3. The relatively low R_{eco} values observed during the study further increase the margin between net C losses and net C gains (Strack & Zuback 2012). Rewetting creates conditions that lead to a reduction in the aerobic zone within the peat, lower oxidation rates and, consequently, reduced CO_2 emissions (Waddington *et al.* 2010). Also, research has shown a correlation between the nutrient status and the rate of decomposition of the peat (Couwenberg *et al.* 2008, Bayley *et al.* 2009). The high C:N ratio measured at the site indicates that the residual peat is nutrient-poor and may result in lower microbial decomposition rates and, therefore, lower CO_2 production (Francez *et al.* 2000).

Even though the rewetted bare peat microsites are still net C sources, their annual CO_2-C (NEE) values (Table 2) are considerably lower than those reported for drained industrial peatlands (reviewed by Wilson *et al.* 2012a) but still reflect significant avoided CO_2 emissions. To provide improved estimates of avoided losses at this peatland, CO_2 fluxes from adjacent drained portions of Bellacorick will be quantified in the next phase of this project.

In this study, the highest CH_4 emissions in each year occurred within the *Sphagnum* dominated microsite, where *Eriophorum angustifolium* (an aerenchymatous species) was a minor component, rather than in microsites dominated by aerenchymatous species (*Juncus*-*Sphagnum* and *Eriophorum*). A considerable body of research has shown that aerenchymatous plant species are associated with higher CH_4 emissions (e.g. Bubier 1995, Frenzel & Karofeld 2000, Leppälä *et al.* 2011, Green & Baird 2012) and that *Sphagnum* species support methanotrophic bacteria communities (e.g. Raghoebarsing *et al.* 2005, Larmola *et al.* 2009) and produce lower CH_4 emissions (Parmentier *et al.* 2011). However, a smaller number of studies have reported findings similar to those presented in this paper and have linked lowered CH_4 emissions with an increased oxygenated rhizosphere in aerenchymatous plants (e.g. Roura-Carol & Freeman 1999, Dinsmore *et al.* 2009a, Dinsmore *et al.* 2009b). Fritz *et al*. (2011) further suggest that a high root biomass in anoxic soils may lead to a greater level of oxygenation in the soil beyond the rhizosphere. The general decrease in CH_4 emissions in the *Juncus*-*Sphagnum* and *Sphagnum* microsites over the duration of this study would suggest evidence of a transitory period. The concept of a spike in CH_4 emissions following rewetting has been advocated (Couwenberg *et al.* 2011) driven by large inputs of labile organic matter. In light of the fact that CH_4 fluxes were not measured in the years immediately after rewetting, it is not clear whether the values reported for 2009 represent such a spike in CH_4 emissions. While reduced CH_4 emissions could be expected in 2010 when mean water table levels were lower, the continued decrease in annual CH_4 emissions in 2011 would suggest that the peatland is developing towards values that would be expected for natural Atlantic blanket bogs (Laine *et al.* 2007b).

N_2O fluxes were not detected in this study as the likely consequence of (1) a high C:N ratio in the peatland (Klemedtsson *et al.* 2005) and (2) removal of nitrogen by vigorously growing vegetation communities (Glatzel *et al.* 2008). However, it is possible that given the size of the chambers used (60 × 60 × 25 cm) and the sampling period employed (20–40 mins) we might not have detected very low N_2O fluxes. With a GWP value of 298 (IPCC 2007), even very low emissions of N_2O would have some relevance in regard to the climate.

Waterborne C fluxes were not quantified in this study. Work by Waddington *et al*. (2008) at a restored cutover peatland in Canada estimated the annual export of dissolved organic carbon (DOC) at 3.4–4.8 g C m^{-2}, with higher exports occurring in wetter years. Furthermore, they estimated DOC losses from the restored site to be significantly lower than losses from an adjacent cutover peatland. However, much higher DOC export values (14–33 g C m^{-2} yr^{-1}) have been reported for blanket bogs in Ireland (Koehler *et al.* 2011) and the UK (Billet *et al.* 2010). Given the large GHG fluxes reported here, the DOC component is likely to be of minor significance over the short-to-medium term but may increase in importance over the longer term as the magnitude of both CO_2 and CH_4 fluxes could be expected to decrease.

While studies elsewhere have shown that GWP may not be the most appropriate measurement for assessing the contribution of peatlands to the global climate (Frolking *et al.* 2006, Frolking & Roulet 2007), GWP does provide a means to gauge the climatic impact of restoration actions (Beetz *et al.* 2013). In spite of increased CH_4 fluxes, rewetting of industrial cutaway peatlands can lead to a reduction in GWP compared to the previous drained state (Wilson *et al.* 2009) and, in this study, recolonisation by the vegetation led to a further reduction in GWP (Figure 10), although the areal distribution of the various vegetated microsites at the landscape level in regard to overall GWP is highly relevant (Strack & Waddington 2007). In this study, spatial variation in GWP was evident and the vegetated microsites ranged from having a strong cooling impact on the climate (*Eriophorum*) to a slightly warming/neutral/cooling impact (*Juncus-Sphagnum*, *Sphagnum*). The key driver of GWP is the relative strengths of CO_2 and CH_4 fluxes during the particular developmental stage of the peatland (Frolking *et al.* 2006, Frolking & Roulet 2007) and while the CO_2 component changed somewhat unpredictably from year to year in all microsites, the relative impact of the CH_4 component became progressively lower.

Rewetting at Bellacorick has not succeeded in returning the peatland to the state that existed immediately prior to peat extraction. The vegetation communities are still not typical of those found in Atlantic blanket bogs of the surrounding region, which are characterised by plant species such as *Molinia caerulea* and *Schoenus nigricans*, a low cover of *Calluna vulgaris* and a lesser cover of *Sphagnum* species relative to Irish raised bogs and mountain blanket bogs (Farrell & Doyle 2003, Sottocornola *et al.* 2008). The current plant communities may represent the early successional stages of the former Atlantic blanket bog - poor fen, which may in time succeed to more typical bog (peat forming) communities (Farrell 2001, Fallon *et al.* 2012). Similarly, while Atlantic blanket bogs have been shown to be modest sinks for CO_2-C (Sottocornola & Kiely 2010, Koehler *et al.* 2011) and a low source of CH_4-C (Laine *et al.* 2007b, Koehler *et al.* 2011), C gas fluxes at Bellacorick 7–9 years after rewetting are characterised by large CO_2 sinks and moderately high CH_4 sources. Rewetting has started a *new* process, along a *new* developmental trajectory (Vasander *et al.* 2003). A number of developmental trajectories with implications for C sequestration may develop over time following the cessation of peat extraction (Charman 2002). At Bellacorick, the direction of the new trajectory will be governed to a large extent by management and climatic factors. In the absence of active restoration measures, the cutaway peatland that existed prior to rewetting would have continued to be a net CO_2 source in the short and medium term (Waddington *et al.* 2001, Wilson *et al.* 2009) and would have a warming effect on the climate (Wilson *et al.* 2009). This would have decreased slightly over time as the more easily decomposable fractions of the peat were oxidised. With minimal human intervention, natural succession would have taken place and the cutaway at Bellacorick would probably have been re-colonised by a range of wet grassland and heathland plant species, rather than wetland/bog species, with extensive pine spread from adjoining plantations (Farrell 2001, Fallon *et al.* 2012). However, GHG flux dynamics under such a mosaic landscape are not known. For industrial cutaways in the Irish midlands (lower annual precipitation, nutrient-rich peatlands), natural colonisation with no active rewetting has generally resulted in the establishment of birch/willow scrub (Renou *et al.* 2006) and studies have shown that these ecosystems are likely to be large net C gas sources, primarily as a consequence of high soil CO_2 emissions and low primary productivity (von Arnold *et al.* 2005, Byrne *et al.* 2007).

If annual precipitation were to increase over the next decades then it is possible that this peatland would continue along a developmental trajectory culminating in the type of Atlantic blanket bog ecosystem that was present before the commencement of milled peat production. Climate modelling exercises have predicted that precipitation distribution and frequency will change in Ireland over the coming decades and that the Bellacorick area will experience higher levels of precipitation in the decades ahead (Sweeney *et al.* 2008). During this study, the region experienced the seventh and eighth wettest years since 1957 and this undoubtedly contributed to the sustained high water tables observed at the study site and the subsequent high rates of C sequestration. However, if rainfall frequency and distribution are below the long-term average, and the first six months of 2010 provide a good example of this scenario, it is likely that the strength of the C sink function will be reduced through increased rates of R_{eco} (Figure 8). Furthermore, prolonged periods of drought would result in a shift from wet, peat-forming conditions, with the vegetation dominated by *Eriophorum* and *Sphagnum* communities, to dry heathland and/or acid grassland with pines expanding their range on the drier peat areas. Extensive tree colonisation would in turn lead to a further drying of the peatland through increased evapotranspiration rates and result in increased soil CO_2 emissions.

Jones *et al*. (2006) have predicted that around 40 % of Irish peatlands could disappear over the coming decades as a consequence of climate change. More recent climate envelope modelling exercises have predicted that there will be a severe decline in the area of blanket peatlands in the British Isles by 2080 as a result of increased global temperatures (Gallego-Sala *et al.* 2010, Gallego-Sala & Prentice 2013) and under increased GHG emissions scenarios (Clark *et al.* 2010). Given that degraded peatlands are likely to be more vulnerable to external changes than natural peatlands, well-informed management decisions will be critical in maintaining optimal conditions for C sequestration. These may involve removing colonising trees to prevent increased evapotranspiration rates and subsequent drying-out of the peatland, preventing unauthorised public access to the site, and the maintenance of dams and bunds (Schumann & Joosten 2008).

Rewetting of drained peatlands as a climate mitigation action has been addressed in the United Nations Framework Convention on Climate Change (UNFCCC) and Inter-Governmental Panel for Climate Change (IPCC) and good practice guidance methodologies for assessing GHG fluxes on rewetted organic soils are currently under development (IPCC 2012). At the UNFCCC meeting in Cancún, Mexico (December 2010), unanimity was reached among Land Use, Land Use Change and Forestry (LULUCF) negotiators on the definition and content of a new activity under the Kyoto Protocol, called “rewetting and drainage”. Furthermore, the utilisation of rewetted peatlands in voluntary C offset projects has been made possible by the Verified Carbon Standard Program (VCS) in the Peatland Rewetting and Conservation (PRC)/Wetland Restoration and Conservation (WRC) modules of its AFOLU Guidelines (Verified Carbon Standard 2012). The voluntary and mandatory C trading schemes that are currently in operation imply that C, both stored and annually sequestered, could have an economic and tradable value if they can be accurately reported and verified (Galatowitsch 2009, Joosten & Couwenberg 2009, Worrall *et al.* 2009). Given the considerable C savings achieved in the years since rewetting at Bellacorick, the potential of rewetted industrial peatlands as C offset projects is good provided (1) the rewetting process is as successful on damaged peatlands elsewhere and (2) the price of C traded on the markets is attractive.

CONCLUSION

Rewetting of industrial cutaway peatlands offers a number of important benefits in terms of GHG exchange. Firstly, the re-establishment and, more importantly, maintenance of hydrological conditions characteristic of natural peatlands leads to a reduction in CO_2 emissions from the peat and to a potential C saving or avoided loss. Furthermore, the re-establishment of the C sequestration capacity of the peatland through re-colonisation by appropriate vegetation communities may further enhance C storage. This three-year study has highlighted the importance of long-term GHG monitoring in order to assess more accurately the capacity of peatland to sequester C. The advantages offered by climate on the west coast of Ireland (persistent rainfall, cool temperatures), coupled with an inherently nutrient-poor peat substrate mean that rewetted industrial cutaway peatlands in this region could be a prime location for climate change mitigation.

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