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Carbon storage in peatlands: A case study on the Isle of Man

L.F. Weissert [a,b,*], M. Disney [b,c]

[a] 3A Wrights Spur, Mt Eden, Auckland 1024, New Zealand
[b] UCL Geogrpahy, Gower Street, London WC1E 6BT, United Kingdom
[c] NERC National Centre for Earth Observation (NCEO), United Kingdom

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ABSTRACT

Peatlands contain about one third of the World's terrestrial carbon (C). Due to their increasing importance in the context of climate change various studies estimated regional and global carbon stocks. The greatest uncertainty in current C stock estimates is peat depth. Information on peat depth is often lacking or spatially variable, which both limit the accuracy of C stock estimates. We present measurements of peat depth on the Isle of Man and evaluate the C sink of the region. We assess the degree to which estimates of *Sphagnum* cover can be used to predict peat depth and we identify and quantify various uncertainties in resulting C stock estimates. Total peatland area was identified through classification of aerial photography. Peat depth and *Sphagnum* cover were measured on a 50 m grid at four study sites in the southern hills on the Isle of Man.

Peatlands at the study sites were generally shallow with low total organic carbon (TOC) contents. Peat depth seemed not to be controlled by local terrain. It is estimated that the C stored per unit area ranges from 14.7 to 22.4 kg C m^{-2}. The results provided in this study were significantly lower than in other studies, which is likely due to the land use history. The large spatial variability of peat depth resulted in large uncertainty in C stock estimates. *Sphagnum* proved to be important for the formation of deep peat and could potentially be used to assess the quality of peatlands. Results suggest that peatlands on the Isle of Man will likely act as a C source in the long-term if not maintained and/or restored.

1. Introduction

Peatlands are one of the World's most important ecosystems covering about 3% of the global land area, with the majority located above 45°N (Madgwick and Parish, 2008; Yu et al., 2011). Peatlands represent a variety of wetlands and are defined as ‘any ecosystem where in excess 0.3–0.4 m of peat has formed’ (Charman, 2002; Harris and Bryant, 2009). Peat is formed in waterlogged and anaerobic conditions that inhibit the complete decomposition of dead plant and animal components (Charman, 2002; Rydin and Jeglum, 2006). Thus, peat largely consists of the partially decomposed remains of plants with an organic matter (OM) content >65%. However, this definition can vary significantly, and the minimum percentage OM required can range from 20% up to 80% (Charman, 2002). Bog peats, dominated by the bog moss *Sphagnum*, can even reach organic values well over 90% (Gorham, 1995).

Most peatlands started accumulating peat in the early Holocene, around 10,000 years ago, and have continued since then (Strack, 2008; Yu et al., 2011). From special importance for the formation of deep peat are peat mosses — the genus *Sphagnum*. *Sphagnum* species are special bryophytes that are adapted to acid, waterlogged and nutrient-poor conditions. Moreover, they create such environments themselves. *Sphagnum* species have the capacity to store up to 15 to 20 times their dry mass of water between their leaves, which results in a continuously high water table and anoxic conditions. These characteristics and their slow decomposition rate make *Sphagnum* species extremely important for peatlands (Charman, 2002; Rydin and Jeglum, 2006). They are the main peat formers and without them peatlands would not be as widely distributed (Rydin and Jeglum, 2006). Thus, an extensive cover of *Sphagnum* is an indicator for high quality peatlands, whereas little *Sphagnum* and large dry areas with hard peat are typically associated with poor quality peatlands (Cross in press, cited in Charman, 2002).

For millennia peat was mainly regarded as a resource that can be exploited, for fuel, horticulture or forestry, which led to major alterations in peatland hyrdology and vegetation (Chapman et al., 2003; Charman, 2002). As a consequence, peat accumulation in Europe stopped in over 50% of former mire areas, which makes Europe the continent with the largest peatland losses (Joosten and Clarke, 2002). Peatlands represent about one third of the World's terrestrial carbon (C) pool, storing 400–500 Gt C and are the most efficient C store of all terrestrial ecosystems (European Environment Agency, 2010; Roulet, 2000). As a result, peatlands are an important long-term sink of atmospheric CO_2 and they could be a cost-effective measure in mitigating and adapting to climate change (Gorham, 1991; Lunt et al., 2010;

* Corresponding author at: 3A Wrights Spur, Mt Eden, Auckland 1024, New Zealand. Tel.: +64 21 047 1063.
E-mail addresses: lwei999@aucklanduni.ac.nz (L.F. Weissert), mdisney@geog.ucl.ac.uk (M. Disney).

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Reed, 2009). Peat accumulation ensures that these regions remain a sink of atmospheric CO_2 and thus impact national C sinks and source inventories (Roulet, 2000). As a consequence, peatland restoration has become increasingly important and numerous peatlands across the UK, including projects at Exmoor peatlands, the RSPB Forsinard Flows nature reserve or the Portmoak Moss Woodland Trust Scotland, have been restored (IUCN UK Committee, 2012). The most widespread restoration method is drain blocking, which aims to restore the water table and hydrological regime to a previous state (Holden et al., 2007). To assess the success of restoration measures and to consider peatlands as a climate change mitigation measure it is essential to provide accurate C stock estimates of peatlands as a baseline against which to measure future changes (Garnett et al., 2001; Rogiers et al., 2008). In particular, knowledge of C storage at regional scales (100 to 10,000 km^2) is crucial as management and restoration measures at these scales are directly affecting C fluxes (Buffam et al., 2010).

Table 1 presents estimates of C stocks (±uncertainties) in peatlands published over the last decade (e.g. Beilman et al., 2008; Buffam et al., 2010; Chapman et al., 2009; Jaenicke et al., 2008; Zauft et al., 2010). However, information on peatland C stocks is still relatively scarce (Zauft et al., 2010) due to uncertainties in peat depth and peat area as well as bulk density (BD) and C content, with peat depth contributing most to the uncertainty (Beilman et al., 2008; Buffam et al., 2010; Garnett et al., 2001; Gorham, 1991). Information on peat depth is often lacking or spatially variable, which both limit the accuracy of C stock estimates (Beilman et al., 2008; Buffam et al., 2010; Wellock et al., 2011).

This study presents estimates of peat depth and C stocks in peatlands on the Isle of Man and we identify the key uncertainties in the resulting C stock estimates. Additionally, we assess the value of remotely sensed data to quantify the peatland area and the importance of *Sphagnum* and topography as predictors for peat depth. This work is of importance for quantifying uncertainties in C stock estimates in other peatlands, over wider areas. Considering these uncertainties should be a central part of informing management strategies for peatland preservation and restoration aimed at maintaining C storage.

2. Materials and methods

2.1. Site description

Measurements were undertaken at four different sites (A–D) in the southern hills on the Isle of Man, which lies in the Irish Sea between Ireland and England (Fig. 1). The Isle of Man is 51 km long and 21 km wide at its widest point and covers an area of roughly 500 km^2 (Robinson and McCarroll 1990, cited in Sayle et al., 1995). The sites were chosen in order to cover the major peatland types found on the Isle of Man, such as wet dwarf shrub heath, dry dwarf shrub heath and flush and spring, which account for 85.22, 4.68 and 6.87%, respectively, of the total habitats found on peat on the Isle of Man (Sayle et al., 1995). Sayle et al. (1995) defined heathland as areas occurring on peat <0.5 m on well drained acid soils. Mires, on the other hand, are typically found on peat >0.5 m, while flush and springs are minerotrophic mires associated with a water movement (Rydin and Jeglum, 2006; Sayle et al., 1995). Peatlands at all study sites, particularly dry dwarf shrub heath, are managed through repeated burning and low density grazing. Further, they have been drained extensively and used for peat extraction in the past (Harris et al., 2001; Tomlinson and

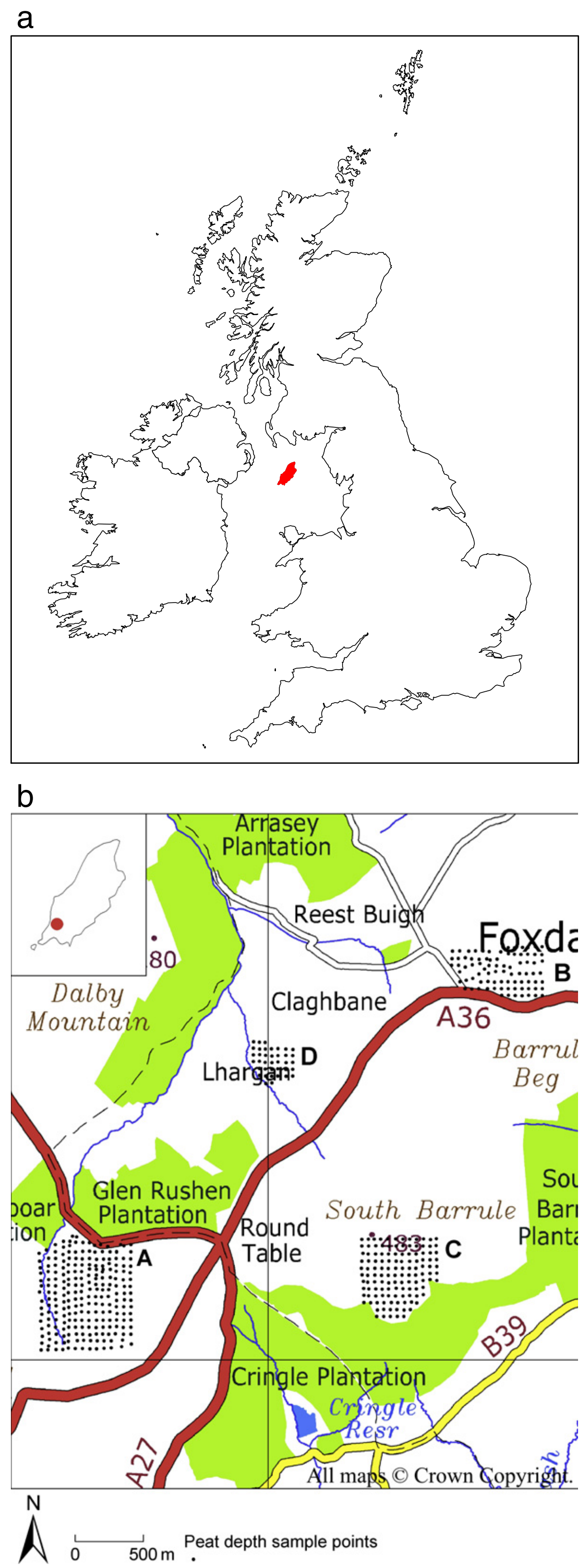

Fig. 1. a) Location of the Isle of Man (red), b) study sites (A: Lanagore; B: Cross Vein; C: south facing slope of South Barrule (referred to as South Barrule in the following); D: Glen Rushen Farm) (Source: Department of Infrastructure, 2011).

Table 1
C stock estimates (±uncertainties) for peatlands from a number of sources.

Source	Country	Peatland area [km^2]	Mean stock (±uncertainty) [Mt C]
Chapman et al. (2009)	Scotland	17,270	1620 (±70)
Buffam et al. (2010)	United States	6397 (20% peatland)	144 (±21)
Beilman et al. (2008)	Canada	25,119 (32% peatland)	982–1025
Zauft et al. (2010)	Germany	2451	430
Jaenicke et al. (2008)	Indonesia	14,960	4150 (±890)