Understanding the interactions between water and carbon within terrestrial and freshwater ecosystems

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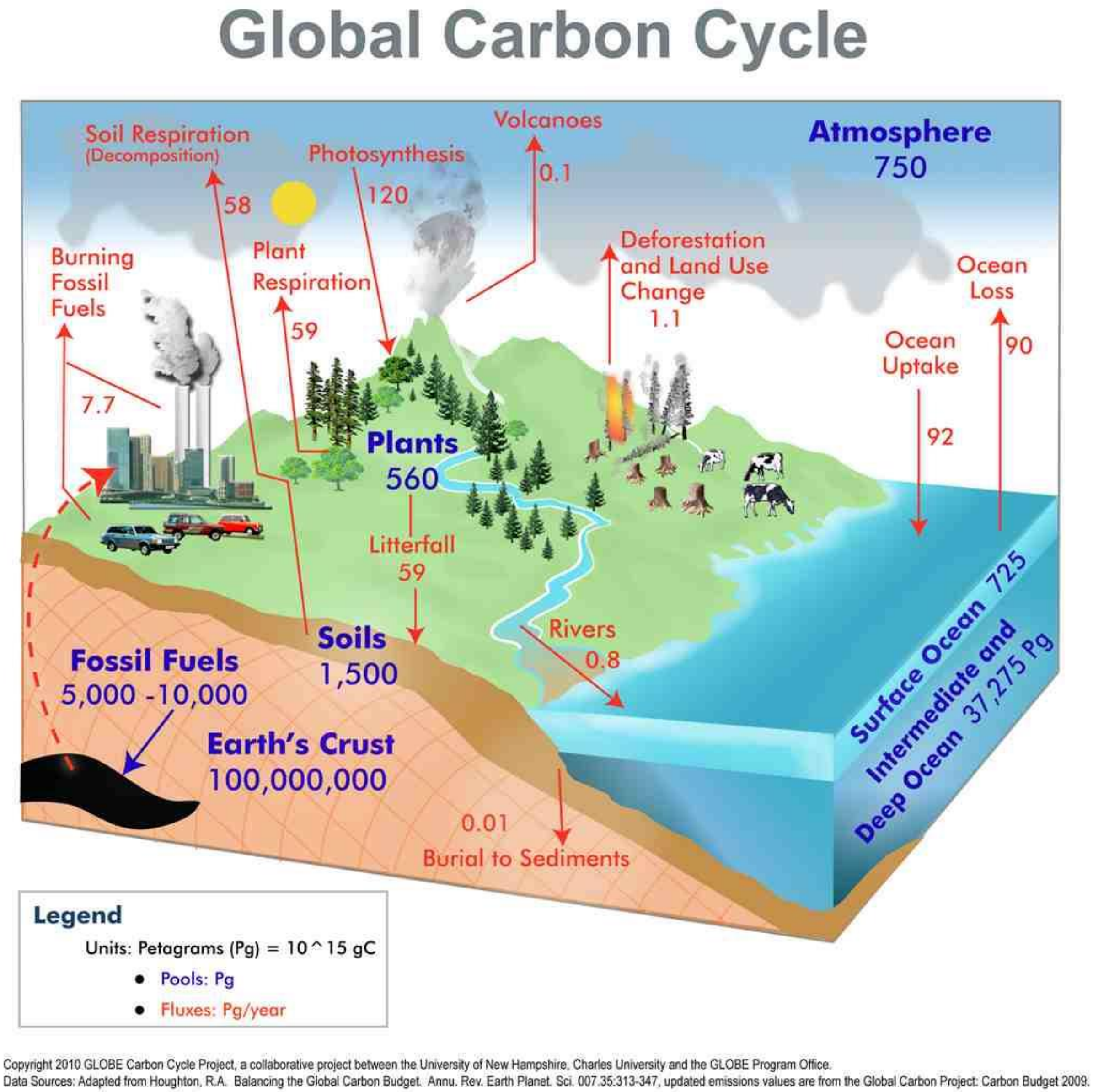
Introduction

- Twenty-65 project
- The carbon cycle and aquatic C pools
- Trends in dissolved organic carbon
- Managing peatland soils?
- Implications for water treatment

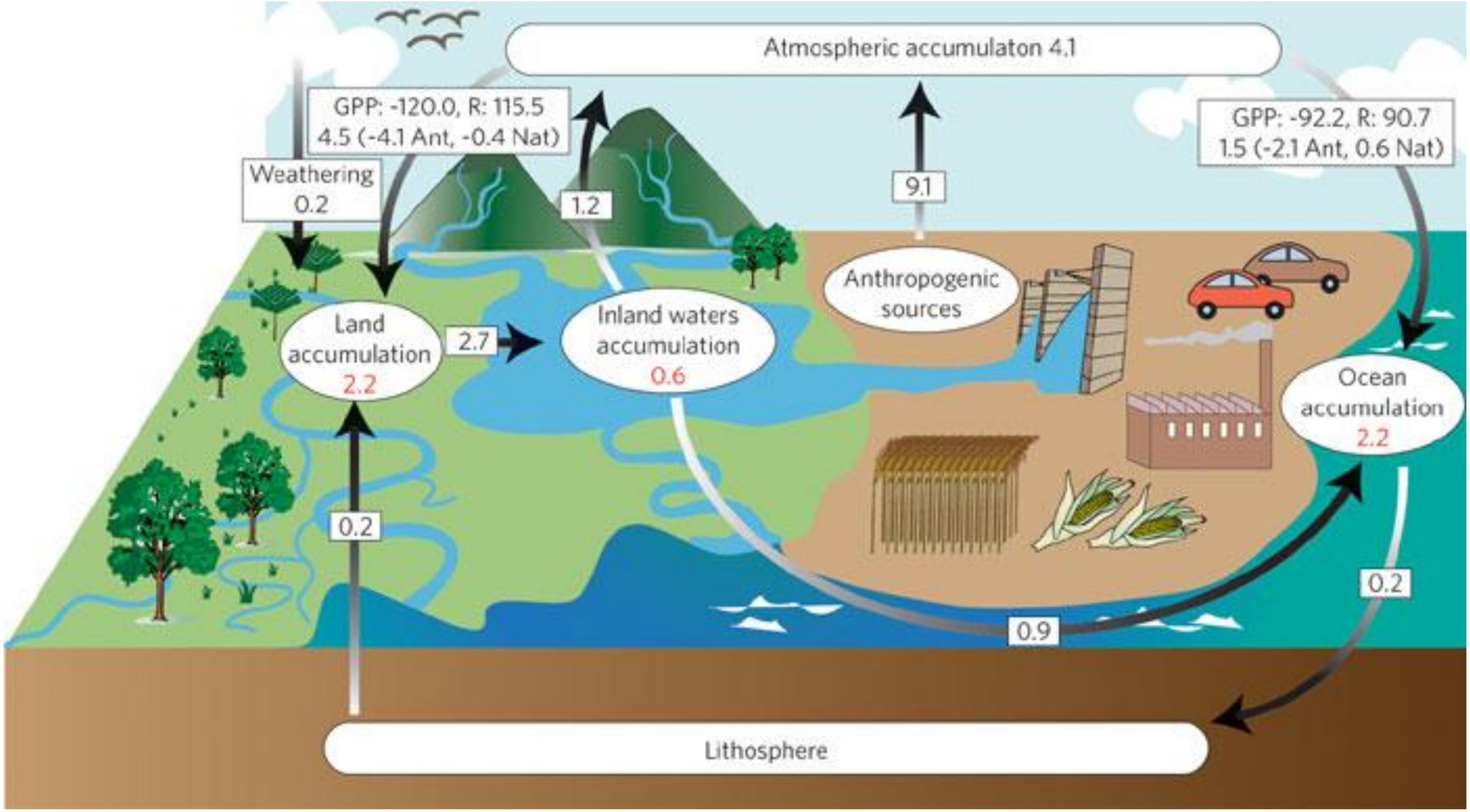
Twenty-65

- 5-year EPSRC funded ‘grand challenge’
- ‘Minimising carbon emissions through synergistic water-energy systems’
- ‘Adapting to changing catchments’
- https://twenty65.ac.uk/



Carbon in surface waters considered an inactive 'pipe' which moves C to ocean

Cockell et al. (2007)



Battin et al. (2009)

A more accurate model includes accumulation in surface waters and degassing/mineralisation to atmosphere

Trends in dissolved organic carbon (DOC)

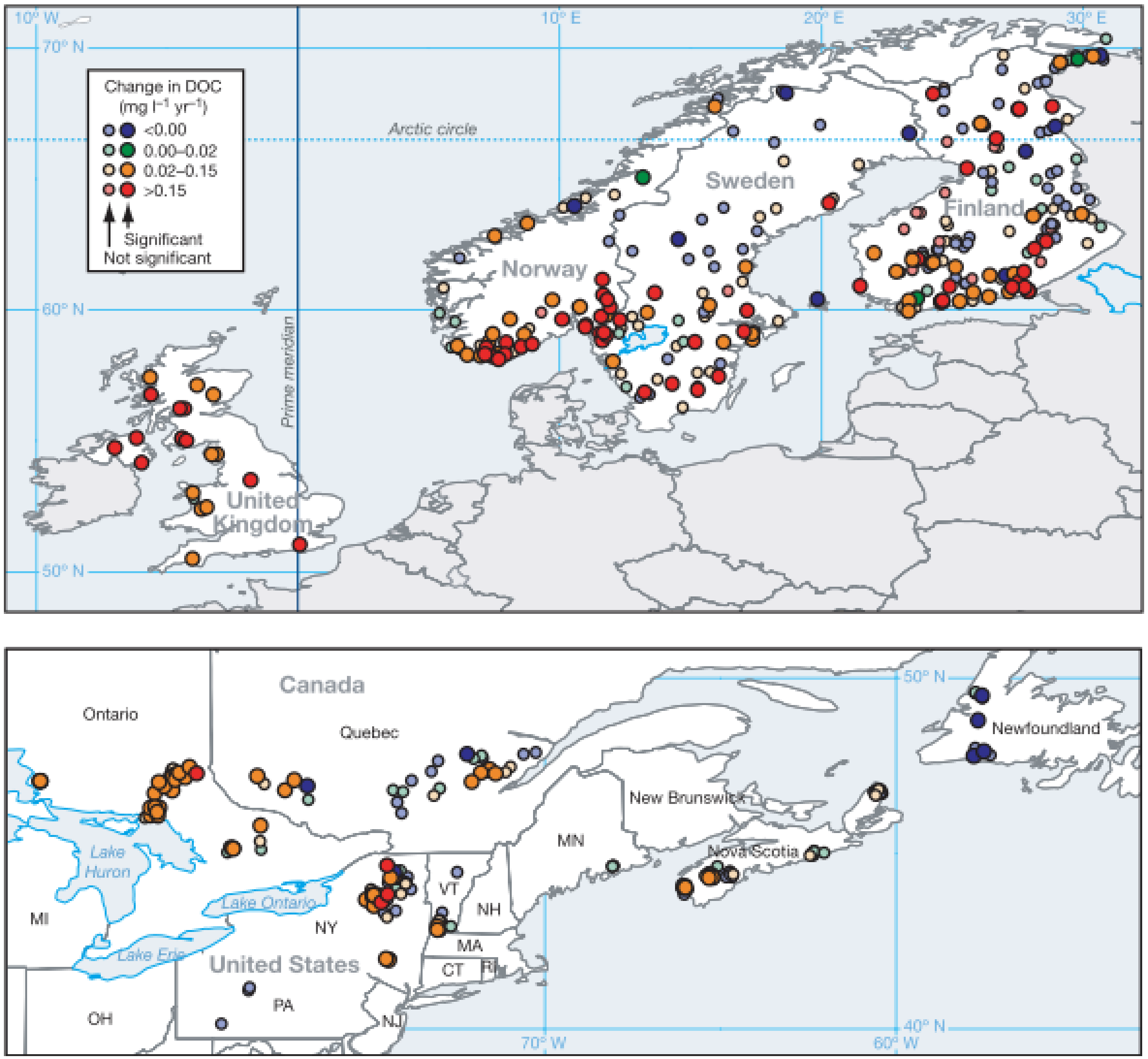
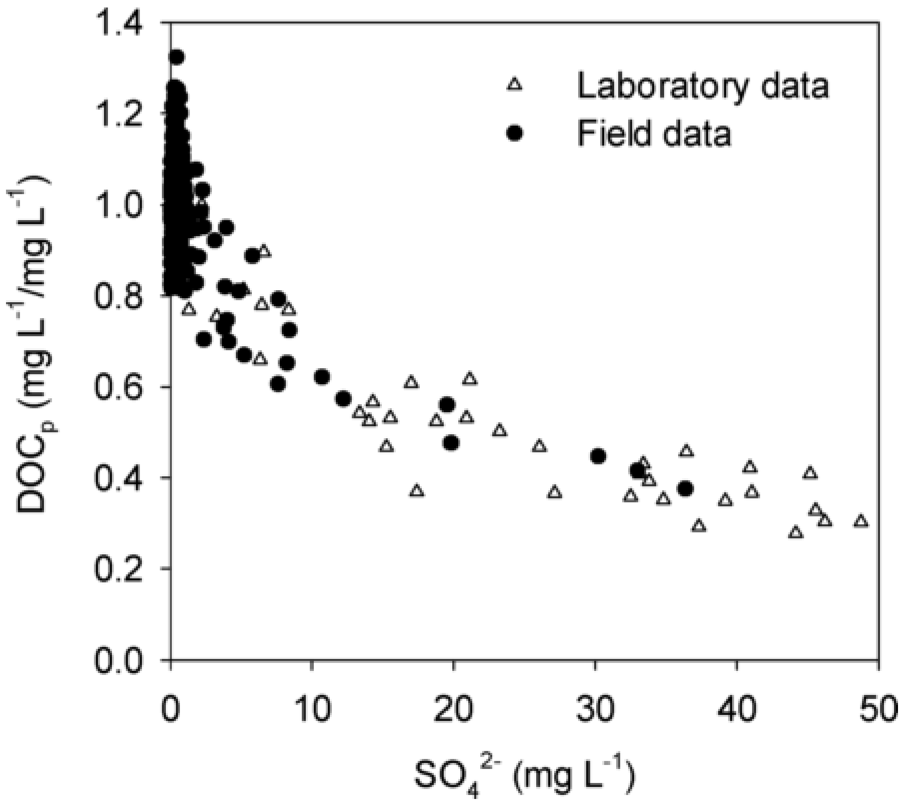


Figure 1 | Trends in dissolved organic carbon ($mg\,l^{-1}\,yr^{-1}$). Data are shown for monitoring sites on acid-sensitive terrain in Europe (upper panel) and North America (lower panel) for the period 1990–2004.

Monteith et al. 2007 (Nature)

Explanations

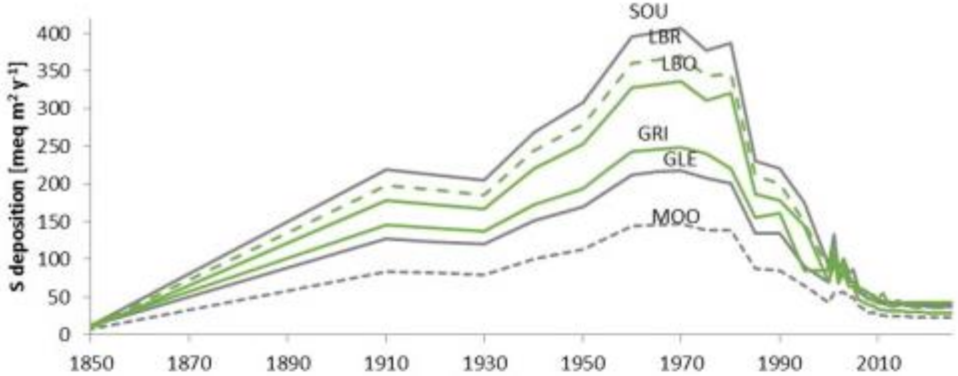
- Acid deposition
- Temperature
- CO_2 enrichment
- Hydrology
- Land use
- Burning
- N fertilisation

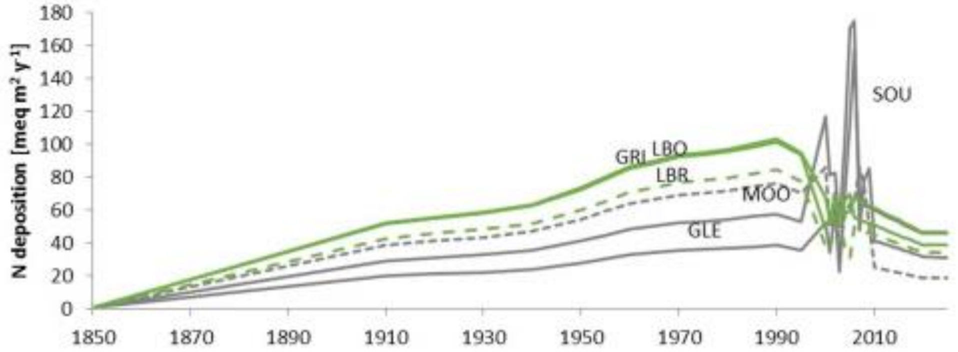


Clark et al. 2006 (ES&T)

Future drivers

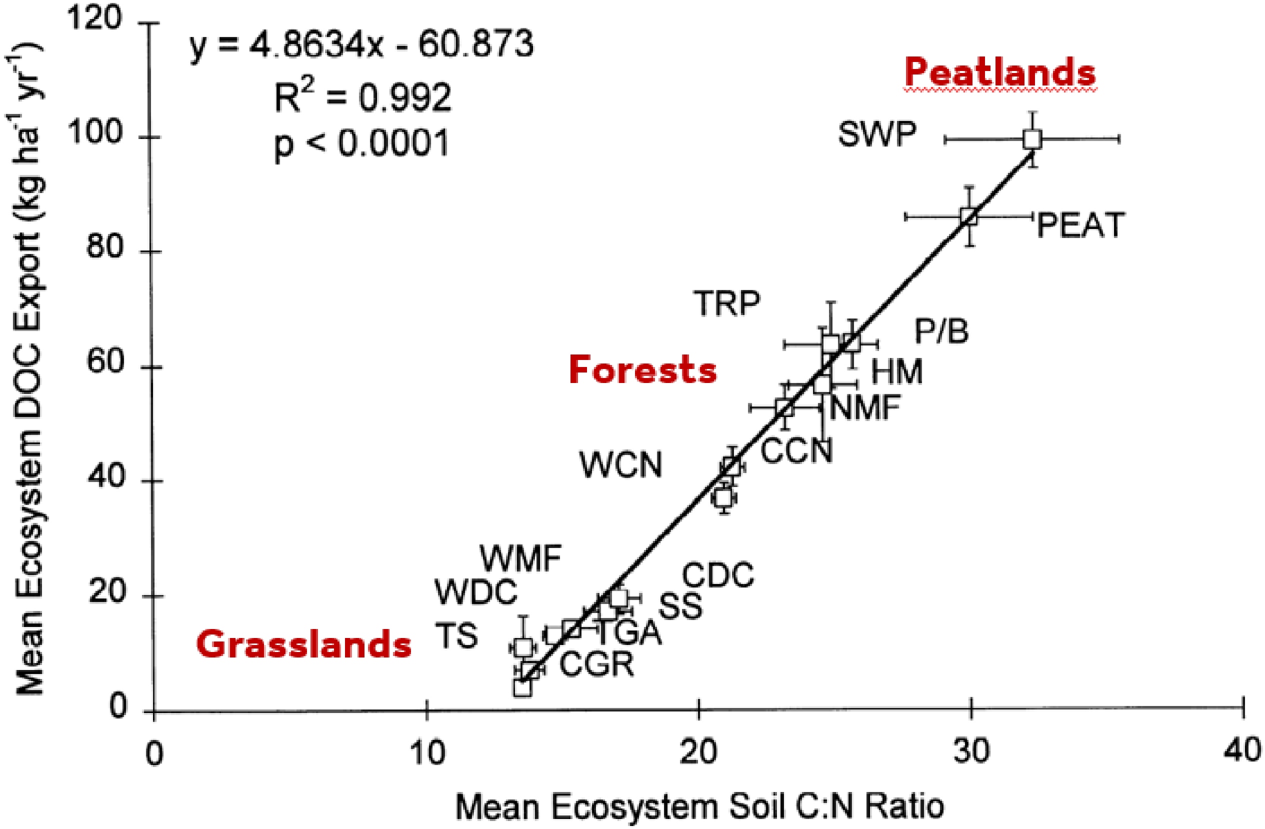
- S deposition returning to pre-industrial levels
- N deposition means DOC likely to be higher than pre-industrial levels
- Catchment specific





Sawicka et al. 2017
(STOTEN)

Land use and DOC



Aitkenhead & McDowell (2000)

Managing peatland soils?

- Organic-rich soils formed due to high water tables limiting decomposition

- 15–30% of the world's total soil carbon

- Most in the UK are degraded through land management and acidic deposition

Peatlands are either…

- ‘wastes, which are at present a disgrace and reproach to the inhabitants of this county’ Fraser (1794)

Or

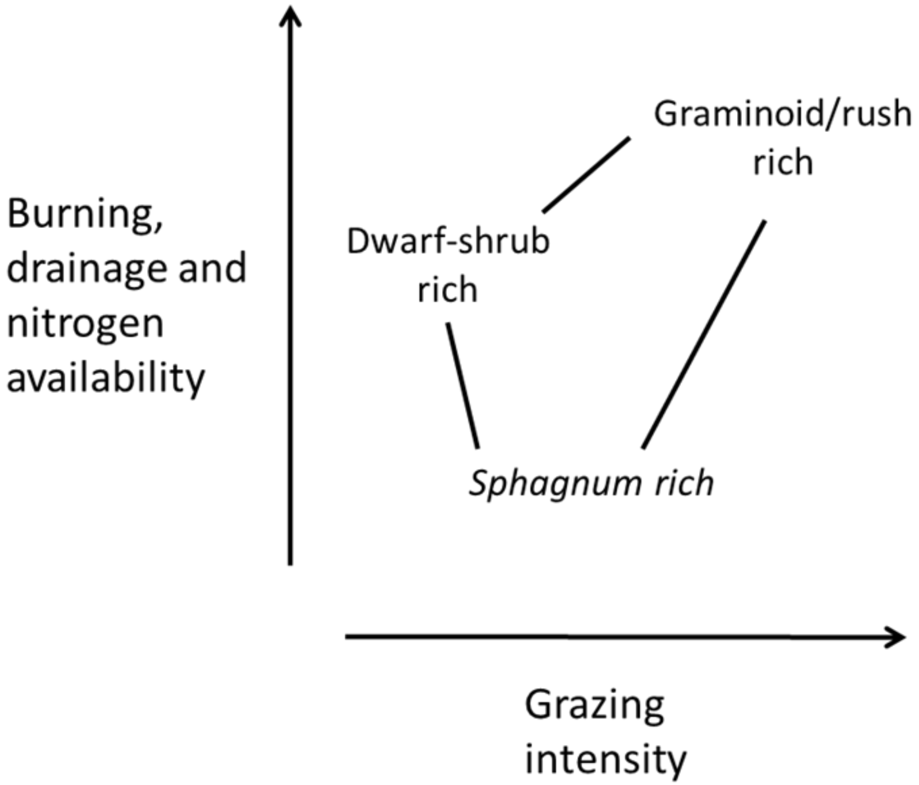
- ‘crucial source of ecosystem services, such as provision of food and fibre, water supply, climate regulation, maintenance of biodiversity, as well as providing opportunities for recreation, inspiration and cultural heritage’ Bonn et al (2010)

Historical management

Photos: South West Water

Drainage, liming, peat cutting, grazing, burning

Vegetation change



Expanded and redrawn from Bragg and Tallis (2001)

Exmoor Mires Project

Photo: South West Water

- Total area restored = 1,019ha
- Total ditch length blocked = 99,097m
- Total number of ditch blocks = 10,546
- Payments for ecosystem services possible?

Exmoor Mires: initial results

Geophysical Research Abstracts
Vol. 16, EGU2014-7926, 2014
EGU General Assembly 2014

Restoration of shallow peatlands on Exmoor (UK): initial effects on water quality

Emilie Grand-Clement (1), David Luscombe (1), Karen Anderson (2), Naomi Gatis (1), Josie Ashe (1), and Richard Brazier (1)

(1) Geography, University of Exeter, UK, (2) Environmental and Sustainability Institute, University of Exeter, UK

[six months post-restoration] "…significant changes in water quantity, such as a reduction in storm flow following restoration, means that, overall, DOC loads have decreased at the scale of the catchment."

Exmoor Mires: initial results

In the Bog Conference September 2014

Exmoor Mires Project: Initial analyses of post restoration vegetation monitoring data

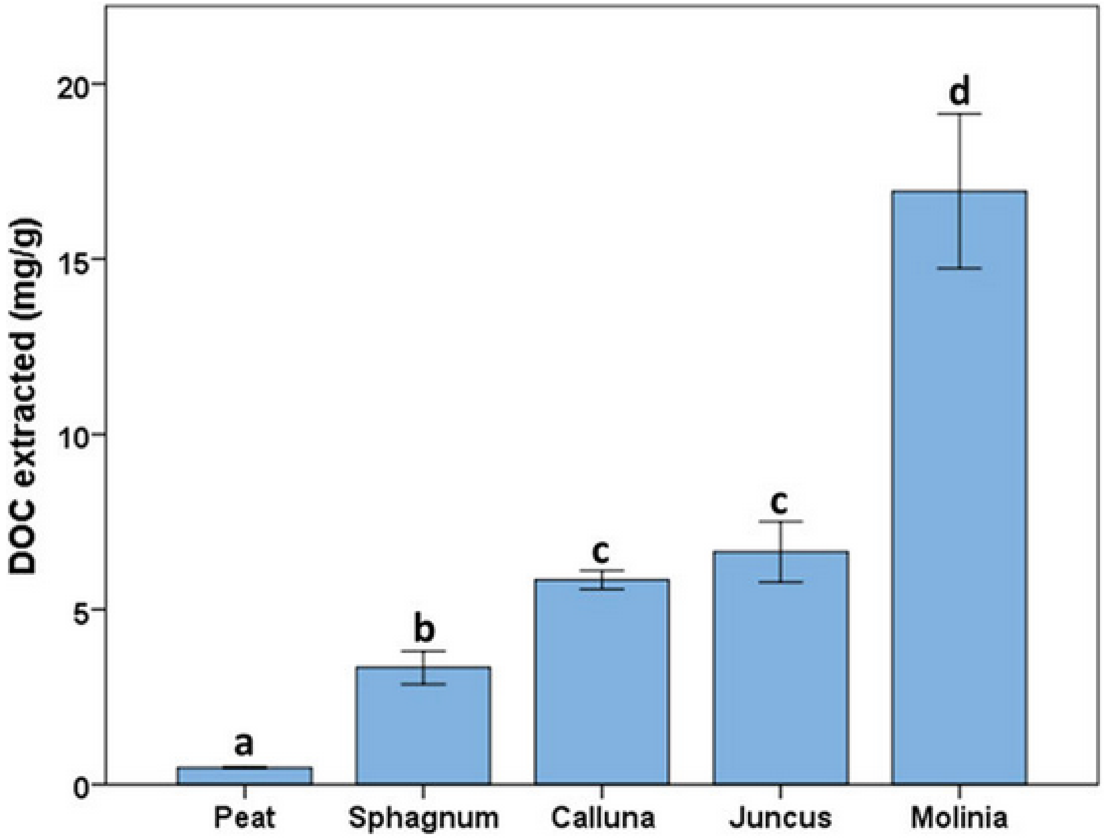
David M. Smith[1, 3], Conrad Barrowclough[2], Andrew D. Glendinning[3] and Anne Hand[3]

South West Water [1], First Ecology (Somerset Wildlife Trust) [2], Exmoor Mires Project [3]

“Where restoration structures have remained intact, botanical communities have significantly changed, reflecting rewetting of underlying peat at all but one site. This indicates that the use of ditch blocking to re-wet peatlands is a successful hydrological rehabilitation strategy.”

Vegetation DOC production

Figure 3: DOC production from different peatland sources (letters indicate statistical subsets).

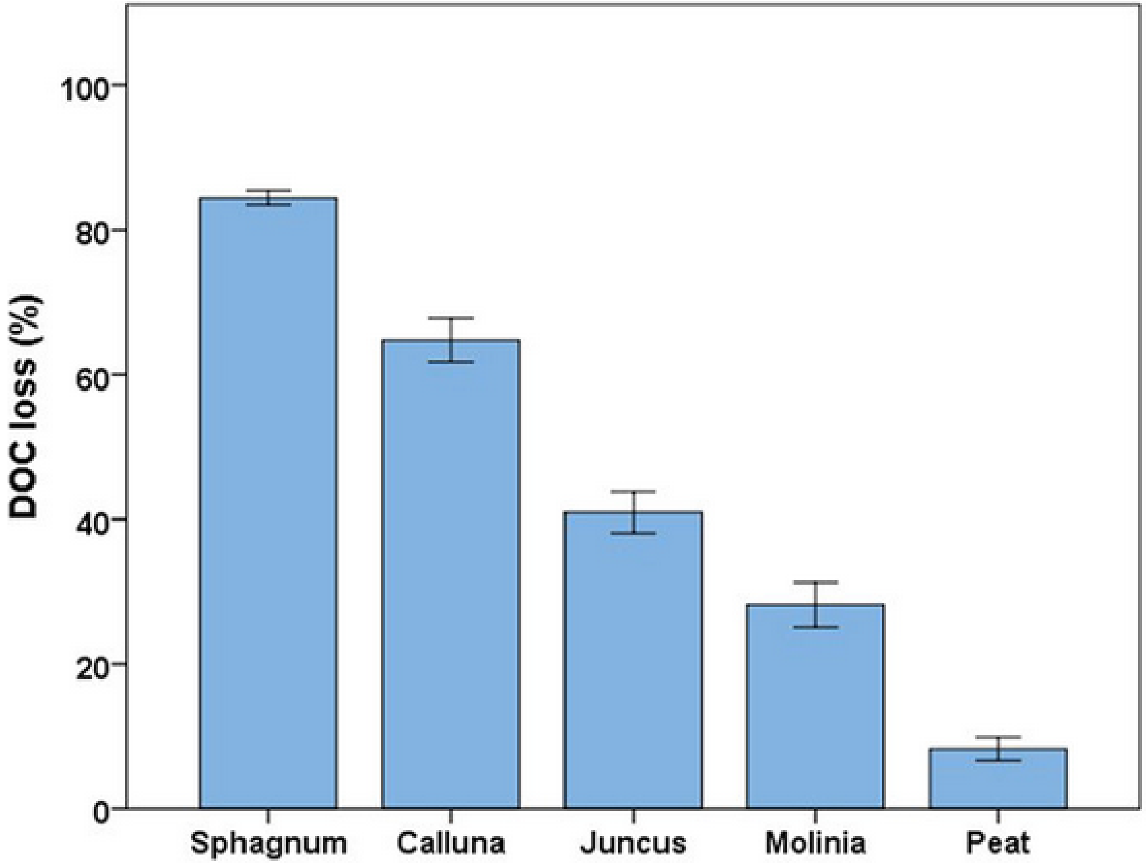


Error bars at one standard error (n = 5).

Ritson et al. 2016

Loss of DOC in the catchment

Figure 2: % loss of DOC on seven day incubation with added nutrients and standardised inoculum for different DOC sources.



Error bars at one standard error (n = 5).

Ritson et al. 2016

Molinia and *Juncus* producing the most DOC and it is the most recalcitrant

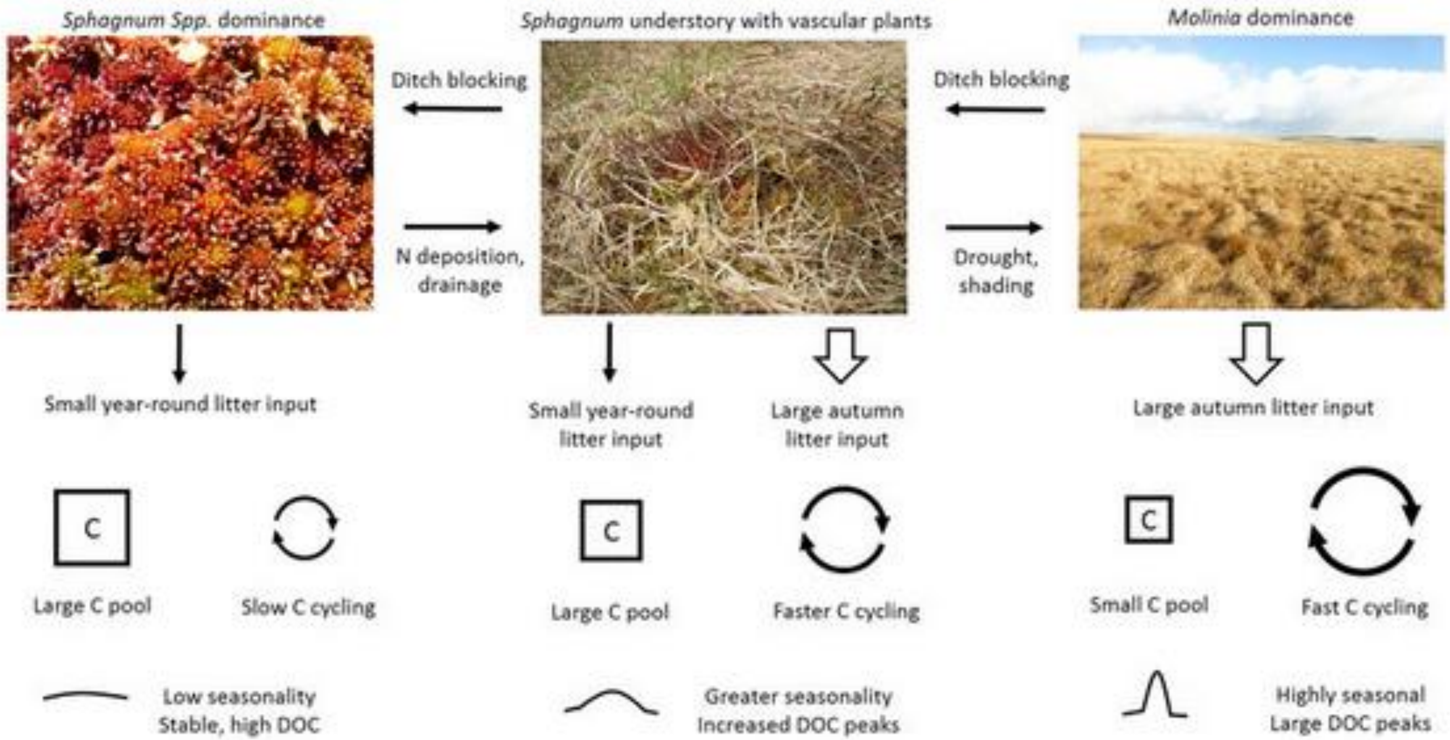
Seasonality and litter quality

- After ten months decomposition in the field, 1.2% loss of *Sphagnum* but 21.3% loss for *Molinia*.

Vegetation	Litter production (g m^{-2} $year^{-1}$)	Timing
Sphagnum spp.	35–156	Year-round
Calluna vulgaris	40–261	Year-round, peaks in autumn/winter
Juncus effusus	690–800	Sept–Nov
Molinia caerulea	536–633	Sept–Nov

Ritson et al. 2016

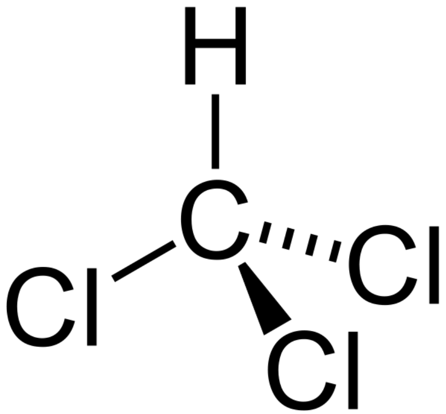
Figure 4: Conceptual diagram showing changes to size, speed of cycling and seasonality of litter carbon pool on transition from *Sphagnum* to *Molina* domination of uplands.



Ritson et al. 2016

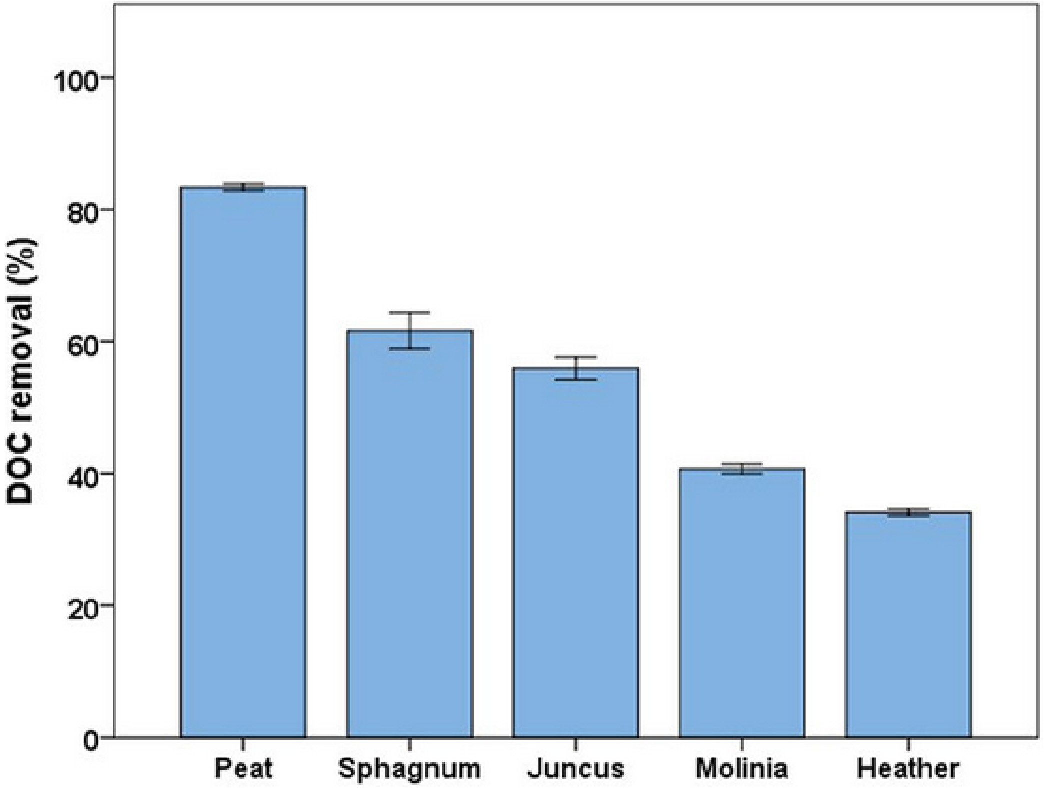
Implications for water treatment

- Taste, odour, colour
- Microbial growth
- Coagulant demand, sludge production
- Filter run times
- Disinfectant demand, disinfection by-products (DBPs)



Influence on coagulation

Figure 1: DOC removal by coagulation for different peatland sources.



Error bars at one standard error (n = 3).

Ritson et al. 2016

Energy and chemical demand

Table 6 Overall C balance (all values shown in t CO_2-eq $year^{-1}$) due to processes associated with organic C removal for each of the WTWs studied, taking account of energy and chemical use, GHG emissions during water treatment and C removal in treatment sludge

Site	Electricity consumption	Production of chemicals	CO_2 degassed during treatment	C removed in sludge	Losses from sludge (as CO_2, CH_4 and DOC)	Net CO_2-eq emission
A	941.3	268.1	4.3	−397.6	64.3	880.4
B	2880.0	425.7	9.7	−605.2	278.7	2988.9
C	1266.9	174.2	93.5	−40.3	126.4	1620.7
D	85.4	248.1	N/A	−8.9	3.9	328.5

Jones et al 2015

- Chemical demand small in comparison to energy demand
- If coagulation can cope, only small increases
- Around 14.5% increase in total embodied energy in peak DOC events (Santana et al. 2014)
- Change in water quality envelope- If new treatment processes required could be large increase in energy/chemical demand

- Possibility of C sequestration via sludge

Likely impacts and responses

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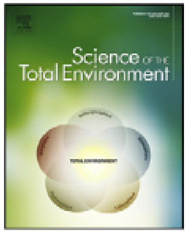


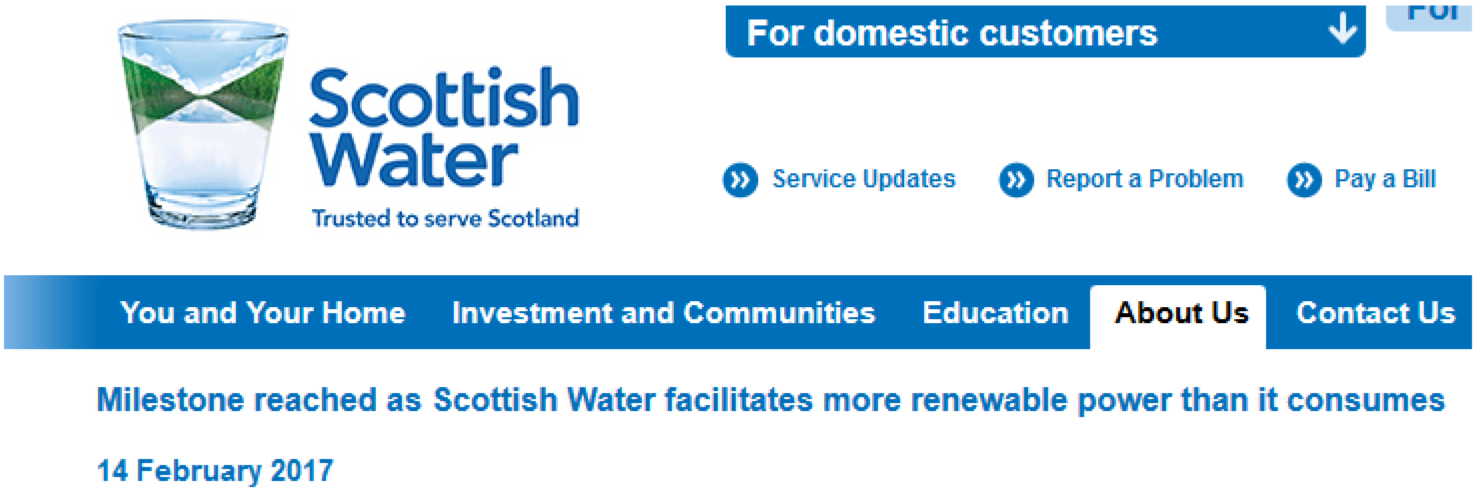
Review

The impact of climate change on the treatability of dissolved organic matter (DOM) in upland water supplies: A UK perspective

J.P. Ritson [a,b,*], N.J.D. Graham [b], M.R. Templeton [b], J.M. Clark [c], R. Gough [d], C. Freeman [d]

[a] *Grantham Institute for Climate Change, Imperial College London, South Kensington, London SW7 2AZ, UK*
[b] *Department of Civil and Environmental Engineering, Imperial College London, South Kensington, London, SW7 2AZ, UK*
[c] *Walker Institute for Climate Systems Research and Soil Research Centre, Geography and Environmental Science, School of Human and Environmental Sciences, University of Reading, Whiteknights, Reading, RG6 6DW, UK*
[d] *Wolfson Carbon Capture Laboratory, School of Biological Sciences, Bangor University, Bangor, Gwynedd, LL57 2UW, UK*

The future?



- One of the largest consumers of electricity in Scotland
- Energy efficiency, generating and hosting private investment
- 29 hydro turbines, 24 PV sites, 18 wind turbines, 2 CHP plants
- 420 GW hours in private wind turbines
- Overall £7 million in annual savings

Conclusions

- Interaction between peatland management for food, sport shooting, tourism and carbon in water
- Restoration of peatlands can improve many ecosystem services
- Carbon in water means higher treatment costs and energy usage
- Not covered: pesticides, nutrients