



CEE review 08-012

HOW DO DRAINING AND RE-WETTING AFFECT CARBON STORES AND GREENHOUSE GAS FLUXES IN PEATLAND SOILS?

Systematic Review Protocol

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1. BACKGROUND

Peat and peatlands are composed of partly decomposed plant material deposited under saturated soil conditions. Peatland is a generic term including all types of peat-covered terrain and many peatlands are a complex of swamps, bogs, and fens, sometimes called a "mire complex" (NWWG 1988)

Global estimates of peatlands land surface cover vary between 2-5% yet they contain between 30-50% of the world's soil carbon store; as much carbon as is held in the atmosphere (Gronlund et al. 2006; Lavoie et al. 2005; Treat et al. 2006). While net accumulation of carbon is relatively low (Vitt et al. 2000), they represent a long term store of carbon when compared with mineral soils that have relatively high turnover and oxidation rates (Yu et al. 2001). Moreover, losses of carbon from peatlands tend to be in the form of highly radiatively active methane (CH₄), as well as carbon dioxide (CO₂) (Moore & Knowles 1989; Moore & Roulet 1993). Therefore, peatlands may become significant sources of atmospheric carbon under a changing climate (Yu et al. 2001).

Although peatland's contribution to long-term fluctuations in these atmospheric gases has been a matter of considerable debate (MacDonald et al. 2006), there is some evidence to suggest that increasing temperature increases the release rate of carbon from soils (Trumbore & Harden 1997), as well as through soil thaw in northern ecosystems (Tokida et al. 2007). Also, hydrological changes play an important role in regulating peatland dynamics, both in terms of the total flux and in terms of the nature (CH₄ vs. CO₂) of that flux (Moore & Knowles 1989; Siegel et al. 1995). For example, a lower water table caused by increased evapotranspiration, altered precipitation, and increased frequency of droughts, along with increased atmospheric temperature, may decrease soil CH₄ and increase CO₂ emissions from the peat surface (Trettin et al. 2006). Also, nitrous oxide emissions in wetlands can be erratic depending on the type of wetland, management and redox potential (Regina et al. 1999; Yu et al. 2008)

Peat soils have traditionally been managed in a number of different ways; such as drainage for forestry production (Gustavsen et al. 1998) and extraction of peat for use as fuel or for use in horticulture (Charman & Warner 2002). While direct measures of changes in peat carbon pool following water table drawdown are rare, both decreases (Sakovets & Germanova 1992) and increases (Minkkinen & Laine 1998) have been reported. Also, drier peat lands increase the risk of peat fires, further altering the carbon balance (Charman & Warner 2002).

Drained peat lands commonly undergo restoration attempts by rewetting, often resulting in reduced CO₂ efflux (Komulainen et al. 1999), but alternatively increasing CH₄ emissions as a result of longer hydroperiods near the soil surface (Komulainen et al. 1998). This review will synthesise the available literature regarding long term change in carbon stores and greenhouse gas flux in peatlands, in response to changing flooding and drying regimes, either as a direct result of environmental management or in comparisons of areas with naturally different water tables in the same region over long periods of time.

2. OBJECTIVE OF THE REVIEW

2.1 Primary question

How do draining and re-wetting affect carbon stores and greenhouse gas fluxes in peat soils?

The question is composed of the following components:

Subject: Carbon and greenhouse gasses in peat soils

Intervention: Draining and re-wetting / cessation of draining, or areas in the same region with different long-term hydrological regimes.

Outcome: Change (storage or release) in amount of carbon or greenhouse gas flux.

Comparator: Control (with no intervention) or before-after studies or comparisons of areas with different hydrological regimes over long periods of time, i.e. not short-term or seasonal hydrological changes.

3. METHODS

This review is part of a collaboration between Environment Agency Wales (EAW) and the CEBC which aims to produce systematic reviews to inform EAW's Climate Change Strategy. The review question has been formulated following consultation with the EAW's policy group through a workshop held in April 2008. Question formulation was further informed by discussions with staff at Bangor and Aberystwyth Universities.

3.1 Search strategy

The search aims to capture an unbiased and comprehensive sample of the literature relevant to the question, whether published or unpublished. Different sources of information will be searched in order to maximise the coverage of the search.

3.1.1. Search terms

Combinations of the following carbon and afforestation search terms (where * denotes a wild card) will be applied to these databases:

Habitat search terms

Peat*
Bog*
Muskeg
Pocosin*
Quag*
Mire

Slough
Aapa*
Turvesuo
Tourbe
Tourbière*
Suo
Fen
Torfmoor
Niedermoortorf
Hochmoortorf
Palsa
Swamp
Carr
Mor
Sedge
Muck

Outcome search terms

Carbon
“Greenhouse gas*”
“Green-house gas*”
“GHG*”
Methane
“Organic matter”
“Organic content”
CO₂
CH₄
N₂O
Nitrous Oxide
DOM
DOC
SOM

Intervention search terms

Flood*
Drain*
Restor*
Grip block*
Rewet*
Re-wet”
Plough*
Ditch*
Drought

As all databases and websites vary in the way they handle complex search strings and the use of Boolean operators, the exact search terms used will be tabulated and recorded in the appendix of the review.

3.1.2. Databases

The search aims to include the following online databases which cover the breadth and depth of available literature on the topic:

- 1) ISI Web of Knowledge (inc. ISI Web of Science and ISI Proceedings)
- 2) Science Direct
- 3) Directory of Open Access Journals
- 4) Copac
- 5) Index to Theses Online
- 6) Agricola
- 7) CAB Abstracts
- 8) ConservationEvidence.com
- 9) CSA Illumina

No time, language or document type restrictions will be applied. Where possible references retrieved from the computerised databases will be exported into a bibliographic software package (Endnote 9) and duplicates removed prior to assessment of relevance using inclusion criteria (Section 3.2).

3.1.3. Websites

An Internet search will also be performed using meta-search engines and recommended sites:

<http://www.alltheweb.com>
<http://www.dogpile.com>
<http://www.google.com>
<http://scholar.google.com>
<http://www.Scirus> (All journal and web sources)
<http://data.esa.org/>

The search will be limited to Word and/or PDF documents where this can be separated and the first 50 hits will be examined for appropriate data which will be retrieved (Section 3.2.).

3.1.4 Specialist sources

Websites of relevant specialist organisations, listed below, will also be searched. Bibliographies of included material will be searched for relevant references. Authors of relevant articles will also be contacted for further recommendations, and for provision of any unpublished material or missing data. Links pages of websites will be followed to look for relevant organisations that may have been missed by these searches.

Agriculture and Agri Foods Canada
Agri-Food and Biosciences Institute
Alterra
British Association for Shooting and Conservation

British Ecological Society
Centre for Ecology and Hydrology
Countryside Council for Wales
Department for the Environment, Food and Rural Affairs
Dŵr Cymru / Welsh Water
Environment Agency
Environment Canada
Environmental Protection Agency
Environment Protection Agency Ireland
EHS –Northern Ireland Environment Agency
European Commission Joint Research Centre
European Environment Agency
Finnish Peatland Society
Farmers Unions - UK
Finland's environmental administration (www.ymparisto.fi/)
Food and Agriculture Organization of the United Nations
Forest Research
Forestry Commission
Global Environment Centre
Greenpeace
Intergovernmental Panel for Climate Change
International Association for the Study of the Commons
International Mire Conservation Group
International Union for Conservation of Nature
International Peat Society
Irish Agriculture and Food Development Authority (Teagasc)
Irish Peatland Conservation Council
Joint Nature Conservation Committee
Macaulay Land Use Research Institute
Ministry of Natural Resources of the Russian Federation
Moorland Association
Moors for the Future
National Council for Forest Research and Development (COFORD)
National Parks
National Soil Resources Institute
National Trust
Natural England
Natural Resources Canada
Peat-Portal.net
Plantlife UK
RAMSAR
Research Councils UK
Royal Society for the Protection of Birds
Russian Guild of Ecologists (www.ecoguild.ru)
Russian Regional Environmental Centre (www.rusrec.ru/en)
Severn Trent Water
Scottish Agricultural College
Scottish Executive
Scottish Environment Protection Agency
Scottish Natural Heritage

Society for Ecological Restoration
Society for Wetlands Scientists
Tyndall Centre for Climate Change Research
UK Climate Impacts Programme
UK Universities
United Nations Environment Programme
United States Environment Protection Agency
United Utilities
Welsh Assembly Government
Wetlands International
Wildfowl and Wetlands Trust
Wildlife Trusts UK
World Wildlife Fund (organised by country)
Yorkshire Water

3.2 Study inclusion criteria

Studies retained in the Endnote database by the above search strategy will be subject to a three stage process to identify the most relevant articles for the review question. The aim of this process is to systematically remove studies that are not relevant or do not contain relevant information or data. At each stage, if there is insufficient information to exclude a study it will be retained until the next stage.

In the first instance, the inclusion criteria, which are identified below, will be applied to title only in order to remove spurious citations. Articles remaining after this filter will be filtered on viewing abstract and then full text.

To assess and limit the effects of between-reviewer differences in determining relevance, two reviewers will apply the inclusion criteria to at least 200 or 20% of articles, whichever is the greater, at the start of title and abstract filter. The kappa statistic (Edwards et al. 1985) will be calculated, which measures the level of agreement between reviewers. If kappa is less than 0.6, the reviewers will discuss the discrepancies and clarify the interpretation of the inclusion criteria. This may entail a modification in the criteria specification. After this discussion, one reviewer will apply the inclusion criteria to the rest of the citations.

To reduce duplication of effort web searches will be performed after inclusion at full text of primary literature from databases. The first 50 hits from web searches will be filtered initially with the inclusion criteria on the title and abstract of articles (or introduction section if an abstract is not available), and then at full text. URLs for hits deemed relevant at title and abstract will be maintained within an Excel spreadsheet, and subsequently viewed at full text.

Each article must pass each of the following criteria in order to be included after each filter. However, on cases of uncertainty, the reviewer will tend towards inclusion.

- **Relevant subject(s):** Carbon in any form, or greenhouse gasses, held in, released from, or sequestered by peat or peat related soils

- **Types of intervention:** Long-term re-wetting or draining of peat or peat related soils. Natural experiments comparing areas of peat or peat related soils in the same region with different long term (not seasonal or sporadic) hydrology.
- **Types of comparator:** Control or no intervention or before after comparisons
- **Types of outcome:** Amount of carbon or greenhouse gas stored in or released from soils
- **Types of study:** Any primary study comparing measures of carbon or greenhouse gas storage or release from peat or peat related soils in relation to flooding or draining.

3.3 Study quality assessment

Before data extraction (section 3.4) study quality assessment is required to add quality co-variables to the analyses. Well-conducted studies of high quality have less potential for bias than their poorer counterparts. Reviewers will assess the methodologies used by all articles accepted at full text.

Study quality will be scored according to a hierarchy of evidence adapted from systematic review guidelines used in medicine and public health (Stevens & Milne 1997) and conservation (Pullin & Knight 2001); e.g. a randomised control trial would be weighed higher than a site comparison study. A second reviewer will examine a random subset of at least 25% of the selected studies to assess repeatability of study quality. Disagreement regarding study quality will be resolved by consensus, or following assessment by a third reviewer. The study quality assessment methodology will be further developed once the articles included in the review have been identified.

3.4 Data extraction strategy

The availability of data will not be known until after applying the inclusion criteria. Where possible, data will be extracted from each article and recorded in a spreadsheet. Data to be extracted will include the data on the outcomes, methodology and other factors that have been identified as reasons for heterogeneity in outcome (effect modifiers). **Potential reasons for heterogeneity are:**

Time since intervention, history of peatland, magnitude of change in water table - in relation to starting point, measurement method, tree and shrub growth, fertiliser application, type of peat (e.g. minerotrophic and ombrotrophic).

Data extraction forms will be piloted on a purposive sample of the articles, to represent the range of articles available, and amended if necessary to improve repeatability and efficiency. Missing data (e.g. sample size or variance) will be calculated or inferred where possible from the summary statistics presented, or the authors contacted.

3.5 Data synthesis

If extracted data are suitable for quantitative synthesis, we will aim to calculate effect sizes and carry out a meta-analysis. Sensitivity analysis will be run to explore the effects of including studies with different designs and methodological quality. Variation in effect sizes between studies will be explored using *a priori* reasons for heterogeneity.

If insufficient data are extracted or data are mainly of low methodological quality (i.e. without a comparator), we will summarise the outcomes of studies in tables.

4. POTENTIAL CONFLICTS OF INTEREST AND SOURCES OF SUPPORT

None identified. The project is funded by the Natural Environment Research Committee UK (NERC).

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