

**CEE REVIEW 11-010**

**Evaluating effects of management on greenhouse gas fluxes  
and carbon balances in boreo-temperate lowland peatland  
systems**

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Keywords:

## 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)

Lowland peat soils occupy a relatively small proportion of the overall peatland area in England and Wales, but store large amounts of carbon (C) and are subject to disproportionately high levels of land-use pressure. To date, most measurements of C and greenhouse gas (GHG) fluxes from UK peatlands have been made within upland blanket bogs, and it is doubtful whether the data obtained from these studies can be extrapolated to lowland systems. The difficulty of quantifying C and GHG emissions for lowland peats is increased by their greater heterogeneity in terms of both typology and management, as well as their fragmented nature across England and Wales. Because of their importance for a wide range of ecosystem services (notably provisioning services, but also cultural services such as access to natural landscapes in otherwise often highly developed regions, and regulating services such as flood control in some areas; Bonn et al., 2009), the role of lowland peats in climate regulation must be weighed against these other ecosystem services to enable appropriate management decisions.

Recent reviews of UK peatland C/GHG fluxes and measurements for Department for the Environment, Food and Rural Affairs (Defra) and Joint Nature Conservation Committee (JNCC), led (and co-authored) by members of this consortium (Baird et al., 2009; Worrall et al., 2011; Evans et al., 2011) have highlighted both the high degree of uncertainty in GHG flux estimates for lowland peats (in particular fens) and their high relative importance in terms of overall C and GHG emissions from UK peatlands. Worrall et al. (2011) estimated that around 54% of total GHG emissions from UK peatlands originate from English lowland peats. On this basis, the assessment by Evans et al. (2011) suggested that existing studies on sites in lowland areas should be augmented in order to provide full C/GHG budgets, and that new measurement sites should be established in fens, particularly in areas under intensive agriculture, for which no existing flux measurement sites could be identified. A clear distinction was made in this assessment between emissions from sites undergoing a transition in land-use/management (which may lead, for example, to a short-term pulse of methane emission), and emissions from sites under stable long-term management.

The systematic review will incorporate both peer-reviewed and 'grey' literature (e.g. agency reports), and will include both UK and international studies; this broad approach is considered necessary in order to provide a sufficient number of studies to support statistical analysis. However, the studies used will be rigorously screened based on typological factors, to ensure that only peatland types, climatic conditions and management practices considered sufficiently relevant to the UK situation will be included. The systematic review will provide a meta-analysis of the magnitude of each component of the C and GHG budget (i.e. CO<sub>2</sub> exchange, CH<sub>4</sub> emission, N<sub>2</sub>O emission, dissolved and particulate C loss) as a function of peat type and management, to the extent that existing literature allows an assessment to be made. The analysis will also provide an indication of uncertainty ranges and current

weaknesses in the evidence base. This review will utilise and make reference to the recent meta-analysis (including upland and lowland peats) undertaken by Worrall et al. (2011).

## 2. OBJECTIVE OF THE REVIEW

### 2.1 Primary question

How do greenhouse gas and carbon fluxes of boreo-temperate lowland peatland systems alter under different land management?

The question has the following components:

**Population:** Boreo-temperate lowland peat systems.

**Exposure:** Areas with different long-term hydrological regimes.

**Intervention:** Draining and re-wetting / cessation of draining, extraction, conversion to agricultural production, agricultural or forestry practice.

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

**Outcome:** Net change (sequestration or release) in carbon or greenhouse gas balance.

## 3. METHODS

This review forms an initial stage of a Defra funded project to evaluate emissions and storage of carbon and greenhouse gasses and as such, has developed the primary research question from the research requirements stipulated by Defra.

### 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 search terms (where \* denotes a wild card that may represent zero or more characters and \$ represents zero or one character only) will be applied to these databases:

#### Habitat search terms

Aapa*	Mor	Sedge
Bog*	Muck	Slough
Carr	Muskeg	Suo
Fen\$	Niedermoortorf	Swamp\$
Fenland	Palsa	Torfmoor
Histosol*	Peat*	Tourbe
Hochmoortorf	Pocosin*	Tourbière*
Mire	Quag*	Turvesuo

### Outcome search terms

Accret*	Erosion	“Organic content”
Accumulation	“GHG*”	“Organic matter”
Carbon	“Green\$house gas*”	Shrink*
CH <sub>4</sub>	Methane	SOM
CO <sub>2</sub>	N <sub>2</sub> O	Subside*
Depth	Nitrous Oxide	Wastage
DOC		
DOM		

### Intervention search terms

Afforest*	Fertili*	Plow*
Arable	Flood*	Re\$veg*
Cut\$over	Forest*	Re\$wet*
Cutt*	Graz*	Restor*
Ditch*	“Grip block*”	Till*
Drain*	Pastor*	Turf\$strip*
Drought	Pastur*	
Extract*	Plough*	

As all databases and websites vary in the way they handle complex search strings and the use of Boolean operators, the exact search strings 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) CSA Illumina
- 9) Scopus

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 X3) and duplicates removed prior to assessment of relevance using inclusion criteria (Section 3.2).

### 3.1.3 Search engines

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

<http://scholar.google.com>

<http://www.Scirus> (All journal and web sources)

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  
Centre for Ecology and Hydrology  
Countryside Council for Wales  
Department of Energy and Climate Change  
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/](http://www.ymparisto.fi/))  
Finnish Environment Institute SYKE  
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  
Royal Society for the Protection of Birds  
Russian Guild of Ecologists ([www.ecoguild.ru](http://www.ecoguild.ru))  
Russian Regional Environmental Centre ([www.rusrec.ru/en](http://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  
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 100 or 10% 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, in cases of uncertainty, the reviewer will tend towards inclusion.

- **Relevant population(s):** Lowland peatland systems in temperate and boreal regions.
- **Types of exposure/intervention:** Long-term re-wetting or draining of peat or peat related soils. Agricultural conversion of peat or peat-related soils. Afforestation of peat or peat-related soils. Agricultural or forestry management on 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, sequestered or released from soils. Other physical measures of carbon loss or gain from peat or peat-related soils, e.g. erosion, efflux of DOC, subsidence and/or accumulation.
- **Types of study:** Any primary study including measures of carbon or greenhouse gas storage or release from peat or peat-related soils.

### 3.3 Study quality assessment

Individual studies will be critically appraised and their study design recorded by a single reviewer. Most studies are expected to be site comparisons or within-site plot designs. 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:**

Peat or peat-related soil type (e.g. bog and fen peats), depth of drainage, vegetation, annual mean temperature.

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 Declared. This review is funded by the UK Department for Environment, Food and Rural Affairs. The systematic review is led by CEBC but significant contributions in the development of this protocol have been made by CEH Bangor staff who are coordinating the entire project.

## **5. REFERENCES**

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