Institution: Imperial College London

Unit of Assessment: 5 Biological Sciences

Title of case study: 7 - Demonstrating the vulnerability of upland peatland ecosystems to climate change

1. Summary of the impact (indicative maximum 100 words)

UK upland peatlands constitute the world's greatest area of blanket bog, an endangered biome, and are the UK's largest natural habitat, carbon store, and pure water resource. The multi-institutional project "Climate Change Impacts on UK Upland Soils" identified models to predict the response of blanket bog to climatic and environmental changes and drew the attention of diverse stakeholders to the challenge of conserving these peatlands in a warming climate. The results have had impact on public policy and the environment by stimulating and informing debate. Since 2011, they have been (i) used by local and national agencies such as the Forestry Commission, (ii) included in the UK Climate Change Risk Assessment, (iii) cited by the International Union for Conservation of Nature (IUCN) Commission of Enquiry on Peatlands, and (iv) used in evidence for policy making by Defra and the Scottish Parliament.

2. Underpinning research (indicative maximum 500 words)

Statistical and process-based models were used to predict the distribution of blanket peat in Britain today, and to project its future distribution under climate change scenarios obtained from the UK Climate Impacts Programme. All models could predict accurately the present distribution and all agreed that the area suitable for blanket peat to form will shrink to a core area in NW Britain, the degree of shrinkage depending on the severity of the scenario. High-end climate change scenarios reduce this core area to a limited region of NW Scotland, whereas low-end scenarios are less drastic but go in the same direction. Modelling also showed, however, that extant peatland areas could continue to exist and function – if current pressures (tending to promote erosion) could be removed or reversed.

The initial funding for the research was in the form of a project, "*Climate Change Impacts on UK Upland (peatland) Soils*", jointly funded by the Environment Agency and the NERC research programme Quantifying and Understanding the Earth System (QUEST). This project was initially led from the University of Bristol by the QUEST Science and Policy Officer, Joanna House, supervised by the QUEST Leader, Colin Prentice. Work was carried out during this initial phase by Angela Gallego-Sala (then a postdoctoral scientist at Bristol) and Joanna Clark (then a Ph.D. student at Bangor University). The project's goals were to characterize and model the distribution of upland peatlands and similar ecosystems nationally and globally, to assess the consequences of climate change for their distribution and condition, and to assess (in consultation with national and regional stakeholders) the implications for policies regarding the use and conservation of peatland landscapes.

By the start of 2010, both Prentice and Clark had moved to Imperial College London. The project's publications, and the greater part of its impact, date from 2010 and onwards. The research formed the subject of a special issue of the journal Climate Research [1, 2, 3], a paper in Nature Climate Change [4], and a paper in preparation for Nature Geoscience. The research contributing to [1, 2, 3] was completed, written up and published by Clark during her time at Imperial. The global analysis published in [4], and subsequent research, have been led by Colin Prentice at Imperial. Research outcomes can be summarized as follows:

i. The area suitable for the initiation of blanket bog in the UK is projected to shrink, but existing areas of blanket bog could persist is appropriately conserved.
ii. Statistical models constructed in several different ways can accurately predict the present distribution of blanket bog in the UK. They agree on the magnitude and direction of change in the area suitable for the initiation of blanket bog, i.e. a progressive shrinkage towards a core area in NW Britain, the degree of shrinkage dependent on the extent of climate change.
iii. A simple process-based model (based on known requirements of Sphagnum, the dominant

type of moss that composes blanket peat, for cool summers and year-round wet conditions) makes similar predictions to the statistical models.

iv. This same process-based model, initially developed for the UK, also predicts with remarkable accuracy the highly disjunct global distribution of the blanket bog biome. With climate change, this distribution is projected to shrink in many regions, although some potential new regions appear.

The paper in preparation confirms (using palaeoclimate modelling and palaeoecological evidence) that the distribution of blanket bog in the British Isles has been closely controlled by climate changes over the past 12,000 years. This is an important finding because there is a residual belief, based on work published in the 1970s, that blanket peats extended after about 6,000 years ago because of human deforestation. This can now be rejected. Policy should not now be based on the assumption that these peatlands are anthropogenic.

The key researchers contributing to this work at Imperial College were Professor I. Colin Prentice, Professor of Climate and Biosphere Interactions at Imperial College from 1 Jan 2010 (now AXA Professor of Biosphere and Climate Impacts, since 1 Mar 2013) and Dr Joanna M. Clark, a full time Grantham Institute postdoctoral fellow from Jan 2010. Dr Clark left Imperial to take up a lectureship at Reading University in Oct 2010. Publications [1-3] are all from her time at Imperial.

The key external partner and principal funder of the initial project was the Environment Agency. Other stakeholders who were consulted and attended meetings included the Countryside Council for Wales, Defra's Soils Policy Team, Forestry Commission, Macaulay Institute, Moors for the Future, Natural England, the North Pennine Area of Outstanding Natural Beauty, Royal Society for the Protection of Birds, United Utilities and the Welsh Assembly Government.

3. References to the research (* References that best indicate quality of underpinning research)

[1] * J.M. Clark, M.F. Billett, M. Coyle, S. Croft, S. Daniels, C.D. Evans, M. Evans, C. Freeman, A.V. Gallego-Sala, A. Heinemeyer, J.I. House, D.T. Monteith, D. Nayak, H.G. Orr, I.C. Prentice, R. Rose, J. Rowson, J.U. Smith, P. Smith, Y.M. Tun, E. Vanguelova, F. Wetterhall & F. Worrall (2010), '*Model inter-comparison between statistical and dynamic model assessments of the long-term stability of blanket peat in Great Britain (1940-2099)'*, Climate Research, 45, 227-248 (2010). DOI.

[2] * J.M. Clark, A. Gallego-Sala, T. Allott, S. Chapman, T. Farewell, C. Freeman, J. House, H.G. Orr, I.C. Prentice and P. Smith, '*Assessing the vulnerability of blanket peat to climate change using an ensemble of statistical bioclimatic envelope models'*, Climate Research, 45, 131-150 (2010). DOI.

[3] * A.V. Gallego-Sala, J.M. Clark, J.I. House, H.G. Orr, I.C. Prentice, P. Smith, T. Farewell and S.J. Chapman, '*Bioclimatic envelope model of climate change impacts on blanket peatland distribution in Great Britain*', Climate Research 45, 151-162 (2010). DOI.

[4] A. Gallego-Sala & I.C. Prentice, '*Blanket peat biome endangered by climate change'*, Nature Climate Change, 3, 152-155 (2013). DOI.

4. Details of the impact (indicative maximum 750 words)

How to conserve and restore peatlands is already a major and controversial issue for the relevant UK and devolved authorities, while information about climate change impacts (on top of all the other pressures) has previously been virtually non-existent.

Before the start of the "*Climate Change Impacts on UK Upland (peatland) Soils*" project, many national and local agencies were aware of the importance of peatlands to the UK carbon balance, water supplies and biodiversity, and the tangible current threats to the integrity of peatlands. But there was very little awareness of the potential for climate change to add to these threats. The project changed that situation radically (see source [A]). Information about potential climate change impacts on UK upland peatlands is now well known to the relevant stakeholders as a direct result of this project. The relevant transfer of knowledge began via knowledge exchange meetings held in 2009, and continues today.

The specific benefits of the research include: knowledge of where peatlands are not threatened by

climate change; and knowledge of where conservation measures are most important to preserve the integrity of peatlands, both nationally [1, 2, 3] and worldwide [4]. There has been impact through various public bodies including the following detailed below.

The peatlands climate change project produced a policy briefing [A], which covered biodiversity, water, greenhouse gas emissions and land management aspects. For each of these, it summarised the likely effects of climate change and recommended actions to mitigate the changes. **DEFRA** used this briefing in its **UK Climate Change Risk Assessment**, "Climate Change Risk Assessment for the Biodiversity and Ecosystem Services sector" [B]. This report presents research completed as part of the "*UK Climate Change Risk Assessment (CCRA) for a selected group of risks in the Biodiversity and Ecosystem Services sector*" [B]. Paper [2] is cited several times and forms the principal evidence base for the assessment of climate change impacts on blanket bogs.

The **IUCN** conducted a **'Commission of Inquiry on Peatlands'** which was published in Oct 2011 [C, D]. The report represented the "*culmination of 18 months of focused collaboration between peatland experts from land management, science and policy from across the UK, and revealed the enormous importance of peatlands for people and wildlife*" [D]. The Inquiry "*identified a clear strategy for action to bring peatlands back from the brink, and point[ed] the way forward to avoid the social and environmental costs of further deterioration*" [D]. The assessment focused on blanket bog and raised bog peatlands which represent over 95% of all UK peatland habitat and which offer an opportunity to make early and substantial progress in delivering a combination of economic, social and biodiversity gains. The inquiry cited [2], as well as other related Imperial College publications by Clark (DOIs: 10.1016/j.scitotenv.2010.02.046, 10.3354/cr00923, 10.3354/cr00982), concluding that the UK needs a policy to conserve peatland carbon stores [C, D].

In June 2012 an international conference, 'Investing in Peatlands – Demonstrating Success', was held at Bangor University which included a broad cross-section of academics and stakeholders concerned with peatlands [E]. The conference was sponsored jointly by the British Ecological Society and the IUCN's UK Peatland Programme. It coincided with the release of a report, **'Opportunities for UK Business that Value and/or Protect Nature's Services'**, which was commissioned for the **Ecosystem Markets Task Force** by the **Valuing Nature Network** and was financed by Defra and NERC [F]. The report outlined the business case for valuing and protecting nature's services and highlighted a series of drivers that are leading businesses to increasingly consider and manage impacts on ecosystems and to look for business opportunities while they do so. The report ranked a carbon funding proposal for peatlands as the UK's top ranked business opportunity from the natural environment [F].

Forest Research, the research agency of the **Forestry Commission** published 'A Strategic Assessment of the Afforested Peat Resource in Wales' in October 2012 [G]. The report assessed the distribution of the Welsh peatlands and provided an overview of the likely factors impacting peat formation and afforested peat restoration, and management of the biodiversity, hydrology and greenhouse gas benefits. Papers [1] and [2] are cited in the report numerous times in relation to the climate change impacts on peat distribution and the viability of sites for restoration ([G], sections 4 and 5.2.6).

The work [2, 3] has been cited in a briefing report by the **Scottish Parliament**, intended as background to policy making for peatlands [H]. The following is an excerpt from this Scottish Parliament report ('*Box 5 The effect of climate change on Scottish peatlands'*, p22), where the references cited are [3] and [2] respectively: "*Peatlands are vulnerable to climate change. As temperatures increase, the areas suitable for peatlands in Scotland could reduce with the south and east of their range likely to be under greatest stress* [3]*. High water tables in peatlands are maintained by high rates of precipitation and low evapotranspiration. Peatlands are particularly sensitive to changing weather patterns for the following reasons:*

- *Higher temperatures lead to drying out of peat, falling water table, cracking and erosion*
- *Increased likelihood of wildfire, leading to significant vegetation loss*

- *More heavy rainfall events are likely to cause more erosion on damaged peatlands*

However, specific changes to particular peatlands are very difficult to predict. Climate model predictions apply over large regions and their implications are often difficult to interpret at small scales. Warming is expected to have the most significant effect on peatlands that are already degraded and under pressure – pristine bogs may be more resilient to small changes in temperature [2]" [H].

The project has generated favourable commentary and further requests for access to the model outputs by stakeholders including Forest Research, the James Hutton Institute, the Peatscapes project in the North Pennines and Scottish Natural Heritage. Some examples (extracted from e-mails to Jo House) are:

From Judith Stuart, Soils Policy Team, **DEFRA**:
"*I thought the [Climate Research] special issue was very useful. …. there are so many interesting and relevant papers….. I have been weaving the information into policy work on peat. So if influencing policy is a measure of success ...*"

From Iain Brown, **James Hutton Institute**, lead author of the UK Climate Change Risk Assessment for the biodiversity and ecosystem services sector:
"*Do you think it would be possible for us to use the information, particularly the headline bioclimate map, in the UK Climate Change Risk Assessment, appropriately referenced of course? In the Biodiversity & ESS sector I asked them to look at Blanket Bog as a key habitat under risk from climate change (we also have changes in soil organic carbon as another related risk). However the analysis on this currently in the CCRA is somewhat lacking and I disagree with its findings. Based upon work we have done previously…your method and findings are much more robust.*"

Continuing impacts are expected on two fronts: (a) ongoing policy shifts at the level of the UK and devolved administrations, recognizing the implications of climate change for policies concerning upland peatlands: and (b) increasing global recognition (by IUCN and other bodies) of the unique nature of the blanket bog biome, the potential restriction in its area due to climate change, and the importance of identifying and taking steps to conserve "refugial" areas of this biome.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[A] House, J., Clark, J., …, Prentice, C., et al., "*Vulnerability of peatland ecosystem services to climate change*", Environment Agency Report SC 070036 (2011). [Can be supplied on request.]
[B] "Climate Change Risk Assessment for the Biodiversity and Ecosystem Services sector", UK Climate Change Risk Assessment, Defra project code GA0204 Brown I., Ridder B., Alumbaugh P., Barnett C., Brooks A., Duffy L., Webbon C., Nash E., Townend I., Black H. and Hough R., (2012) (available here)
[C] IUCN Commission of Inquiry on Peatlands Final Report, http://www.iucn-uk-peatlandprogramme.org/resources/188 (archived here on 2/7/13)
[D] IUCN UK Committee, Peatland Programme, 'Commission of Inquiry on Peatlands', Oct 2011 (available here)
[E] Investing in Peatlands – Demonstrating Success, British Ecological Society, http://www.britishecologicalsociety.org/blog/2012/06/29/investing-in-peatlands-demonstrating-success/ (archived here on 3/7/13)
[F] Ecosystem Markets Task Force, Final Report, 14/6/12, http://www.valuing-nature.net/sites/default/files/EMTF-VNN%20study%20final%20report%20140612.pdf page 53 (archived here)
[G] Forestry Commission document, Oct 2012, http://www.forestry.gov.uk/fr/INFD-8Z7BSH (archived here)
[H] Scottish Parliament Information Centre (SPICe) briefing, 20/4/12, http://www.scottish.parliament.uk/ResearchBriefingsAndFactsheets/S4/SB_12-28.pdf (archived here)

Individual users/beneficiaries who could be contacted by the REF team to corroborate claims:
[I] Research Fellow, Environment Agency.