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Spatial statistics to estimate peat thickness using airborne radiometric data

A. Keaney *, J. McKinley, C. Graham, M. Robinson, A. Ruffell

School of Geography, Archaeology and Palaeoecology, Queen's University Belfast, Northern Ireland, United Kingdom

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ABSTRACT

Soil carbon stores are a major component of the annual returns required by EU governments to the Intergovernmental Panel on Climate Change. Peat has a high proportion of soil carbon due to the relatively high carbon density of peat and organic-rich soils. For this reason it has become increasingly important to measure and model soil carbon stores and changes in peat stocks to facilitate the management of carbon changes over time. The approach investigated in this research evaluates the use of airborne geophysical (radiometric) data to estimate peat thickness using the attenuation of bedrock geology radioactivity by superficial peat cover. Remotely sensed radiometric data are validated with ground peat depth measurements combined with non-invasive geophysical surveys. Two field-based case studies exemplify and validate the results. Variography and kriging are used to predict peat thickness from point measurements of peat depth and airborne radiometric data and provide an estimate of uncertainty in the predictions. Cokriging, by assessing the degree of spatial correlation between recent remote sensed geophysical monitoring and previous peat depth models, is used to examine changes in peat stocks over time. The significance of the coregionalisation is that the spatial cross correlation between the remote and ground based data can be used to update the model of peat depth. The result is that by integrating remotely sensed data with ground geophysics, the need is reduced for extensive ground-based monitoring and invasive peat depth measurements. The overall goal is to provide robust estimates of peat thickness to improve estimates of carbon stocks. The implications

* Corresponding author. Tel.: +44 2890973302.
E-mail address: a.keaney@qub.ac.uk (A. Keaney).

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from the research have a broader significance that promotes a reduction in the need for damaging onsite peat thickness measurement and an increase in the use of remote sensed data for carbon stock estimations.

1. Introduction

The Kyoto Protocol, an agreement within the United Nations' (UN) Framework Convention on Climate Change committed its Parties to internationally binding emission reduction targets (United Nations, 2008). The first commitment period started in 2008 included a reduction of emissions of greenhouse gases by 12.5% between 1990 and 2012. The Doha Amendment to the Kyoto Protocol, adopted in December 2012 (United Nations, 2012), endorsed the commitment to emission reduction targets. Soil carbon stores and changes within these stores are major components of the annual returns required by governments to the Intergovernmental Panel on Climate Change (IPCC). Peat has a high proportion of soil carbon due to the relatively high carbon density of peat and organic-rich soils. Therefore it has become increasingly important to measure and model soil carbon stocks and changes in peat stocks to facilitate the management of carbon changes over time. This is particularly important for Ireland (and other western European countries), where some 16% of the land surface is covered by peat bog. In Northern Ireland, the total amount of carbon stored in vegetation has been estimated to be 4.4 Mt compared to 386 Mt stored within soils such as peat (Cruickshank et al., 1998). Robust peat volume estimation is essential for accurate carbon stock calculation and the investigation of peat thickness, the focus of this research, forms an integral part of any calculation.

The importance of peatlands particularly in relation to conservation and restoration has been recognised for many years. Globally, this issue was highlighted at the IUCN World Conservation Congress, September 2012 in Jeju, South Korea and the IUCN One programme 2013–2016 includes the UK's peatland conservation and restoration projects along with countries including China, Russia, Germany and Australia. These initiatives highlight the crucial balance required between monitoring changes in peat and limiting the risk to a fragile peatland habitat. This paper presents research funded by the EU INTERREG IVA programme which investigates the use of spatial analysis techniques to quantify soil carbon.

In this paper we use remotely sensed radiometric data to estimate peat thickness validated with a limited number of ground peat depth measurements combined with non-invasive geophysical surveys. This reduces the need for extensive ground-based monitoring and invasive peat depth measurements. The approach involves the evaluation of the use of airborne geophysical (radiometric) data to investigate the relationship between reduced radioactivity signal and peat depth in peat covered areas. Geostatistical analysis, comprising variography, kriging and cokriging, is used to assess the relationship between recent remote sensed geophysical monitoring and previous historical peat depth modelling. Field-based case studies are used to validate the results. The overall goal is to provide robust estimates of peat thickness to improve estimates of carbon stocks.

2. Material and methods

2.1. Field site locations

Two case studies are used to validate the use of airborne geophysical data to investigate the relationship between reduced radioactivity signal and peat thickness. Irish peatland is divided into blanket peatland (approximately 85%) and raised peat bogs (approximately 15%; Tomlinson and Davidson, 2000). Raised bogs develop primarily in lowland areas ($<$200 m above Sea Level (SL); Wheeler and Shaw, 1995). Accumulating peat in fens becomes isolated from the groundwater supply and this process of accumulation gradually forms a dome of ombrogenous peat above the fen. Raised bogs display a distinct topography, with the steep margins to the main bog expanse. Blanket bogs typically form