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Selecting land-based mitigation practices to reduce GHG emissions from the rural land use sector: A case study of North East Scotland

Diana Feliciano[a,*], Colin Hunter[b], Bill Slee[c], Pete Smith[d]

[a] Aberdeen Centre for Environmental Sustainability, University of Aberdeen, The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH Scotland, UK
[b] School of Geography & Geosciences, Sustainable Development, Irvine Building, St Andrews, KY16 9AL Scotland, UK
[c] The James Hutton Institute, Craigiebuckler, Aberdeen, AB15 8QH Scotland, UK
[d] Institute of Biological and Environmental Sciences, School of Biological Sciences, University of Aberdeen, 23 St Machar Drive, Aberdeen, AB24 3UU Scotland, UK

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ABSTRACT

The Climate Change (Scotland) Act 2009 commits Scotland to reduce GHG emissions by at least 42% by 2020 and 80% by 2050, from 1990 levels. According to the Climate Change Delivery Plan, the desired emission reduction for the rural land use sector (agriculture and other land uses) is 21% compared to 1990, or 10% compared to 2006 levels. In 2006, in North East Scotland, gross greenhouse gas (GHG) emissions from rural land uses were about 1599 ktCO_2e. Thus, to achieve a 10% reduction in 2020 relative to 2006, emissions would have to decrease to about 1440 ktCO_2e. This study developed a methodology to help selecting land-based practices to mitigate GHG emissions at the regional level. The main criterion used was the "full" mitigation potential of each practice. A mix of methods was used to undertake this study, namely a literature review and quantitative estimates. The mitigation practice that offered greatest "full" mitigation potential ($\approx$66% reduction by 2020 relative to 2006) was woodland planting with Sitka spruce. Several barriers, such as economic, social, political and institutional, affect the uptake of mitigation practices in the region. Consequently the achieved mitigation potential of a practice may be lower than its "full" mitigation potential. Surveys and focus groups, with relevant stakeholders, need to be undertaken to assess the real area where mitigation practices can be implemented and the best way to overcome the barriers for their implementation.

1. Introduction

The rural land use sector is a net contributor of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions, and these are mainly influenced by land (e.g. soils, crops) and livestock management decisions. Carbon dioxide, CH_4 and N_2O are long-lasting gases in the atmosphere and contribute to global warming (IPCC, 2006). According to the Climate Change Delivery Plan (Scottish Government, 2009a), which establishes the GHG reduction targets for each sector of the Scottish economy, the rural land use sector needs to reduce its GHG emissions in 10% by 2020 from 2006 levels.[1] A previous study estimated that, in 2006, in North East Scotland, GHG emissions from agriculture were about 1565 ktCO_2e and from sporting land[2] and peatlands[3] about 34 ktCO_2e (Feliciano et al., 2013). To achieve the GHG emission reduction target established in the Climate Change Delivery Plan, mitigation practices have to be implemented in the rural land use sector, and these should focus on the main sources of emissions, i.e. agricultural activities.

Mitigation practices can abate GHG emissions through the sequestration of carbon in soil and plants, or by avoiding or reducing the release of GHGs. In the case of land-based mitigation practices, which are those implemented on arable land, grassland, peatland and moorland, emissions reduction can be achieved through land use change and land management change, i.e. change

* Corresponding author. Tel.: +44 (0) 1224 395 297; fax: +44 (0) 844 928 5429.
E-mail addresses: diana.feliciano@hutton.ac.uk (D. Feliciano), ch69@st-andrews.ac.uk (C. Hunter), bill.slee@hutton.ac.uk (B. Slee), pete.smith@abdn.ac.uk (P. Smith).

[1] Table 1, pp. 12, Climate Change Delivery Plan.

[2] Emissions from sporting land include emissions from burning of moorland habitats for the purpose of vegetation re-growth for livestock or red grouse, and emissions from wild deer. In Scotland, moorland is a semi-natural habitat usually found in upland areas characterized by low-growing ericaceous vegetation on acidic soils and which have often been managed by people for sheep, upland cattle, grouse and (in some areas) deer.

[3] Peatland is any wetland with peaty soils whether or not the natural vegetation remains where, peat is still being formed, and where land management is minimal.

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of management practices. In the case of livestock-based mitigation practices, the only possibility is the reduction of GHG emissions, through animal and manure management.

Many authors and studies have listed GHG mitigation practices in the rural land use sector for different climatic regions of the world (Smith et al., 2008), Europe (Smith et al., 2000a), the United Kingdom (UK) (Moran et al., 2008) and England (Radov et al., 2007). Smith et al. (2008), for example, grouped mitigation practices in cropland management (e.g. improved nutrient management, improved tillage), grazing land management and pasture improvement (e.g. optimised grazing intensity, species introduction), improved management of agricultural organic/peaty soils, restoration of degraded lands, livestock management (e.g. improving feeding practices), manure management and bioenergy production.

Each mitigation practice is associated with a technical mitigation potential which is the amount by which it is possible to reduce GHG emissions by implementing a practice that has already been demonstrated as technically feasible (IPCC, 2007). There are, however, barriers to the implementation of mitigation practices. According to Smith (2012), these include physical, biological, economic, social, political, institutional, educational, and market barriers. Since the implementation of mitigation practices is necessarily constrained by physical barriers, such as land availability, the technical mitigation potential can be renamed as "full" mitigation potential after these have been considered. Barriers to the implementation of mitigation practices might reduce the area where they can be implemented and consequently their "full" mitigation potential.

Mitigation practices should satisfy the requirements of 'additionality', 'permanence', 'lack of knowledge', and 'mechanism uncertainty'. To satisfy the 'additionality' requirement, the net reduction needs to be additional to what would have happened if the mitigation practices were not implemented (Smith et al., 2007). This requirement is important because several practices that increase soil carbon sequestration have been devised for other purposes than to mitigate climate change. Since these practices have been implemented, the relevant GHG emissions reduction would be considered in the baseline (Robbins, 2011). In the case of soil and above-ground carbon sequestration practices, the 'permanence' requirement has to be taken into account because they only promote carbon sequestration if they are maintained (Robbins, 2011). Finally, 'mechanism uncertainty' is related to the uncertainties about the complex biological and ecological processes involved in tracing gas emissions and carbon storage in agricultural systems (Smith et al., 2007). This reflects the need to 'get the science right and then act' Robbins (2011). Smith et al. (2007) also noted that when the processes of implementation of mitigation practices are not well known (lack of knowledge), farmers and other land managers are much more doubtful about implementing mitigation practices.

Previous studies have reviewed the technical mitigation potential in agriculture and agricultural soils (Freibauer et al., 2004; Smith et al., 1997, 1998, 2000a, 2000b, 2008), have examined options for mitigation of GHG emissions from agricultural activity (Radov et al., 2007; Prosser et al., 2008), and have developed marginal abatement cost curves for GHGs emissions from UK agriculture (Moran et al., 2010). None, however, have evaluated the mitigation potential of practices taking into account the unique characteristics of a particular region. According to Smith et al. (2007), rural land use systems are substantially variable between locations. McCarl et al. (2005) consider that multi-region studies are important to overcome this variability. This study aims to select suitable land-based mitigation practices for North East Scotland by analysing the barriers described by Smith (2012) and by taking into consideration the specificities of the region. Two of the three council areas covered by the North East Scotland (Aberdeenshire, Aberdeen City) are strongly committed to reducing their GHG emissions (SAC, 2008).

To select the most suitable mitigation practices for the region, the main stages undertaken were to:

1) Estimate the "full" mitigation potential of land-based mitigation practices in North East Scotland based on their technical mitigation potential and the area where these could be implemented;
2) Select land-based mitigation practices with the highest "full" mitigation potential, dismissing those which did not satisfy the requirements of 'additionality', 'permanence', 'lack of knowledge' and 'mechanism uncertainty';
3) Estimate the GHG emissions reduction that would be achieved if the selected mitigation practices were implemented;
4) Discuss the suitability of the selected mitigation practices, including identification of economic, social, political, institutional and educational barriers to implementation.

Whilst recognising the desirability of including livestock based emission reduction strategies, this paper focuses on the capacity of land management practices to reduce emissions. In practice, in selecting optimal strategies for emissions reduction there is a need to explore whether they lie within the management of livestock or the management of the land. Although the wider research project on which this paper is based considers livestock related emissions reduction, this paper follows Macleod et al. (2010) in considering land management alone.

In this study a methodology to select suitable mitigation practices to implement in the rural land use sector of a specific region is suggested. The steps followed can be readily adapted for other regions in the world.

2. Methodology

Mixed-methods were used to identify the most suitable land-based mitigation practices for the rural land use sector. According to Creswell and Clark (2007), mixed-methods combine the collection and analysis of both qualitative and quantitative data in a single study or series of studies. The main principle is that the joint use of quantitative and qualitative approaches provides scope for a better understanding of research problems than either approach alone (Creswell and Clark, 2007). In this study, a literature review was undertaken in order to identify land-based mitigation practices for rural land uses in Europe, the UK and Scotland and barriers to implementation. The technical mitigation potentials, and associated uncertainty ranges, of these practices were also collected from the literature. Official statistics were consulted in order to ascertain the maximum area where these mitigation practices could be implemented. Greenhouse gas emissions from rural land uses in North East Scotland for the period 2011–2020 were estimated through an extrapolation of GHG emissions between 1999 and 2010.

Barriers to implementation of a practice (e.g. economic, social, political, educational, market) are likely to reduce the maximum area where the mitigation practices could be implemented, and consequently, the "full" mitigation potential. The "full" mitigation potential was defined as a result of the multiplication of the technical mitigation potential (measured in tCO_2e ha^{-1} yr^{-1}) by the maximum area (in ha) where a practice could be hypothetically implemented.

Fig. 1 presents the relation between the three types of mitigation potential – technical, "full" and "reduced" mitigation potential.

In this study, the "full" mitigation potential of each land-based mitigation practice was first estimated. Then, practices with the