The scope of the land-based sector to mitigate climate change in North-east Scotland: opportunities and challenges with particular reference to the role of forests

Bill Slee*

Socio Economic and Geographical Sciences Group,
The James Hutton Institute,
Craigiebuckler, Aberdeen,
AB15 8QH, Scotland
E-mail: bill.slee@hutton.ac.uk
*Corresponding author

Diana Feliciano

Aberdeen Centre for Environmental Sustainability,
The James Hutton Institute,
University of Aberdeen,
Craigiebuckler, Aberdeen,
AB15 8QH, Scotland
E-mail: diana.feliciano@hutton.ac.uk

Maria Nijnik

Socio Economic and Geographical Sciences Group,
The James Hutton Institute,
Craigiebuckler, Aberdeen,
AB15 8QH, Scotland
E-mail: maria.nijnik@hutton.ac.uk

Guillaume Pajot

Brittany Regional Council,
Conseil Régional de Bretagne,
283 avenue du général Patton,
CS 21101, 35711 Rennes Cedex 7, France
E-mail: guillaume.pajot@region-bretagne.fr

Abstract: This paper reviews the scope for the rural land use sector to support emissions reduction with particular reference to the role of forestry. A bottom-up approach is adopted to explore the relative contribution of different land-based activities in the region and explore the Scottish policy context and the scope for emissions reduction through new tree planting. It is concluded that the institutional architecture is incomplete, in that although the Rural Development Programme supports afforestation, informal institutions, especially farmer antipathy, militate against afforestation. Ground-truthing indicates scope for major efficiency gains in emissions reduction if tradable solutions are pursued. There is scope for policy enhancement and, if land use sector carbon emissions were offset against farm-produced renewable energy and carbon emissions were taxed, a significant flow of money from low ground farms to the disadvantaged hill areas would be likely, as these areas have the greatest potential with respect to climate change mitigation.

Keywords: land use sector; forestry; climate change; carbon trading; ground truthing; Scotland.

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Biographical notes: Bill Slee is an experienced Researcher in the field of rural development and former Head of the Social Economic and Geographical Sciences Group (SEGS) which seeks to address major contemporary social and economic research challenges, such as natural resource governance, ecosystem services valuation, sustainable behaviours, rural community vibrancy, and wellbeing and socio-economic transitions in rural economies. He was previously a Senior Lecturer in the University of Aberdeen and Director and Research Professor of Rural Economy at the Countryside and Community Research Unit at the University of Gloucestershire, where he retains a visiting chair.

Diana Feliciano is a PhD student in Geography and Environment, registered at the University of Aberdeen and The James Hutton Institute and funded by Aberdeen Centre for Environmental Sustainability (ACES). Her first degree is in Forestry Engineering and she holds an MSc in Economics. She is currently working in her PhD which topic is: 'The contribution of rural land uses to greenhouse gas neutral regions'.

Maria Nijnik is a natural resource, ecological and climate change Economist who has worked at the Institute since 2002, after a period of postdoctoral research at the Free University, Amsterdam, and Wageningen University, in the Netherlands. She holds a PhD in Social Sciences from Wageningen University in cooperation with the University of Victoria in Canada. Also, she has post-graduate qualifications from the Mansholt Institute and the Netherlands Network of General and Quantitative Economics (NAKE), an MSc in Environmental Policy and Management (EPCEM) from the Network of Dutch Universities, and an MSc/Dipl. Engineer's degree with Distinction in forestry and wood-processing technology.

Guillaume Pajot is a Researcher with a background in forest and environmental economics. His PhD research concerned the economic implications of carbon sequestration in forestry, for the forests of south-western France. He is currently working to support renewable energy developments in Brittany.

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1 Introduction

This paper explores the scope for the rural land use sector in Scotland to contribute to the mitigation of climate change and support sustainable development, with particular reference to afforestation in North-east Scotland (Aberdeenshire, Morayshire and Aberdeen City). The centrality of climate change as a factor in sustainable development is widely recognised (IPCC, 2001). Accordingly, both the UK and Scottish Governments have set challenging greenhouse gas (GHG) emissions reduction targets as part of their response to anthropogenic climate change in their respective Climate Change Acts passed in 2008 at UK level and 2009 in Scotland.

The rural land use sector, which in Scotland consists of agriculture, forestry, and land used for sport shooting[1] and conservation, is a global net GHG emitter. Agricultural use is the major source of greenhouse gases in the rural sector. Forestry has the capacity to sequester carbon, as may pastoral farming associated with permanent grassland. Sport shooting is often on carbon rich soils and peat and this land contains large reserves of carbon threatened by overgrazing and some other management practices (e.g., drainage).

The extensive use of nitrogen (N) fertiliser in cropland and grassland contributes to nitrogen (N_2O) emissions and livestock and poultry production directly and indirectly emit N_2O and methane (CH_4) (Dale et al., 2005). In addition, land-use change, such as forest conversion to arable land and grassland, impacts on the atmospheric flux of carbon dioxide (CO_2), and subsequently on climate change (Dale, 2007; Rounsevell and Reay, 2009). Emissions from agricultural activities globally are expected to increase in the next 30 years due to rise in population, income, agricultural intensification and meat and dairy consumption (Wollenberg et al., 2012).

A change in land use from cropland to forest or grassland, the maintenance and increase of existing carbon in forests and agricultural soils and the replacement of fossil fuels by biomass could deliver zero and negative carbon emissions (Richards et al., 2006; Harper et al., 2010). As well as offsetting its own emissions, the rural land use sector could also offset residual emissions from other sectors of the economy that cannot be entirely eliminated. The land use sector has, therefore, a pivotal role in contributing to the Scottish GHG emission reduction targets.

The Kyoto Protocol recognised the mitigation potential of the ‘land use, land use change and forestry’ (LULUCF) and allowed Annex 1 countries to use LULUCF emissions and removals as credits or debits contributing to their emission reduction objectives (UN, 1998). Article 3.3 of the protocol states that “the net changes in greenhouse gas emissions by sources and removals by sinks, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments of the Parties”. Forestry has also been identified as a significant achievable sink at European level by the IPCC 4th Assessment Report (IPCC, 2007). Afforestation is a prominent and cost-efficient method to sequester carbon because it is cheap and clean and can provide other ecosystem services at the same time (Nijnik, 2010). In Scotland, the forest sector has been recognised as a potentially significant contributor to emissions reduction (Committee on Climate Change, 2010; Scottish Government, 2009) and the Scottish Government’s Low Carbon Economic Strategy recognised the forest sector as a priority industry with the scope for ‘wood fuel and biomass for renewable heat and power; locally-sourced timber for construction; (and) carbon sequestration' (Scottish Government, 2010a).

However, the Scottish food and drink policy aiming at increasing the country's food production, with likely increases in GHG emissions, will make the targeted emissions more difficult to achieve. New forestry will need to displace alternative uses which are associated with entrenched political positions held by farm and other stakeholder groups. A recent report of the Woodland Expansion Advisory Group (WEAG, 2012) recognised that 'those who want to plant woodlands feel that 'the system' is not helping them'. Nijnik et al. (2010) consider that together with an institutional setting, incentives and sources of investment are central for the establishment of forest plantations to offset CO_2 emissions. The support of a rapidly growing wood-fuel industry in Scotland is also seen as an opportunity to establish new woodlands (Scottish Government, 2009). Many landowners could develop wood energy enterprises and there is considerable current interest. The high transaction costs of overcoming regulatory hurdles are seen as a barrier, but both rural development policy (with the Rural Development Programme) and energy policy (with the recent adoption of Feed-in-Tariffs and the Renewable Heat Initiative) create significant economic potential. Further, energy-related diversification opportunities would assume particular significance in the rural land use sector if carbon taxing was introduced on land-based emissions, if reduction targets allowed the offsetting of land management unit emissions against renewable outputs, or if enhanced scope for carbon trading into forestry offsets were created.

In Scotland, in 2008, agricultural emissions accounted for approximately 13% of the total anthropogenic emissions (Scottish Government, 2010a). In the same year, net LULUCF offset about 8% of Scottish total GHG emissions (Scottish Government, 2010a). In some regions of Scotland, such as North-east Scotland, with a relatively intensive agricultural sector and a large land area, but with relatively low regional population densities (by UK standards), the proportion of agricultural emissions in the total GHG emission budget is much higher. Given such high levels, it is inconceivable that the rural land use sector can be 'spared' from the emissions reductions that are sought as a result of the demanding (80% reduction by 2050) legislative commitments already made.

The scope for emissions reduction within the rural land use sector is a function of its specific characteristics. Current emissions in Scotland are derived more from CH_4 and N_2O than from CO_2 (AEA, 2012). This reflects the prevailing biophysical conditions in Scotland, with a dominance of grassland and associated ruminant livestock and much poor quality upland grazing, often on high carbon soils. The high water content of some Scottish soils and the relatively high rates of nitrogen fertiliser application in certain areas combine to produce hotspots of N_2O emissions.

Current sequestration is driven largely by the size of the forest sector and much influenced by the type of forest species. In terms of the proportion of land area and the productive nature of its forests, Scotland has a proportionately larger and more productive forest sector than other parts of the UK. The national forest is predominantly coniferous with growth rates varying from around Yield Class 8 to Yield Class 18.[2] Over the last 100 years, forest cover has increased nationally from about 5% to over 17% of the land area (19% in North-east Scotland).

A further significant rural land use of both Scotland and the study region is sport shooting of game animals and birds. The principal animal quarry is deer and includes red, sika and roe deer. The principal bird quarry is the native red grouse, which is dependent on heather moorland as a habitat. Better quality moorland used for sport shooting has capacity for conversion to forestry which has the potential to sequester rather more carbon, but the social prestige of sport shooting means that a significant area of uplands in Scotland are used for such purposes.

Several studies (Freibauer et al., 2004; Radov et al., 2007; Moran et al., 2008; Smith et al., 2008) have looked at the mitigation potential of land use practices in the rural land use sector, including tree planting to increase carbon sequestration but none appraises the scope of forestry to contribute to both GHG reduction and sustainable development in an analysis grounded in the specificities of a particular region within the framework of existing policy measures.

In this paper, a synoptic view of the rural land use sector is taken in exploring the options to mitigate climate change drawing on a number of different bodies of work. Further, rather than attempting to produce gross estimates of the possibilities of sequestering more carbon by using standard marginal abatement cost curves, a typical upland area in which all the major land uses in Scotland are represented is explored. By undertaking a synthesis of studies of different land uses and their emissions and sequestration possibilities, a holistic view of the capacity of the rural land use sector to contribute to climate change mitigation is taken. In this grounded modelling approach, the relative costs of non-traded emissions reductions are considered. The approach hinges not only around recognition that afforestation offers the most likely means of reducing net emissions from the rural land use sector, but also that selecting both biophysically suitable land and land with low opportunity costs in terms of its 'release' from farming would benefit from traded solutions between landholdings. Similar approaches to this are needed to scope out regional scale opportunities for mitigation elsewhere in Europe and more widely, grounded in regional specificities.

2 The Scottish policy framework

Despite a very modest contribution of 0.2% of all emissions in global terms in 2000 (Scottish Executive, 2006), the Scottish Government has committed to work in partnership with the UK Government and other devolved administrations to develop and implement the UK's response to climate change. The Climate Change (Scotland) Act 2009 establishes a target to cut emissions of GHGs across all sectors of the Scottish economy, including international aviation and shipping, by 80% by 2050 relative to 1990, with an interim target of 42% by 2020. Under the Act, emissions must fall year-on-year from 2010 and by at least 3% per year from 2019 onwards.

The greenhouse gases considered in the accounting process are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFT) and sulphur hexafluoride (SF_6); the baselines are 1990 for CO_2, CH_4, and N_2O and 1995 for HFC, PFT and SF_6. The Act emphasises that contributions to meet the annual targets should be made through energy efficiency, energy generation, land use and transport and that strategies should be guided by the independent UK Committee on Climate Change in the short term and by a Scottish-specific body at a later date.

Prior to the 2009 Act, a range of disparate policies existed which are summarised in 'Scotland's Climate Change Programme – Changing our Ways' (Scottish Executive, 2006). These have been built on and now include the Scottish Forestry Strategy (with a target for 25% forest cover in Scotland by 2050), the Renewable Heat Strategy, the Biomass Action Plan, the Scottish Rural Development Programme, the Climate Change Delivery Plan and these have been supplemented more recently by the 2020 Routemap for Renewable Energy in Scotland and the Low Carbon Economic Strategy and the 2011 Review of Proposals and Policies.

Scottish policy, developed under a set of devolved responsibilities, is also shaped by UK-wide policy in a number of respects. For example, policies relating to Feed-in-Tariffs for renewable energy production and for renewable heat production under the Renewable Heat Initiative are UK-wide in their design and application and offer opportunities to both rural land managers in general and the forest sector in particular. In both cases, per unit supplements are offered to those producing renewable electricity or heat.

To date the only measures to reduce GHG emissions in the rural land use sector are based on advice or grant-aided support for forestry and renewable energy production. Very large energy-intensive firms face a Climate Change Levy. Larger firms and public sector organisations meet a specified carbon reduction commitment (CRC) under the Energy Efficiency Scheme or face financial penalties (Scottish Government, 2011a).

The recently launched Land Use Strategy for Scotland (Scottish Government, 2011a) is a direct requirement of the Climate Change (Scotland) Act 2009 and explicit recognition of the importance of taking an overarching view of rural land use in any strategy to reduce GHG emissions. Several Scottish programmes and strategies recognise the key role of rural land use in climate change mitigation. The Scottish Rural Development Programme (SRDP) 2007–2013 (Scottish Government, 2006) aims to tackle climate change and to meet relevant international and UK commitments on air quality through reducing gaseous emissions from management and use of rural land, enhancing carbon sinks such as peat bogs and woodlands, conserving soil organic matter and encouraging the reduction of fertiliser application. Proposals to adopt these measures are competitive and successful uptake depends on the number of applications and their relative scores under a quasi-objective assessment procedure. Under forest expansion targets, the forestry sector was set to deliver 0.6 MtC savings per year from 2010 onwards, reaching 1 MtC saving per year in 2020 (Scottish Government, 2009). These targets are now embodied in the Rural Development Programme. The SRDP aims to help to tackle climate change through carbon sequestration, wood fuel supply and enhancing forest habitat networks, and these measures were rolled forward into the 2007–2013 SRDP. The opportunities in the forest sector are further flagged in the Climate Change Delivery Plan (Scottish Government, 2009).

The principal guiding documents for effecting the necessary changes in GHG emissions in Scotland are the Climate Change Delivery Plan (Scottish Government, 2011b) and the Scottish Government's statement (Scottish Government, 2009) on meeting emissions reduction targets. The first states that Scotland will take: *"a comprehensive approach to ensure that carbon (including the cost of carbon) is fully factored into strategic and local decisions about rural land use through: appropriate protection for Scotland's carbon rich soils; minimising emissions from agricultural and other land use businesses; encouraging the sequestration of carbon, for example, through woodland planting; and the use of natural resources to generate renewable energy"* (Scottish Government, 2011b).

The document details actions needed to achieve a significant emissions reduction target by 2020. A raft of sector-specific strategies remains but the Delivery Plan provides a synoptic document detailing the expectations of reductions from different sectors. It is clear that the government targets will require a major increase in current levels of planting and substantial technical changes within the farm sector. Further guidance on potential of different sectors to deliver to these targets was provided by Committee on Climate Change (Committee on Climate Change, 2010) which identifies a significant contribution from forestry. These ideas are rolled into the statement on meeting emissions reductions targets (Scottish Government, 2011b) which calls for a speeding up of the needed emissions reduction in the next ten years. The same document details a need to factor in the cost of carbon to strategic and local decisions about rural land use.

At regional level, the rural priorities for forestry, agriculture and conservation are set by the SRDP 2009–2013. For North-east Scotland, the priorities are to improve carbon sequestration through conservation of soil organic matter and expansion of woodlands, to reduce GHG emissions from land-based operations (organic conversion, fertiliser application, supply chain), to improve carbon sinks (forests and peatlands) and to implement an efficient and reliable woodfuel supply chain (based on short rotation coppice, short rotation forest, biomass and bio-crops).

3 A GHG budget for North-east Scotland

A necessary first step in any attempt to reduce emissions is the estimation of where GHG emissions arise in that sector. Aggregate emissions of GHGs in North-east Scotland are collected annually by the National Atmospheric Emissions Inventory (NAEI), the UK's official GHG estimating body. The NAEI use standard Intergovernmental Panel on Climate Change (IPCC) approaches. The aggregate emissions from North-east Scotland are presented in Table 1. They show the importance of the land use sector in this region in contrast to Scotland as a whole. According to the NAEI, in 2010, total GHG emissions in North-east Scotland were approximately 6.5 $MtCO_2e$. The main sources of CH_4 and N_2O were agriculture and waste management, and the main sources of CO_2 were industrial and commercial electricity production and road transport. Approximately 21% of the total GHG emissions (1.45 $MtCO_2e$) are allocated to agriculture and a mere 0.4% (0.006 $MtCO_2e$) to nature.

Table 1 Scottish and North-east Scotland GHG emissions, 2010

	Scotland	*North-east Scotland*
Total GHG emissions ($MtCO_2e$)	53.7[a]	6.5[c]
Agricultural emissions ($MtCO_2e$)	7.6[b]	1.45[c]
Net land use, land use change and forestry ($MtCO_2e$)	–4.5[b]	–0.55[d]

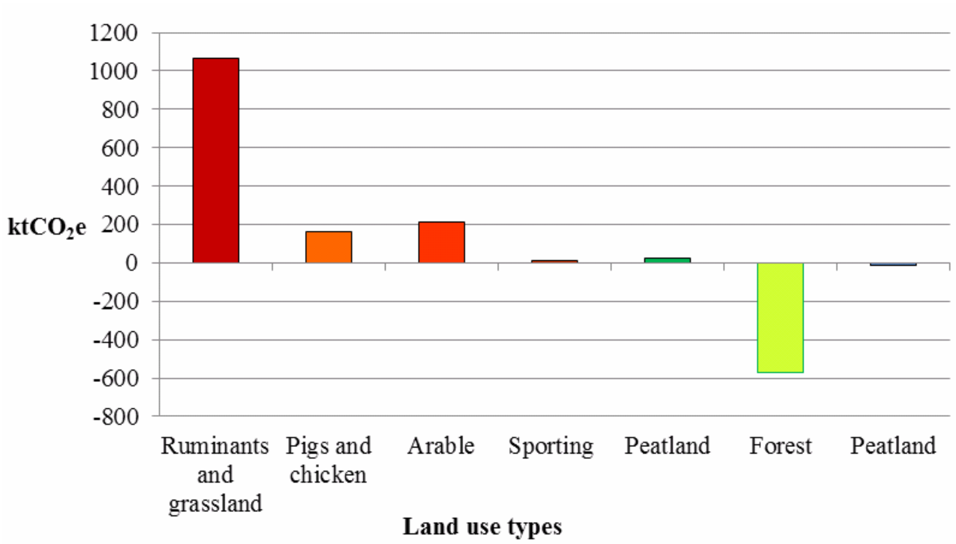
Notes: [a]Binkley et al. (2002)
[b]Scottish Government (2010b)
[c]AEA (2012)
[d]Own estimates.

An essential starting point for any analysis of the rural land use sector's capacity to mitigate GHG emissions must be an understanding of the region's varied land use systems and their emissions and the scope for cost-effective mitigation. As the data from NAEI are not available in disaggregated form, a recalculation was necessary to reveal intra-sectoral emissions. This poses a particular challenge in North-east Scotland because of the existence of a substantial sport-shooting land use sector, the exact size of which is hard to establish as it often co-exists with agricultural and forestry land uses.

Emissions and removals of GHGs were estimated for the land use sector in North-east Scotland for the last decade using IPCC emission factors. The rural land uses and activities considered were agriculture, forestry, sporting areas and peatland.[3] The estimations used regional activity data and default emission factors from the IPCC 2006 Revised Guidelines for National Greenhouse Gas Inventories and other published studies.

Figure 1 indicates the relative importance of the different rural land uses in emissions and removals of GHGs in North-east Scotland in 2010. The breakdown of the land use sector reveals that the agricultural sector is overwhelmingly responsible for aggregate GHG emissions, with sporting use (moorland burning and wild deer) generating modest net emissions.

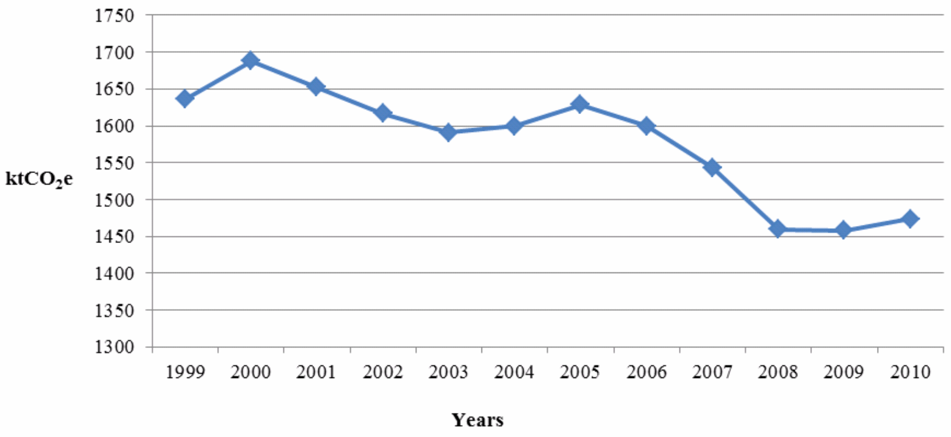
Figure 1 GHG emissions from rural land uses and net LULUCF in North-east Scotland in 2010 ($ktCO_2e$) (see online version for colours)



Source: Feliciano et al. (2012)

Over the last decade, North-east Scotland's rural land use emissions have fallen significantly (Figure 2), primarily due to two factors. First, livestock numbers are signficantly lower, as a result of a long period of poor returns in that sector. Second, substantial reductions in N_2O emissions have arisen, largely as a result of reductions in applications of ammonium nitrate to grassland and arable crops. This is in part science-driven, based on evidence that lower total applications of nitrogen applied later and more frequently during the growing period are optimal for grass and crop responses, and in part driven by rising costs of artificial fertilisers. Nonetheless, an increase in emissions between 2009 and 2010 is reported as a result of rising grain prices and associated increased applications of fertiliser.

Figure 2 GHG emissions from rural land uses over 12 years in North-east Scotland (see online version for colours)



Source: Feliciano et al. (2012)

4 Principles for exploring the scope for emissions reduction through forestry

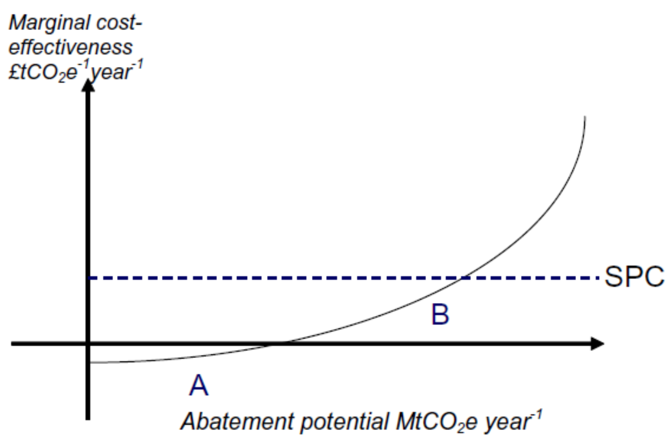
The underlying rationale for any attempt at regional scale emissions reduction is an understanding of the net costs of sequestration of carbon. A range of assertions has been made about forestry's potential to mitigate GHG emissions. It is regarded as technically feasible in that methods are widely known; cost-efficient (Nijnik and Bizikova, 2008; The Royal Society, 2002); and synergistic in delivering a range of ecosystem services (The Royal Society, 2002; van Kooten et al., 2004). However, a meta-analysis of 68 studies to estimate carbon sequestration costs, with a total of 1,047 observations worldwide, has identified huge variability of estimates of sequestration costs across countries. These studies reveal that the costs of carbon sinks in forests range from €35 to €199 per tonne of carbon and, when opportunity costs are taken into account, they range from €89 to €1069/tC (Enkvist et al., 2007). These costs suggest that by no means all afforestation projects can be seen as cost-effective carbon sequestration.

In lightly afforested countries such as the UK, new forestry can displace existing GHG-emitting land uses, thus turning what was an emissions source into a sink. Storage in the wood production and products is more or less temporary and the length of the storage period is contingent on the forest production cycle and the uses to which the forest products are put. However, the benefits are very case specific, and to assess whether forestry development offers an economic opportunity for carbon sequestration, marginal costs per tonne of sequestered carbon are usually computed.

Two issues must be factored in to any analysis. First, the extent of carbon sequestration by forestry depends on the type of land on which trees are grown. On bare ground sites, planting on soils with high carbon content may significantly reduce net sequestration because land drainage is frequently a necessary precursor to afforestation and the drying out of soil organic matter can significantly increase GHG emissions. This is only a significant issue in first rotations. Second, where the wood product provides a substitute for a high-emitting product (such as cement or steel in construction or oil or gas in energy production), the total effects of the wood product on GHG emissions arise both from the savings in the production process and the avoided emissions arising from the alternative. In the case of wood energy, these emissions reductions will take place on a cyclical basis as long as the displaced alternative continues to be a high GHG emitting energy source.

The overarching economic principle in exploring emissions reduction potential is the marginal abatement cost curve (MACC). The analysis of the economics of reducing GHG emissions in the land use sector is framed in the analysis of marginal abatement costs of carbon (MACC). The principal question addressed by MACC analysis is how much it costs (in this case) a land manager to reduce his/her carbon consumption. Evidence on these costs has been estimated at international level (Enkvist et al., 2007) and for the UK (Moran et al., 2008). The general principle in the application of MACC analysis to emissions reduction is that it is efficient to reduce all emissions up to the point where the cost of emissions reduction is less than the shadow price of carbon (Figure 3). In a situation where different emitters of carbon have different abatement costs, those with the lowest abatement costs can be expected to change their emissions behaviour first. Abatement costs (when carbon storage is considered) are in fact the costs per tonne of carbon sequestration (costs of the C benefits generated). These costs per tonne of C provide benchmarks for comparison of alternative scenarios: for choosing those which provide benefits with the lowest possible costs per unit. It is likely that some abatement generates a win-win situation, such as where reduced nitrogen fertiliser application reduces emissions but leads to better targeted applications (area A in Figure 3), but the scope for win-win situations may be limited in the land use sector.

Figure 3 Stylised MACC for CO_2e (see online version for colours)



Source: Macleod et al. (2010)

Forestry's potential contribution to GHG emissions reduction in North-east Scotland is thus contingent on the scope for new afforestation with net sequestration benefits and the scope for woodfuel to displace fossil fuels in space heating or electricity production.

The effects of avoiding carbon release to the atmosphere through a continual cycle of forest harvesting, regeneration, and replacing carbon intensive materials and/or fossil fuels with wood, are repeatable and therefore more sustainable. The social benefits of wood product and bio-energy scenarios in the long run are expected to be higher than those arising from the strategy of carbon fixation alone. However, the rising demand for wood fuel and wood products could result in the increase in timber harvesting elsewhere, for example, in the tropics. Therefore, a holistic view, with consideration of displacement effects and of possible ‘leakages’ is needed. Estimating the size of the carbon sink must take into account the carbon debit from land use changes and timber harvesting, carbon stored in wood product sinks (not considered under the Kyoto Protocol), various carbon ‘leakages’, and additional carbon sequestered as a result of forest management.

In the UK, forestry projects for carbon sequestration combined with wood production and/or renewable energy strategies offer better opportunities for innovation, employment, development of markets and enhancement of rural economies than narrowly-based carbon sequestration forests (Read et al., 2009). In some localities, short-rotation plantations for bioenergy might generate cost-effective emission reductions. However, it is important that measures for carbon sequestration in forests are considered: generally, within spatial planning; in relation to forest, agricultural and rural policies; and as part of measures for sustainable energy systems and sustainable rural development (Nijnik and Bizikova, 2008). This will save costs, deliver cost-effective outcomes and assist in coping with environmental problems associated with climate change.

The extent of uptake of new afforestation or new wood-based heat and/or energy production is likely to be strongly shaped by policy support, as well as markets, and in the case of new supply chains for woody biomass may well be constrained by the infancy of the industry in the region.

5 Emissions reduction and forestry: farm level-emissions MACCs for Glenlivet

Glenlivet is an upland area in the west of the study area, in which a study of the scope for GHG emissions reduction was explored in a number of farms by one of the co-authors of Moran et al. (2008). Given that the land use sector contributes significantly to GHG emissions in Scotland, a strategy aiming to reduce GHG emissions by 80% cannot ignore the potential role of the land use sector,

1 to reduce emissions
2 to enhance carbon sequestration
3 to supply land for renewable energy generation.

MACCs were estimated for an upland part of our study area in which both individual farm and traded (between-farm) solutions are considered.

Rural land-using activity, including increasing soil carbon storage, afforestation, and biofuel production are widely recognised as potential means of abatement. The relative efficiencies of these depend on the current nature of land use and the costs of achieving change, including the opportunity cost of land. In a UK rural land use context, there would appear to be significant abatement potential in the rural land use sector. Moran et al. (2011) argue that “the results indicate that in 2022 around 6.4 MtCO_2e could be abated at negative or zero cost. Furthermore, in the same year, 8.8 Mt CO_2e could be abated at a cost less than the 2022 Shadow Price of Carbon (£35/tCO_2e)”.

It is doubtful, however, at least in the land use sector, whether average MACCs can be used with any degree of meaningfulness, without considering the particular configuration of individual land holdings. For example, two neighbouring hill farms, one with extensive mineral soil rough grazing and the other with only rough grazing on high carbon content soils will face very different MACCs. The first farmer can plant trees and sequester carbon to offset farm emissions, most likely with zero or very low opportunity cost to his farming enterprise, whilst the farmer with high-carbon rough grazings (on peaty soils) would increase emissions of carbon if he/she drained the deep peat rough grazing as preparation for tree planting and must therefore sacrifice better quality farmland to reduce carbon emissions. The latter strategy is likely to be much more costly than the former.

In the example below, evidence of further ground-truthing based on local knowledge is shown. An analysis based on a group of farmers located in the Cairngorms National Park in the western part of our study area aims to fill the knowledge gap. The study covers 16 farms, covering a range of farm types from relatively intensive cereal/meat producers, to extensive hill farming which is representative of the wider area. A survey was conducted by SAOS in order to gather data on each farm (crop types, production levels, herd sizes, areas, fertilisers used). These data have then been computed in C-Plan (http://www2.cplan.org.uk/), a UK web-based carbon emissions calculator for farmers. Using these data as a starting point, a simulation was undertaken in which farmers had to reduce their emissions by 20%. Data on strategies to reduce emissions and on the costs of these strategies were found in Moran et al. (2008).

To reduce emissions, farmers were confronted by two options: to reduce emissions on farm or trade carbon credits (it is assumed that farmers know the costs of reducing GHG emissions and the carbon price; and that their actions are sufficiently small so as not to affect market conditions). The trade-off between buying a carbon credit and reducing on-farm is based on economic parameters and it is assumed that farmers will implement the most cost-effective strategy.

The analysis shows that the carbon trading solution is far less costly (for the group) than individual reductions (farm scale solution); it reduces the total cost by ca. 30% (Table 2). Further than the individual solutions, there is also the possibility of generating offsets. Offsets have been proposed as an option allowing achievement of emission reduction targets at least cost by Jiang et al. (2009), MAF (2008), and by Bakam et al. (2012) who have investigated the inclusion of the agricultural sector in an emission trading scheme. In the Glenlivet example, it can be shown that in order to offset 20% of GHG emissions, 1,058 hectares would have to be converted to forests (which amounts to just over 5% of the total farms area, covering in total 21,000 hectares), assuming a conservative sequestration rate of 3.6t C/ha/yr (Sitka spruce, YC 16) (Nijnik et al., 2009). Some farms, on which the opportunity costs of land is low (extensive farms) could convert some land to forests and sell carbon credits to farmers having to bear high carbon emission reduction costs.

The cheapest carbon sequestration through tree planting is almost certainly where good quality land for forestry exists alongside low agricultural stocking rates. Even within a single catchment there are likely to be very considerable variations in mitigation costs, which reflect the opportunity costs, which are essentially the displaced agricultural activity arising from new tree planting.

Table 2 Individual costs, farm scale solution costs and carbon trading costs[1]

	CO_2 emissions (tonnes)	Target (tonnes CO_2)	Achieved reduction %	Achieved reduction tonnes CO_2	Carbon trading solutions		Farm scale solutions	
					Unit cost (£/t CO_2)	Total cost £	Unit cost (£/t CO_2)	Total cost £
Farm 2	1,358	1,086	20%	271	100	£27,114	£100	£27,114
Farm 4	1,289	1,032	20%	257	237	£61,027	£237	£61,027
Farm 5	1,471	1,177	20%	294	315	£92,548	£315	£92,548
Farm 6	1,502	1,201	20%	300	100	£29,953	£66	£19,800
Farm 7	745	596	20%	149	165	£24,549	£260	£38,758
Farm 8	1,197	957	20%	239	156	£37,450	£290	£69,408
Farm 10	1,493	1,194	20%	299	100	£29,838	£260	£77,620
Farm 11	3,322	2,658	20%	664	330	£219,483	£340	£225,899
Farm 12	593	474	20%	119	109	£12,929	£109	£12,929
Farm 13	805	644	20%	161	103	£16,538	£280	£45,083
Farm 14	2,171	1,737	20%	434	142	£61,445	£280	£121,577
Farm 15	2,216	1,773	20%	443	101	£44,603	£260	£115,246
Farm 16	909	727	20%	182	135	£24,470	£290	£52,710
Total	19,071			3,812		£681,947		£959,718

Note: [1]Data on farm 1 and 3 were incomplete and could not be used in the analysis.

6 Ground truthing – exploring the social limits and possibilities

Our analysis of North-east Scotland clearly shows that there are very significant variations in the costs of emissions reductions through tree planting on Scottish farms, even at local level and possibly between adjacent farms. This implies a strong case for traded solutions. There is clear technical and economic potential for additional tree planting in North-east Scotland, which, except on the limited areas of high carbon soils, would generate a significant reduction in net emissions from the land use sector. However, the extent of uptake of measures depends not only on the technical possibilities but also on land manager attitudes (Read et al., 2009).

At present, the uptake of the SRDP afforestation measures is a long way short of target. Current planting is at about only 40% of targeted level. There is strong evidence of farmer opposition to new tree planting, especially by the core farming community. Historically, trees and woodland were landlord's property and North-east Scotland was dominated by tenant farmers. A negative attitude towards additional forestry is strongly evident in the farming press and in the hill and upland farming community, which sees forestry more as a threat than an opportunity. Recent public debate about the need for increased global food supplies has added fuel to the farmers' negative rhetoric about forestry.

Some farmers have begun to change their practices and have undertaken a carbon budget for the whole landholding and developed both commercial and amenity forestry to reduce net emissions, but this is as much the result of forward thinking by the land owner as a result of policy incentives. Several online carbon calculators for estimating farm emissions are now available but attempts to mitigate to date are largely based on adoption of win-win practices, such as more effective fertiliser application or improved feeding of livestock, rather than tree planting.

There is evidence of an incipient wood energy supply chain in the region. Although historically rural dwellings would have made extensive use of wood energy for space heating, this practice has declined and now oil or electrical space heating of rural homes is the norm. New technologies offer new opportunities (Nybakk et al., 2011). Two suppliers of pellets operate within the region and the largest local council in the area (Aberdeenshire Council) has made commitments to the sector by installing wood energy heating schemes in two secondary schools. Further, other parts of the public and voluntary sector, especially housing associations, have also been able to draw down public support for wood energy developments.

The extent of uptake of new forestry will be shaped in part by grant levels both for planting and for related development in wood energy supply chains, including support for renewable heat under the Renewable Heat Initiative, and in part by the willingness of land managers in the region to take up incentives when they are on offer. Whilst some of the larger land owners elicit a strong traditional interest in woodland management and have turned their attention towards wood energy possibilities (not least for their own often quite large residences), the traditional farming community has an almost visceral dislike of forestry, which is likely to severely inhibit the uptake of farm forestry. It is unsurprising that some of the largest grants paid out in the SRDP are to large landowners for new forestry projects.

If emissions reduction targets were to become an obligation for farmers, forestry would establish itself alongside other GHG reduction opportunities such as changed tillage practices, reduced livestock emissions (by changes in breeding or feeding) or reduced fertiliser applications. Individual farmers would be required (assuming a desire to optimise their emissions reduction strategy) to estimate farm-level marginal abatement costs from the suite of different possibilities. Forestry would almost certainly figure more prominently. At present, it is highly questionable as to whether an adequate knowledge of the farm-level MACCs currently exists and, additionally, considerable extension effort would be needed to enhance farmer knowledge and persuade farmers to act.

7 Conclusions

New forests provide a major opportunity as carbons sinks. The scope for additional forestry to support sustainable development in North-east Scotland resides in its ability to sequester GHGs, to provide a renewable energy resource that into the foreseeable future would displace fossil fuels in space heating needs and to provide a sustainable bio-material to substitute for fossil energy-intensive products such as steel and concrete in construction. If, at the same time, forestry replaces carbon intensive farming on low grade land there is a greater net beneficial effect. There is little doubt that there is substantial opportunity in technical terms to deliver on these possibilities in North-east Scotland. However, not all forestry provides a cost-effective carbon sink. This is determined by the costs of any displaced farming and the type of land on which forests are planted. A more localised farm-specific approach is needed to be able to optimise land-based mitigation.

In practice, it is likely that increasing the forest cover in North-east Scotland from its current 17% of the land area to reach the 2025 target of 25% will be extremely difficult, in spite of suitable land being available. Current planting rates are at about 40% of those required to meet emission reductions targets set in the Climate Change Delivery Plan (Scottish Government, 2009). Even enhanced grant levels appear unlikely to attract mainstream farmers for whom forestry is anathema. The current debate about future shortages of food may offer enhanced returns to farmers and increase the opportunity costs of afforestation. There is already evidence that increased food prices have driven up fertiliser use, which even when applied using best practices, will almost certainly generate increased GHG emissions.

It seems likely that new afforestation – the single greatest potential contribution to reduced emissions from the land use sector – will be amongst the least preferred strategies by the traditional farming communities. It may be that a combination of new entrepreneurial farmers and estate managers will engage to a degree in higher levels of tree planting, but the behavioural barrier with the core farming community seems very considerable in the short term. The coming on stream of the Renewable Heat Initiative will provide incentives for firms to adopt wood energy heating solutions and this will create additional markets for woodfuel, but the time lag before new forest output is available is likely to reduce farmer interest.

The greatest barrier impeding the land use sector's enhanced contribution to climate change mitigation is the formal and informal institutional arrangements which subvert tree planting even where it is economically rational and cost-effective. This will mean a reduction in the sector's capacity to contribute to climate change mitigation and slow down the development of a wood energy sector. The balance between informal institutional arrangements (farmer attitudes) and formal institutional arrangements (policy measures) in impeding land manager responses still needs teasing out, but both appear to be important. Because of broadly similar land use systems, the Scottish Government and other Scottish institutions often look to forest-rich Nordic countries for inspiration, ideas and parallels in policy making. In this respect, Scottish farmers might beneficially explore the much more synergistic role of farm forestry in all the Nordic countries and the well-developed state of wood-energy heating systems. Such an exploration would expose the particular significance and distinctiveness of land ownership and tenure structures in Scotland which have long militated against farmer interest in forestry.

In forestry, many effects are long-lived, and growing forests provide some of their benefits far into the future. These benefits run across a range of ecosystem services. The mitigation capacity for forests in relation to climate change varies both across territory and over time. The multifunctional nature of forestry requires careful analysis to reflect the realistic possibilities for delivering multiple ecosystem services through well designed forestry projects at local and regional scales (Nybakk et al., 2011). Forests might reduce flooding, enhance landscapes and sequester significant amounts of carbon.

Further economic opportunities will almost certainly emerge if fossil fuel prices rise and wood-based bio-energy supply chains develop in more durable forms. The inevitable 'teething troubles' of making boiler technologies compatible with appropriate pelleting or chipping technologies in an infant industry are likely to be overcome, but these may have had a short-term negative effect on demand. As the wood energy market develops in the medium term, such developments may sit more comfortably with the productivist values of the farming community than the recent practices of grant-aided afforestation premised on a need to reduce agricultural surpluses.

There remains a need for advisory effort and institutional developments to steer change. The current exhortatory measures embodied in the Scottish Government supported ‘Farming for a Better Climate’ initiative and the grant-aided support of the SRDP are likely to be insufficient to persuade many land managers to change their approaches and reduce emissions in the absence of a price being put on emissions. Further development of carbon trading may offer opportunities (Ciccarese et al., 2011) but uptake of tree planting remains the fundamental obstacle. The threat of the ‘stick’ of carbon pricing might engender some additional response and pricing may be a necessary adjunct in order to realise the ambitious targets, but any fair tax would require accurate estimation of emissions on a farm-by-farm basis. Such an approach would almost certainly create new commercial opportunities, especially in more disadvantaged farming areas, if the generally more economically efficient model of tradable emissions reductions were adopted. It is in these hill and upland areas that low cost afforestation and renewable energy production has greatest bio-technical potential and lowest opportunity cost. It is considered that energy enterprises could easily become a central part of future hill and upland farms in North-east Scotland, thereby contributing both nationally and regionally to objectives for sustainable development and that further hill and upland farmers could be the beneficiaries of traded carbon from other sectors within farming and from other industries. The principal barrier to new forestry, which is one of the most cost-effective land-based mitigation strategies is and will remain farmer attitudes. This is compounded by policy structures which although offering incentives to forestry are insufficient to overcome the levels of farm support and fail to reward land managers fully for the carbon sequestered.

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Notes

1 The hunting of deer or game birds, especially grouse, in North-east Scotland.

2 Yield class is a measure of production of cubic metres of woody biomass per ha/yr.

3 Peatland comprises raised and lowland bogs, peat upland areas and extensive areas of peaty moorland.