GREENHOUSE GAS EMISSIONS FROM LAND USE, LAND USE CHANGE AND FORESTRY

JOHN DOWENS

In recent decades, global land use change has made a significant contribution to increasing greenhouse gas levels and related climate change (Intergovernmental Panel on Climate Change 2007). This briefing outlines the Land Use, Land Use Change and Forestry (LULUCF) sector and its contribution to storing and releasing greenhouse gases in Scotland. It provides a brief introduction to what is included in the LULUCF sector, and the methods used to estimate emissions from these sources, and removals from the atmosphere.
CONTENTS

KEY POINTS ................................................................................................................................................................3

INTRODUCTION ..........................................................................................................................................................4

AN OVERVIEW OF THE CARBON CYCLE ...................................................................................................................5
KEY LAND USE TYPES IN SCOTLAND .......................................................................................................................6
Land converted to forestry since the early twentieth century .................................................................................6
Blanket bog peatlands ........................................................................................................................................7
Heath and moorland ........................................................................................................................................7

MONITORING AND REPORTING OF GREENHOUSE GAS EMISSIONS .................................................................8
THE LAND USE, LAND USE CHANGE AND FORESTRY INVENTORY ....................................................................8
SCOTLAND’S GREENHOUSE GAS EMISSIONS AND REMOVALS FROM LULUCF ..................................................9
SINKS AND SOURCES INCLUDED IN THE SCOTTISH INVENTORY ....................................................................10
WHAT IS NOT INCLUDED IN THE LULUCF INVENTORY? .....................................................................................11

ENHANCING LAND USE AND FORESTRY SINKS IN SCOTLAND .................................................................13
PROJECTION OF FUTURE TRENDS IN LULUCF EMISSIONS .............................................................................13

INTERNATIONAL COMPARISONS .......................................................................................................................15

SOURCES ..................................................................................................................................................................16
KEY POINTS

- As plants grow they remove carbon dioxide from the atmosphere and store it as biomass, some of which may eventually become soil carbon. When plants and soils decompose they release greenhouse gases back into the atmosphere.

- Disturbed or damaged soil is a large source of carbon dioxide emissions. In Scotland, land that has been converted to cropland over the past several decades is responsible for around 12% of emissions. This is the fourth largest source of greenhouse gas emissions after power stations, transport, and domestic fuel use.

- Land Use, Land Use Change and Forestry (LULUCF) is one of the principal categories used internationally to report greenhouse gas emissions. It accounts for the transfer of carbon and greenhouse gases between plants, soils and the atmosphere due to land management activities.

- Overall, LULUCF activities in Scotland add up to a net sink for greenhouse gases, and remove more greenhouse gases than they produce. The size of this sink is equivalent to around 8% of Scotland’s total emissions.

- The briefing does not consider agriculture explicitly, as agricultural emissions are accounted for separately, although some of the figures in the LULUCF sector do relate to agricultural activities.

- Forests cover 17% of Scotland’s land area and remove more than 10 million tonnes of carbon dioxide from the atmosphere each year. This “carbon sink” is equivalent to nearly 20% of the country’s total greenhouse gas emissions.

- Soils contain nearly three quarters of Scotland’s carbon stores. Most of this is contained in deep peat, which contains more carbon in a given area than tropical rainforests.

- Blanket bog peatlands can remove carbon dioxide from the atmosphere, but can also be responsible for emissions of methane. It is presently unclear whether peatlands in Scotland are a net source or sink of greenhouse gases, and they are not explicitly included in national emissions statistics as they are not intensively managed; currently, only managed land is included in inventories for the Kyoto Protocol.

- It is anticipated that the size of the LULUCF sink will decline over the next decade, partly as a result of a reduced tree planting regime since the 1970s and due to trees reaching maturity.

- Greenhouse gas inventories, including LULUCF, are compiled annually for each of Scotland, England, Wales and Northern Ireland.

SOME KEY TERMS

- LULUCF – Land Use, Land Use Change & Forestry
- IPCC – Intergovernmental Panel on Climate Change
- UNFCCC – United Nations Framework Convention on Climate Change
- Greenhouse Gas Source - A process, activity or mechanism which results in the production of a greenhouse gas
- Greenhouse Gas Sink - A process, activity or mechanism which removes a greenhouse gas from the atmosphere. Forests and other vegetation are considered sinks because they remove carbon dioxide (CO₂) through photosynthesis
- Sequestration – The process of removing, in particular, CO₂ out of the atmosphere
INTRODUCTION

The land, and the plants which grow on it, naturally absorb or emit greenhouse gases depending on how they are managed, or the type of soil involved. In recent decades, land use change has made a significant contribution to increasing global greenhouse gas levels (Intergovernmental Panel on Climate Change (IPCC) 2007).

The United Nations Framework Convention on Climate Change (UNFCCC) requires all member states to submit inventories of their greenhouse gas emissions at regular intervals. This briefing outlines one of the main sectors in these inventories, Land Use, Land Use Change and Forestry (LULUCF), and how it stores and releases greenhouse gas emissions in Scotland. It provides an introduction to the activities that are counted as LULUCF, and explains the methods used to estimate emissions from these sources and removals by land sinks. The briefing does not consider agriculture explicitly, as agricultural emissions are accounted for separately, although some of the figures in the LULUCF sector do relate to agricultural activities. More information on agriculture and climate change can be found in the recent Scottish Government publication on the topic (Scottish Government 2008a).

Whilst many emissions are a result of the burning of fossil fuels for electricity generation, transport, etc., it is sometimes forgotten that land use can also contribute to emissions. Deforestation still causes nearly 20% of global greenhouse gas emissions (Forestry Commission 2007), and the LULUCF sector is very significant in many parts of the world, such as regions with tropical forests, and regions where fossil fuel emissions are low. It is also particularly relevant in Scotland, where natural stores of carbon, such as peatlands and forestry make up a significant proportion of the country’s land area. Coupled with Scotland’s low population density, this means that LULUCF activities can contribute significantly to greenhouse gas emissions and sinks here, and to the UK as a whole. LULUCF activities in Scotland absorb more greenhouse gases than they produce i.e. the sector is a net 'sink', and this means future land management practices are important.

The consultation on a Scottish Climate Change Bill (Scottish Government 2008b) states:

“The way we use agricultural, afforested and other undeveloped land has a major impact on net greenhouse gas emissions. Scotland has huge amounts of carbon locked up in, peatlands, organo-mineral soils, and vegetation, including forests. Maintaining the overall level of these carbon stocks is an important priority, particularly as climate change itself might make them more vulnerable to oxidation, thereby adding to emissions. Land use changes like deforestation and conversion of grassland to arable all result in CO₂ emissions. Livestock and use of fertilisers are sources of methane and nitrous oxides. On the other hand, woodland creation and conversion of arable to grassland create carbon sinks, with CO₂ being locked up in biomass and soils. Given Scotland’s significant land resource, emissions reduction from, and carbon sequestration through, land use will remain a key part of our climate change strategy”.

More recently Stavros Dimas Member of the European Commission responsible for environment stated (European Commission 2008):

“soil organic matter is the second biggest carbon pool in the planet after the oceans. In the EU alone there are more than 70 billion tonnes of organic carbon in our soils. This is a huge amount if we bear in mind that the Member States of the European Union altogether emit approximately 1.5 billion tonnes of carbon annually. Indeed, releasing to providing research and information services to the Scottish Parliament
the atmosphere just a small fraction of that carbon currently stocked in our soils runs the risk of wiping out all the savings that other sectors of the economy are achieving in order to contain anthropogenic greenhouse gas emissions. This is not a theoretical scenario, unfortunately, and some of the scientists who will speak here today will present data suggesting that large amounts of carbon from soil organic matter have indeed already been lost to the atmosphere in the recent past”.

AN OVERVIEW OF THE CARBON CYCLE

To understand the greenhouse gas fluxes involved in land use and forestry activities it is important to understand a little about the natural cycle that carbon goes through. Carbon is continuously transferred between stores in the ocean, on land, and in the atmosphere. In the atmosphere it occurs primarily as carbon dioxide, while on land it is mostly stored in living biomass or in soils (see Met Office). When more carbon is removed from the atmosphere than is released back into it these are known as carbon sinks, and when the opposite occurs and there is a net release of carbon they are called emission sources.

Carbon dioxide is absorbed by plants through photosynthesis, and the carbon content is used to form roots, wood and leaves. When leaves are shed or plants die some of this carbon is transferred to the soil, where it can be stored for long periods of time before being broken down and released back to the atmosphere as carbon dioxide. This stored carbon can also be released back into the atmosphere when vegetation or soils are burnt, or through decay in damp conditions that releases methane (see Met Office). Figure 1 displays this terrestrial carbon cycle, which, along with some emissions of nitrous oxide, is responsible for most of the greenhouse gas emissions discussed in this briefing.

Human activity that changes land use can affect the carbon stored by the biosphere in biomass and soils. For example, cutting down trees removes a sink for carbon dioxide, and if the wood is burnt or left to decay, then the stored carbon is released back to the atmosphere. This also affects the ability of the soil to store carbon, and deforestation or other disturbances can cause significant emissions of greenhouse gases for up to hundreds of years after they take place (Thomson et al 2007)
Figure 1 shows the main sinks and sources of carbon between the atmosphere and terrestrial ecosystems. Greenhouse gases are either in flux, or stored as carbon in a “pool”, such as soil or biomass.

Source and with permission from: http://www.physicalgeography.net/fundamentals/9r.html Image created by Dr. Michael Pidwirny Department of Geography, Okanagan University College

KEY LAND USE TYPES IN SCOTLAND

Scotland has a relatively low population density and large areas of unsettled land which contribute to the carbon cycle as sources or sinks of greenhouse gases. The most widespread habitats in the Scottish uplands, which together account for significantly more than half of Scotland’s land area, are introduced below.

Land converted to forestry since the early twentieth century

The Forestry Commission was created in 1919 to strategically increase the cover of forestry in the UK. Since then forest coverage in Scotland has risen from 5% to 17% and now stands at around 1.3 million hectares. Most of these new forests are coniferous plantations (dominated by species such as Sitka Spruce), but around a quarter is mixed woodland containing native species. While much of the forest land expansion has been for commercial timber, the Forestry Commission and organisations such as the Woodland Trust Scotland have also made efforts to promote the wider social, environmental and health benefits of the forest resource.

Trees and forest soils are a significant carbon store, and as a forest develops it sequesters large amounts of carbon dioxide from the atmosphere. Eventually forests reach a stage where they emit as much greenhouse gas through natural decay as they sequester through new growth, and are deemed to be in carbon balance. It is presumed that the small amount of
forestry in Scotland dating from before 1921 is in this stage of equilibrium, while all forests that have been planted since then continue to act as carbon sinks.

The long term carbon storage potential of forest plantations is dependent on the management practices and subsequent use of the timber. For example, the amount of carbon sequestered by the soil depends on the harvesting cycle, and whether stumps are left in the ground before replanting (Scottish Forestry Forum 2008). If harvested wood is used for timber or building products then the carbon will remain locked up for as long as the wood survives; but if the wood is burned or left to rot then it will quickly release its carbon content back into the atmosphere.

**Blanket bog peatlands**

Soils account for 70% of Scottish carbon stores, with the majority of this in blanket bogs across the north and west highlands and islands (FCS 2008). These blanket bogs, which consist of a mantle of peat that can be up to five metres deep or more, cover around 14% of Scotland's land area, and are the single largest carbon store in the country. Globally, peatlands cover only 3% of land surfaces but contain at least a third of all soil carbon, with deep peat containing more carbon per hectare than tropical rainforests (Charman 2002, Tremblay 2005).

Peat consists of the waterlogged, slowly decomposing remains of bog vegetation. When plants generate new growth faster than dead material can decay, peat accumulates and the peatland sequesters carbon from the atmosphere. Such “active” bogs are a sink for carbon dioxide, but also a large source of methane – which is 25 times more potent a greenhouse gas than carbon dioxide. Consequently the overall balance between peatlands being a sink or source of greenhouse gases is subject to debate (Charman 2002).

When bogs are drained and the peat is able to mix with air, emissions of carbon dioxide increase. If this coincides with the removal of vegetation then emission rates increase further. This occurs, for example, when peatlands are prepared for forest planting, or where they are drained to improve grazing. Scotland’s blanket bogs, which for generations were considered valueless wet deserts, are now viewed as important “living landscapes” (Scottish Natural Heritage 2008) which provide a unique habitat for a range of birds, plants, and insects and are an international priority for conservation, as well as important carbon stores.

**Heath and moorland**

One of the most characteristic landscapes in the Scottish uplands is heather moorland, or dry heath, with its treeless patchwork of shrubby vegetation and characteristic purple flowers in the late summer covering large areas of hillside (more information at Scotland's Moorland Forum). These areas are semi-natural habitats and, without land management, would revert to grassland or native woodland. The most common management methods, used to promote grazing habitats for grouse and red deer, is periodic “muirburn” to remove older plants and provide a variety of habitats.

Although burning vegetation releases greenhouse gases into the atmosphere, replacement plant growth will balance this out over the 10-20 year period of the management cycle. However, surface burning can also affect the carbon stored in the soil beneath, particularly when it is peat. Current guidance is to avoid burning heather on peat as the risks of causing damage to the carbon stores are high and carbon emissions from moorland management are not currently included in LULUCF calculations.
MONITORING AND REPORTING OF GREENHOUSE GAS EMISSIONS

UK greenhouse gas inventories are compiled annually for each of Scotland, England, Wales and Northern Ireland, and are delivered to DEFRA and the devolved administrations by AEA Technology (AEA Energy & Environment 2007).

All greenhouse gas emissions are reported using the units of carbon dioxide equivalent (CO$_2$e). This takes account of the global warming potential (GWP), or relative potencies, of different gases, and allows simple comparisons between emissions from a variety of sources (IPCC 2007). The UK Greenhouse Gas Inventories are used to fulfil the UNFCCC requirements, and also to monitor progress towards targets set by the Kyoto Protocol, European Union, and UK legislation. The process of reporting emissions in the UK is further explained in a National Audit Office report published in March 2008 (National Audit Office, 2008).

LULUCF is a unique sector because carbon sinks, which remove carbon dioxide from the atmosphere, are included as well as sources of greenhouse gas emissions. The Land Use, Land Use Change and Forestry section of the greenhouse gas inventory is completed by a consortium led by the Centre for Ecology and Hydrology (CEH) (Thomson et al 2007). It estimates greenhouse gas emissions and removals due to changes in the amount of carbon stored in plant material and soils occurring due to land management practices, or by the conversion of one land use type to another.

Whereas industrial or transport sources can have their emissions directly measured, emissions from LULUCF activities require estimates based on scientific understanding of the processes involved. The LULUCF sector has been reported consistently since the publication of IPCC’s 1996 revised guidelines for national greenhouse gas inventories, and has since been improved by IPCC Good Practice Guide in 2003, and new revised guidelines in 2006. There are different requirements for climate change reporting under the UNFCCC: for example the UK’s Kyoto Protocol reporting excludes emissions from the management of cropland and grazing land as these were not elected by the UK, and limits the emissions counted from forestry activities occurring before the Kyoto baseline year of 1990 (National Audit Office, 2008). Consequently, reports of emissions statistics are still sometimes given both including and excluding the LULUCF sector.

THE LAND USE, LAND USE CHANGE AND FORESTRY INVENTORY

In the UK, emissions from LULUCF are estimated using the Intergovernmental Panel on Climate Change Good Practice Guidelines (Intergovernmental Panel on Climate Change 2003) and the 2006 Revised Guidelines (Intergovernmental Panel on Climate Change 2006), and are based on a standard classification of land into six main categories: forest land, cropland, grassland, wetlands, settlements and other land (Thomson et al 2007).

Land cover data produced periodically by the Countryside Survey is used to identify areas where land use change has occurred, and is supplemented by annual updates of forest management data from the Forestry Commission, along with other relevant land management data. Together these sources are used to estimate the amount of land use change that has occurred each year since 1990. Estimates are then made, for all relevant managed areas, of changes in biomass and in soil carbon stores; and from these changes, greenhouse gas emissions to the atmosphere, and sequestration from the atmosphere, are calculated.

The inventory reports emissions at the national scale (although reporting on a 20 km$^2$ grid is in the final stages of development), accounting for most medium to large scale land use changes. Because this mostly involves longer term land use changes recorded in the Countryside Survey,
it is difficult to attribute trends in emissions to individual policy decisions or events, or to focus on particular sites.

The calculations involved in the LULUCF inventory involve a number of assumptions, parameters and models that lead to significant uncertainties in the reported results. Research is ongoing into emission processes and estimation methods, and the inventory is updated regularly (Thomson et al 2007). When this occurs, the historical emissions since 1990 are recalculated to ensure consistency in the results. The methodology is also quality controlled by the UNFCCC to ensure that the methods meet international standards for best practice.

SCOTLAND’S GREENHOUSE GAS EMISSIONS AND REMOVALS FROM LULUCF

The activities counted by the Land Use, Land Use Change and Forestry sector add up to a net carbon sink in Scotland. This means that, overall, they remove more greenhouse gases from the atmosphere than they produce. In 2005 this sink totalled 4.6 million tonnes of carbon dioxide equivalents (Mt CO$_2$e), and reduced Scotland’s emissions by around 8% to 54.5 Mt CO$_2$e (Thomson et al 2007).

This overall figure of a -4.6 Mt CO$_2$e source can be broken down to reveal that the LULUCF sector includes even larger sinks totalling -13 Mt CO$_2$e, balanced out with sources totalling 8.4 Mt CO$_2$e (Figure 2). These significant sinks are mostly due to forest plantations, which along with land converted to grassland are equivalent to around 20% of Scotland’s total emissions. However the LULUCF sector also includes the fourth largest source of greenhouse gas emissions, land converted to cropland, which accounts for 12% of total emissions by itself.

The overall value of the LULUCF sink in Scotland has nearly doubled since 1990, largely due to the forests planted throughout the middle part of the 20$^{th}$ Century. Over the same period of time total greenhouse gas emissions in Scotland fell by 15.5%, or 7.8 Mt CO$_2$e.

---

$^1$ By convention sinks are given –ve values for emissions, and sources +ve.
SINKS AND SOURCES INCLUDED IN THE SCOTTISH INVENTORY

For each land use category, emissions can be summarised in two main groups. The first of these contains management activities on unchanged land, and the second contains emissions from land that has been converted into a new category (Thomson et al 2007). The specific activities for which emissions are estimated in Scotland are listed in Table 1, which shows that emissions and removals in the LULUCF sector are dominated by two entries:

- **Land converted to forestland** is the largest carbon sink listed in the inventory resulting from the continuing carbon storage in areas of forest planted since 1922. Emissions/removals in this category are calculated using the C-Flow forest carbon model, which estimates the carbon stored by standing trees, litter, dead wood, and soil, and the model is based on annual records of forest planting and management since 1922. It takes into account different growth rates for coniferous and broadleaf trees, and uses a national soil carbon map (Bradley et al 2005) to make precise estimates of emissions from each area of forest in the country (Thomson et al 2007). Part of the management cycle of commercial forestry is harvesting and replanting, and some account of the carbon stored in the timber removed in this way is made in the Harvested Wood Products counted in “Other Activities” in the inventory.

- **Land Converted to Cropland** accounts for 12% of Scotland’s total greenhouse gas emissions, and is the fourth largest single source behind power stations, road transport, and household combustion. The total emission reported here is the sum of two activities: a very small source from removal of non-forest biomass, and significant emissions from changes in soil carbon stocks (Thomson et al 2007). Although only small areas of land have been converted to cropland in recent years, the process of carbon loss from soils takes time, and most of the reported emission is due to historical land use changes. The majority of land converted to cropland in recent history has been from grassland, and
despite some reversal in recent years, soil carbon is lost far more rapidly than it can be replaced (Thomson et al 2007).

WHAT IS NOT INCLUDED IN THE LULUCF INVENTORY?

Although the LULUCF inventory covers a wide range of activities occurring in the Scottish landscape, there are a number of greenhouse gas fluxes that are not directly included in the figures. These omissions are in part due to the standard international format of emissions reporting, but also represent areas where gaps in scientific knowledge mean that estimates cannot be confidently made.

One such area is the full role of peatlands and other organic soils in the carbon cycle, and it has not been possible to accurately estimate whether blanket bogs in Scotland are a net sink or source of greenhouse gases. There are currently several research projects in Scotland and the UK attempting to better understand the impact of peatland processes, management and restoration on carbon emissions (e.g. Thomson et al 2007) Recent research commissioned by the Scottish Executive resulted in a new model for estimating the sequestration and emissions from organic soils (Scottish Executive 2007). The results from this ‘ECOSSE’ project and its follow up may be included in the LULUCF inventory in future. The Scottish Government is working on ‘ECOSSE II’ and a linked exploratory project with the British National Space Centre to evaluate satellite images for their ability to detect greenhouse gas emissions from the land use sector (Scottish Government 2007).

There are also sources of emissions resulting from land use and agriculture, including emissions from fertilisers added to soils, which are counted separately in the Agriculture sector of the national greenhouse gas inventory (More on this available on the website of the Institute of Grassland and Environmental Research).
Table 1 lists the LULUCF emissions estimated for Scotland in 2005. For each land use type the net emissions/removals of greenhouse gases are listed for land remaining in that category and land converted to it. (adapted from Thomson et al 2007)

<table>
<thead>
<tr>
<th>Land Use Category</th>
<th>Land management activities</th>
<th>Land use conversions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest land</td>
<td>All old forests planted before 1921 – Emissions and removals of CO₂ from forests in this category are assumed to be in balance, resulting in net zero emissions</td>
<td><strong>NET SINK: -10.1 MtCO₂</strong> All new forests planted since 1922 – All recent planting is assumed to occur on land that has not been forested for at least several decades. Harvesting and replanting are assumed, and these forests will act as a net sink of carbon until their soil carbon stocks reach equilibrium.</td>
</tr>
<tr>
<td>Cropland</td>
<td><strong>NET SINK: -0.007 MtCO₂</strong> Liming of agricultural soils – CO₂ is released after the addition of limestone, chalk or dolomite to cropland soils. Changes in biomass due to increasing crop yields over time – A small sink due to improved crop strains</td>
<td><strong>NET SOURCE: 6.6 MtCO₂</strong> Changes in non-forest biomass stocks resulting from land use change – A small emission source from cleared vegetation Changes in soil carbon stocks due to land use change – A large source of long term emissions due to carbon emissions from disturbed or ploughed soils. In Scotland this occurs mostly from grassland.</td>
</tr>
<tr>
<td>Grassland</td>
<td><strong>NET SOURCE: 0.2 MtCO₂</strong> Liming of grassland soils – Calculated as for Croplands Peat extraction for horticultural use – Estimates the carbon released when extracted peat decomposes. Note: Peat extraction for fuel is covered in the Energy sector the Greenhouse Gas Inventory</td>
<td><strong>NET SINK: -2.8 MtCO₂</strong> Emissions from biomass burning after conversion of Forest land to Grassland – Emissions of CO₂, CH₄ and N₂O are estimated, assuming that 40% of standing biomass is burned. The other 60% is assumed to be converted into timber products (see Other Activities) Changes in non-forest biomass and soil carbon stocks – Emissions are calculated as for “land converted to Cropland”, usually resulting in increased vegetation cover and increasing soil carbon stocks.</td>
</tr>
<tr>
<td>Wetlands</td>
<td>Note: in the UK wetlands are defined as either saturated land (e.g. peatlands) and included in Grassland, or else open water (e.g. reservoirs) and included in Other land</td>
<td></td>
</tr>
<tr>
<td>Settlements</td>
<td>No changes in carbon stocks, and hence no emissions, are reported in this sector</td>
<td><strong>NET SOURCE: 1.7 MtCO₂</strong> Calculations are made for the same categories as “land converted to Grassland”</td>
</tr>
<tr>
<td>Other land</td>
<td>No emissions reported for this category, which includes bare rock, sand and open water</td>
<td></td>
</tr>
<tr>
<td>Other activities</td>
<td>Emissions from the carbon stock in Harvested Wood Products from post-1920 forests are estimated, taking into account the life cycle of different product types</td>
<td><strong>NET SINK: 0.07 MtCO₂</strong></td>
</tr>
</tbody>
</table>

2 Surveys show that conversions from Forest land to Cropland are negligible, so only conversion to grassland and settlement are calculated.
ENHANCING LAND USE AND FORESTRY SINKS IN SCOTLAND

Public sector bodies and non-governmental organisations are implementing a number of strategies to better manage or enhance land use sinks and sources in Scotland, some of which are introduced here.

Forestry Commission Scotland are developing a Climate Change Action Plan for 2008-2010 covering a wide range of issues (Forestry Commission Scotland 2008). One of the principal aims is to further increase the area of forestry in Scotland to 25% by 2050, requiring around 10,000 hectares of new planting to occur each year. This expansion will include a mixture of native mixed woodland and coniferous plantations, with correspondingly different carbon sequestration and offset potentials; there will also be increasing focus on commercial energy crops as well as timber production.

Although peatlands and heathlands are not explicitly included in the LULUCF inventory, both are priority habitats in the UK Biodiversity Action Plan, which requires damaged or degraded areas to be restored to a more natural condition. One consequence of this is that the carbon stored in these areas is protected, and may be enhanced. Initiatives such as the Life Peatlands Project in the Flow Country of Caithness and Sutherland have begun to successfully implement restoration measures such as drain blocking, and across the UK research is ongoing to better understand the carbon cycle in peatlands and the effects of these interventions and other processes (e.g. Thomson et al 2007; Scottish Executive 2007). It is likely that as the knowledge base is expanded, more detailed emissions from these areas, as modelled in the ECOSSE project commissioned by the devolved administrations in Scotland and Wales, may be included in the greenhouse gas inventory.

Delegates at the Scottish Forestry Forum (2008) discussed how a wider land use strategy for Scotland would be helpful in guiding the proposed expansion of forestry. This need has also been identified by the Macaulay Institute, which in its report on The State of Scotland’s Farm Environment (Macaulay Institute 2005) reported that:

> It is clear [that] different government commitments, obligations and strategies are strongly inter-related. […] Overall, environmental benefits would potentially be improved by an integrated approach to define an integrated land use strategy, including aspects related to the water environment, instead of following a sectoral approach.

PROJECTION OF FUTURE TRENDS IN LULUCF EMISSIONS

The UNFCCC and EU require projections of future emissions trends to be reported periodically, and for the LULUCF sector these are completed alongside the emissions inventory by CEH (Thomson et al 2007). The projections are based on three main scenarios (termed Low, Mid and High) representing a range of land use changes and potential policy choices (such as forest planting rates) in the coming years. The most recent report suggests that the size of Scotland’s LULUCF sink will decline by 2020 due to the reducing rate of forest planting since the 1970s (figure 3).

These projections are based on a small number of specific scenarios and are not forecasts; but even their most ambitious estimates (the Low scenario in figure 3) suggest that the annual capacity of the LULUCF sink will diminish over the next decade. This will mean that the impact of LULUCF in Scotland’s total greenhouse gas emissions will not follow the trend between 1990 – 2005, and that, in comparison to a 2005 or 1990 baseline, the change in total emissions from LULUCF may not be viewed positively by 2020. This will require greater efforts in other sectors...
to make the same overall progress. However, because many LULUCF emissions are excluded from international climate change targets such as the Kyoto Protocol, this may not have a substantial impact on the reductions required for international obligations.

Figure 3 – Projection of net LULUCF emissions for Scotland until 2020 (with trend from 1990). Note that even with high rates of new forest planting (Low scenario) the sink still decreases slightly.

Source: Thomson et al 2007
INTERNATIONAL COMPARISONS

The EU collects emissions data annually for all member states, but LULUCF is only reported by the 15 nations that were members before the expansion in 2004. In 2005 the net LULUCF sink for these countries had risen by 43% from 1990, equivalent to 7.5% of their total greenhouse gas emission emissions (European Environment Agency 2007). Portugal and the Netherlands are the only EU-15 states to have net emissions from LULUCF, while Finland has the largest sink, with large forests removing carbon dioxide from the atmosphere equivalent to nearly 45% of its emissions.

Figure 4 shows \textit{per capita} values for emissions from the EU-15 for 2005 compared to Scotland (European Environment Agency (2007), Eurostat 2006). Scotland has the sixth largest LULUCF sink in the group of nations, and is responsible for greenhouse gas emissions slightly higher than the EU-15 average, but slightly below the UK average. When the LULUCF sector is excluded, Scotland’s \textit{per capita} emissions are higher than both the EU-15 and UK average.

Figure 4 showing \textit{per capita} values for emissions from the EU-15 for 2005 compared to Scotland

---

\[ \text{2005 per-capita greenhouse gas emissions from EU-15 countries and Scotland} \]

- total LULUCF emissions/removals
- net GHG emissions

---

3 Compared to 84% increase in Scotland, offsetting 7.8% of emissions

\textit{providing research and information services to the Scottish Parliament}
SOURCES


Centre for Ecology and Hydrology - C-Flow Model. [Online]. Available at: http://www.nbu.ac.uk/ukcarbon/models.htm

Centre for Ecology and Hydrology Land Use. Land Use Change and Forestry. [Online]. Available at: http://www.edinburgh.ceh.ac.uk/ukcarbon/index.html


providing research and information services to the Scottish Parliament


Scottish Forestry Forum (2008) *Meeting to discuss the launch of the consultation on the Climate Change Action Plan 2008-2010.* Available at: [http://www.forestry.gov.uk/forestry/infd-7fbj3f](http://www.forestry.gov.uk/forestry/infd-7fbj3f)


Scottish Government (2008a) *Climate Change and Scottish Agriculture: Report and Recommendations of the Agriculture and Climate Change Stakeholder Group (ACCSG).* Available at: [http://www.scotland.gov.uk/Publications/2008/05/15115150/0](http://www.scotland.gov.uk/Publications/2008/05/15115150/0)

Scottish Government (2008b) *Consultation on Proposals for a Scottish Climate Change Bill.* Available at: [http://www.scotland.gov.uk/Publications/2008/01/28100005/0](http://www.scotland.gov.uk/Publications/2008/01/28100005/0)


*UK Greenhouse Gas Inventory National System* [Online]. Available at: http://www.ghgi.org.uk/index.html

*United Nations Framework Convention on Climate Change (UNFCCC)* [Online]. Available at: http://unfccc.int/2860.php


*Woodland Trust* [Online]. Available at: http://www.woodland-trust.org.uk/index.htm