The role of plantation forestry in Ireland in the mitigation of greenhouse gas emissions

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Abstract
Forests are a major component of the global carbon cycle and can make a significant contribution to the mitigation of greenhouse gas emissions. This can be achieved through a range of means including carbon sequestration and the use of forest biomass for bioenergy. Ireland's plantation forests are a net sink for carbon and contribute significantly to national greenhouse gas reduction targets under the Kyoto Protocol. Maintenance of this carbon sink requires an annual afforestation rate of 15,000 ha for the next two decades. Forestry is likely to play an increasing role in bioenenery through the delivery of biomass for energy production.

Keywords
Carbon sequestration, soil, biomass, bioenergy, harvested wood products

Introduction

It is now widely accepted that increasing atmospheric levels of greenhouse gases (GHG) are causing changes to the Earth's energy budget with consequent changes in climate (Solomon et al. 2007). If irreversible climate change is to be avoided there is an urgent need for strategies to reduce and mitigate GHG emissions. Forestry is recognised as having a clear role to play in the development and implementation of such strategies (Nabuurs et al. 2007).

Forests store vast quantities of carbon and are a key component of the global carbon cycle. According to Bolin et al. (2000) forests account for 39 and 77% of global carbon stocks in vegetation and soil (to 1 m depth) respectively. This is one of the principal reasons why forests were included in the Kyoto Protocol as a mechanism to mitigate greenhouse gas emissions. Forests can act as a source or a sink of carbon depending on the balance between uptake through photosynthesis and release through respiration, decomposition, fires, or removals by harvesting. Forests in the northern hemisphere are net carbon sinks (Ciais et al. 2008) and are largely influenced by human activity (Magnani et al. 2007). Forest areas in tropical regions have become large sources of carbon due to deforestation, with emissions from deforestation during the 1990s estimated at 5.8 Gt CO_2 yr^{-1} (Barker et al. 2007). Forest biomass is a significant source of energy, Nabuurs et al. (2007) estimate that biomass from forestry can contribute from a few percent to 15% of current global primary energy consumption. Combustion is the most common way to derive energy from biomass but numerous technologies are available to achieve cleaner and more efficient conversion (IEA Bioenergy 2007).

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There are many ways to mitigate GHG emissions using forests. These include afforestation, reducing deforestation, forest management, carbon storage in harvested wood products, product substitution and producing biomass for bioenergy. This paper will describe the role which plantation forestry in Ireland can play in mitigating GHG emissions.

The policy context

The main policy driver in relation to forestry and GHG emissions is the Kyoto Protocol. The protocol sets specific targets for GHG emissions reductions during 2008-2012 relative to the baseline year 1990. As a Party to the Protocol, Ireland is committed to limiting its GHG emissions to 13% above 1990 levels over the period 2008-2012. According to McGettigan et al. (2009) emissions in 2007 were 25% higher than in 1990. Specific provision is made in the protocol for the use of forest carbon sinks to offset GHG emissions. Article 3.3 refers to carbon stock changes due to afforestation, reforestation and deforestation since 1990 and its application in national carbon accounting is mandatory. Article 3.4 deals with management activities in existing forests (as well as other land use activities) and is not mandatory.

Modalities for accounting for both articles are set out in the Marrakesh Accords. While there is no cap on the carbon credit (or debit) a country accounts under Article 3.3, the maximum amount that can be used for compliance from forest management under Article 3.4 is set out in the Marrakesh Accords. For Ireland this was set at 50,000 t C yr^{-1}. Ireland subsequently decided not to elect the activity for the first commitment period 2008-2012. In addition, the Marrakesh Accords identify five carbon pools which Parties must account for: aboveground biomass, belowground biomass, litter, deadwood and soil organic matter[1]. Guidance on the compilation of GHG inventories for the forest sector is provided by the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (Penman et al. 2003) and the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Eggleston et al. 2006). The IPCC methodology is a tier-based system with the lowest tier (Tier 1) based solely on IPCC default data and approaches. Tier 2 requires nationally specific data and Tier 3 is more complex with the possible inclusion of models. Reporting at higher tiers should reduce the associated uncertainty. For further information on the forestry provisions of the Kyoto Protocol see Byrne and Green (2004) and Hendrick (2008).

At European Union and national level a range of bioenergy policies exist. The European Union Biomass Action Plan (Commission of the European Communities, 2005) foresees a doubling of the use of biomass for energy (principally wood) to reach 8% of the overall energy supply by 2010. The Renewable Energy Directive (European Union 2009) states that 'it is appropriate to establish mandatory national targets consistent with a 20% share of energy from renewable sources and a 10% share of energy from renewable sources in transport in Community energy consumption by 2020'. It makes specific reference to the forestry sector as follows 'In order to exploit

[1] A Party may exclude a pool from accounting provided it is not a net source of carbon emissions.

the full potential of biomass, the Community and the Member States should promote greater mobilisation of existing timber reserves and the development of new forestry systems'. At national level, the Bioenergy Action Plan (Anon. 2007) foresees that the peat-fuelled electricity generation stations will be co-fired by 30% renewable material by 2015, and that 12% of all residential and commercial heating will be powered by renewable sources by 2020. The National Renewable Energy Action Plan (Anon. 2010) states that Ireland's target is to achieve 16% of energy from renewable sources by 2020.

National forest policy has a direct impact on the role of forestry in meeting national targets under the Kyoto Protocol. It was most recently defined in 1996 (Department of Agriculture, Food and Forestry 1996) and aimed to increase the total forest area to 1.2 million ha by 2030, with an afforestation rate of 25,000 ha yr^{-1} up to 2000 and 20,000 ha yr^{-1} thereafter. The National Climate Change Strategy (Department of Environment, Heritage and Local Government 2007) estimates that afforestation since 1990 will create a carbon sink of 20.8 m t CO_2 equiv. during 2008-2012 and recognises the potential of wood fuel to displace fossil fuel.

Setting the scene – current status of Irish forests

For many centuries the story of forestry in Ireland was largely one of decline and exploitation. This reached its nadir in the early 20th century when less than 1.5% of the land area was under forest (Pilcher and Mac an tSaoir 1995). Following the establishment of a state afforestation programme in 1906 this decline was reversed. In the intervening period the forest estate has continued to expand, and by 2007 the total forest area was 697,730 ha (Redmond et al. 2007). The public forest estate accounts for 57% of the area, with the remainder in private ownership. The relatively high level of afforestation in the last 20 years is reflected in the age-class structure, with approximately 62% of plantations being less than 20 years old. Coniferous species account for 74% of the total forest area with broadleaf species comprising the balance. Sitka spruce is the dominant species, occupying 53% of the stocked forest land. Peats are the dominant soil type, accounting for approximately 43% of the forest area. Wet mineral soils are also common, with gleys accounting for 26% of the forest area (Redmond et al. 2007).

Afforestation since 1990 is the key driver of C sequestration in Ireland's Kyoto-eligible forest. Over the period 1990-2008 266,098 ha were afforested, with ~80% of this taking place in the private sector. While the rate of afforestation increased during the early 1990s (Figure 1), it has been in general decline since and fell to 6,900 ha in 2008, the lowest annual area since 1986.

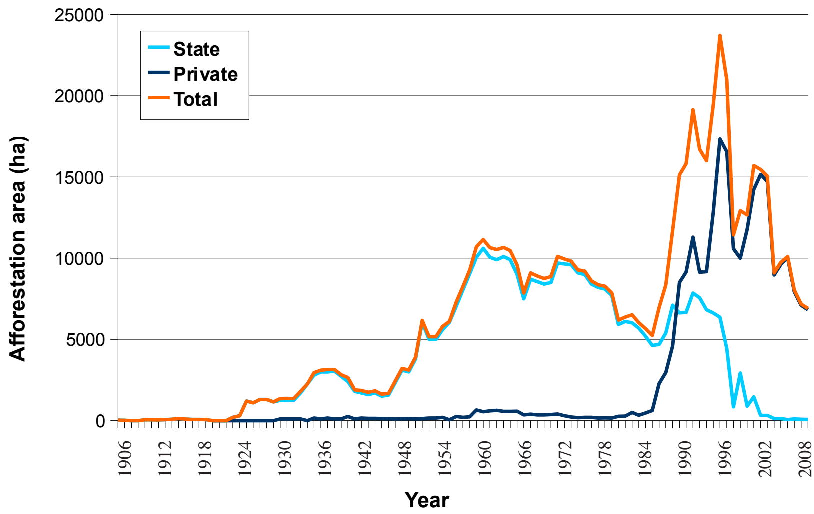

Figure 1: *Annual area of total, state and private sector afforestation in the Republic of Ireland during 1920-2008.*

Carbon sequestration in Irish forests

Prior to the mid-1990s little attention had been paid to carbon sequestration in Irish forests. The first assessment was carried out by Kilbride et al. (1999), who used forest area data for the main species and the model of Dewar and Cannell (1992) to estimate the average rate of carbon sequestration in Irish forests as 3.36 t C ha^{-1} yr^{-1}. This report indicated that afforestation since 1990 (i.e. Article 3.3 forests) could make a large contribution to Irelands GHG reduction commitment under the Kyoto Protocol. While this was a useful step it was clear that specific research was required to collect scientific information on carbon dynamics in Irish forests. This would underpin the development of a carbon accounting system for Irish forests and enable the role of forestry in mitigating GHG emissions to be assessed.

The CARBiFOR project (Black and Farrell 2006) was set up to investigate carbon dynamics in a first rotation Sitka spruce chronosequence on wet mineral soils. This project has provided information on ecosystem scale biosphere-atmosphere CO_2 exchange (Black et al. 2007), soil respiration (Saiz et al. 2007; Saiz et al. 2006a; Saiz et al. 2006b), soil carbon stocks (Green 2006; Reidy et al. 2006), biomass expansion factors (Black et al. 2004; Tobin and Nieuwenhuis 2007) and decomposition of coarse woody debris (Tobin et al. 2007). In a synthesis paper, Black et al. (2009) reported that first rotation Sitka spruce stands are a carbon sink at 10 years and that this reaches a maximum of 9 t C ha^{-1} yr^{-1} before the time of first thinning. This subsequently declines to 2 t C ha^{-1} yr^{-1} in older stands. This decrease was associated with a decline in gross primary productivity, an increase in respiration and harvest related decomposition losses. The rate of carbon sequestration is similar to that found in Sitka spruce stands in the United Kingdom (7 t C ha^{-1} yr^{-1} at canopy closure to 3 t C ha^{-1} yr^{-1} in older stands (Kowlaski et al. 2004, Magnani et al. 2007) and higher than those reported for coniferous stands across Europe (0.2 – 6.5 t C ha^{-1} yr^{-1} (Magnani et al. 2007). Other studies have delivered useful information regarding carbon dynamics in peatland forests (Byrne and Farrell 2001, Byrne and Farrell 2005, Byrne et al. 2001), biomass expansion factors in unthinned Sitka spruce (Green et al. 2007) and young lodgepole pine and Sitka spruce (Green 2006).

A carbon reporting system for Irish forests (CARBWARE) was initially developed to meet reporting requirements to the United Nations Framework Convention on Climate Change (UNFCCC) and was described by Gallagher et al. (2004). The model estimated the current and future carbon storage in Irish forests but its reliance on generalised stand growth models to estimate carbon stock changes was a shortcoming. With the recent availability of National Forest Inventory data (Redmond et al. 2007) CARBWARE is now being redeveloped and improved to meet the reporting obligations of the Kyoto Protocol as well as the UNFCCC (Black and Gallagher, 2007). This will deal with all five carbon pools specified in the Marrakesh Accords (aboveground biomass, belowground biomass, litter, dead wood and soil organic matter) (Black and Gallagher 2007). A pilot study by Green (2006) has shown that it is possible to report at Tier 2/3 for all five carbon pools but that there is high uncertainty associated with carbon emissions from organic soils.

Harvested wood products, bioenergy, substitution

Harvested wood products are an important carbon store. Discussion has been ongoing for a number of years as to how to estimate and account carbon stocks in this pool with three approaches being identified (Penman et al. 2003). These are the stock-change approach, the production approach, and the atmospheric-flow approach. Green et al. (2006) examined these in the Irish context and found that, for 2003, the stock-change approach yielded the highest carbon sink (relative to the IPCC default approach) of 375,000 t C yr^{-1} ± 40% with the production approach and atmospheric-flow approach estimating the stock change at 271,000 t C yr^{-1} ± 48% and 149,000 t C yr^{-1} ± 31%, respectively.

Over the period 1990-2007, the output of the Irish renewable energy sector grew by 182%. The share of primary energy consumption increased from 2.7% in 2006 to 2.9% in 2009 (Knaggs and O'Driscoll 2009) (Table 1). It is estimated that 2.1 million tonnes of CO_2 emissions are saved due to this use of renewable energy. The sawmilling and wood-based panel (WBP) sectors dominate the market for wood biomass with the use of sawmill residues, WBP residues and post consumer recovered wood to generate heat and electricity for processing and drying facilities. Knaggs and O'Driscoll (2009) estimate that in 2007 this use of wood biomass equated to a CO_2 emissions saving of 369,000 t CO_2. Wood pellets are being increasingly used to fuel domestic heating systems. In 2007 25,000 tonnes were imported. In the following year, 2008, a wood pellet production facility with an annual production capacity of 75,000 t was opened in Co Kilkenny (Knaggs and O'Driscoll 2009). Considerable progress has been made in bioenery-related harvesting operations through the ForestEnergy programme which established 15 commercial scale demonstrations of forest harvesting supply chains for wood energy (Kofman and Kent 2009). Thinnings from young plantations are likely to supply significant volumes for the generation of wood energy in the near future.

Biomass can displace fossil fuels by providing substitute products for energy intensive materials such as steel, aluminium and plastics. During the recent building boom there was an increase in the proportion of timber-framed houses built in Ireland, accounting for an estimated 15% of the total output in 2002 (Timber Frame Housing Consortium 2002). In addition, Quigley (2002) has shown that timber-framed houses can be more energy efficient than traditional concrete block houses with a consequent reduction in energy-related CO_2 emissions.

Table 1: *Contribution of renewables to total primary energy requirement (TPER) in Peta Joules (PJ) for 2007 (Knaggs and O'Driscoll 2009).*

Renewable energy type	PJ	%	% TPER
Wind	7.03	37.67	1.00
Biomass	7.16	38.35	1.10
Wood	4.82	25.79	0.75
Tallow	2.34	12.56	0.35
Hydro	2.39	12.77	0.40
Other	2.09	11.21	0.40
Landfill gas	1.00	5.38	
Biogas	0.42	2.24	
Liquid biofuel	0.63	3.36	
Solar	0.04	0.22	
Total	**18.67**	**100.00**	**2.90**

Discussion

During the last decade considerable progress has been made regarding our knowledge of carbon sequestration in Irish forests. This has been focused on first rotation Sitka spruce (Black et al. 2009; Black and Farrell 2006) and has provided not only scientific insight into carbon dynamics in these forests but also nationally specific information for carbon accounting (Black et al. 2006). Current COFORD funded projects are addressing a broad range of issues such as soil carbon stock and stock changes, biomass expansion factors for a range of conifer and broadleaf species, and carbon emission factors for afforested peat soils. As post-1990 forests mature and undergo harvesting associated disturbances, there will be a need for research to examine the impact of these practices on carbon sequestration.

Current estimates suggest that the gross uptake of carbon in Irish forests was 6.2 million tonnes in 2008 (Hendrick and Black 2009). When harvest removals of 2.6 million tonnes are subtracted the net carbon sink is 3.6 million tonnes CO_2 per year. Afforestation since 1990, or 'Kyoto forests', account for 2.0 million tonnes CO_2 per year and forests established before 1990 1.6 million tonnes CO_2 per year.

Afforestation is the key driver of carbon sequestration and will deliver a large carbon sink in the short term. However, forestry is a long-term activity and requires planning over decades in order for it to contribute consistently to GHG mitigation. A key element is a stable afforestation rate so that goods and services are delivered at an even rate. If there is an even age-class distribution then the rate of carbon removal through harvesting will be compensated by carbon uptake in other forests. Recent analysis by Hendrick and Black (2009) shows that if the annual afforestation rate falls to about 7,500 ha then by 2035 these forests will be net sources of carbon. This is because by 2035 forests planted during the afforestation peak in the mid 1990s will be entering the harvesting cycle, and therefore undergoing reductions in carbon stocks, and there would be insufficient areas of younger forests where carbon sequestration could compensate for these losses. Hendrick and Black (2009) suggest that the afforestation rate be maintained at 15,000 ha yr^{-1} for the next two decades to ensure sustainable delivery of wood biomass.

It is also vital that forest cover be maintained. If forest is lost the carbon sequestered is returned to the atmosphere and the potential of the forest estate to deliver wood energy diminished. Possible reasons for deforestation often recently include peatland restoration and wind farm development. Hendrick and Black (2009) estimate that an annual deforestation rate of 1,000 ha would reduce the Kyoto forest sink by 500,000 tonnes of CO_2.

The CARBWARE carbon accounting system has been greatly strengthened by the recently completed National Forest Inventory. A repeat inventory would not only be consistent with international practice but would also allow a direct estimate of carbon stock change over time and enable validation of carbon accounting models. Other changes to CARBWARE will include the inclusion of a sub-model to account for carbon stock changes in HWP (Donlan and Byrne 2010).

International climate change policy is a key factor in determining the contribution of forestry to GHG mitigation. The Kyoto Protocol only runs until 2012; efforts are currently underway to negotiate a successor agreement before it expires. In order to be successful this should include both developing and developed economies as well as countries that did not ratify the Kyoto Protocol (US and Australia). If such an agreement emerges it is almost certain to include forest carbon sinks. Among the new issues that are likely to be included (as well as being contentious) are:

- a mechanism in relation to reducing emissions from deforestation and degradation in developing countries – REDD;
- new accounting rules for the Forest Management activity under Article 3.4, including provisions to deal with the compliance risk of large scale disturbances and the inclusion of harvested wood products as a carbon pool similar to the carbon pools in the Marrakesh Accords.

While forest carbon sinks are a vital part of efforts to mitigate global GHG emissions, their inclusion should not undermine the overarching need to tackle emissions - carbon sinks should only be considered a short to medium term solution and should not detract from efforts to reduce emissions. Within the European Union there is likely to be continued efforts for carbon sinks to be included in the Emissions Trading Scheme. Such an outcome could offer new sources of investment in forestry, e.g. large industrial emitters could invest in forestry as a means to offset their emissions. It is vital that any mechanisms regarding the inclusion of carbon sinks in future climate change agreements are based upon scientific information and not short-term political considerations. This will ensure that such mechanisms are both environmentally sustainable and deliver real reductions in GHG emissions.

Forestry is likely to play an increasing role in bioenergy through the use of harvest residues, thinnings and bioenergy-specific forestry systems such as short rotation crops. While burning biomass is considered to be carbon neutral, activities such as ground preparation, harvesting, processing and transport may produce GHG emissions. There is a need to quantify these emissions using Life Cycle Analysis and inventory systems so they are included in the accounting framework, and to enable quantification of the net GHG benefit of bioenergy systems (e.g. Styles and Jones 2008).

Conclusions

Plantation forestry is making a significant contribution to the mitigation of GHG emissions in Ireland. This represents a considerable financial saving for the state and emphasises the need to maintain the afforestation rate at 15.000 ha yr^{-1} for the next two decades. Failure to do so may lead to Kyoto forests becoming a carbon source in the future as carbon removals through harvesting are not compensated by carbon sequestration. Forestry will also play a significant role in the delivery of bioenergy. Continued investment in research will be necessary to ensure that GHG mitigation by forestry is environmentally sustainable, maximises the use of indigenous resources and provides secure employment.

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