Forestry and a low carbon economy – a background paper

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Abstract
The forest sector plays and will play an important role in relation to climate change mitigation and the development of a green economy. Sequestration of carbon dioxide through forest cover expansion and management of forests, allied to the production of wood and wood products to replace fossil fuels and energy intensive materials, are the main contributions that the forest sector in Ireland makes to climate change mitigation. Significant potential exists to increase this contribution. Looking to the global scale, reduction and avoidance of deforestation is the key forest policy that will contribute to reduction in greenhouse gas emissions. However, there are a number of uncertainties and unknowns that need elucidation and clarification before the full potential of the forest sector can be determined and optimised. This article provides an overview of the current state of knowledge in relation to the forest sector's existing and potential contributions to the development of a green economy and follows this with a discussion of important issues that need clarification and research. It is essential to ensure that the contribution of the forest sector as an efficient carbon sink and as a producer of renewable, low-carbon materials does not adversely impact on forests as providers of a wide range of other ecosystem goods and services.

Keywords: *Green economy, renewable energy, low carbon materials, forest sector.*

Introduction

The forest sector plays and will play an important role in relation to climate change mitigation and the development of a green economy. Sequestration of carbon dioxide through forest cover expansion and management of forests, allied to the production of wood and wood products to replace fossil fuels and energy intensive materials, are the main contributions that the forest sector in Ireland makes to climate change mitigation. Significant potential exists to increase this contribution. This article provides an overview of the current state of knowledge in relation to the forest sector's existing and potential contributions to the development of a low carbon economy, and follows this with a discussion of important issues that need clarification and research.

The global picture

Next to peatlands, forests are the largest terrestrial store of carbon on the planet and their use and management play a significant role as drivers of climate change on the

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one hand, and in climate change mitigation and adaptation on the other. Recent estimates by Pan et al. (2011) suggest that the entire terrestrial carbon sink can be accounted for by the uptake by globally established forests, and consequently that non-forest ecosystems are collectively neither a major sink nor a major source. While these estimates are at a global scale and there are very significant regional divergences, they point to the strength of the forest sink, even after netting out emissions from deforestation.

Deforestation and subsequent land-use change, mainly in tropical regions, accounts for up to 18% of greenhouse gas emissions, about 5.8 billion tonnes of carbon dioxide (CO_2) equivalent per year, which is more than the total of global transport and aviation combined (IPCC 2007). Measures to address forest loss in tropical countries have been underway for many decades, through development aid and other means, but these have had limited impact. Since the Montreal United Nations Framework Convention on Climate Change conference in December 2005, discussion and negotiation has continued in the process of what has become known as REDD+: Reducing Emissions from Deforestation and Forest Degradation + conservation and management of carbon stocks. Some progress has been made, the Cancun agreement at the end of 2010 included measures to slow, halt, and reverse forest loss and the related emissions in developing countries. Before, and increasingly since Cancun, capacity building in the measurement, reporting and verification of forest carbon stocks and stock change has been underway in developing countries. One of the key issues that remain is how to provide a link between verified emission reductions and removals in REDD+ and compliance with greenhouse emission reduction targets in developed countries. There is little doubt that a successful REDD+ mechanism will need to be in place if the EU is to achieve emission reductions of the order of 80–95% on 1990 levels (the EC's *Roadmap for moving to a competitive low carbon economy in 2050*), notwithstanding the emphasis the roadmap places on domestic action in Member States. As for other Member States, REDD+ is of strategic interest for Ireland, especially having recently become more closely engaged through becoming a member of the European Forest Institute's (EFI) EU REDD facility, and providing funds for its activities.

Conceptual and accounting frameworks for land use, land use change and forestry

The Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCCC 2007) provides a conceptual framework to consider the contribution of the forest sector to climate change mitigation. It can be summarised as sequestration, replacement and substitution:

- net sequestration or uptake of atmospheric carbon, through avoidance of deforestation, extending forest cover and enhancing carbon uptake in existing forests, and through related measures;
- replacement of fossil fuel by biomass from forests and other sources (provided the wood comes from sustainably managed forest and preferably from forests within the international accounting system); and
- materials substitution using wood products in construction and other end

uses, with the benefits of reduced emissions from manufacture and placing carbon in storage.

The role of the global forest sink in tackling climate change has been recognised from the outset by the United Nations Framework Convention on Climate Change (Article 4.2 of Convention). Following on from the Convention, the Kyoto Protocol provided the accounting framework for forest sinks. The most recent set of rules for land use, land-use change and forestry (LULUCF) for the post 2012 period were agreed in Durban at the end of 2011. In principle the rules will apply only to those parties that will commit to take on legally-binding emission reductions for the post-2013 period, though other developed country parties who have stated an unwillingness to take on commitments in the absence of global agreement to reduce emissions have indicated that they intend to apply the rules in meeting unilateral emission reduction pledges.

The Durban rules (FCCC/KP/CMP/2011/10/Add.1) were negotiated taking into account the IPCC guidance, and for those countries that will sign up to a second commitment period under Kyoto they will:

- extend the mandatory nature of forest carbon accounting to all managed forests, and, through the use of a reference level for forest management and the rules for afforestation, provide the basis for an incentive structure that rewards activity that will result in sequestration levels over and above business-as-usual;
- strengthen the environmental integrity of the use of forest-based biomass sourced within and from countries that sign-up to a second commitment period; and
- provide, for the first time, an accounting framework for harvested wood products that is based on actual service-life.

The new rules should help to level the playing field between the three different mitigation contributions and enable cost-effective mitigation strategies and technologies to emerge.

National and EU policies and measures

Forest sinks are part of the compliance regime for the first commitment period under the Kyoto Protocol, which runs from 2008 to the end of this year (2012). Forests will contribute substantially to Ireland's target: about 14 million tonnes of carbon dioxide, sequestered over the period 2008–2012, in new forests established since 31st December 1989. National projections made using the COFORD CARBWARE model (Black et al. 2012) indicate that this level will increase to 4.6 million tonnes of carbon dioxide per annum by 2020 (EPA 2012). It remains to be seen if and how this quantum of carbon will be included or recognised in target setting and compliance. In-so-far as activities such as afforestation are funded to address climate change mitigation, there is a logical link to target-setting and then compliance. Going further, the interchangeable nature of the carbon sink units within the Emission Trading Scheme (ETS) is a logical link in the context of enabling the most cost-effective mitigation systems and technologies to emerge over time, as long as issues such as reversibility and any consequent liability are addressed.

Inclusion of sequestration post 2012 will depend on the outcome of the discussion of the European Commission's LULUCF proposal. Also important are the international negotiations and the EU's emission reduction target, bearing in mind that the EU has said it would consider moving towards a 30% reduction by 2020 if certain conditions were fulfilled. The Commission's proposal, issued on the 12th March 2012, is for a decision on accounting rules and action plans on greenhouse gas emissions and removals resulting from activities related to land use, land-use change and forestry. The proposal states that "The main objective of this Decision is to establish robust and comprehensive accounting rules for LULUCF as well as to enable future policy development towards the full inclusion of LULUCF in the Union's greenhouse gas emission reduction commitments when the conditions are right." The proposal is currently under discussion between the Commission and the Member States.

The forest estate and its outputs

Forest cover in Ireland and in Europe

Forest cover in Ireland reached 731,650 ha in 2012, or nearly 10.5% of total land area. This compares to a European average of 43% (FOREST EUROPE, UNECE and FAO 2011). In Ireland, most new plantings were undertaken by the State up until the mid 1980s. However, the introduction of EU co-funded support programmes at that time was a catalyst for a significant increase in private afforestation.

The level of planting by the private sector exceeded public planting by the mid to late 1980s, with the latter virtually ceasing since 2001 (Figure 1). Private planting peaked around the mid 1990s and although levels had increased somewhat in recent years, in 2011 there was a 20% decrease to 6,653 ha in the area of grant-aided afforestation. (One of the factors at play in reducing the level of uptake seems to be uncertainty as to how the level of single farm premium payments will be calculated in the post 2013 period.) The proportion of privately-owned forest land has now reached 47% (end 2011). There has been a significant increase in broadleaf planting since 1996 reflecting the revised support structure for such plantings. Broadleaves accounted for nearly 37% of new planting in 2011, exceeding the 30% target.

Irish timber harvest and woodflow

In 2010, 2.88 million m^3 of roundwood was harvested in the Republic of Ireland[1]; 2.7 million m^3 of which was utilised by the processing sector (Table 1), with the balance of 199,000 m^3 being used for firewood. Private forest harvest grew by 356% over 2009 driven by strong demand across all assortment classes. Of the roundwood that was processed in the Republic of Ireland, 82% was supplied by Coillte with 17% provided by the private forest sector; the balance was supplied by imports.

[1] For further information on wood harvest and forest products trade see Woodflow and forest-based biomass energy use on the island of Ireland – COFORD Connects Note: Processing/Products No 27.

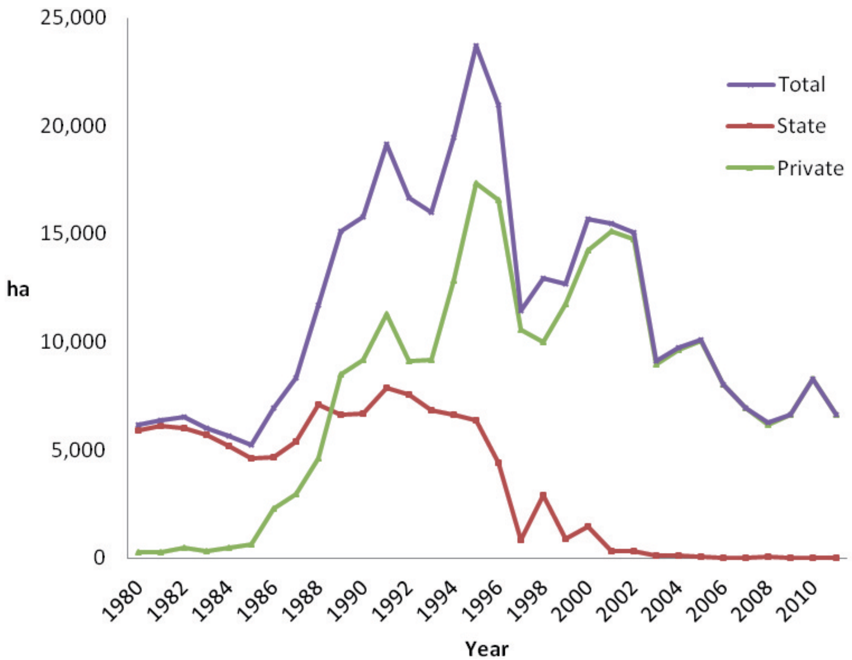

Figure 1: *Public, private and total afforestation from 1980 to 2011. Source: Forest Service*

Table 1: *Roundwood available for processing in the Republic of Ireland (2008–2011).*

	2008	2009	2010	2011
	000 m³ OB			
Imports less exports	106	−63	28	55
Coillte harvest	2,279	2,354	2,217	2,299
Private sector harvest	118	130	463	386
TOTAL	2,503	2,421	2,708	2,740

Source: Knaggs, G. and O'Driscoll, E. 2011. Woodflow and forest-based biomass energy use on the island of Ireland (2011) – COFORD Connects Processing/Products.

Forest-based biomass for energy use, policy drivers and markets

Past and current use

In 2010, 34% of the roundwood harvested in the Republic of Ireland was used for the production of biomass energy (Table 2). Since 2006, the use of wood biomass energy in Ireland has resulted in an estimated greenhouse gas emission saving of 2.03 million tonnes of CO_2.

The results of a recent study (referred to in O'Driscoll and Knaggs 2012) has shown that the Irish market for firewood has grown by 35% over the period 2006–2010. In 2010, 199,000 m³ of firewood was sold in Ireland to a value of €28.80 million. The harvest level is significantly above that which had been estimated for previous years and shows that the Irish firewood market is providing a

Table 2: *Use of forest-based biomass (in 000 m^3 over bark, round wood equivalent) and as a proportion of total roundwood harvest (2010–2011).*

	2010	2011
	000 m^3 OB RWE	
Forest-based biomass use by Edenderry Power	79	85
Forest-based biomass used for energy production and process drying in sawmills and wood-based panel mills	475	487
Roundwood chipped for primary energy use	39	41
Domestic firewood use	199	214
Short rotation coppice	1	5
Wood pellets and briquettes	121	129
Charcoal	2	2
TOTAL	**916**	**963**
Roundwood available for processing	2,708	2,740
Firewood harvest	199	214
TOTAL	**2,907**	**2,954**
Forest-based biomass as a % of total roundwood harvest	**31.5**	**32.6**

Source: UNECE Joint Wood Energy Enquiry (JWEE): 2009–2012.

steady and a growing market for first thinnings. An important consideration here is the need for advice on efficient and environmentally friendly wood fuel combustion systems, such as wood gasification boilers.

The use of forest-based biomass for energy production is dominated by the forest products sector, which uses it for process drying and for energy purposes. Since 2007, the use of forest-based biomass for energy production by commercial and domestic users has risen considerably (Table 3). Between 2005 and 2009, the

Table 3: *Wood biomass fuel use by sector in the Republic of Ireland (2008–2011).*

Fuel category	**End use**	**000 m^3 RWE**			
		2008	**2009**	**2010**	**2011**
Firewood	Domestic heating	171	184	199	214
Wood chips	Commercial heating	63	53	39	41
Short rotation coppice (SRC)	Commercial heating	1	4	1	5
Wood pellets and briquettes	Domestic and commercial heating	82	110	121	129
Charcoal	Domestic use	2	2	2	5
Biomass use by the energy and forest products industry	Process drying/heating /CHP	384	438	554	572
TOTAL		**703**	**791**	**916**	**966**
Use by the energy and forest products sectors (%)		55	55	60	59

Source: Knaggs, G. and O'Driscoll, E. 2011. Woodflow and forest-based biomass energy use on the island of Ireland (2011) – COFORD Connects Processing/Products.

Table 4: *Output use of forest-based biomass and associated greenhouse gas emissions mitigation (2008–2011).*

	Unit	2008	2009	2010	2011
		Output			
Heat	TJ	4,857	5,273	6,306	6,604
Electricity	TJ	112	240	372	378
TOTAL	TJ	4,969	5,513	6,678	6,982
CO_2 abated	000 tonnes	380	422	511	534

Source: Knaggs, G. and O'Driscoll, E. 2011. Woodflow and forest-based biomass energy use on the island of Ireland (2011) – COFORD Connects Processing/Products.

domestic use of forest-based biomass grew by 18% per annum. The output of the forest-based biomass energy sector is shown in Table 4.

Projected forest sector contribution to supply and demand of biomass

Work on forest-based biomass supply and demand has been published in two COFORD reports issued in early 2011:

a) The All-Ireland Roundwood Production Forecast 2011–2028 (Phillips 2011) covers all roundwood but includes separate estimates of forest-based biomass supply to 2028 (Table 5). It estimates that annual net realisable roundwood volume production will increase to 4.64 million m^3 by 2020 and shows that supply of forest-based biomass has the potential to increase by up to 50%, or 1.5 million m^3 by 2020. The report notes: "The total is not an estimate of new or additional volume available for wood energy over and above current usage. Wood energy will have to compete with other end uses for the volumes indicated." There is potential to increase the level of supply of forest-based biomass in the period up to 2020 by:
   1. harvesting occurring in a higher proportion of forests that are due for thinning;
   2. removing larger amounts of biomass in thinning by using whole-tree harvesting systems (Kent et al. 2011); and
   3. removing harvesting residues and stumps from selected clearfell sites (Kent 2012).

b) The All-Ireland Roundwood Demand Forecast 2011–2020 (COFORD Roundwood Demand Group 2011) estimates that annual demand for roundwood will increase to ca. 6.04 million m^3 by 2020, including an estimated demand of 3.08 million m^3 of wood biomass for energy purposes. The estimated shortfall in supply of roundwood is around 1 million m^3 on the island of Ireland by 2020, mainly in the Republic of Ireland and almost all in the forest-based biomass category. The shortfall could be partly addressed by recovery of harvesting residues from suitable clearfell sites, and from increased fibre recovery from first and subsequent thinning. In addition, short rotation coppice could make a contribution to closing the

Table 5: *Estimate of wood fibre potentially available for energy (in 000 m³) and its energy content. (PCRW = post-consumer recovered wood.)*[a]

Year (PJ)	Tip to 7 cm	Roundwood 7–13 cm	Downgrade + wood residues	PCRW	Total	Energy content
2011	48	199	737	86	1,069	7.38
2012	45	202	626	87	959	6.61
2013	44	177	639	88	948	6.54
2014	47	203	726	88	1,065	7.35
2015	48	232	735	89	1,104	7.62
2016	48	251	692	91	1,083	7.47
2017	52	303	734	93	1,182	8.16
2018	50	265	712	95	1,122	7.74
2019	53	296	784	97	1,230	8.49
2020	58	382	915	99	1,453	10.02
2021	59	374	910	101	1,444	9.97
2022	59	369	901	103	1,431	9.88
2023	63	378	982	105	1,527	10.53
2024	60	369	942	107	1,478	10.20
2025	56	325	882	109	1,372	9.47
2026	55	331	1,052	111	1,549	10.69
2027	63	398	1,236	113	1,809	12.49
2028	61	382	1,191	116	1,750	12.07
Total	**970**	**5,435**	**15,395**	**1,776**	**23,575**	**162.67**

Source: Phillips, H. 2011. *All-Ireland Roundwood Production Forecast 2011–2028*. COFORD, Department of Agriculture, Food and the Marine, Dublin.

[a] There are three main sources of raw material for wood energy – small roundwood from thinnings, wood residues from the processing sector and post consumer recycled wood (PCRW). Additional raw material is potentially available through the harvesting of tree tips (tip to 7 cm diameter) and through the collection of harvesting residues and some harvest-abandoned material on suitable sites.

anticipated supply gap. Supply could be supplemented by areas of short-rotation coppice and short-rotation forestry[2].

Forest-based biomass is by far the dominant component of biomass supply and is likely to remain so. Recent work (Phillips 2012) points to an afforestation level approaching 15,000 ha per annum in the period leading up to 2020 and beyond, as necessary for forests to provide a sustainable level of supply of forest-based biomass.

[2] In this context short rotation forestry is a tree crop grown on a typical cycle of 10-15 years followed by regeneration. Short rotation coppice includes tree species such as willow harvested on a two to three year cutting cycle with the stools being replaced every 20 to 24 years.

Economic output and employment in the forest sector

The contraction in the domestic economy since 2007 has been balanced by a significant increase in wood product exports. In value terms, exports of wood products grew by 18% in 2010 to reach €286 million, €179 million of which comprised wood-based panels. This was largely due to increased demand in the UK as a result of reduced production of wood products in the Nordic countries in response to falling markets and the ability of Irish sawmillers to adapt to changing market conditions.

The increasing use of wood biomass in the renewable energy sector is also providing private forest owners with a long term sustainable market for wood, especially for small-diameter logs and harvesting residues from early thinning operations. Use of forest-based biomass is likely to increase substantially with the availability of REFIT 3 from early 2012. At the end of 2010, Ireland's consumption of electricity from renewable sources stood at 14.8% and this needs to increase to 40% by 2020, if we are to meet our legal obligations. In order to contribute towards our target, REFIT 3 sets out to encourage the development of biomass resources through REFIT (Renewable Energy Feed in Tariff) for biomass generation.

Economic output for the forest sector can be divided into the growing and processing subsectors. In 2010, direct output of the growing subsector was €379.8 million (Ní Dhubháin et al. 2012). When the indirect effects (i.e. the impacts of the spending by suppliers to the growing sector on goods and services) and induced effects (i.e. the additional consumer expenditure that takes place when the wages and salaries generated from the direct and indirect contributions of the growing subsector are in turn spent) are taken into account, the overall value of the growing subsector to the Irish economy was €673.0 million in 2010. Direct employment was 3,125. Accounting for the induced and indirect effects, the total employment supported by the growing subsector was estimated to be 5,531.

Direct output in the processing subsector (panel board mills, sawmills and other wood products) was €1,330.9 million. Direct employment was 3,907. Accounting for the induced and indirect effects, the total employment supported by the processing subsector was estimated at 6,408. The total value to the economy of the processing subsector was €2.20 billion, nearly 3.3 times the growing subsector figure of €673.0 million (Ní Dhubháin et al. 2012).

The future of forestry: fundamental issues

Heretofore, the main focus underpinning forest policy was to ensure a consistent, continuous supply of roundwood to the wood processing industry. In latter times, this focus has extended to encompass renewable energy policies and associated measures (through the provision of wood biomass for the wood energy sector – thereby also developing a market for thinnings) and climate change mitigation (Government of Ireland 2012). At the same time, the emphasis on the environmental and societal benefits associated with forestry has also increased.

In order to continue to develop forestry into the future for the above purposes, particularly the productive functions, and to ensure it is "fit for purpose" into the future, it is important to assess the following fundamental issues as they apply to forestry in Ireland:

- appropriate level of afforestation;
- efficient and economic management of the current forest estate;
- cost-effective mobilisation of roundwood timber from the forest estate;
- silviculture and management systems;
- the sustainability of residue and stump harvesting;
- optimal use of wood;
- sustained provision of public goods;
- forest protection and health;
- governing legislation.

Afforestation
The main focus is to increase the level of annual afforestation to 14,700 ha, in line with the commitment in the Programme for Government. This level of afforestation, if sustained over an extended period of two decades, would contribute to achieving a sustainable supply of goods and services from the forest sector. Given the current annual afforestation levels of ca. 6,000 ha, this target seems to be quite unrealistic. Additional factors to be considered in this context are:

- the species mix that would take account of the implications of climate change, future market requirements and carbon sequestration capacity;
- the necessity to comply with environmental and regulatory procedures; and
- the availability of suitable land.

While the availability of funding is a major factor limiting the ability to achieve this target, there are also other contributory factors including the attitude of landowners to forestry. The provision of information on forestry, especially in relation to cost and projected income (both in the short and long-term), will help to increase the return on investment, as will learning of the experiences of landowners who have already committed to a forest enterprise.

The management of the current forest estate
The effective and optimal management of the current forest resource is also essential in order to maximise the return to both the forest owner and the sector in the future. For the benefit of the overall sector, it is important, at a policy level, to support sustainable forest management (SFM), facilitate certification, have systems in place to forecast future roundwood supply and ensure compliance with felling requirements. It is therefore necessary to engage at forest owner level to convey the importance of sustainable forest management and certification. Certification of timber from sustainably managed forests has become a pre-requisite for the sale of processed timber into many timber outlets, particularly in the UK.

In recognition of the importance of the thinning of plantations, as and when appropriate, to ensure the viability of the remaining stand and to contribute to the long term financial return, it will also be necessary to focus on investment in the forest road infrastructure. Once again, the availability of funding will be a major determinant.

The mobilisation of timber from the privately owned forest plantations
A challenge that has been identified in relation to roundwood supply has been the mobilisation of the private timber resource. The age profile of the current forest estate and the need to leverage supplies from the private sector to meet the increasing demand for wood energy (met through the extraction of thinnings) have combined to highlight this issue. Research conducted by Teagasc indicates that if only 50% of private forest owners thin their plantations, the output from farm forestry first thinnings alone would exceed 200,000 m^3 each year. Coillte is currently the main supplier of roundwood to the sawmilling / processing industries; however, COFORD estimates that the private sector's market share could rise from approximately 10% at present to 23% by 2015. There are at least three issues in relation to the extraction of roundwood from private forest plantations, namely:

- Strong demand for roundwood at prices that will enable and encourage private sector investment and involvement. This is allied to the policy and regulatory framework; for example the roll out of REFIT III and the consent system for forest roads.
- Knowledge about thinning: the forest owner knows the financial benefits and importance of thinning and how to go about it. This information is available in the private sector and through the Teagasc Forestry Development Department's Training and Advisory Programme. It is also being promoted through the formation of forest producer groups with the assistance of the Teagasc Forestry Development Department.
- The requirement for forest roads to facilitate the harvesting and extraction of the thinnings – also necessary in the long term for clearfelling (i.e. harvesting of final timber crop) – as outlined above, the availability of funding is a major determinant while compliance with planning regulations is also now a factor.

Silviculture and management systems
It has been demonstrated that changes in forest management can result in enhanced carbon sequestration and as a result a mitigation of climate change (Magnani et al. 2007, Ciais et al. 2008). However, a robust metrics system to compare the impacts of each forest management system on different ecosystem services is still missing. The overlapping challenge is to deal with the interactions between carbon sequestration and other forest ecosystem services (wood and non-wood products; wood for bioenergy; water quality and quantity; soil fertility and protection; recreation). Candidate silvicultural and management practices to increase climate change mitigation capacities in managed forests may include:

- afforestation/reforestation with species adapted to climate change;
- the use of mixed stands (for better use of soil resources and potentially increased resilience to climatic events);
- the use of coppice and coppice with standards (for an increased carbon storage in the roots and the provision of wood for energy);
- changes in rotation length (longer periods for a better nutrient use-efficiency,

versus shorter periods due to an increased sensitivity to climatic events and other risks such as pests, fires, etc.);
- adapted thinning and clearfelling schedules and intensities (to reflect a stand's sensitivity to storms); and
- appropriate forest fertilisation (to increase wood production and nutrient exports compensation).

These forest practices may potentially attenuate global warming through carbon sequestration, but they may lead to other biophysical changes that can enhance or diminish this effect.

The sustainability of residue and stump harvesting

Stump and root harvesting is increasingly practised in Scandinavia, and the techniques involved are now becoming established in the British (Moffat et al. 2011), and to a lesser extent in the Irish, forest sectors. However, analysis of available evidence has shown that under certain conditions these harvesting operations pose a significant risk to the environment and to sustainable forest management (Whittaker et al. 2011). Walmsley and Godbold (2010) identified many practical and perceived benefits of stump harvesting, including: 1) the production of woodfuel; 2) fossil fuel substitution; 3) additional revenue for forest owners; 4) improved site preparation and 5) potential reduction of the root rot *Heterobasidion*. However, evidence suggests that, in the absence of appropriate precautionary measures, stump harvesting will also lead to many undesirable environmental impacts. These include: 1) removal of soil organic matter inputs; 2) adverse impacts on forest soil carbon stores and greenhouse gas emissions; 3) increased soil erosion; 4) increased soil compaction; 5) depletion of soil nutrient stocks and changes in nutrient cycling; 6) unknown impacts on future productivity; 7) loss of valuable habitat for fungi, mosses, bryophytes and insects and 8) increase in non-forest vegetation and additional herbicide requirements. Environmental impacts tend to be greater in the uplands due to the preponderance of poorly drained, nutrient poor, carbon rich and acidic soils. Forest Research (2009a and b) in Britain developed operational guidelines in relation to stump harvesting and brash removal; however, research is required to understand fully the environmental impacts, particularly how stump harvesting influences the forest soil carbon balance and forest nutrient stocks.

The longer-term effects of intense biomass removal from a range of forest sites in the UK were investigated by Mason et al. (2012). They analysed three experiments that were established in the 1990s to examine the impact of complete residue (brash) and above-ground biomass removal (i.e. whole-tree harvesting) at clearfelling on the subsequent growth and yield of replanted Sitka spruce (*Picea sitchensis* (Bong.) Carr.). After 10 years at the two medium-risk sites, the growth in plots with brash retained was 5–9% greater for height and 5–7% greater for diameter than in plots where brash had been removed. However, at the poorest site, the equivalent differences were ~9% and 19%.

Forest protection and health

Not only is it important to increase the forest estate in size, it is also important to put in place the necessary conditions to protect and maintain the existing, growing forest. Current risks that need to be addressed include damage from deer, potential loss due to forest fires, pests and disease. In relation to damage by deer, the development of deer management policy addressed by the Forest Policy Review Group and the Inter-Agency Group on deer, which have widely consulted with stakeholders, have a recommendation to establish a permanent deer management competence in the public forest sector. Work is ongoing in relation to the implementation of the recommendations of the Forest Service Land and Forest Fires Working Group – once again this requires collaboration with the Local Authorities and relevant stakeholders to facilitate a co-ordinated system of fire plans for forest plantations. The Department of Agriculture, Food and the Marine will continue to identify pest risks and maintain biosecurity and phytosanitary measures addressing pests, diseases and invasive alien species. However, the vigilance of forest owners, and their active involvement in identifying and implementing measures to deal with risks, is a key element in the protection of the forest estate.

Optimal use of roundwood

Managed forests serve as a store of carbon and a renewable source of energy and materials. By using forest products as substitutes for fossil fuels or non-renewable materials, emissions from fossil C sources can be displaced. The efficiency of emissions displacement depends on the product, its lifecycle and the fossil-fuel based reference system that is substituted. Thornley and Cannell (2000) calibrated a mechanistic forest-ecosystem simulator, which couples carbon, nitrogen and water to mimic the growth of a pine plantation in a Scottish climate. They concluded that there is no simple inverse relationship between the amount of timber harvested from a forest and the amount of carbon stored in the forest. Pingoud et al. (2010) developed an integrated, steady-state analysis comparing various equilibrium states of managed forests and wood product pools that represent sustainable long-term forestry and wood-use strategies in Finland. When sawlog supply is directed to production of long-lived materials substituting for fossil-emission and energy intensive materials, and recycled after their useful life to bioenergy, the benefits for the climate were greatest. Hofer et al. (2007) carried out a similar study in Switzerland. Recommendations resulting from this study were:

1) the maximum possible increment that is also sustainable should be generated in the forest;
2) this increment should be utilised through wood harvesting;
3) the harvested wood should be processed in accordance with the principle of cascaded use[3]; and
4) waste wood that is not suitable for further use should be used for energy generation.

Haberl and Geissler (2000) identified similar benefits of cascade utilisation of

[3] Cascade use involves first using the wood in solid wood products and other longer term end-uses and then reusing or recycling the materials when they have come to the end of service and where it is no longer feasible to combust the material.

biomass. A detailed study of the energy and carbon balances of various cascade chains for recovered lumber was carried out by Sathre and Gustavsson (2006). Energy and carbon balances of chains of cascaded products were compared to the balances of products obtained from virgin wood fibre or from non-wood material. The authors found that land-use effects had the greatest impact on energy and carbon balances, followed by substitution effects, while direct cascade effects were relatively minor. In a study by Backéus et al. (2006), mitigation of carbon emissions through carbon sequestration in forest biomass and the use of forest biofuel for fossil fuel substitution were considered for northern Sweden. The objective was to maximize the combined net present value for harvested timber, biofuel production and carbon sequestration. Increasing the carbon price led to decreasing harvest levels of timber and decreasing harvest levels of forest biofuel. Also, thinning activities decreased more than clearcut activities when the carbon prices increased.

An alternative use of biomass to burning is conversion to chemicals and energy through biorefining. Biorefining is a concept for the collection of processes used to convert biomass to chemicals and energy (Amidon et al. 2008). Ragauskas et al. (2006) carried out a review of the potential contribution of the forest products industry to liquid biofuel production in the United States. They identified that the forest products industry was one of a few nationally based industries that had the necessary skill-set and infrastructure available to process sufficient biomass for the rapid, short-term development and commercialisation of biofuel and biochemical technologies. Their review describes the operational considerations by which the biofuels and pulp industries could operate in synergy. Pu et al. (2008) also identified the importance of research into cellulosic ethanol to generate higher volumes of biofuels at lower cost. Their review examined the major chemical constituents of biomass and the recent advances in their conversion to biofuels, with a special emphasis on the conversion of forest residues and woody-energy crops to bioethanol.

Potential for perverse incentives

The rapid rise in crude oil prices and the geo-political uncertainty associated with ensuring uninterrupted supplies have compelled researchers, economists and politicians to look for indigenous substitutes (Srinivasan 2009). Before investing public and private resources towards biomass production, the sustainability of these production systems should be considered carefully, with the ecological limits of forests clearly identified and understood (Hesselink 2010). Perverse incentives should be avoided; a precautionary path is therefore required that makes ecosystem sustainability a priority, and that operates under a regulatory regime that integrates bioenergy harvesting in forest management plans. Schubert and Blasch (2010) showed that under free market conditions, undersupply of sustainable bioenergy will prevail. Two types of market failures – information asymmetry and externalities in bioenergy production – will lead to less sustainable bioenergy production. The authors concluded that to regulate the bioenergy market, mandatory certification combined with binding minimum standards are required. Likewise, Smith et al. (2011) argued that while biological carbon dioxide removal may play a valuable role in future climate change mitigation, many of its proponents fail to account for the full range of biological, biophysical, hydrologic, and economic complexities associated with proposed land-use changes. At a more immediate scale, Searchinger et al. (2009) identified that the accounting used for assessing compliance with carbon limits in the Kyoto Protocol and in climate legislation contained a flaw which treated all bioenergy as carbon neutral, regardless of the source of the biomass. For example, the clearing of long-established forests to burn wood or to grow energy crops is counted as a 100% reduction in energy emissions, despite causing large releases of carbon. These issues have been addressed to some extent in the LULUCF rules agreed at Durban (UNFCCC/2/CMP.7). These deal with developed countries and extend mandatory accounting to all managed forests and provide a way to better account for harvested wood products. A critical consideration is how many parties will agree to emission reductions for the post 2012 period and then the extent to which they will include the LULUCF sector in commitments. If emissions are not accounted for in the forest sector then the carbon-neutral accounting arrangement for wood fuels can be called into question. An even larger issue is when and to what extent developing countries will enter an accounting framework that will enable emissions from biomass harvest to be accounted and netted-off. The EU's Renewable Energy Directive does address the accounting of greenhouse gas emission savings from liquid biofuels and has a range of qualitative criteria for solid biomass. The European Commission has recently undertaken consultations on the need to update criteria for solid biomass to qualify for meeting renewable energy targets.

Public goods arising from forestry

There has been growing recognition of the non-wood benefits of forestry (Upton et al. 2012). The public goods most commonly associated with forestry include:

- leisure and recreation – with benefits for public health;
- landscape;
- climate change mitigation – particularly carbon sequestration;
- soil and erosion control;
- bio-diversity and conservation.

While ascribing values to non-wood benefits can be difficult, they were estimated at over €88 million per annum by Bacon and Associates (2004). It is estimated that the carbon sequestrated by Irish forests could be worth an average of €33 million annually for the first commitment period of 2008–2012 inclusive.

In relation to climate change mitigation, as the ownership and liability for carbon stocks resides with the State, the carbon stocks from the forest estate (planted post 1990) form part of the compliance accounting framework when calculating Ireland's liabilities. From 2013, all forests will come under a new EU-wide reporting and accounting framework. Harvest levels in pre-1990 forest (85% of which are owned by Coillte) will be included for the first time. Under the new rules agreed at Durban at the end of 2011, Ireland has a projected business-as-usual level of harvest in pre-1990 forests over the period 2013–2020. An increase in harvest levels over business-as-usual would result in debits at national level.

However, increasing Ireland's forest cover and avoiding deforestation (permanent removal of forest cover) would ameliorate any potential deficit.

Governing legislation

The current legislative basis for the regulation of forestry is the Forestry Act 1946 as amended. The drafting of a Bill (the Forestry Bill) to replace it is at an advanced stage of preparation. The Bill was presented to the Dáil (parliament) in April 2013 and will be subject to the parliamentary process over the course of 2013. In view of the nature and extent of changes over the intervening 66 years, the overall purpose of the Bill is to update provisions in relation to felling and other associated matters.

Research needs

Based on the above discussion of important issues that the forest sector faces in the future, the following main research needs have been identified:

- factors affecting the afforestation programme: land availability and suitability; environmental constraints; attitudinal, socio-economic factors; and grant schemes;
- tree improvement, silviculture and integrated forest management systems, including cascade utilisation of wood and life cycle analysis of wood products;
- wood supply chain technology and logistics;
- sustainability and certification of removal of harvesting residues and stumps;
- bio-refinery and other new uses of wood;
- carbon and greenhouse gas dynamics associated with land-use change and in the full range of forest types and for all management systems;
- forest adaptation, both at the medium and long-term, to ensure a sustained provision of public goods under climate change conditions.

It should be noted that the COFORD Council, within the Department of Agriculture, Food and the Marine, has set up a Forest Research Working Group to develop a national strategic research agenda for the forest sector for the period 2013–2017. This agenda should underpin competiveness and environmental performance, with reference to previous national forest policy initiatives, the work of the Forest Policy Review Group, Food Harvest 2020, the National Research Prioritisation Exercise and other relevant policies, such as the National Renewable Energy Plan. The research needs identified in this paper, especially those related to the green economy, will feed into this national research agenda.

Conclusion

The forest sector plays and will play an important role in relation to climate change mitigation and the development of a green economy. It is important to develop and implement sector specific policies and measures that will enable this role and potential to be expressed in a coherent and cost-effective manner. Likewise, the role of the forest sector across the green economy and in national greenhouse gas mitigation and climate change adaptation strategies needs to continue to be clearly reflected in policies in these areas. By mobilising the forest sector's potential, the task of decarbonising the Irish economy over the coming decades will be easier to achieve in a cost effective and sustainable manner.

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