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The Society of Irish Foresters

Comann Foraoiseorí na nEireann

Mission Statement
To lead and represent the forestry profession, which meets, in a sustainable manner, society's needs from Irish forests, through excellence in forestry practice.

Objectives

- To promote a greater knowledge and understanding of forestry in all its aspects, and to advance the economic, social and public benefit values arising from forests.
- To support professionalism in forestry practice and help members achieve their career goals.
- To establish, secure and monitor standards in forestry education and professional practice.
- To foster a greater unity and sense of cohesion among members and provide an appropriate range of services to members.

Submissions of articles to *Irish Forestry*

Submissions

1. Original material only, unpublished elsewhere, will be considered for publication in *Irish Forestry*. Where material has been submitted for publication elsewhere, authors must indicate the journal and the date of submission.

2. All submissions must be in MS Word, submitted electronially to the Editor, *Irish Forestry* at sif@eircom.net (see Guidelines). Authors are requested to keep papers as concise as possible and no more than 12 pages in length (including tables and figures).

3. Submissions will be acknowledged by the Editor. Authors will be informed if the paper is to be sent for peer review. If peer review is not envisaged an explanation will be provided to authors.

4. On submission, authors should indicate up to three potential referees for their paper (providing full contact details for each referee). Choice of peer reviewer rests in all cases with the Editor.

5. Peer reviews will be communicated to authors by the Editor. Changes suggested by the reviewer must be considered and responded to. The decision to publish will be taken by the Editor, whose decision is final.

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EDITORIAL

Forestry - serving the nation?

"These are strange queer times", accompanied by a worried shake of the head, is a refrain I hear ever more frequently while visiting an engineer situated at the edge of a forest in Co Laois. And indeed he is right. Events throughout the last year appear to squeeze the country's economy ever more tightly in a cold, clammy embrace, and to such an extent as to provoke discussions of sovereignty as the angels of international financial doom flock to our shores.

As ever, the long-term nature of forestry brings to mind the importance of stability of investments. The current economic crisis can teach us to recognise the importance of good and strategic management, with an eye to the future, but without forgetting the obligations of the present. We are placing increasing numbers of demands on our forests, or perhaps to see the glass half-full, our forests are already providing us with many more services than some of our forbearers might have imagined (though having read the Trees, Woods and Literature article one realises that some had quite a clear view of the future possibilities).

Quite aside from the significant economic value of an industry we have relatively recently developed from scratch, there are social, cultural and recreational values, as well as watershed and landscape management, carbon sequestration and biodiversity protection. It is timely that we present here the Proceedings of the Annual Conference of the European Forest Institute, which took place in Dublin Castle in September 2009, whose theme was forest ecosystem management in the 21st century. All of the above themes are discussed in some detail, and the content fits well with the preceding three papers – indeed there is quite a degree of cross-over between many of the papers and articles in this issue.

Problems looming on the horizon for the forestry sector as a whole include the unevenness of the age-class distribution of our national estate. This will have serious consequences for the timber and wood processing industry across the board, not to mention environmentally as pointed out by Black et al. and Byrne herein.

Another significant difficulty is one of public perception. For an entire society to realise the true value of their own forest and woodland resource, there needs to be a respect and understanding of the benefits to be derived. Even still, even after campaigns such as the NeighbourWood Scheme (described by Collins), there is a singular lack of appreciation of what our silvic heritage is (warts and all), and what it can and may be. Magners new book (*Stopping by Woods*), reviewed here, will surely contribute to the cause.

Of course this shortcoming has been a product of our history; however, we too must accept some responsibility. As the professionals it falls first to us to be the drivers and to start from the bottom. If we want the country to ever draw close to possessing a knowledge-based economy, we should acknowledge that it will not happen while the majority of our national-school children cannot name the trees outside their own homes. Drawing the circle wider still, I wonder how many on the streets realise the new importance wood products have taken on due to their roles in energy production, low cost provision and carbon storage? Hendrick points out that roundwood demand has never been higher, despite the current deflationary circumstances.

Increased public awareness and appreciation of these and other aspects of forestry would help in securing and maintaining investment, to ensure afforestation rates do not dwindle beyond a point which the industry, and the entire nation, would regret deeply.

Irish Land Use Change and the Decision to Afforest: An Economic Analysis

James Breen[a], Daragh Clancy[a], Mary Ryan[b] and Michael Wallace[c]

Abstract
Considerable variability in the price of commodities, such as milk and cereals, occurred in the 2007-2009 period. This was compounded by a high degree of volatility in the price of inputs such as fertiliser, animal feed and energy. Previously, Irish farms have used the returns from off-farm employment as well as agricultural support payments, such as the Single Farm Payment (SFP) and the Rural Environmental Protection Scheme (REPS), to protect their living standards against low and uncertain agricultural market returns. However, the downturn in the Irish economy has led to a reduction in the availability of off-farm employment as well as the discontinuation of REPS. This in turn may lead to an increase in afforestation on Irish farms, as forestry offers greater certainty through the provision of an annual premium in addition to the SFP. The decision to afforest represents a significant long-term investment decision and therefore, should not be entered into without careful economic consideration. The aim of this paper is to use Discounted Cash Flow (DCF) analysis to calculate the returns from forestry enterprises, taking into account the opportunity costs associated with the conventional agricultural activities which would potentially be superseded by forestry. The returns from forestry were calculated using the Forestry Investment Value Estimator (FIVE), an economic decision support tool developed by Teagasc. These returns are then incorporated into a DCF model along with the agricultural returns foregone from five superseded agricultural enterprises. This approach allows for the calculation of the net present value (NPV) of three different forestry options and shows that the forest investment options examined all offer a positive NPV. The results also indicate that planting fast growing conifer species offers a substantially higher NPV than planting a broadleaf species such as ash. Scenarios which assess the impact of the inclusion of the cost of reforestation after clearfelling and the impact of participation in the Forest Environment Protection Scheme (FEPS) are also examined as part of a sensitivity analysis.

Keywords
Farm forestry, net present value

Introduction

The discontinuation of the Rural Environment Protection Scheme (REPS), the possibility of a switch from the current Single Farm Payment (SFP) to a flat area-based payment and the recent volatility in the price of agricultural outputs and inputs, all suggest that Irish farmers are heading into a period of greater uncertainty and possibly lower farm incomes. Over the past 15 years, the incomes of many farmers

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were buoyed by off-farm employment and the one-off sale of land for development and housing construction. However, with the decline in the construction sector, those sales that do take place in the future are likely to be at substantially reduced prices. In their Spring 2009 Land Market Review, Irish Auctioneers Knight Frank estimate that the Irish property market is now tracking 2004 levels and they "see no reason why agricultural land prices will not follow this trend" (Ganly 2009). The likelihood is, therefore, that given the increased uncertainty regarding the returns to traditional agriculture, changes in land use will receive greater consideration amongst Irish farmers. Converting land from agricultural to forestry production represents one such land use change that is likely to receive more attention in the future.

Despite the presence of establishment grants for forest planting and increases in the value of the forest premium payments, afforestation rates within Ireland have been on the decline since the mid nineties. Breen et al. (2008) argue that the increase in land value brought about by the construction boom of the last 15 years could be a more important factor in this decline than the relative rate of returns between forestry and agricultural enterprises. However, with the downturn in the Irish construction industry and its subsequent impact on land values, it is expected that the relative rate of returns between forestry and agricultural enterprises will once again become a key factor in the decision to afforest. Behan and McQuinn (2005) recommend the need to analyse the economic returns from forestry in the context of existing agricultural policy.

While a number of studies have examined the reluctance of Irish farmers to afforest (Frawley and Leavy 2001, McDonagh et al. 2009, Breen et al. 2008), few studies have conducted an economic appraisal of the land use change decision facing farmers who opt to afforest a portion of their land. When contemplating afforestation, a farmer must consider not only the silvilcultural factors but also the income foregone from the agricultural enterprise that is superseded, or replaced by the forest. To accurately assess the afforestation decision, these foregone returns from the superseded agricultural enterprise should be directly incorporated into the analysis. Therefore, this paper presents an analysis of the returns to three alternative afforestation options in the context of five superseded agricultural enterprises, with sensitivity analysis used to assess the impact of key parameters on the economic returns of forestry.

Background

Trends in Irish Afforestation rates

Major changes in the rate of Irish afforestation, and in the number of landowners planting forests, have occurred in the past 30 years. Until 1980, public afforestation accounted for almost all planting in Ireland. The introduction of support packages for farm afforestation led to a complete reversal of this trend, with farm afforestation currently accounting for close to 100% of afforestation. However, the level of farm afforestation has also experienced significant change, as farmers respond to a variety of incentives and disincentives to afforest, including changes in the value of the forest premium payments, agricultural policy reforms and developments in land markets.

The introduction of the Western Package Grant Scheme in 1985 marked the beginning of supports for private afforestation in Ireland. The Forest Premium Scheme, introduced in 1989 and the Forestry Operational Programme, introduced in 1990, were significant in that as well as providing establishment grants for the planting of forests, the farmer also received an annual forest premium payment for the first 20 years after planting (Gillmor 1998, Farrelly 2008). More recently, the Common Agricultural Policy (CAP) Afforestation Scheme, introduced in 2000, increased the incentives to plant broadleaved species on better quality land, by offering a considerably higher premium payment than that offered for planting conifers.

In 2007, the Forest Environment Protection Scheme (FEPS) was introduced with the aim of providing farmers with an additional payment for including specific environmental measures in their forests to improve both biodiversity and recreation potential. The scheme would also offset the loss of payments to farmers participating in the REPS, if they chose to afforest a proportion of their farm. Interest in FEPS has grown rapidly to the extent that by the end of October 2009, FEPS accounted for 50% of the 2009 planted area (pers. comm. Fogarty, 2009). However, as a result of the closure of REPS to new applicants, entry to FEPS is now limited to farmers who are already participating in REPS.

Figure 1 presents the trends in Irish private and public afforestation from 1982 to 2009. Despite regular increases in the grant and premium, the trend since the mid-nineties has been largely downward, despite a short revival in private afforestation from 1999 to 2002. In 2008, approximately 6,128 hectares (ha) were afforested, which is well below the current national annual afforestation target of 10,000 ha (National Development Plan 2007-2013). This trend continued in 2009 as just over 6,600 ha were afforested by the end of the year (Forest Service 2009).

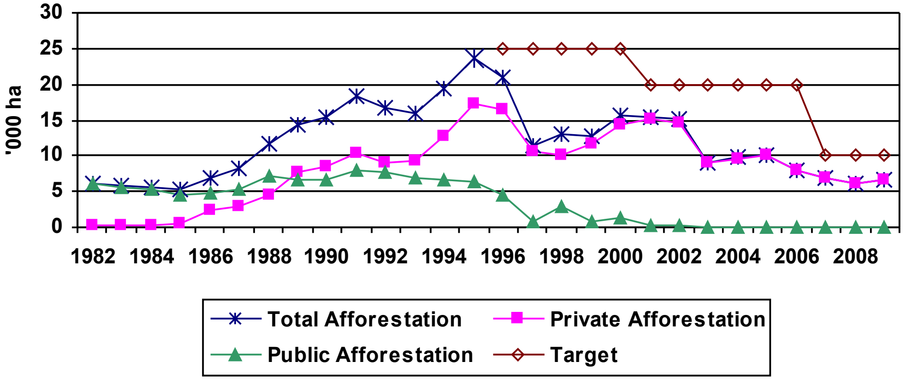

Figure 1: *Irish afforestation levels 1982 – 2009. Source: Forest Service Statistics (2009).*

Prior to 2005, Irish farmers could potentially avail of a number of "coupled" premium payments (i.e. payments that were linked to production levels), such as Special Beef Premium or Area Aid Payments, to supplement their market based income (value of sales less costs). With the introduction of decoupling, these payments that were previously paid on the basis of the number of eligible animals or hectares of a crop were now replaced with a single annual decoupled payment. This payment, referred to as the SFP, is paid on the basis of historical production levels rather than current production levels. The decision to decouple these direct payments from production allowed farmers to leave their agricultural land un-stocked but in "good agricultural and environmental condition" (European Commission, 2003) or to convert it to forestry and still receive their SFP income support. This offered a potential windfall for Irish farmers who could continue to receive their SFP while also receiving a forest premium for 20 years. However, despite this potential gain, Irish afforestation levels have continued to decline from 10,030 ha in 2005 to 6,128 ha in 2008.

The reluctance of Irish farmers to afforest has been the focus of a number of published works, with Frawley and Leavy (2001) and McDonagh et al. (2009) both using farm surveys to identify farmers' primary motivations for not planting. Taking into account that the McDonagh et al. (2009) survey was conducted almost ten years after that of Frawley and Leavy, and that a significant agricultural policy reform had taken place in 2005, the results of the surveys were remarkably similar. Frawley and Leavy (2001) found that 88% of the farmers surveyed were not considering afforestation. Frawley and Leavy (2001) also found that 51% of those farmers, who stated they would not plant, perceived the main difficulty with farm forestry as "farm too small/need the land". The most recent work conducted by McDonagh et al. (2009) echoes the earlier findings of Frawley and Leavy (2001). They found that for 48% of the farmers who stated that they would not plant, the most important barrier to planting land was that they needed all of their land for agriculture. This is despite the introduction of the SFP and the potential for farmers to plant up to 50% of their land without losing any payments. Surveyed farmers also cited the fact that there were no REPS payments on forests as a significant barrier to the decision to afforest (McDonagh et al. 2009). Earlier work conducted by Ní Dhubháin and Gardiner (1994) also found that Irish farmers were largely unwilling to plant land; only 10% of those farmers surveyed stated an intention to plant. Furthermore, of those farmers who stated an intention to plant land in the future, 58% said that their land was "good for nothing else" while 39% of those who said they would not plant said they did not have suitable land (i.e. they felt their land was "too good for forestry").

Similar studies conducted by Watkins et al. (1996) in the UK also found that new policy instruments such as special farm woodland planting grants and regional forestry initiatives did not bring about any significant change in the general opposition of farmers to the conversion of agricultural land to woodland.

In addition to the factors cited above, Breen et al. (2008) provide a discussion of the motivations for farmers' reluctance to plant, citing the introduction of environmental regulations which have restricted the afforestation of large tracts of land, particularly of less productive marginal and peat soils. Breen et al. (2008) also note that the significant increase in the value of agricultural land from 1992 to 2007 was another likely factor in the reluctance of farmers to afforest their land.

A land use change from agriculture to forestry in Ireland is a permanent decision, due to the legal requirement under the 1946 Forestry Act to replant after clearfelling a forest. Given the high prices that were paid for agricultural land in recent years (Ganly 2009), this permanency was a major obstacle to planting. Wiemers and Behan

(2004) used a real options approach to examine the role of uncertainty in the decision to plant, with particular attention paid to the potential value of agricultural land for development. They concluded that for farmers whose land had development potential, the returns to forestry would need to increase by more than 150% in order to trigger an investment in forestry. It remains to be seen as to whether or not the decline in the wider economy, and in particular the decline in the construction industry, will lead to a long-term reversal of current trends and an increase in the rate of farm afforestation.

McCarthy et al. (2003) used a panel regression model to examine the factors that influenced afforestation rates in Ireland. They found that the afforestation grant, forest premium payments, expected forest returns and the area in REPS were all statistically significant at the 1% level. However, agricultural returns were not statistically significant. They noted that in the early 1990s most of the land planted was marginal land, and this may explain why agricultural returns are not significant in explaining the afforestation rate.

Each of the three studies conducted over a period of 15 years examining factors affecting farmers' willingness to plant (Ní Dhubháin and Gardiner (1994), Frawley and Leavy (2001) and McDonagh et al. (2009)), indicated that the size of the farm and the need to retain all their land for agriculture were significant factors in the decision not to plant. This response may be motivated by the farmer's perception of him/herself as a farmer rather than a forester, and therefore they may believe that they need to retain all of their land in agricultural production. However, it may also be a reflection of the individual farmers' perceptions regarding the relative rate of returns from agriculture and forestry, and a belief that agricultural activities offer a greater return than forestry. Therefore, this paper uses a discounted cash flow (DCF) analysis to compare the returns to three alternative forest options, each with five superseded agricultural activities.

Materials and methods

A discounted cash flow analysis

Given the long-term nature of farm afforestation, this paper uses the DCF method to evaluate the afforestation investment decision. The investment returns from the decision to afforest are evaluated as an alternative farm enterprise. Risk and uncertainty elements need to be considered when developing forest management models (Diaz-Balteiro and Romero 2008), so the effects of variation in key parameters, such as yield, price and production life-span, on the performance of each investment can be evaluated. As the afforestation grant and forest premium are paid on a per ha basis, the evaluation of the alternative investment decisions is also conducted on this basis.

The DCF approach to calculate the returns from forestry is prevalent in the literature and has been employed by a number of authors including Brukas et al. (2001), Nieuwenhuis and Gallagher (2001), Rasul and Thapa (2006), and Hepburn and Koundouri (2007). A number of criteria exist for evaluating the returns from a long-term investment decision; with net present value (NPV) being one of the more commonly used. The DCF method evaluates an investment decision in terms of its NPV, which is defined as the sum of the project's net cash flows discounted at the businesses' opportunity cost of capital (Boardman et al. 2001). The investment project is deemed to be 'worthwhile' if it generates a positive NPV.

While the DCF approach represents a deterministic analysis of the returns to the investment decision, sensitivity analysis allows for the impact of variability in key parameters such as grants and replanting costs on the returns to the afforestation investment decision to be evaluated. The discount rate used will also have an effect on the present value of returns from a forestry investment. A 5% discount rate was used in this study, primarily as it is the rate most commonly recommended for examining the relative value of different long-term agricultural land use options (e.g. Toivonen and Tahvanainen 1998, Clinch 1999, Styles et al. 2008).

The farm afforestation decision entails converting land from a conventional agricultural enterprise to forestry. As a result of this change, the margin previously earned by this superseded agricultural enterprise will be foregone and must be accounted for when evaluating the returns to the farm afforestation decision. While Venn (2005) noted that land cost is an important factor in forestry investment decisions, Lewandowski et al. (2000) point out that some studies have omitted it from the calculation of the returns to the investment decision. Given the importance of the opportunity cost of land, in this analysis it is accounted for through the inclusion of foregone returns from a number of superseded agricultural activities. Therefore, our calculation of the NPV for forestry takes into consideration the cash margin foregone from selected superseded enterprises, which are deducted annually from the gross margin earned by the three alternative forestry enterprises. Our baseline analysis assumes that the superseded activity is land rental, and the opportunity cost of the market rental value of the land is included. Given the prevalence of grassland based agriculture in Ireland (covering approximately 80 percent of Ireland's agricultural area, Department of Communications, Marine and Natural Resources 2007), the average rental value of grazing land is used.

In addition, a number of alternative superseded enterprises have also been included as part of a sensitivity analysis. Data from the Irish National Farm Survey (NFS) have indicated that sheep, tillage and cattle farmers have signaled the greatest intention to convert land to forest (Ryan et al. 2008); therefore the superseded enterprises chosen for the sensitivity analysis were lowland sheep, store to finished beef, spring barley and winter wheat. Thus, the results presented in subsequent sections comprise the estimated investment returns from a decision to switch a hectare of land from a conventional enterprise to forestry.

One of the strengths of DCF is its capacity to allow for the comparison of investments with different cash flow profiles, such as annual versus multi-period systems, allowing for the timing of cash flows from year to year over the project life (Clancy et al. 2009). The model assumes that there are no changes in the productivity of the forestry enterprises or of the superseded enterprises throughout the project lifespan.

Cost and Return Estimation of Forestry Options

The capital invested in forestry comprises the start-up costs of the enterprise in the initial period, less planting grants, less the average working capital released from the superseded enterprise. The returns from forestry were taken from the Forestry

Investment Valuation Estimator (FIVE), developed by the Forestry Development Unit in Teagasc. The NPV of different forestry options can be calculated using this forest advisory and research support tool. In this paper, FIVE was used to calculate the costs and returns to three alternative forest options. These costs and returns are then inputted to the DCF model, where the annual returns from the superseded enterprises are included, to compare the NPV of the three alternative forest options. FIVE was constructed using Forestry Commission yield models (Edwards and Christie 1981), to give the estimated timber volumes depending on the assigned Yield Class of the land. FIVE allows for the inclusion of five alternative tree species: Sitka spruce (*Picea sitchensis*, (Bong.) Carr.), Norway spruce (*Picea abies* (L.) Karst.), Japanese larch (*Larix kaempferi* (Lamb.) Carr.), lodgepole pine (*Pinus contorta* Douglas) and ash (*Fraxinus excelsior* L.)/sycamore (*Acer pseudoplatanus* L); the appropriate GPC (Grant/Premium Category) is selected for the species mix being examined. The level of grants and premiums payable are calculated based on the GPC, with total planting costs and initial maintenance costs assumed to be equal to the value of the afforestation and maintenance grants.

The conifer roundwood prices were based on 10 years of standing sales data provided by Coillte Teoranta[1], while Irish and UK data were used to estimate a price/ size curve for broadleaves. The roundwood price data, along with the tree size and volume data from the yield models, allow for the calculation of revenues from roundwood sales. Standard harvest losses were deducted and it was assumed that the harvestable material was sold at average prices. The road cost net of grant was also included in the analysis.

Data and assumptions regarding superseded enterprises

This section presents a description of the assumptions made relating to costs and revenues of the five superseded enterprises. Table 1 details the gross margins and average working capital released per ha from the superseded enterprises.

Table 1: *Gross margin and working capital released for enterprises superseded by forestry.*

	Grazing land rental value € ha^{-1}	**Spring barely € ha^{-1}**	**Winter wheat € ha^{-1}**	**Sheep € ha^{-1}**	**Store to finished beef € ha^{-1}**
Gross margin[i]	236	260	435	389	210
Working capital released[ii]	-	291	487	436	1,392

[i] Gross margin for production enterprises assume average levels of technical efficiency.

[ii] Working capital released is the average capital tied up in stock and variable inputs for each enterprise.

[1] The Irish State Forestry Board.

The grazing land rental value was calculated as the average paid per ha by farmers engaged in this activity in the NFS (Connolly et al. 2008) from 2005-2007. Any rental value less than €20 ha^{-1} was considered a nominal value, and so was excluded from the analysis. To avoid problems of allocation of fixed costs associated with owned machinery, calculations assume contractor charges for all field operations. All machinery and labour costs are therefore assumed to be variable costs. For a variety of reasons, such as the requirement that planted land be kept in forestry for perpetuity (Breen and Ryan 2008), it is likely that only a small part of individual Irish farms will be converted to forestry. This is borne out by average farm forest size of 7.9, 7.4 and 7.9 ha established in 2006, 2007 and 2008 respectively (Forest Service 2008). Thus, the size of each superseded enterprise may be reduced, but they are unlikely to be eliminated at farm level. In this context, the reduction in fixed costs (e.g. labour) from reducing a conventional enterprise is likely to be quite small (Clancy et al. 2009).

The contractor prices were obtained from survey data reported in Management Data for Farm Planning 2006/2007 (Teagasc 2007) and inflated to 2009 prices using FAPRI-Ireland (Food and Agricultural Policy Research Institute) input cost and output price projections (Binfield et al. 2007). Obtaining long range forecasts of costs and prices is a formidable task in any farm investment appraisal (Clancy et al. 2009). In this analysis, estimates of input costs assumed normal input levels under average production conditions as estimated by enterprise specialists. Average levels of technical efficiency, based on National Farm Survey data, were assumed for all the superseded enterprises. Prices for all inputs and outputs of the superseded activities are conservative estimates based on medium term FAPRI projections. The resulting normalised margins for forestry and the superseded enterprises are held constant over the economic life of each project. The level of the premium payment for forestry is the current rate available in the Afforestation Scheme.

Afforestation options

Sitka spruce has been the most widely grown tree for commercial purposes in Ireland, and is typically planted with another conifer species such as Japanese larch in order to comply with the species diversity requirements of the afforestation scheme. In recent years, there has been an increase in the planting of broadleaves in Ireland (Forest Service 2009). The increase in broadleaf planting was largely a result of higher premium payments for broadleaf species and more recently the introduction of FEPS has led to a further increase. Based on the recent average farm forest sizes, this analysis assumes that most farmers plant between 6 and 12 ha. Therefore, this analysis uses the Grant and Premium rates for 6 - 12 ha. The three afforestation options included reflect the compositions of many Irish farm forests:

- SS: This option assumes a plantation that is comprised of Sitka spruce and Japanese larch and is consistent with Grant and Premium Category (GPC) 3.
- Ash: This option assumes a plantation that is comprised of ash and is consistent with GPC 5.
- Mixed: This option assumes a plantation that is comprised of Sitka spruce, Japanese larch and ash and is a combination of GPC 3 and GPC 5.

Table 2: *Assumptions used in alternative afforestation options.*

	SS	***Ash***	***Mixed***
Species mix	Sitka spruce 80% Japanese larch 20%	Ash 100%	Sitka spruce 48% Japanese larch 12% Ash 40%
Productivity (Yield Class)	Sitka spruce –22 Japanese larch –12	Ash –10	Sitka spruce –22 Japanese larch –12 Ash –10
Grant and Premium Category (GPC)	GPC 3	GPC 5	GPC 3 (60%) GPC 5 (40%)
Forest Environment Protection Scheme (FEPS)	No	No	No
Establishment grant (€ ha^{-1})	2,700	4,000	3,220
Establishment cost (€ ha^{-1})	2,700	4,000	3,220
Cleaning/filling-in (€ ha^{-1})	873	1,200	1,004
Grant maintenance (€ ha^{-1})	873	1,200	1,004
Rotation length	40 years	40 years	40 years
Productive area	85%	85%	85%
Forest management	Thin	Thin	Thin
Annual maintenance and insurance cost (€ ha^{-1})	35	35	35
Roading year	Year 15	Year 15	Year 15
Roading cost net of grant (€ ha^{-1})	90	90	90

Sensitivity analysis

Sensitivity analysis was conducted to examine the impact of two key factors on farm forest returns. The inclusion of reforestation costs on the NPV of each option was analysed as well as the impact of participation in FEPS. The initial afforestation costs are covered by the provision of a planting grant. However, as discussed above, in Ireland after clearfelling forest owners are legally obliged to re-plant and the cost of this re-planting is not covered by a grant. One argument for including replanting costs as part of the first forest rotation is that the profit from the first rotation is not realisable without incurring the replanting cost. On the other hand, it could be argued that replanting is part of the cost of the second rotation and should not be included as a cost against the first rotation. Similar to Clinch (1999), the cost of reforestation is not included in the baseline scenarios of this analysis. However, the cost of reforestation is included as part of the sensitivity analysis in order to assess its impact on the forest NPV's. The cost of reforestation was estimated as €3,000 per ha for conifers and €3,500 for broadleaves due to the higher stocking rate for broadleaves (Pers. comm. Phillips 2009).

Table 3: *Assumed cost of reforestation.*

Afforestation option	*€ ha^{-1}*
SS	3,000
Ash	3,500
Mixed	3,200

Further sensitivity analysis was conducted to examine the impact on NPV of FEPS participation. Farm forest owners who are currently in REPS may avail of an additional FEPS payment. While entry to REPS 4 is not possible after July 2009, farmers currently in REPS (approx 62,000) are still eligible to apply for FEPS (Pers. comm. DAFF 2009). As farmers in REPS have the option to enter FEPS, and as 50% of the land being planted currently is in FEPS, we included the FEPS payment in a sensitivity analysis. This analysis assumes a FEPS payment of €200 annually for five years, with no loss of REPS payment. It is not possible to avail of FEPS if only conifers are being planted, so the FEPS sensitivity analysis is only run for the mixed and ash forest options.

Results

An initial baseline comparison of the NPV of land for all three afforestation options is made with land rental as the superseded enterprise. Despite receiving the lowest level of forest premium payments per ha, the SS option returns the highest NPV (€4,406). In comparison the Ash option, which received the highest level of forestry premium, had the lowest NPV, mainly as a result of the significantly lower estimated volume of timber produced.

Table 4: *Baseline investment performance of three different afforestation options.*

		***Net present value** (€ ha^{-1})*[i]
Superseded: Land Rental	Sitka spruce	4,406
	Ash	2,568
	Mixed species	3,670

[i] At a discount rate of 5%.

Table 5 presents the NPV for the three afforestation options, when the alternative superseded enterprises were winter wheat, spring barley, lowland sheep production and store to finished beef. All of the forestry options examined with the exception of ash superseded by winter wheat, offer a positive NPV. However, there is a considerable degree of variability in the size of the respective NPV's for different forestry options. For example, the SS option where the superseded agricultural enterprise was store to finished beef has the highest NPV, €6,156. This is largely due to a combination of the high level of working capital released by not having to purchase cattle, and the high timber returns achieved from the Sitka spruce forest. However, for the ash plantation where the superseded enterprise was winter wheat, there is a negative NPV of - €273.

Table 5: *Investment performance of afforestation with alternative superseded agricultural enterprises.*

Farm enterprise superseded		***Net present value** (€ ha^{-1})*[i]
Spring barley	SS	4,279
	Ash	2,440
	Mixed	3,542
Winter wheat	SS	1,565
	Ash	-273
	Mixed	829
Lowland sheep	SS	2,282
	Ash	444
	Mixed	1,546
Store to finished beef	SS	6,156
	Ash	4,318
	Mixed	5,420

[i] At a discount rate of 5%.

Impact of inclusion of reforestation costs

The first stage of the sensitivity analysis compares the baseline NPV with a second scenario where we assumed a reforestation cost is incurred after clearfelling (See Figure 2). While the replanting cost is estimated to be between €3,000 and €3,500 ha^{-1}, the change in the NPV is substantially smaller, varying from €368 for Sitka spruce to €430 for ash. This reflects the fact that the replanting cost is incurred at the end of the investment decision and as a result is highly discounted.

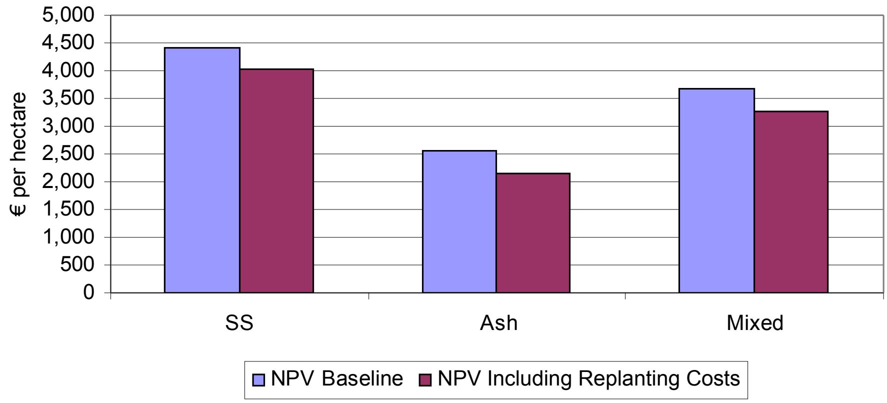

Figure 2: *Impact of Inclusion of Replanting Cost on the Net Present Value for the three different afforestation options.*

Impact of Participation in FEPS

The results indicate that participation in FEPS will lead to a higher NPV per ha for both forestry options when compared with the baseline superseded enterprise of land rental. The increase in the NPV for ash is €787. However, Figure 3 shows that the returns are still lower than the returns to the Sitka spruce option. The increase in the NPV for the mixed forestry option is €701, however it is still less profitable than the SS without FEPS. This analysis takes into account that participation in FEPS will lead to a lower productive area, 80% compared with 85%, due to the greater requirement for biodiversity area (pers. comm., Phillips 2009). The lower productive area will result in reduced volume production and a consequent reduction in income from roundwood sales, which has a more adverse effect on the mixed forest option than on the ash option, as a greater proportion of the returns to this option come from roundwood sales.

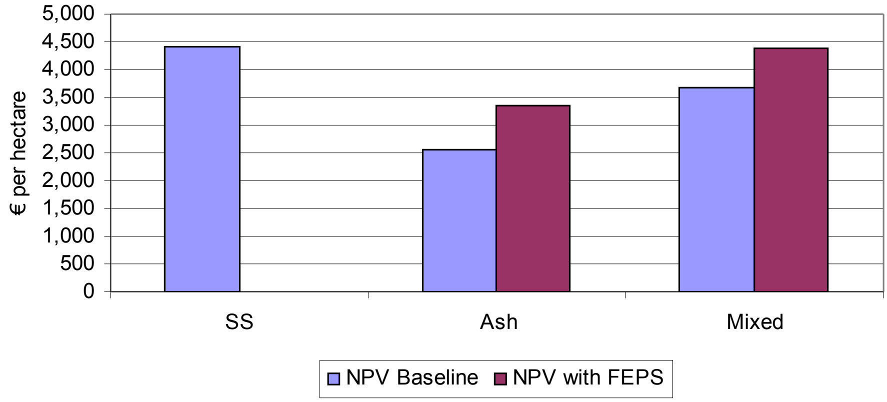

Figure 3: *Impact of FEPS participation on the net present value for the three afforestation options*

Discussion

The main approach to analysing forestry investment decisions is the use of traditional DCF techniques such as NPV (Duku-Kaakyire and Nanang 2004). However, these analyses have not, to date, included the income foregone from a superseded enterprise, thus making direct comparisons between our findings and the literature inappropriate. All of the forestry options examined, with the exception of ash superseded by winter wheat, offer a positive NPV. This finding is supported by Donnellan and Hennessy (2008) who compared the returns to forestry with the returns to a number of other enterprises and concluded that only dairy and winter wheat offered a higher gross margin per ha than forestry. Given the wide range of available combinations involving alternative afforestation options and superseded enterprises, we focus on a limited number of combinations of such investment options. Therefore, it should be noted that combinations which were not examined in this paper may yield different findings.

Despite the stated reluctance of a majority of Irish farmers to afforest (Ryan et al. 2008), the forest investment options examined offer a positive NPV, with the exception of ash where the superseded enterprise is winter wheat. There are already signs that trends are reversing, and that forestry is becoming a more attractive option for farmers. The number of applications for planting approval to the end of September 2009 is up 78% on the same period in the previous year (Forest Service 2009). Possible reasons are the continuing downward trend in returns from conventional agricultural systems and the higher forestry returns as evidenced in this analysis.

The results indicate that planting fast growing conifer species offers a substantially higher NPV (approximately €1,840 ha^{-1}) than planting a broadleaf species such as ash. However, in recent years Ireland has seen an increase in the planting of broadleaves, which may be a reflection of the higher annual premium payments payable on broadleaves, as well as changes in the preferences of farm-foresters and increased afforestation on better quality soils. It should also be noted that while the DCF methodology shows the highest return from the Sitka spruce option, the analysis does not consider any potential future earnings from the forest for its conservation, biodiversity or amenity value.

The low afforestation rate that has been witnessed over the past 10 years has in part been attributed to the economic growth and its consequent impact on the construction sector and land values. The requirement to reforest after clearfelling imposes restrictions that limit the price that can be realised for forest land. While the DCF approach allows for a comprehensive analysis of the returns to forestry when compared with the returns foregone from alternative agricultural enterprises, it does not evaluate the potential loss in the land value that might arise from the decision to afforest.

A final point worth making is that the forest premium payments received and the revenue from roundwood sales (up to a threshold) are tax-free, while it is likely that the revenue from each of the superseded enterprises would be subject to tax. The impact of the afforestation decision on the tax liability of an individual farm will vary considerably, depending not only on the value of the returns to the enterprise that is foregone, but also on the returns from other enterprises on the farm and the value of non-farm income.

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The suitability of the private forest estate in Ireland for thinning

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Abstract

Government projections for timber supply from Irish forests assume that private forests will be managed and harvested in a similar way to State forests. However, little is know about the harvesting intentions of private forest owners and the suitability of their stands for thinning. A survey of a sample of 120 forest owners and their forests, stratified by afforestation grant scheme, was carried out in 2007. The average size of plantation was 8.8 ha, with plantations established under the Common Agricultural Policy (CAP) Scheme more likely to have a lower risk of windthrow and to be on sites with better ground conditions than those established under the Western Package (WP) Scheme. Almost three-quarters of the WP forest area was adjacent to a public road, while just over half of the CAP area was similarly situated resulting in higher road density requirements in the CAP area. Almost three-quarters (72%) of all forest owners surveyed planned to thin their forests in the future. The suitability of the area they planned to thin was assessed taking account of access, ground conditions and windthrow risk. Only one-half of this area was found to be suitable for thinning with poor ground conditions and/or excessive roading requirements the main constraints. While the self-selected nature of the sample makes it difficult to make inference to the population of private forest owners in Ireland, the results do raise questions as to whether the timber production targets as laid down in Government policy will be achieved.

Keywords

Thinning intentions, non-industrial private forest owners, access, windthrow risk, silvicultural suitability

Introduction

The aim of Government policy for forestry is to "develop forestry to a scale and in a manner which maximises its contribution to national economic and social well-being on a sustainable basis and which is compatible with the protection of the environment" (DAFF 1996). This scale of timber production, i.e. critical mass, was set at 10 million m^3 per annum, a substantial increase from the two million m^3 per annum being produced when the policy was being devised. Afforestation targets of 25,000 ha per annum to the year 2000 and 20,000 ha per annum thereafter to the year 2030 were set, with 70% to be undertaken by the private sector. To achieve critical mass, it was assumed that private plantations would be managed and harvested in a similar way to State plantations. This assumption was also made in the forecasts of roundwood production from Irish private forests produced by Gallagher and O'Carroll (2001) and more recently, Phillips et al. (2010).

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Research from other countries has identified however, that the silvicultural management that takes place in what are typically referred to as non-industrial private forests (sometimes known as small-scale forests or family forests) often differs from that undertaken in industrial forests (Herbohn 2006). Many of the owners of the non-industrial private forests place a low priority on timber harvesting and rate objectives such as wildlife, recreation and scenery as more important goals for their forests (e.g. Rickenbach et al. 1998 in the USA; Wiersum et al. 2005 in Europe). Owners' objectives are not the only factor influencing whether harvesting takes place in private forests. Dennis (1989; 1990) and Newman and Wear (1993) found that growing stock, species and productive area were important variables influencing whether stands were harvested. Prestemon and Wear (1998) also found that the distance to the forest road influenced the occurrence of harvesting.

In Ireland the national forest inventory has provided a range of statistical information on the private estate (Forest Service 2007a). However, little is known about the characteristics of private stands that influence thinning, including owners' objectives. There is an urgent need for such information as many private stands are, or soon will be, due to be thinned. It is not known whether forest owners will thin their stands, or indeed whether their forests are silviculturally suited to being thinned. The aim of this study therefore was to gather information in this regard. Specifically it set out to:

- characterise the private forest resource, with specific emphasis on aspects relating to the thinning of the forests;
- determine the harvesting intentions of forest owners;
- determine the suitability of the stands for thinning.

Methods

A random sample survey of private forest owners was conducted during the summer of 2007. The sample was drawn from the Forest Service database of landowners who had received afforestation grant-aid during the period 1981 to 2006. The database was divided in two; the first section comprised the names and contract numbers[1] of those that had received grant-aid under the Western Package (WP) scheme from 1981 to 1989 (1,860 records accounting for 20,517 ha), while the second section included those who had planted thereafter under the Common Agricultural Policy (CAP) scheme (16,239 records accounting for 198,584 ha) (Forest Service 2007b). To comply with Data Protection Legislation, the Forest Service was responsible for contacting respondents and they initially wrote to a random sample of 1,000 owners inviting them to take part in the study. Over 380 agreed to do so and from these a random sample of 120 forest owners (25 WP; 95 CAP) was selected for survey.

All forest owners were visited and interviewed. During the interviews information on owners' objectives and on the management and silvicultural activities owners

[1] A unique contract number is assigned by the Forest Service to each individual application for grant-aid for afforestation.

had undertaken was obtained. The extent of the involvement of owners in extension activities was also recorded. A summary of the results of these interviews can be found in Maguire (2008). A survey of the forests owned by those interviewed was also undertaken. Where respondents owned more than one forest, only the forest associated with the contract number that had been selected by the Forest Service was surveyed. Two 0.01 ha plots were randomly assigned to this forest; where it was comprised of multiple stands, one stand was randomly selected and within it two plots were randomly located. Where mixtures of species were present, the plot size was extended.

A field sheet was drawn up to record site, forest and stand characteristics. Site characteristics, such as soil type, fertility, exposure, stability, elevation, topex, slope, ease of access, etc., were recorded on a forest basis (Table 1). The area of the forest and the stand were also recorded (forest and stand area were synonymous where a forest comprised only one stand). At the stand level, species, stocking levels, diameters and heights were recorded (Table 2).

Table 1: *Attributes recorded at forest level.*

Variable	***Category***	***Source where recorded***
Forest age	Years	*GIS database / Owner records*
Forest area	Hectares	*GIS database / Owner records*
Drainage status	Good = stable, dry, elevated, sloping site Average = Peaty/Gley base material with waterlogging potential, or where water cannot readily get away Poor/very poor = where surface water is visible	*Forest*
Ground bearing conditions	Good = stable, dry site Average = Rutting would occur in wet weather, dry weather site only Poor = Peaty/ Gley base material render site unstable. Rutting would occur Very Poor = where surface water is visible	*Forest*
Terrain classification	Smooth/Easy = with no obstructions present Moderate = where occasional obstacles occur Difficult/Hindrance = where movement is greatly prohibited	*Forest*
Forest slope	Degrees	*Forest*
Elevation	Metres above sea level	*GIS database / OSI Discovery Series Map (1: 50,000)*
Probability of windthrow occurring	Percentage	*Windthrow risk model (Ní Dhubháin et al. 2009)*

Variable	*Category*	*Source where recorded*
Thinned	Yes / no	*Forest*
Roading required		
Construction	Metres	*Forest*
Maintenance	Metres	*Forest*
Bellmouth	Number per forest	

Table 2: *Attributes recorded at stand level.*

Variable	*Category*	*Source where recorded*
Stand age	Years	*GIS database / Owner records*
Stand area	Hectares	*GIS database / Owner records*
Land status	Enclosed / unenclosed	*1910 Ordnance Survey (6 inch: 1 mile) map, to represent stand*
Fertility class	A = Agricultural pastures, herbaceous plants / rushes B = Bracken and Furze (old ditches/walls) C = Scruff pasture, *Calluna* / *Molinia* spp. X = Old Woodland	*Stand* *(OCarroll 1975)*
Soil type	e.g. Peat, Gley, Brown earth, Podsol, etc.	*Stand*
Tree species	Name	*Stand*
Stocking	Stems per hectare; recorded as live measurable stems within a 0.01 ha plot × 100	*Stand*
DBH (diameter at breast height)	Centimetres	*Stand*
BA (basal area)	m^2/ha	*Quadratic function of DBH*
Height		
Top	Metres	
Timber	Metres	
Yield Class	$m^3ha^{-1}yr^{-1}$	*Forestry Commission General Yield Class Curves (Edwards and Christie 1981)*

A number of sources were used to assign a thinning year to each stand including:

1. GROWFOR - Dynamic Yield Models (COFORD undated);
2. Forestry Commission (FC) Thinning Control Tables (Rollinson 1999);
3. Coillte Inventory Manual (Coillte 2002);
4. Growing Broadleaves (Joyce et al. 1998);
5. Silvicultural Guidelines for the Tending and Thinning of Broadleaves (Draft Version) (Short and Radford 2008).

In most cases, GROWFOR was used. However, this model could not be used when the basal area in the stands was less than 10 m^2 per ha. In these instances, the BFC Thinning Control Tables were used. If the crop characteristics were outside the range allowed for those tables, an alternative method from the above list was used.

Suitability for thinning

The suitability for thinning of all stands visited was assessed under three headings:

1. Ground conditions;
2. Access;
3. Windthrow risk.

The stand areas were first classified subjectively according to the ground conditions on the sites, i.e. good, average, or poor-very poor ground conditions. This classification was used as an indicator as to whether a machine could extract timber on the site. The areas were further classified according to access, i.e. whether there was good or poor road access. Forests classed as having poor access were those requiring roads to be constructed at a density in excess of 20 m/ha. Densities in excess of this level are considered not economically viable (Henry Phillips pers. comm.). Finally the silvicultural suitability of the stand for thinning was estimated by assessing windthrow risk using Ní Dhubháin et al.'s (2009) windthrow risk model. This model takes into account top height, soil type, altitude, location and whether the stand has been thinned. Stands were classified according to three levels of risk;

1. Low – probability of windthrow < 11%;
2. Medium - probability of windthrow ≥ 11% but < 50%;
3. High - probability of windthrow ≥ 50%.

Stands on sites which had good to average ground conditions, good road access and where the risk of windthrow was less than 50%, were considered suited for thinning.

Results

The mean WP forest size was 6.8 ha, while the mean CAP forest area was slightly higher (9.2 ha) (Table 3).

Table 3: *Size distribution of forests surveyed.*

Area range	*All Forests*		*WP Forests*		*CAP Forests*	
Ha	*ha*	*%*	*ha*	*%*	*ha*	*%*
0 – 1.9	22	2	4	2	18	2
2 - 4.9	129	12	24	15	105	12
5 – 8.9	190	18	42	26	148	17
9 – 13.9	132	13	10	6	122	14
14 – 19.9	201	19	18	11	183	21
20 – 29.9	150	15	28	17	122	14
30 – 49.9	150	15	37	23	113	13
50+	61	6	0	0	61	7
TOTAL	1035	100	163	100	872	100
Mean	8.8		6.8		9.2	

Elevation

Less than one-fifth of the WP forest area was at elevations greater than 100 m, compared with 43% of the CAP forest area (Table 4).

Table 4: *Forest area by elevation.*

Metres above sea level	*All forests*		*WP Forests*		*CAP Forests*	
	ha	*%*	*ha*	*%*	*ha*	*%*
<50	104	10	49	30	55	6
50-99	527	51	85	52	442	51
100-149	217	21	16	10	201	23
150-199	104	10	13	8	91	10
>200	83	8	0	0	83	10
TOTAL	1035	100	163	100	872	100

Ground conditions, terrain classification and drainage

While half (52%) of the CAP forest area was considered to have ‘good’ ground conditions (Table 5) only 22% of the WP forest area was similarly classed. A greater percentage of the WP forest area had difficult terrain compared with the CAP forest area. Many of the sites visited were adequately drained and only 15% of the total forest area was poorly or very poorly drained (Table 5).

Table 5: *Ground conditions by forest area.*

	All Forests		*WP Forests*		*CAP Forests*	
	ha	*%*	*ha*	*%*	*ha*	*%*
Ground bearing conditions						
Good	482	46	36	22	447	52
Average	285	28	81	50	204	23
Poor - very poor	267	26	46	28	221	25
TOTAL	1035	100	163	100	872	100
Terrain classification						
Smooth	404	39	54	33	351	40
Moderate	476	46	64	39	412	47
Difficult	155	15	46	28	109	13
TOTAL	1035	100	163	100	872	100
Drainage status						
Good	673	65	104	64	569	65
Average	207	20	13	8	194	22
Poor - very poor	155	15	46	28	109	13
TOTAL	1035	100	163	100	872	100

Access

Almost three-quarters of the WP forest area was adjacent to a public road, while just over half of the CAP area was similarly situated (Figure 1). Road remediation works were required in 96% of the forest area surveyed (Table 6) with over two-thirds of the WP area requiring only a bell-mouth entrance. Over one-third of the CAP area surveyed required in excess of 300 m of roading (Table 6) largely because so many CAP forests were not adjacent to county roads (Figure 1). As a result, road density requirements were high in the CAP area with almost one-third requiring road construction at a density in excess of 20 m/ha (Figure 2).

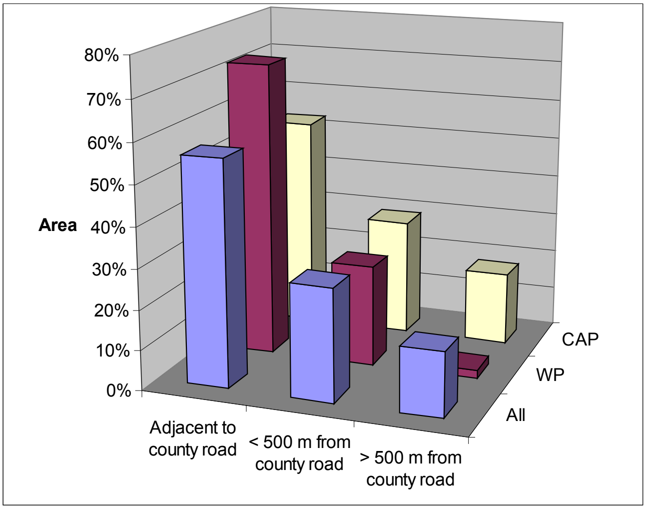

Figure 1: *Distance of forest properties to county road.*

Table 6: *Road remediation requirements by forest area.*

Road length (m)	*All Forests*		*WP Forests*		*CAP Forests*	
	ha	*%*	*ha*	*%*	*ha*	*%*
None	43	4	6	4	37	4
Bell-mouth only	412	40	108	66	304	35
30-99	80	8	18	11	62	7
100-199	108	10	19	12	89	10
200-299	96	9	12	7	84	10
300-499	163	16	0	0	163	19
500-749	105	10	0	0	105	12
750-999	25	2	0	0	25	3
1000+	3	< 1	0	0	3	0
TOTAL	1035	100	163	100	872	100

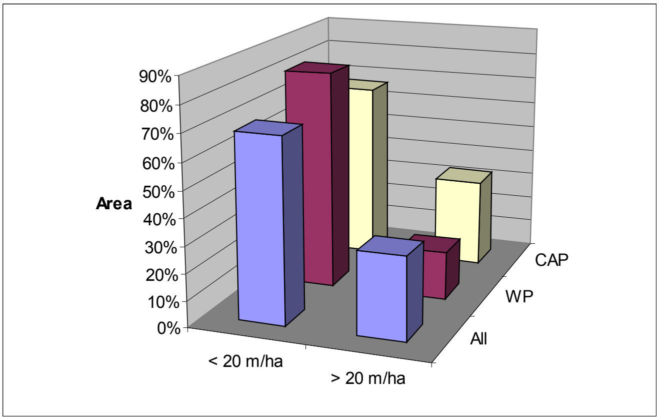

Figure 2: *Roading density requirements.*

Windthrow risk

Only 25% of the total forest area had greater than a 20% chance of windthrow (Table 7). Reflecting the older age classes within the WP area, the risk of windthrow was greater in these areas, with 63% of the area having at least a 1 in 5 chance of experiencing windthrow.

Table 7: *Windthrow probability in forests surveyed.*

% probability of windthrow occurring	*All Forests*		*WP Forests*		*CAP Forests*	
	ha	*%*	*ha*	*%*	*ha*	*%*
0 – 10	743	72	50	31	693	79
11 – 20	36	3	3	2	33	4
21 – 30	108	10	53	33	55	6
31 – 40	53	5	37	22	16	2
41 – 50	78	8	12	7	66	8
51 – 60	8	1	8	5	0	0
61 – 70	0	0	0	0	0	0
71 – 80	9	1	0	0	9	1
81 – 90	0	0	0	0	0	0
91 – 100	0	0	0	0	0	0
TOTAL	1035	100	163	100	872	100

Soil type and land status

Poorer quality soil types were commonly found in the WP forests with peats accounting for 72% of the WP stand area (Table 8). However, brown earth soils were the most common soil type encountered in the CAP stands (39%). The majority of the WP stand area was unenclosed (66%) compared with only 18% of the CAP area.

Table 8: *Stand area by soil type.*

Soil type	*All stands*		*WP stands*		*CAP Stands*	
	ha	*%*	*ha*	*%*	*ha*	*%*
Peat	276	37	43	72	233	33
Brown earth	268	36	0	0	268	39
Gley	128	17	6	10	122	18
Podsol	62	8	11	18	51	7
Lithosol	12	1	0	0	12	2
Alluvium	6	1	0	0	6	1
TOTAL	752	100	60	100	692	100

Crop composition

The WP stand area was almost exclusively conifer high forest with only 70% of the CAP area similarly classed (Table 9). Sitka Spruce accounted for three-fifths of the stand area surveyed while ash was the most common broadleaved species planted (16%).

Table 9: *Stand area by land use type and canopy composition.*

Land Use Type	*All stands*		*WP stands*		*CAP Stands*	
	ha	*%*	*ha*	*%*	*ha*	*%*
Conifer High Forest Pure	408	54	47	78	361	52
Conifer High Forest Mixed	113	15	13	21	101	15
Broadleaf High Forest Pure	76	10	<1	<1	76	11
Broadleaf High Forest Mixed	37	5	0	0	37	5
Mixed High Forest	117	16	0	0	117	17
TOTAL	752	100	60	100	692	100

Stocking

Almost half (47%) of the Sitka spruce stand area had stocking levels (live stems) in the region of 2001-2500 stems per ha.

Productivity

All species greater than nine years of age were assigned a yield class. Half of the area of Sitka spruce established under the WP programme was of yield class 22 to 24, while a further 26% was of yield class 24+ (Table 10). Over half (54%) of the WP Norway spruce was of yield class 14 to 16. Given the relative youth of the CAP plantations a considerable proportion of the area was too young to be assigned a yield class. Yield classes were relatively high where assigned. For example, 65% of the Norway spruce area had a yield class between 22 and 24. Similarly, 44% of the Sitka spruce area was assigned a yield class greater than 24.

Table 10: *Coniferous area by yield class and species.*

				Species			
Yield class	*DF*	*EL*	*JL*	*LP*	*NS*	*SP*	*SS*
All Forest				%			
None (< 10 years)	0	71	73	11	29	43	33
<14	13		4	13			3
14-16		29	23	76	6	57	12
18-20					5		2
22-24	87				59		9
24+							41
Area ha	2	2	11	60	41	3	457
WP forest							
None (< 10 years)							
<14			100				
14-16				100	53		13
18-20					41		11
22-24					6		41
24+							24
Area (ha)	0	0	<1	2	5	0	52
CAP forest							
None (< 10 years)		71	77	12	33	43	37
<14	13			13			2
14-16		29	23	75		57	11
18-20							2
22-24	87				67		4
24+							44
Area ha	2	2	10	57	36	3	407

DF: Douglas fir, EL: European larch, JL: Japanese larch, LP: lodgepole pine, NS: Norway spruce, SP: Scots pine, SS: Sitka spruce.

The only broadleaved species recorded under the WP programme was ash, which had a yield class of between 4 and 6. Broadleaves were more common under the CAP programme, with one-quarter of the sycamore assigned a yield class between 8 and 10 and one-third the alder with a yield class of 4 to 6.

Thinning history and thinning intentions

Only seven percent of stands visited (i.e. 31 ha), had been previously thinned. Sixty-five percent of the area thinned was in WP plantations of which 83% was pure Sitka spruce with an average general yield class of 22 $m^3ha^{-1}yr^{-1}$. All thinning performed was for merchantable purpose, including firewood production. Over three quarters (77%) of forest stands (or 85% of stand area) were in pre-thin status at time of survey.

Almost three-quarters (72%) of all forest owners surveyed planned to thin their forests in the future. However, a much smaller proportion (56%) of WP owners than CAP owners (77%) planned to do so.

The owners' estimates of the timing of thinning were assessed. Half of those intending to thin planned to do so before 2010. However, stand growth data suggested that only half of those forests would be ready within that timeframe. Additionally, over half (57%) of those WP respondents planning to thin did not realize that their forests had passed their "appropriate" first thin age. CAP respondents intending to undertake thinning were relatively accurate with their intended timing of proposed thinning.

Suitability for thinning

The suitability of all stands for thinning was assessed taking into account owners' intentions. First, the area, which owners planned to thin, was considered. Just over three-quarters (77%) of it was classed as having average to good ground conditions (Figure 3). Of this area, 41% (470 ha) was classed as having good road access, with the majority (454 ha) of this have a low to medium risk of windthrow. On this basis, out of a total area of 854 ha, only half (53%) was "suitable" for thinning.

Seven percent of the total area surveyed was owned by respondents who were unsure as to whether or not to thin their forest. Three-fifths (59%) of it was classed as having average to good ground conditions (Figure 4). Of this area, one-half (22 ha) was classed as having good road access, with all of that area having a low risk of windthrow. On this basis, out of a total area of 74 ha, less than one-third (30%) was "suitable" for thinning.

Ten percent of the area surveyed was owned by respondents who had no intention of ever thinning their forest (Figure 5). A review of this area indicated that 57% (60 ha) of it was classed as having average to good ground conditions. Of this area, one-half (30 ha) was classed as having good road access and having a low to medium risk of windthrow. On this basis, out of a total area of 106 ha, one-quarter (28%) was "suitable" for thinning.

Summary of results

1. Sampled forests had generally low elevations;
2. CAP forests had high road density requirements;
3. There were poorer ground conditions in WP areas;
4. Sampled forests had high productivity;
5. Sampled forests had a low windthrow risk at the time of survey;
6. Only one half of the area that owners had planned to thin was identified as suitable for thinning.

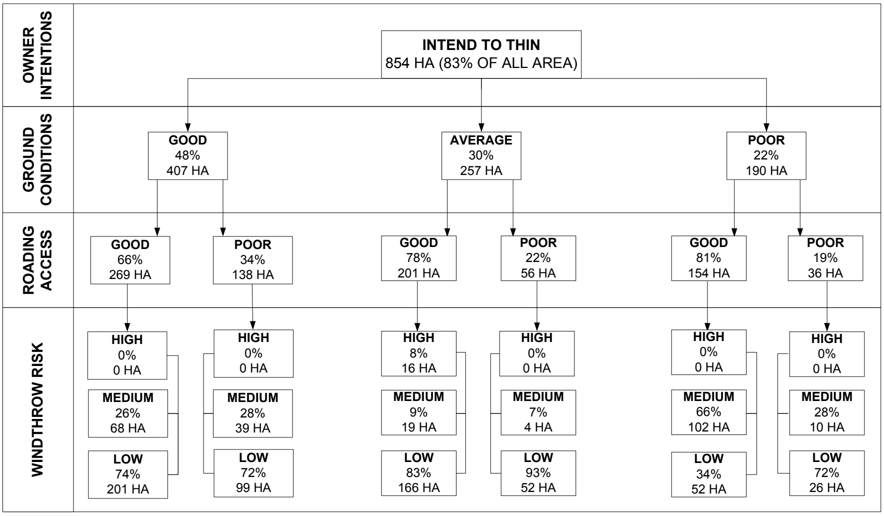

Figure 3: *Constraints on areas respondents planned to thin.*

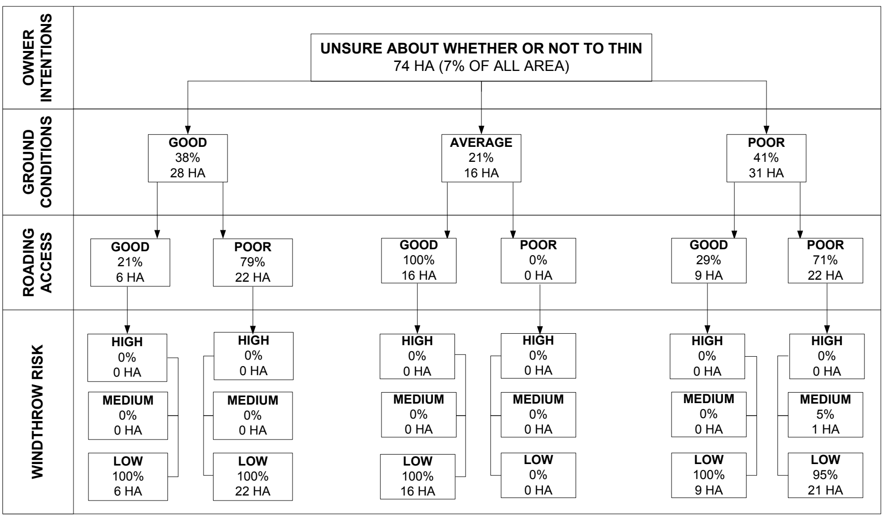

Figure 4: *Constraints on areas respondents were unsure about thinning.*

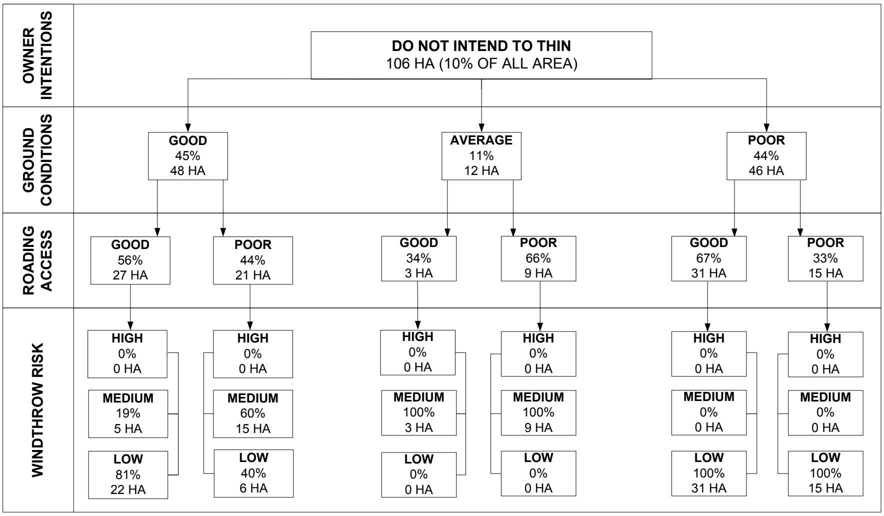

Figure 5: *Constraints on areas respondents planned not to thin.*

Discussion

Private forests now account for 45% of the forest estate in Ireland. The Government's plan to achieve critical mass relies on these forests being managed and harvested. This study first identified whether forest owners plan to thin their forests. It then attempted to assess the "suitability" of the owners' thinning intentions in light of the location and composition of their forest resource. In this section some of the findings in relation to the forest resource are discussed, followed by a discussion of the links between these findings and owners' plans to thin.

Access

Doyle (2002), Prestemon and Wear (2000), and Ryan et al. (2007) indicated that road access is an important factor influencing thinning/harvest practice. Access refers both to access from public roads to facilitate the transport of the harvested timber and to access within the stand, i.e. will the site support the movement of machines. Contrary to anecdotal evidence regarding the poor access to WP plantations, the results showed that 66% of the WP stands required only a bell-mouth entrance to be constructed to provide access to the site for a harvester, forwarder or truck-trailer. This finding agrees with that of Redmond et al. (2003), who discovered that 51% of the WP area they surveyed was accessible to timber trucks. The estimated average road construction density required for the stands surveyed in this study was 20 m/ha. The main factor contributing to this relatively high density was the fact that so much of the CAP forest area was not close to the road.

Stand productivity

The inventory found relatively high yield classes for the stands surveyed. For example, Sitka spruce, which accounted for 87% of the WP stand area, had a weighted average general yield class of 20 $m^3ha^{-1}yr^{-1}$, which agrees with the findings of Redmond et al. (2003). In the CAP stands, Sitka spruce accounted for 59% of the area and also had a weighted average yield class of 20 $m^3ha^{-1}yr^{-1}$. These high yield classes contributed to the fact that 56% of the WP area surveyed was past first thinning age; only 10% of the CAP area was similarly classed. Carrying out a delayed thinning could have serious consequences for crop stability. The assessment of windthrow risk indicated that the risk of windthrow (post thinning) was less than 20% in 75% of the area surveyed. This low level of risk can be attributed to a number of factors, including, the predominantly low elevations and inland location of many of the sites. However, the relatively low top heights (mainly as a result of young age classes) of the stands were also a factor and windthrow risk will increase as top height increases (Ní Dhubháin et al. 2009). On the positive side, the high yields suggest that a considerable volume of timber can be removed during thinning making it more likely that the thinning operations will be economically viable, *ceteris paribus*.

An analysis was undertaken to assess the suitability of the forest resources surveyed for thinning. This analysis only took into account two factors, i.e. can the stands be thinned and should the stands be thinned. Access and ground conditions were the two factors chosen to determine whether stands "could" be thinned. Crop stability, post thinning, was the sole factor considered when determining "should" a stand be thinned. It is important to note that the results from the analysis are sensitive to this choice of factors. Furthermore, assumptions were made regarding levels of factors. For example, the "good" and "bad" access categories were determined by a recommendation by Henry Phillips (pers comm.) that roading densities in excess of 20 m/ha were not economically viable ("bad" access). Similarly, a subjective decision was made by the authors that where the risk of windthrow, post thinning, was less than 50%, according to the Irish Windthrow Risk Model (Ní Dhubháin et al. 2009), the risk was classed as low or medium. Others might consider a lower threshold more appropriate.

Taking the assumptions outlined above into account the results showed that only one-half (i.e. 448 ha) of the area respondents plan to thin is suitable for thinning. A further 22 ha of forest, owned by those unsure as to whether they will thin, is suitable for thinning while 30 ha owned by those planning not to thin is suited for thinning. The main constraints were:

- poor ground conditions – 22% of the area owners planned to thin was classed as having poor ground conditions. These areas were composed of peaty and gley soil types which have inherently poor drainage capacity. Remediation works within this category are unlikely;
- unfeasible roading network – 27% of the area owners planned to thin was classed has having poor road infrastructure, which was considered economically unfeasible to improve.

Conway et al. (2000) and Loyland et al. (1995) highlighted similar constraints impacting on their respondents harvesting propensity in the USA and Norway respectively.

Limitations to the study

The main limitation to the study was that only those forest owners who agreed to take part in the study were included. Thus the sample was self-selected. Nevertheless, the response rate of 38% was relatively high compared to previous studies (e.g. Ní Dhubháin and Greene 2009). Due to restrictions associated with the Freedom of Information Act it was not possible to obtain any details on non-respondents. Hence it was impossible to determine whether this self-selection had biased the sample. However, given that the letter of invitation to participate in the survey specifically mentioned that the survey would deal with the harvesting and management intentions of owners, it may be that those who had not considered harvesting may have thought that the survey was not relevant to them and may have opted not to participate. This would suggest that the percentage of owners who indicated that they planned to harvest may be overestimated. Another limitation to the study is the relatively small sample size. However, the high costs of site visits meant this was the maximum number of respondents that could be interviewed.

Conclusion

Because of the limitations outlined it is difficult to make inference to the population of forest owners in Ireland. However, the results do raise questions as to whether the timber production targets as laid down in Government policy will be achieved. There is a strong willingness amongst owners to thin their stands but only half of the area they planned to thin was identified as being suitable for thinning. Poor access and ground conditions were the major limiting factors. While little can to done remediate the poor ground conditions, the access issue could be addressed by providing higher roading grants. Furthermore the results highlight the need for further targeted education of forest owners to ensure that silviculturally and economically sound decisions are made regarding thinning.

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Forest recreation in Ireland: a close-up of the NeighbourWood Scheme and Sculpture in Woodland

Kevin Collins[a]

Abstract
Recent years have seen an increased focus on the role of Ireland's woodlands and forests as a recreational resource. Numerous initiatives have emerged, including the Forest Service NeighbourWood Scheme and Sculpture in Woodland. The NeighbourWood Scheme provides funding for the development of 'close-to-home' woodland amenities for regular use by local people, through partnerships involving local authorities and communities. Numerous critical success factors underpinning successful projects are identified and explored, as they will have relevance to similar projects elsewhere. Sculpture in Woodland in Devil's Glen, Co Wicklow, is an example of a project that received support under the NeighbourWood Scheme. This project represents a partnership between foresters and artists in the development of a sculpture collection in the forest. An overview of the development of the project, and the opportunities and challenges experienced, will be of relevance to similar projects involving foresters and other groups focused on enhancing the recreational use of Irish forests.

Introduction

In August 2008, the author was invited to present a paper on forest recreation in Ireland at the 73rd Annual Meeting of the Icelandic Forestry Association, held in Ísafjörður in the northwest of the country. The Icelandic Forestry Association (Skógræktarfélag Íslands), founded in 1930, represents a nationwide alliance of over 60 local and regional forestry societies, the objective of which is to promote tree planting, forestry and nature conservation. The Association is a non-governmental organisation and has a membership of approximately 7,500. The meeting in Ísafjörður was attended by over 200 delegates from various forestry societies around the country.

Of particular interest to the Association was the development of Ireland's NeighbourWood Scheme, in particular, the critical success factors underlining successful projects. In recent years, the Association has become increasingly involved in community-based projects, as its focus moves from rural afforestation to the creation of forests in and around expanding urban centres, primarily for recreation and other multi-benefit objectives. Members were also eager to learn about the Sculpture in Woodland project in Ashford, Co Wicklow, which the Association visited during its tour of Ireland in 2003. The structure, funding and commissioning process were of particular relevance, given early plans emerging for a similar woodland sculpture project near Reykjavík.

While originally aimed primarily at the Icelandic forester, the following paper, compiled in 2008, is also of relevance to the Irish reader. It gathers together a wide range of experience gained over a number of years under the Forest Service NeighbourWood Scheme, particularly in relation to key success factors invariably

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associated with successful projects. By studying the Sculpture in Woodland project, it also tracks the development of a cooperative initiative between foresters and artists, setting out the opportunities and challenges faced along the way. The lessons learnt will have a wider application beyond both initiatives, as the focus on the multi-benefit nature of Irish woodlands and forests continues to grow.

The NeighbourWood Scheme

Funding 'close-to-home' woodland amenities

The Forest Service NeighbourWood Scheme is a financial package aimed at encouraging 'close-to-home' woodland amenities in Ireland. These woodlands are developed and managed in partnership with the local community, and provide local people with an easily accessible public resource to be visited and enjoyed as part of their daily or weekly routine. Neighbourwoods are designed to cater for a wide range of general activities – walking, family visits and picnics, wildlife watching, jogging and fitness training – and also for use by local schools as an 'outdoor classroom', for young people to learn about nature and the environment. Neighbourwoods can be located in and around towns and cities, or can be more rural in nature, situated near a village or in the countryside.

Although once predominantly rural in nature, Ireland's society has become rapidly urbanised, and towns and cities have expanded greatly, particularly over the last two decades. These trends have the same impact on people's lives in Ireland as they do elsewhere: lifestyles that are more stressful, unhealthy and resource-rich but time-poor, an increase in obesity and heart disease, and a general distancing from nature and the outdoors. Thankfully, recent years have seen a renewed increase in the recreational value of the Irish countryside, with organisations such as Comhairle na Tuaithe, Coillte, the National Trails Office and Leave No Trace having a major positive impact. However, the Forest Service NeighbourWood Scheme is focused specifically on developing closer to home woodland amenities that provide a sense of nature and the outdoors, all within walking distance from where people live.

The NeighbourWood Scheme is implemented by the Forest Service of the Department of Agriculture, Fisheries and Food, and is funded nationally under Ireland's National Development Plan 2007-2013. The scheme has its origins back in the early and mid 1990s, in three former grant packages: the Planned Recreational Forestry Scheme, the Amenity Woodland Scheme and the Urban Woodland Scheme. The NeighbourWood Scheme itself was first launched in 2001. A major revision was undertaken in 2007, based on extensive consultation with users and aimed at expanding the scheme's application and streamlining its procedures. The revised scheme was relaunched in December 2007, and a new scheme manual published in April 2008.

Criteria, funding elements and application procedure

The NeighbourWood Scheme is aimed primarily at local authorities. However, a recently introduced change is the opening up of the scheme to private woodland owners who may wish to develop their woodland for recreational use by local people. In all cases, various criteria have to be fulfilled. For example, there must be a clear potential for the development of attractive amenity woodland that will be strategically located, easily accessible, and well-used by local people. Also, in every case, the project must be developed in partnership with the local community and (where relevant) specific recreational user groups.

Funding is available under three separate headings or 'elements':

- **Element 1: NeighbourWood Enhancement** funds the silvicultural enhancement of *existing* woodland, to improve its suitability and attractiveness for recreation. The maximum grant is €5,000/ha, and eligible operations include general woodland restoration work, coupe planting, woodland edge management and the clearance of invasive species, such as rhododendron and laurel.
- **Element 2: NeighbourWood Establishment** funds the establishment of *new* woodland on open 'green field' sites, specifically for recreational use. The maximum grant is €6,920/ha, covering fencing, plants and planting, vegetation management and other related operations.
- **Element 3: Recreational Facilities** funds the installation and upgrade of recreational facilities within the woodland, including paths, seats, signage, nature trails and carparking. Facilities associated with a particular activity can also be supported, e.g. fitness training equipment, birdwatching hides, playground equipment. The grant paid under Element 3 is on a sliding scale: €4,500/ha for the first 10 ha, and €3,000/ha for subsequent hectares, up to a limit of 40 ha.

Figure 1: *The NeighbourWood Scheme is aimed at developing 'close-to-home' woodland amenities for local people to access and enjoy on a regular basis. Belleek Wood, Ballina, Co Mayo.*

Element 1 and 2 can include up to 30% open space, for paths, carparking, woodland glades, picnic areas, viewing points, etc.

The application procedure has been made as streamlined as possible. The applicant develops a NeighbourWood Plan with the local community, following a template contained in the scheme's manual and designed to keep people focused on the key considerations involved. The plan is then submitted to the Forest Service and is assessed by the relevant Forestry Inspector for the area involved. The Forest Service also consults with other statutory bodies, if there are issues surrounding designated sites, watercourses, sensitive landscapes, etc. If all is in order, approval is issued and the work can commence. Once completed, a second inspection is made to ensure that the work has been carried out to the required standards. At this stage, approximately 75% of the grant available under each relevant element is paid. The remaining 25% is paid as a second instalment four years later, following a further inspection to ensure that the woodland and associated facilities are being well maintained.

Critical success factors

The NeighbourWood Scheme has had many highs and lows since its launch in 2001. For example, at various points during the scheme's lifetime, funding issues limited the number of projects that could be approved. However, over 40 projects have received funding to date under the scheme, and taken together, these have given the Forest Service a wealth of experience regarding 'critical success factors' that can make the difference between a successful and an unsuccessful project. These factors are outlined below. While relating specifically to the NeighbourWood Scheme, these critical success factors may also be relevant to other types of projects and initiatives elsewhere, involving the creation of a woodland amenity with local input.

- **Adopt a 'catchy' title:** The use of the word 'NeighbourWood' in the scheme title helps to capture people's imagination and gets across the type of woodland amenity intended under the scheme. It conjures up associations with neighbourhoods, communities working together, and a friendly, welcoming amenity on people's doorstep. The word also helps grab the attention of the media as something that represents a new 'spin' on forest recreation.
- **Adopt strict criteria:** The NeighbourWood Scheme is underpinned by strict criteria regarding what is and what is not funded. For example, as mentioned above, there must be a clear potential for the development of attractive amenity woodland that will be strategically located, easily accessible, and well-used by local people. Also, in every case, the project must be developed in partnership with the local community and with specific recreational user groups. The Forest Service is keen to focus on quality over quantity, to promote the development of a smaller number of key, well-located and well-maintained amenities, as opposed to a high number of lower quality projects.
- **Allow flexibility:** Within the framework of clearly defined criteria, it is important to allow as much flexibility as possible in how the NeighbourWood Scheme is used. Every project is different, and a unique combination of local issues – local 'players', local politics, site conditions, opportunities and

constraints, additional sources of funding, etc. – will apply. In effect, every project has its own character, and this has to be taken into account when assessing applications.

- **Site suitability:** The Forest Service requires that each site is fertile and capable of supporting healthy woodland development. This helps ensure quick growth and the rapid development of a healthy, vibrant woodland amenity for people to use and enjoy. Substandard sites entering the scheme invariably take a long time to establish, require repeated inputs in terms of replanting, look neglected, and simply do not satisfy the expectation of local people. Occasionally, altered sites such as former landfills are submitted for consideration. In these cases, the Forest Service requires a soil analysis to be carried out, to ensure that compaction, poor substrate quality, possible contaminants, etc. do not pose a risk to woodland development.
- **Strong community input:** It is vital that local people are involved as partners in the project, to ensure the development of an amenity tailored to local needs and preferences. It also encourages ownership and pride in the project, and a sense of involvement and interaction that can have wider benefits within the community. Local ownership also reduces vandalism and other forms of damage, through the involvement of young people and the encouragement of a general 'watchfulness'. Working closely with communities can create challenges for local authorities, putting a strain on time and resources. However, it is a central component of the NeighbourWood Scheme.
- **Strategy for participation:** Local participation must entail an ongoing programme of events and activities, as opposed to a once-off meeting followed by the obligatory tree planting ceremony. For example, a series of activities can be planned on a rolling basis to gain as wide a level of participation as possible, from early inception through to establishment and later on, into ongoing management. Activities include the distribution of information, questionnaires, public and focus group meetings, events for young people and for people from ethnic minorities, etc. These can be initially instigated by the local authority. Later, a local woodland group may gradually emerge to take over the reins, with ongoing back-up and support from the local authority. Key to successful community participation is that it is ongoing, genuine, imaginative and fun for those involved. To assist projects in this regard, a manual is available, entitled *Interacting with Greenspace: Public Participating with Professionals in the Planning and Management of Parks and Woodlands* (Van Herzele et al. 2005).
- **Enthusiastic drivers:** Often with NeighbourWood Scheme projects, an individual emerges who leads the charge on the ground. This person might be from within the local authority itself (e.g. a planner, engineer, heritage officer, biodiversity officer). Equally, s/he might be from the community, such as a local activist or a member of a local environmental group. This person is the 'mover and shaker' on the ground, the person who gets things done, who gets people to turn up to meetings, who shakes out further sponsorship from local businesses.

Figure 2: *A key requirement under the NeighbourWood Scheme is a partnership between the local authority and the local community in the development of the woodland amenity. Poulgorm Wood, Glengarriff, West Cork.*

- **Project 'embedded' in the local infrastructure:** Integration of the project with the local infrastructure is vital. This takes many forms, including integration in local landuse policy, development plans and budgets. It also means integration with other types of local amenities (e.g. wider walking routes, heritage trails and visitor attractions), transport routes, and residential developments. This simply ensures that there is a greater onus on looking after the neighbourwood other than just the neighbourwood itself, i.e. it is part of a bigger picture within that local area.
- **Seed capital:** Funds under the NeighbourWood Scheme are sometimes used as 'seed capital' to draw in additional funding from other local authority budgets and outside sponsorship sources. This puts the project on a more secure financial footing and broadens the number of players with an interest in seeing it succeed. However, double funding for the same work must be avoided.
- **Simple, realistic proposals:** It is important that each project is realistic and achievable. Ideally, projects – particularly larger ones – should be broken down into phases. For example, the first year might involve planting, the second year might involve the installation of pathways, and the third year might involve the installation of seats and other facilities. This breaks the project down into bite-size pieces according to local capacities. This means that people can get used to working together and that the project progresses steadily and on a sustainable basis. Occasionally, expectations are too high

Figure 3: *Balrath Woodland in Co Meath is an example of a woodland developed specifically as an 'outdoor classroom' for local schools.*

and too much is attempted, and this often leads to tension and disappointment, and to failure.

- **The involvement of foresters:** Neighbourwood projects often involve a range of professionals within the local authority, including horticulturists, landscape designers, heritage officers, engineers, planners, etc. However, the involvement of a forester as the core member of the team is vital, as this individual will know about the practicalities of woodland establishment and management, will have the contacts with relevant forestry contractors, and will be familiar with working with Forest Service grant schemes. The involvement of a Forest Service Registered Forester is a requirement under the NeighbourWood Scheme.
- **Practical design and management:** The Forest Service looks out for signs that the applicants are pursuing a practical design and management approach to the development of the neighbourwood. Key indicators include the following:
    - The design of the neighbourwood should be simple, focusing on getting the basic woodland blocks established quickly on the ground, to provide a framework for facilities. Complex designs are difficult and expensive to achieve, and are very prone to failure.
    - It is important to adopt natural desire lines (which show how people are already moving across the site) into the pathway network within the new neighbourwood, as people will continue to use these routes in the future.

Figure 4: *Castle Demesne in Newcastle West, Co Limerick, offers an attractive and diverse woodland experience within a few minutes walk from the town's square.*

- Pioneer species such as birch, alder, rowan and pine should be favoured, particularly on more difficult sites and in areas where damage is expected. These species are robust and grow rapidly on many sites, giving a sense of woodland within a few years. They can provide screens for slower growing and more sensitive species such as oak and beech, or can be used to establish a footing on a site, paving the way for future phased replanting once the idea of woodland has become established in people's minds.
- Forestry techniques relating to ground preparation, transplant nursery stock and vegetation management are the cheapest and most effective way of establishing and managing neighbourwoods, and should be adopted.
- Vandalism and concerns surrounding safety and security are invariably associated with neighbourwoods, and the Forest Service needs to see that these issues have been taken into account in the project.

The role of the NeighbourWood Scheme

The NeighbourWood Scheme is a relatively minor member of the range of schemes available from the Forest Service. However, it plays a key role, as it brings the public benefits of forestry – recreation, biodiversity, landscape, contact with the natural world – to people's very doorsteps. It promotes the wider forestry sector in a positive light, offering urban dwellers a first-hand experience of how forests are managed on a sustainable basis. Moreover, it provides communities with the funding to realise a local resource that will make a meaningful contribution to the health, well-being and quality of life of local people, and that will help reconnect people with the natural world. Such resources are vital, as we continue into the 21st century.

Full details regarding the scope, procedures and standards under the NeighbourWood Scheme are set out in the *NeighbourWood Scheme Manual* (2008), available from the Forest Service, Department of Agriculture, Fisheries and Food. The publication entitled *Forest Recreation in Ireland: A Guide for Forest Owners and Managers* (Forest Service 2006) is also designed to assist the development of projects under the scheme. Potential applicants should contact the Forest Service for an update on the current status of the scheme and the level of grant and (in the case of private landowners under Element 2) premium rates available.

Sculpture in Woodland: an example of art in the forest

Bringing together art and the forest

A major project funded in part by the Forest Service NeighbourWood Scheme is Sculpture in Woodland (SinW). SinW is perhaps the most developed example in Ireland of the blending together of art and the forest. Formed in 1994, the group has brought together artists and foresters in the creation of an outdoor gallery in the dramatic semi-natural forest environment of Devil's Glen, situated near the village of Ashford in Co Wicklow.

Devil's Glen is a Coillte-owned forest centred on a deep gorge formed by the Vartry River after the last Ice Age. The woodland contains a variety of forest types, including

Figure 5: Into the Dark *by Eileen Mac Donagh (Ireland), Sculpture in Woodland, Devil's Glen, Wicklow. "The idea for this sculpture came to me from an image I saw many years ago in a wood in Japan. The image remained with me and I adapted it to create this 10 metre long intervention over the pathway beside the river."*

semi-natural woodland cover, and is designated as a proposed Natural Heritage Area due to its conservation value. It also provides fantastic views over the surrounding Wicklow countryside and the Irish Sea, looking across to Wales. The woodland has long been used as a recreational resource, with a network of well-defined walking routes already in place. In fact, its use for recreation dates back to the 19th century, when travellers visited the area as part of tourist packages that also took in other highlights in the county. Devil's Glen also has a rich social and cultural history. For example, it provided a temporary hiding place, and eventual trap, for doomed insurgents fleeing after the collapse of the 1798 Rising, and has strong associations with the playwright J.M. Synge. All in all, the Devil's Glen provided the ideal home for SinW, having within its boundaries layers and layers of geological, natural, historical and cultural heritage.

SinW was formed with the clear mission to help establish a wood culture in Ireland, by creating a greater awareness of wood as an artistic and functional medium (Magner 1998). Members of the group include foresters and artists from the local area and from further afield, and representatives from various organisations such as Coillte, Wicklow County Council Arts Office and the Forest Service. As with all such organisations, funding is a mixed bag that changes every year as existing sources of sponsorship dry up and new ones emerge. However, the core funders of the project have included Coillte, Wicklow County Council, the Forest Service and the Arts Council. As well as providing office space, Coillte also undertakes most of the onsite work involved with the project in the Glen.

Figure 6: 0121-1110=10210 *by Lee Jae-Hyo's (Republic of Korea), Sculpture in Woodland, Devil's Glen, Wicklow. "[The artist] borrows natural materials that are complete and ordered in themselves and uses them so that the finalised figure/sculpture, although a new entity in itself, still has the untouched properties of these natural materials."*

Sculptures

Core to SinW's activities is the commissioning of new sculptures. To date, 18 sculptures have been commissioned, involving artists from Ireland and Europe, and from as far away as Korea, Japan, Mexico and Canada. The commissioning process is centred on the acquisition of funding and the drawing up of an outline brief by SinW, to which artists are invited to respond with proposals, based on visits to the Glen. These proposals are then scrutinised, and a selection made. The artist then commences the realisation of the piece, sometimes in his or her own workshop, sometimes *in situ* within the Glen itself. Once engaged, the artist is supported by SinW and Coillte in terms of sourcing the timber, preparing the site (e.g. foundation work) and installing the piece, which often requires heavy machinery. Commissions can take place singly or in groups, whereby several artists come together to work on pieces, allowing collaboration and synergies to emerge. SinW tries to give artists as free a hand as possible. However, the piece must comprise timber from Ireland (ideally sourced from within the Glen itself), and must be appropriately sited. Another requirement is that it is robust, sturdy and resistant to damage, for public safety reasons and to counter a degree of vandalism that unfortunately is a factor with these types of projects.

Commissions have varied greatly over the years, forming a unique collection that visitors discover as they walk through the wood. Some, such as Lee Jae-Hyo's (Republic of Korea) *0121-1110=10210* defy explanation but are just marvellous objects to look at. Others, such as Janet Mullarney's (Ireland) *Panorama* and *Bella Vista*, bring a smile to the face while also challenging us to view things differently. Some have caused considerable controversy, such as *The Seven Shrines* by Kat O'Brien (Canada), which is a commentary on the lives of the seven generations of women born since Ireland's Great Famine.

A major challenge facing SinW is the maintenance of the pieces. The organisation accepts that, over time, pieces will decay back into the forest or will have to be removed on the grounds of safety. However, the life of the sculptures can be extended by care and maintenance, and repeated repairs are invariably required, as pieces attract the unwelcome attention of vandals. However, while there are usually resources available to create new pieces of work, finding the resources necessary to carry out ongoing maintenance is more difficult, and the collection has suffered as a result. This poses a major challenge for SinW.

New directions

SinW's artistic pursuits also extend beyond sculptures. In the past, it has commissioned paintings and photographs of the Glen. A major addition recently made to the Glen was the inauguration of the Seamus Heaney Walk, developed with the support of the poet himself, who lives nearby. Various excerpts from Heaney's poems have been carved into the backrest of seats positioned at key points along the walk, turning a visit to the Glen into a truly poetic experience.

The most recent commission, *Stone Voices* by Suky Best, also marked a big change in direction. The project originated from a bringing together (or charrette) of 10 artists, sociologists and historians from Ireland, Europe and Australia in September 2005, to explore new ways in which SinW could advance. A proposal by one of the participating artists, UK's Suky Best, was subsequently adopted by SinW with funding from Wicklow County Council. In this project, Suky spent several weeks in Wicklow collecting accounts about the Glen from local people. These included excerpts from historical records and folklore, and personal stories and experiences. Suky selected 20 short pieces of text from these, which were then mounted in gold leaf onto limestone plaques and placed at key locations throughout the Glen, where the watchful visitor would discover them. Each piece contains an unexplained excerpt – "Every time we come here we get lost", "They say no one has ever drowned here", "When we find the ring, I'll propose" – and it is up to the observer to draw her or his own meaning from it. This project has proven to be highly successful and popular, possibly because it links people directly with the historical, social and cultural layers underpinning the Glen.

SinW has also been involved in a range of other activities in the Glen.

- With funding under the Forest Service NeighbourWood Scheme, SinW has worked with Coillte and Wicklow County Council in a programme involving the upgrade of the recreational infrastructure in the Glen. Existing pathways have been improved and new routes installed. Information boards, waymarkers and seats have also been added. Carparking facilities have received a major upgrade, and facilities for people with disabilities installed. A visitor's guide was also produced (SinW 2004a), pointing out the various things to see and experience along the Upland Walk and the Waterfall Walk, the two major routes through the forest.
- SinW has run a series of educational projects targeted at local schools. A recent project entitled *Through My Eyes* gave school children the basic skills of photography. The children then visited the Glen and took images, which they subsequently mounted and exhibited at a public venue in nearby Wicklow Town. The project – overseen by an educational artist and a photographer – captured what the Glen means for local young people, and was a huge success.
- SinW has also produced a range of publications associated with the project, including a catalogue of the works in the Glen (SinW 2004b) and a publication entitled *Ecologies of Distance* (SinW 2007), capturing the creative process of the *charrette* that culminated in Suky Best's *Stone Voices* proposal.

Challenges and successes

Although employing an Administrator for much of its time, SinW is basically a voluntary organisation that relies on the goodwill of its committee members and its partner organisations and funders. This leads to a certain ebb-and-flow in activities, as periods of intense activity are followed by those during which the organisation is ticking over. The organisation has also faced various challenges. For example, it is often perceived as a 'forestry' project by the arts community, and as an 'arts project' by the forestry community, and so falls between two stools. Securing ongoing funding for general day-to-day running is also very difficult. Retaining a proper balance between foresters and artists on the committee itself is also a challenge, as is the maintenance of the existing collection. However, with the support of its partners, SinW has achieved much since its formation in 1994, establishing a major sculpture collection within the dramatic setting of Devil's Glen, and exploring the undeniable common ground shared by both foresters and artists, two vocations firmly embedded in time and place.

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Forest Ecosystem Management in the 21st Century

Proceedings of the Scientific Seminar of the Annual Conference of the European Forest Institute

Dublin, September 2009

Foreword

The Annual Conference of the European Forest Institute (EFI) was held in Dublin Castle, in September 2009. The European Forest Institute is the leading forest research network in Europe. It is an international organisation established by European States; currently, 22 countries, including Ireland are members of EFI. It has an extensive network of 125 Associate Members, universities and research institutes, including four from Ireland, Coillte, UCD, COFORD[1] and IFIC.

The Annual Conference is the annual business meeting of the Institute. A Scientific Seminar is held in conjunction with the Annual Conference. The theme of the Dublin seminar was forest ecosystem management in the 21st century.

Scientific forest management has until recently, been directed at one product of the forest only, wood. This involved regulation of the harvest so as to ensure a constant supply of timber, in perpetuity. The forest, in particular the plantation forest, was seen as a wood factory.

This view of the forest has changed within the past three decades. The forest is now valued for the wide range of goods and services it offers. The need to manage the forest in order to produce multiple benefits is now recognised. In effect, forest managers are being called upon to act as ecosystem managers. This can be difficult because in many cases, forests established with the single objective of wood production are now expected to deliver wider benefits. In addition, foresters trained within the narrow constraints of traditional forest management, are being called upon to deal with the broader issues of multifunctional management. The proceedings of the seminar address the 21st century view of the forest.

Climate change is one of the great issues of our generation. Kremer, in his paper, considers the evolutionary response of naturally occurring tree species to climate change. The rapidity of changes in climate gives rise to concern about the ability of trees to adapt to this change. While the potential of species to migrate to more favourable climates is limited, natural selection may allow sufficient local adaptation for the survival of a species. It is recommended that managers consider introducing

[1] COFORD (National Council for Forest Research and Development) is now an agency within the Department of Agriculture, Fisheries and Food.

non-local seed or plant material into native populations in order to increase genetic diversity and adaptive capacity.

Black and his co-authors address the impact of climate change on the potential productivity of our forest estate, consisting as it does, almost entirely, of introduced species. Understanding the potential impact of future climate change is key to developing adaptation and mitigation strategies. Adaptive strategies should be based on empirical and processed-based approaches using ecological site classification as the spatial framework.

Climate change is closely associated with the global carbon cycle. Forests can make a significant contribution to the mitigation of greenhouse gas emissions. Ireland's plantation forests are a net sink for carbon and contribute significantly to national greenhouse gas reduction targets under the Kyoto Protocol. However, as pointed out by Byrne in his paper, "The role of plantation forestry in Ireland in the mitigation of greenhouse gas emissions", it is essential that we maintain our 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.

The importance of forests, including plantations, for outdoor recreation and human health is being increasingly emphasized in numerous policy and research documents. Hahn et al. discuss the contribution of urban forests (and afforestation in general) to human health and well-being. They anticipate that, in the future, we will see an increasing need for developing some plantation forests specifically to serve the public health and welfare sector. There is a growing recognition too, that outdoor education makes an important contribution to the physical, personal and social education of young people. There is a need for strategic planning on how to manage the growing need for sporting activities (mountain-biking, gps/geocaching, tree-climbing, off-road (motorized) skateboards etc.), reconciling them with the aspirations of those who go to the forest in search of peace and tranquillity.

The development of the ideas and recommendations put forward in the seminar must be underpinned by well-resourced and long-term research programmes. This is a central theme of Hendrick's paper, "Forest research for 21st century Ireland". Forest research is needed to provide guidance to policy makers and practitioners through scientifically-based, timely and well-communicated information. His comprehensive treatment of the topic covers the purpose of forest research, the contribution of research to forest policy, development of research priorities, research funding and dissemination of research findings.

The Conference was a fitting celebration of Ireland's accession to membership of the European Forest Institute. The vision of forestry presented at the seminar was enlightening and can serve as a guide to forest management in the future and to the education which must underpin it.

Edward P. Farrell

Evolutionary responses of European oaks to climate change

Antoine Kremer[a]

Abstract
There are widespread concerns that trees, as long lived species, may not be able to cope with future climate change. Trees experienced large climatic changes over much longer time periods during many previous interglacial periods. The evolutionary trajectories of trees during these periods were reconstructed in this study, in an attempt to predict how trees might respond to future environmental changes caused by climate change. Taking the European oaks as a study case, this review shows that rapid migration and adaptation, extensive gene flow and hybridisation were the main processes that permitted oak to track climatic warming in the past. Future evolutionary trends of oak populations in response to climate change are then considered. The potential for species to migrate via seed dispersal to more favourable locations (e.g. northwards) will be limited. On the other hand, it is likely that natural selection will act on a diverse gene pool (in part due to large population sizes), perhaps allowing local adaptation even if this ultimately reduces diversity. Substantial evolutionary shifts can be expected in a limited number of generations. The high levels of genetic diversity and gene flow from other populations will favour rapid adaptation. However, many tree populations may be tested to the limits of their adaptive potential, so some intervention may be needed. To enhance the adaptive potential of populations, it is recommended that genetic diversity should be increased by 'mixing' local stock with non-local material (seeds or seedlings). Guidelines, providing information on permitted directions and distances for the transfer of reproductive material (seed or seedling), should be developed based on current scientific information, especially data from existing provenance tests.

Introduction

Concerns about the adaptation of trees to ongoing climatic changes have been repeatedly raised, particularly due to the rapid rate of environmental change relative to the long life span of trees (Aitken et al. 2008). Indeed recent climatic predictions released by the Intergovernmental Panel on Climate Change raised considerably the magnitude of the earlier estimates of temperature changes by the end of this century (Solomon et al. 2007). Trees, being long-lived organisms, exhibit lower evolutionary rates than short generation species (Smith and Donoghue 2008), so there is some concern that the pace of evolutionary change may not match environmental change. Trees, in common with other living plants, have experienced similar or larger environmental changes over longer time periods during the recurrent interglacial periods (Dynesius and Jansson 2000). Although the rates of environmental change were lower then than is now occurring in response to climate change, the evolutionary mechanisms may be similar. It is therefore of utmost importance to reconstruct the evolutionary trajectories of trees in response to previous climates, to help inform current decision making

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about climate change. Furthermore there is a growing body of evidence from different sources (Quaternary evolutionary history; observations from population and species transfers; provenance experiments) that trees may have resources and mechanisms to respond to climate change (Kremer, 2007). The genetic and ecological mechanisms that have facilitated adaptation of trees during historical "natural" warming periods, taking European oaks as example species, are reviewed in this paper. Oaks are ideal species for this purpose. The postglacial history of temperate oaks in Europe has been reconstructed in detail by combining genetic and historical approaches (Kremer 2002). Oak population variation has been monitored extensively from the molecular to the phenotypic level, making it possible to document the spatial and temporal differences in genetic diversity across Europe. Assembling information from phylogeography, paleobotany and provenance research, this paper shows how oaks have responded rapidly to environmental change in the past, despite their low evolutionary rate at the gene level. Furthermore, the mechanisms that trees are likely to exploit in response to ongoing climatic changes will be explored, particularly regarding migration, local adaptation or extirpation.

What have we learned about the evolutionary responses during natural warming?

The earth's climate has been dominated during the quaternary era by the succession of more than 15 glacial and interglacial periods. Glacial periods lasted on average from 70 to 100,000 years, while interglacial periods were much shorter (from 10 to 20,000 years) (Hays et al. 1976). These repeated drastic environmental changes were followed by important alternating retractions and expansions of tree species distributions, placing them in different habitats over time and space. These changes also represented very severe selection filters. Indeed, extinctions of European forest tree species occurred between 2.4 to 1.7 million years ago, during the early severe glacial cycles of the Quaternary period. Many species that existed in Europe at the end of the Tertiary, based on fossil evidence, disappeared and are now only present in North America and/or Asia (e.g. species belonging to the *Fagaceae* genera, such as *Lithocarpus* and *Castanopsis*). There has been no tree species extinction during the most recent periods, suggesting that extant tree species in Europe demonstrated an efficient ability to migrate and adapt to environmental change. Quaternary evolutionary history suggests, therefore, that these species have developed mechanisms to help reduce the likelihood of extinction, despite the drastic environmental changes. Recent investigations in evolutionary and population genetics allowed the identification of at least four of those mechanisms: rapid migration, extensive gene movement through pollen dispersal, interspecific hybridisation and rapid adaptation.

Rapid migration

The distribution of temperate white oaks in Europe has shifted repeatedly from the Mediterranean to the boreal regions during interglacial and glacial periods (Cheddadi et al. 2005). At the end of the last glacial maximum, oak forests were restricted to the Iberian Peninsula, Italy, and the Balkan peninsula (Greece and the western Coast of the Black Sea). A pan-European survey of the pollen fossil remains (Brewer et al.

2002) showed that all refugial sites were located in mountainous areas (e.g. Sierra Nevada in Spain, the Southern Apennine chain in Italy, and the Pindos mountains in Greece). During the postglacial period, between 13,000 and 10,000 BP[1] oaks increased in abundance in mountainous areas (Pyrénées, South-eastern Alps and Carpathians). The cooling of temperatures during 11,000 BP to 10,000 BP stopped this expansion and eventually resulted in a decrease in the size of the species geographical range. After 10,000 BP, oaks spread throughout Europe and reached their current distribution at about 6,000 BP. The expansion was more rapid in the west and was reduced in the centre and east due to the Alps and the Carpathian mountains. The velocity of oak migration during the post glacial recolonisation period (between 15,000 to 6,000 BP) averaged 500 m year^{-1} (Brewer et al. 2002, Huntley and Birks 1983), reaching in some cases up to 1,000 m year^{-1} (Brewer et al. 2005). These figures are much larger than predicted by migration models based on dispersal agents. However, if rare long distance dispersal (LDD) events (Nathan 2006) are included in the models, then the overall expansion rate generated by the aggregation of the many populations that were founded by the LDD events may account for these rapid migration rates. Rates of occurrences of LDD events as low as 10^{-4} may be sufficient to account for the rapidity of the expansion, as deduced from fossil pollen records (Le Corre et al. 1997, Bialozyt et al. 2006). Considering the very high fecundity of oaks, LDD may have occurred repeatedly even if the frequency was low.

Extensive gene flow through pollen dispersal

As migration proceeded northwards from the different source populations, the colonisation routes merged in central Europe resulting in genetic homogenisation as these different populations interbreed. The resulting genetic diversity was so great that the genetic imprint of the original refugia from which they were derived was virtually erased. Large scale analysis of nuclear gene diversity across Europe has consistently found very low levels of genetic differentiation among modern oak populations, regardless of the markers used (Zanetto and Kremer 1995, Mariette et al. 2002), which may be attributed to extensive gene flow. Pollen flow dynamics in Quercus petraea or Q. robur stands have been studied (Valbuena-Carabana et al. 2005, Streiff et al. 1999). These studies revealed that more than half of the pollen contributing to the next generation came from outside the study stands, and pollen dispersion curves are characterised by long “tails”. The results of recent large-scale genetic surveys indicate that the level of genetic diversity at the northern edges of the natural distribution range reach the same levels as in the refugial glacial areas (Zanetto and Kremer 1995). This was also most likely the case as migration progressed. The end result of extensive gene flow is the maintenance of genetic diversity even at the migration front, allowing rapid adaptation of the newly colonising populations.

Hybridisation as a colonisation process

A very intriguing result of the pan-European genetic survey of chloroplast DNA diversity was the almost complete sharing of chloroplast genomes between different

[1] Before present.

oak species when they occupy the same forest stand (Petit et al. 2002). For example, when *Q. petraea* and *Q. robur* are present in the same forest they usually share the same chloroplast genetic variant; they may share a different chloroplast variant in a different forest where they coexist just a few km away. The almost complete sharing of chloroplast variants among the two species occupying the same stand was observed across the natural distribution of the oaks, suggesting that hybridisation was common and widespread during post glacial colonisation. Because chloroplast genomes are of maternal origin, hybrids will inherit the chloroplast of the female parent. Hybridisation may play an important role in the colonisation process, since repeated hybridisation events accelerate species migration and succession rates. The effect of hybridisation can be traced, as described in detail by Petit et al. (2003) for *Q. petraea* and *Q. robur.* Because *Q. robur* tends to be a more pioneering species than *Q. petraea*, it was assumed that *Q. robur* was present at the northern edge of the oak migration front, and that *Q. petraea* was somewhat behind it, but still capable of hybridising with *Q. robur* through pollen flow. If the first generation hybridisation is followed by later backcrosses (e.g. between hybrids and parents) with *Q. petraea* as male parent, then successive introgression will lead to restoration of *Q. petraea* trees within the *Q. robur* stand, consequently enhancing species succession. The peculiar role of hybridisation shows that colonisation of newly available territories by oaks (for instance following successive ice ages) is facilitated by interspecific gene exchanges, allowing one species to rapidly invade new sites despite colonisation by the other species.

Rapid adaptation

After colonising a new site, the newly established populations begin to differentiate genetically from the source populations from which they were derived. For obvious biological reasons, it is impossible to monitor evolutionary change of a given population from one generation to the next, but some indirect assessment of evolutionary change from today's genetic divergence among populations planted in provenance tests is possible. There is now evidence that the genetic divergence among extant populations resulted from adaptive evolution due to local selection from the time of establishment of populations on new sites (Kremer et al. 2010). Assuming that the Spanish and Italian-Balkan refugial populations were genetically separated for more than 100,000 years during the last glacial period, genetic differentiation may have accumulated between the two source populations and may be partly responsible for the differentiation between extant populations of different refugial origin. In two previous papers (Kremer et al. 2002, Kremer et al. 2010), it was shown that there was little evidence of genetic separation relating to the original source population, based upon the patterns of variation observed in current provenance tests. Indeed most phenotypic traits show clinal variation, with different clinal patterns of variation for different traits (Ducousso et al. 2005).

There is little evidence in current populations of any phenotypic or adaptive trait differentiation relating to refugial origin, even in neighbouring central European populations that are known to have originated (through migration) from different refugia. This is usually interpreted as the result of extensive gene flow during admixture followed by local adaptation (Kremer et al. 2010). One may conclude from these analyses that most variation in provenance tests is the result of recent adaptive evolution. However, there is little information on the precise rate of evolution during adaptation. Theoretical approaches have however, shown that the interaction of extensive gene flow and strong diversifying selection will accelerate differentiation of complex multi-locus traits (Le Corre and Kremer 2003) and achieve adaptation in less than 20 generations. The rapid process is generated by allelic associations among different loci that increase population differentiation of adaptive traits in response to diversifying selection. The mechanism is enhanced by gene flow that provides the diversity needed to create different allelic associations. The overall process is accelerated if the number of loci contributing to the trait of interest increases.

How will evolutionary processes stimulate adaptive responses under climate change?

The response of natural tree populations to climate changes has been sketched in three different scenarios: "persistence through migration to track ecological niches spatially, persistence through adaptation to new conditions in current locations, and extirpation" (Aitken et al. 2008). The actual outcome for oak populations will depend on the interplay among the different evolutionary processes just described. It is important to evaluate how natural mechanisms will be activated to determine if human interception would be needed. Predictions on the potential impact of climate change on oak populations are made in the following sections, based on historical as well as on contemporary records.

Migration by seed constrained by natural seed dispersion

There has been considerable research on the shift of bioclimatic envelopes (i.e. the geographic range over which environmental conditions are favourable for the growth of a particular species) of trees species induced by global change. This approach involves constructing a statistical relationship between the current geographic distribution of a given species and the climatic data for the distribution range. This relationship can then be projected under the different IPCC gas emission and climatic scenarios, to predict where the same envelope might be located in the future (Thuiller et al. 2005, 2006). It is beyond the scope of this paper to discuss the limitations of the approach (Hampe 2004), but predicted future bioclimatic envelopes provide some rough indications on the distance that populations would need to be shifted to remain under the "same" bioclimatic conditions. In the case of *Q. petraea*, a shift of 200 to 500 km North and North East by the end of the current century is predicted, depending on the level of greenhouse gas emissions (Thuiller et al. 2005). Under the most severe scenario (gas emission model A1F1; climate model HadCM3) the bioclimatic envelope excludes France, but would cover the Southern half of Finland. Information on seed velocity is available from the post glacial recolonisation period and these data can be used to assess the likelihood that the oak will be able to migrate quickly enough in response to the displacement of the envelope. Palinological records indicate migration velocities ranging from 500 to 1,000 m year^{-1}, amounting to a displacement of 50 to 100 km in one century. At maximum, oaks would be able to shift their range 100 km during the next hundred years, not taking into account the likely negative impact on migration caused by land fragmentation due to agricultural and other land uses. Future migration velocities, in response to climate change, inferred from past migration patterns may not be accurate (where it is assumed that dispersion capacities are the same under different environmental conditions). There is a large gap between the velocity estimates and the actual velocity needed to cope with the shift of the bioclimatic envelope. However, it is clear that dispersion by natural means will not allow the species to track rapidly enough the displacement of the bioclimatic envelope.

Hybridization facilitating migration and succession

While there are only two temperate oaks species (*Q. petraea* and *Q. robur*) in Europe, there are more than 20 species and sub species located in central and Mediterranean areas (Schwarz 1964). They belong to two main oak sections (*cerris* and *lepidobalabnus sensus* Camus) and hybridisation within sections is quite common (Curtu et al. 2007, Lepais et al. 2009). Climatic change is expected to cause species migrations, with more range overlaps and competition for new niches on the newly invaded sites. Consequently, this might be expected to increase the opportunities for hybridisation and introgression among species. There are two ways in which hybridisation may enhance adaptation of oak populations to climate change:

- By accelerating species migration, just as hybridisation permitted *Q. petraea* to migrate northwards during the postglacial period, by repeated unidirectional interspecific crosses with *Q. robur*. Similar hybridisation events may occur with other species combinations involving Mediterranean oaks, facilitating the establishment of Mediterranean species at more northerly latitudes. Hence hybridisation may help overcome the limitations of species migration via seed that was limited to less then 100 km because pollen is dispersed over longer distances than seed.
- Hybridisation may facilitate establishment and species succession on new sites. Oak species are characterised by strong differences in site preferences. Just as *Q. robur* and *Q. petraea* differ in their water requirements, the Mediterranean oak species have different soil type preferences. As hybridisation will accelerate the migration of species, it will subsequently facilitate their establishment on the most suitable sites, those that are already occupied by temperate species. In the long run, this process will end in the replacement of one species by another, which may accelerate ecological succession.

Finally, the combination of introgression and selection may further contribute to novel allelic combinations, enhancing the adaptation of newly introgressed forms (Seehauzen 2004). The outcome is largely dependent on the relative fitness of introgressed forms versus those of the parental species under the new environmental conditions, but these suggestions are speculative at this time. The process may be extremely rapid if transgressive segregation occurs, but could require several successive generations, including some backcrosses, to increase the fitness of the introgressed forms.

Gene flow enhancing adaptation

Local adaptation can be increased by "incoming genes" via pollen from populations exhibiting higher fitness than the receiving population. In the case of directional environmental changes towards higher temperature, it is likely that populations from more southerly latitudes may be an important source of this pollen. The question raised here is whether pollen dispersal distances will be of sufficient magnitude to shift species bioclimatic envelopes.

Gene flow may contribute to increasing the fitness of a given population that is under severe selective pressures. Migration of alien genes through gene flow will change the genetic composition of the receiving population. Subsequent changes might be unfavourable or favourable, depending on the source population (Lenormand 2002). If the migrating gene has a positive effect on fitness, it will rapidly increase its frequency in the receiving population. The dynamics of migrating genes (migration rates, subsequent frequency, variation and change in population fitness) have never been monitored in forest tree populations, but deserve to receive more attention in light of the increasing focus on the impact of climate change. Clearly, a species that has a continuous distribution across contrasting ecological sites might be able to 'import' genes, contributing to higher fitness in areas exposed to severe stress. Extensive research has been done on gene flow in forest trees at a rather narrow spatial scale (Austerlitz et al. 2004, Smouse and Sork 2004). Most of these theoretical and experimental studies have shown that gene dispersion has both local and long-distance components, as revealed by the existence of the 'fat tails' of the dispersion curve. The second component is, of course, more relevant in the context of climate change. Sites that are currently considered moist are likely to become drier in the future, so trees growing on these sites would potentially benefit from genes that convey some drought tolerance. However, such genes are likely to exist only in stands located long distances away. Pollen dispersal in the upper layer of the atmosphere is possible, where it can be transported long distances but is also exposed to potentially damaging high UV radiation levels. Modelling approaches at the landscape level, taking into account pollen release, viability and deposition characteristics suggest that viable pollen of oak can be dispersed up to 100 km (Schueler et al. 2005; Schueler and Schlunzen 2006). Pollen dispersal distances are usually estimated based on observations recorded over a single generation (Austerlitz et al. 2004) but estimates of dispersal distances over a few successive generations is lacking.

Adaptation facilitated by genetic diversity

Local adaptation is the process by which natural selection results in the development of a phenotype that optimises the response to the environmental pressures, with this phenotype corresponding to the highest fitness in the population. Under a changing environment, the required optimum is continuously shifting, but there is a time lag before this optimum phenotype is developed (by which time the environment may have changed again) (Bürger and Krall 2004). The lag causes a reduction of fitness, with the risk that this fitness level reaches a critical level that is too low to allow the population replace itself (Bürger and Lynch 1997). The lag can be maintained at a tolerable level in two complementary ways:

- Maintaining a large, genetically variable population with high rates of fecundity (Bürger and Lynch 1995, 1997);
- The immigration of new genes with higher fitness via gene flow.

When applied to oaks, these predictions suggest that the lag can be reduced substantially if natural or artificial regeneration is used to renew forest stands. Indeed the very high fecundity of trees and the large size of populations within most species will allow a considerable shift in a population's optimum from one generation to the next, allowing it to "track" environmental change. While these conclusions are based on theoretical analysis only, they predict rapid evolution of oaks under environmental change, but they have not been supported by the results of experiments conducted over contemporary time scales. However, there is experimental evidence from model plant species (having shorter generation cycles than oak), that rapid adaptive evolution is possible in situations where population sizes are large (Bell and Gonzalez 2009, Stockwell et al. 2003). Large population sizes will maintain important genetic variation, and hence increase the probability that beneficial alleles favouring adaptation exist within the population.

There is some indirect evidence of significant adaptive change over contemporary time scales from studies of genetic divergence in introduced exotic species in Europe, which may be relevant for the European oaks. Northern red oak (*Q. rubra* L.) is a well documented case. This species was introduced into Europe shortly after the French revolution and is now planted throughout the continent (Timbal et al. 1994). A large-scale provenance test was established in south-western France, and the collection included progenies derived from introduced European stands and from the source populations in North America. Interestingly, the introduced and now naturalised populations, as a whole, exhibited a clear shift in the phenology of bud break and autumn leaf senescence compared with provenances introduced directly from the natural range (Daubree and Kremer 1993). Although the genetic causes of the genetic divergence are not precisely known, this example illustrates the capacity for rapid evolutionary change in oak. If the changes in climate predicted for Europe are realised, then European oaks may have to respond in a similar manner to that illustrated for red oak.

How can we enhance adaptation to climate change?

A comparison of past with projected future trends suggest that migration and local adaptation will be differently affected by evolutionary processes. On one hand, migration via seed dispersion will be limited if the climatic changes occur as rapidly as predicted. On the other hand, adaptation at local level via natural selection may be buffered considerably by significant inherent genetic variability and large population sizes. Interestingly, these data also show that gene flow via pollen will enhance species migration and local adaptation, and will play a central role in species responses to climate change. One can therefore anticipate different responses between species, depending on the nature of each species' geographic distribution. Species that have a continuous distribution are likely to benefit more from positive interactions between natural selection and gene flow than species that have a scattered distribution. It is also predicted that the evolutionary responses between populations located at the leading edge may differ from those at the rear end of a distribution. Populations at the northern and eastern limit will be at the leading front of range shifts and may benefit from immigrating genes via pollen flow from southern latitudes; in contrast, adaptation may be more constrained at the rear edge, where populations are deprived of gene flow from "preadapted" populations.

Artificial measures could be implemented to enhance natural adaptive processes, especially in southern populations at the edge of the range. Suggested actions should mainly be directed towards modifying the genetic composition of stands during the regeneration process. New, non local seeds (or seedlings) can be introduced. This "enrichment" introduces new genes, which may provide additional adaptive buffering capacity. With continuous directional shifts in climate, genotypes other than those of the contemporary populations, eventually will become better suited to the new climate. As the climate changes, planting programmes that involve moving appropriate genotypes between climate zones can accomplish in a single generation what would require several generations in nature. A newly regenerated stand with a mixed genetic composition is likely to have a greater potential to successfully regenerate in the future (i.e. greater fitness). The suitability of the introduced material used in sowing or planting should be determined based either on results of provenance tests or on projected future bioclimatic envelopes (if no provenance test data are available). Guidelines on the transfer range for the direction and distance of movement of reproductive material can be developed from the geographical patterns observed in multi-site provenance tests. Oak provenance tests were established since the mid 1900s, and have shown congruent geographical variation among species (Kleinschmit 1993). The continuous or clinal patterns of variation that follow environmental gradients were observed for most traits (Ducousso et al. 1996, Deans and Harvey 1995, 1996, Liepe 1993). This should therefore ease the choice of source populations. However, the final decision on the type of material to introduce into an area should be based on the potential impact of the new material on the overall fitness of populations rather than on the suitability of individual trait characteristics. Hence an overall meta-analysis should be carried out across all existing provenance tests in Europe to delineate seed zones for operational use.

Conclusions

This review outlines the inherent adaptive capacities of oak species to environmental changes, as witnessed by their history during natural warming over the last post glacial period. It predicts that substantial evolutionary shifts can be expected in a limited number of generations due to their high level of genetic diversity, and that gene flow will be an important driver of adaptive evolution. To enhance their adaptive potential, it is recommended that the genetic diversity of local populations could be increased by mixing local stock with seeds (or seedlings) from external sources during regeneration. Guidelines on the direction and distance of seed (or seedlings) transfers should be based on the results of up-to-date scientific evidence from studies in ecology and genetics, and on information on the patterns of geographic variation observed in existing provenance tests. Although historical patterns have not been reconstructed in as much detail for other forest species as for the oaks, some extrapolation to other species is warranted. Information from other species on the level of genetic variation, the extent of pollen flow, the existence of other interfertile species, and the pattern of distribution of the species (scattered or widespread) are important indicators of the potential adaptive responses of trees to climate change.

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Climate change impacts and adaptive strategies

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Abstract
Forecasted changes in Ireland's climate will have a significant influence on the productivity of managed forests and woodlands. Given the long-term nature of forestry, the selection of suitable provenances or genotypes and adaptable management practices under future climate change scenarios are essential for sustainable forestry in Ireland. In this paper we assess potential impacts of climate change on forest productivity in order to identify and provide adaptation measures. We argue that the impacts of climate change on forest productivity are not as well characterised as expected. Despite these shortcomings, we present an ecological site classification framework to describe species responses to climatic drivers in an effort to develop adaptive strategies to address these problems.

Keywords
Climate change, impacts, adaptation

Introduction

Global forests contribute substantially to atmospheric greenhouse gas emissions, but they also offer the potential to reduce emissions. Future climate change policies and actions need to consider the interaction between the impacts of climate change, adaptation for sustainable forestry and mitigation options, such a carbon sequestration through afforestation activities (Black et al. 2009a). For example, if no mitigation or adaptation actions are implemented, forests may be more vulnerable to a future climate change and this will be exacerbated by further global climate change. On the other hand, if mitigation policy directs the afforestation of areas planted with forest species not suitable to future climates, the advantage of these actions will not be realised unless suitable species are selected. Although national climate change mitigation issues are discussed in a separate paper in this issue (Byrne, 2010), these polices should not be considered in isolation.

Forecasted changes in Ireland's climate (McGrath et al. 2005) will have a significant influence on the productivity of managed forests and woodlands. Given the long-term nature of forestry, the selection of suitable provenances or genotypes and adaptable management practices under future climate change scenarios are essential for sustainable forestry in Ireland. In this paper we discuss the development of support tools to guide a strategic adaptive climate change policy to maintain a robust and sustainable forest resource in Ireland. However, national implementation of adaptive climate change strategies is dependent on a sound knowledge of the impacts of climate change at a local level. This aspect of climate change research represents a significant

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knowledge gap in an Irish context. Here we review numerous climate change impact approaches including ecological site classification (ESC), process based physiological models and medium to long term research data to assess changes in species suitability and yield, resulting from historic, current and future climate change scenarios. We also attempt to highlight some key unresolved research issues, which the climate change scientific community needs to address before the impact of climate change on forest health and productivity are understood and robust adaptive strategies can be implemented.

Observed impacts

In this section we consider both observed historic trends in response to changing climatic variables and review literature from experimental and modelling studies. We also briefly describe an ecological site classification system developed for Irish forestry, which characterises species suitability for specific site and climatic conditions.

Species distribution

a) Historic trends

In order to understand how species distribution is influenced by climate, it is important to consider ways in which trees have responded to climate change in the recent past. There is some evidence of some climatically driven shifts in species distribution until humans first began to have an influence on forests in Neolithic times, ca. 5500 years before present (BP). Tree species started to spread to north-western Europe in the early Holocene following the contraction of the polar ice pack after the last ice age, 11,000 to 13,000 BP (Moore et al. 1996). From about 8,000 BP much of the Irish landscape was dominated by oak (*Quercus* spp.) and elm (*Ulmus* spp.) with some yew (*Taxus baccata* L.) ash and hazel (*Corylus* spp.) in the underscrub (Mitchell and Ryan, 1997). Scots pine (*Pinus sylvestris* L.) occurred in drier sites and at higher elevations with alder in wetter areas. Pine became more prominent as the climate became wetter in about 7,000 BP and elm disappeared about 5,700 BP possibly due to disease. However, since the Bronze Age, Irish forests have suffered relentless deforestation to a level less than 1.4% of the total land area by 1905 (McEvoy 1954).

b) Current trends

There is little evidence of climatically driven alterations in tree species distribution over the past 100 years. Trees growing at the limits of their ecological tolerance would be more sensitive to climate change. Most commonly occurring trees in Ireland, with the exception of non-forest species (e.g. *Arbutus*), are not at the extreme of their range and, therefore, may not show any distribution shifts related to climatic change. This lack of any apparent climatically driven association with species distribution in Ireland may also be due to a limited geographical range and climatic gradient. The small area of remaining natural forest and large areas of plantation forestry means that species distribution is primarily a result of silvicultural management, where species selection (and hence distribution) is determined by site type (Horgan et al. 2004, Ray et al in press) rather than climate. For example, much of the peatland forestry is comprised of lodgepole pine (*Pinus contorta* Loud.) and Sitka spruce (*Picea sitchensis* (Bong.) Carr.). Small areas of other conifers, such as Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco.), are found on the well drained brown earths, or Scots pine on podsolic soils.

The only evidence of recent species distribution shifts are successional changes associated with land-use change or management. For example, encroachments of hazel scrub on the Burren landscape (characterized by limestone pavements and lithosols) due to a reduction in livestock grazing in these areas or birch (*Betula* spp.) and alder (*Alnus* spp.) on abandoned cutaway peatlands (Black et al. 2009b) have been observed.

Species suitability

Since the establishment of plantation forestry in Ireland in the early 1900s, the silvicultural interest, from a climate perspective, was species selection for the correct site type. Forest growth, function and productivity are influenced not only by climate, but by the interaction of climate, soil type and site specific factors (Horgan et al. 2004). These complex interactions between climate and edaphic factors make it difficult to understand and predict species suitability in response to current or future climate. However, predictive models can provide some insight into how species may respond to different climates. Site classification systems, which have been used in Scandinavia (Cajander 1926) and central Europe (Ellenberg 1988) to describe forest cover of regions, use biophysical variables describing site and climatic characteristics. An ecological site classification system (ESC) has been developed for Ireland (for review see Ray et al. 2009), based on a similar GIS system for the UK (Clare and Ray 2001, Ray et al. 2003). This system has since been used to assess the impacts of projected climate change scenarios on species suitability. Multi-factor forest site classification systems, by definition, separate the effects of climate and edaphic factors on tree species or forest type suitability (Figure 1). The ESC approach describes the response of all major forest species in Ireland and the UK to four climatic factors: warmth (AT), drought (i.e. moisture deficit (MD)), wind exposure (measured using the detailed aspect method of scoring, DAMS, see Ray et al. 2009), and continentality, based on Delphi models (see Pyatt et al 2001 for definitions). The suitability class (Very Suitable, Suitable, or Unsuitable) of different tree species was linked to each of the climatic factors, and to two soil quality factors representing soil wetness (soil moisture regime – SMR) and soil fertility (soil nutrient regime – SNR). GIS data describing these variables and Delphi characterisation of current and potential forestry tree species have been compiled, so we are now able to produce suitability maps for 26 tree species (for example see Sitka spruce suitability map, Figure 5). These maps have, however, not been finalised because a recent statistical validation exercise suggest that some edaphic factors such as SMR need to be modified.

The delivery of a web-based application for species suitability under current and most likely future climate scenarios is the major objective of this study (CLIMADAPT, Ray et al. 2009) and is the primary climate adaptation issue facing sustainable Irish forestry in the future.

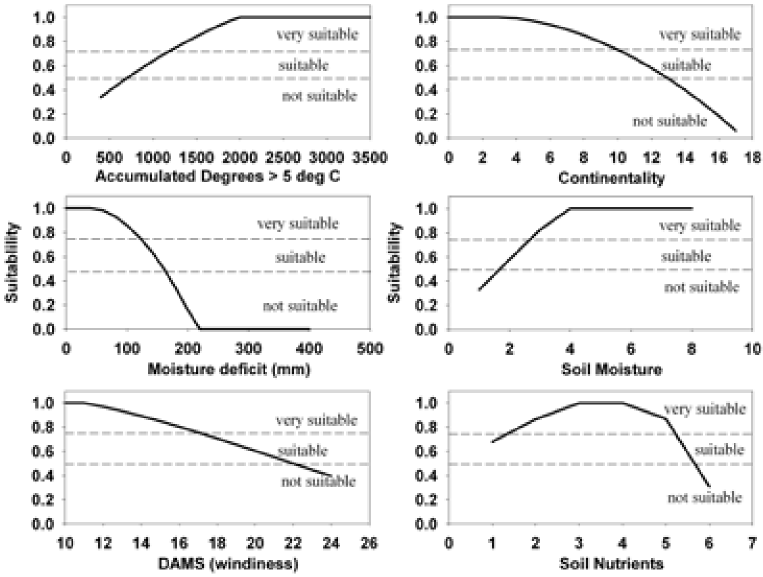

Figure 1: *The suitability of Sitka spruce according to a) AT – (day degrees above 5ºC) and b) MD (mm), DAMS or windiness, continentality, SMR-soil moisture regime and SNR- soil nutrient regime. Suitability is classified on a scale from 0 to 1, where limiting factor (f) values ≥ 0.75 are very suitable (GYC > 20), ≥ 0.5 are suitable (GYC 10 to 20) and < 0.5 are unsuitable (GYC < 10).*

Phenology and dormancy

The International Phenological Gardens (IPG) network was established in 1957 with the aim of collecting phenological data from 50 sites across Europe (Chmielewski and Rötzer 2001). Clones of tree and shrub varieties were planted at each site to account for localised genotypic variations in response to environmental conditions. Analysis of Irish data collected between 1970 and 2000 (Donnelly et al. 2004), suggest that over 50% of the broadleaved species investigated showed significant changes in the timing of leaf unfolding (early growth season (EGS) initiation) and leaf fall (i.e. end of growth season). For many species the length of the growing season (LGS) increased due to both an earlier start to the growing season and a delay in the date on which leaf fall occurred. The greatest increase in LGS was observed in the south-west of the country. In Ireland, along with an increase in mean spring and mean annual temperature, the timing of phenological events has advanced in the case of EGS and delayed in the case of leaf fall over the last 30 years. However, the spring phenological response could not be explained simply by average spring temperature alone, indicating an influence of other environmental factors on phenology (Donnelly et al. 2004).

There is currently no information on changes in phenological development for the major conifer species in Ireland. Difficulties in interpreting any climatically induced changes in conifer species phenology is exacerbated by the introduction of more productive provenances of Sitka spruce such as from Oregon and Washington, in recent years, which show a later onset of dormancy (Thompson 1998, Black unpublished data).

Forest productivity

Previous dendrochronology studies for Irish oak, extending back 7000 years (Baillie and Brown 1995) show notable downturns in growth relating to catastrophic environmental events (Baillie 1999). The effect of recent increases in temperature on growth is not clearly evident in the oak chronology study. This is consistent with preliminary results from a more recent dendroclimatology study, conducted on Sitka spruce in Avoca, which shows no significant temperature related increase in growth over a 70-year chronology (Tene et al. 2009). However, the results of that study showed that where large reductions in radial growth were recorded, these were associated with large MDs above 180 mm (the limiting MD level for Sitka spruce as defined using ESC models; see Figure 1). The study by Tene et al (2009) also shows that radial grown responses to MD were consistent with natural carbon and oxygen isotopic signals of cellulose, extracted from cores. These observations are consistent with the current hypothesis that the increased frequency of stomatal closure in response to moisture stress may be limiting carbon assimilation, resulting in a decrease in tree growth (Barbour et al. 2002).

Since the initial afforestation initiatives were introduced in the 1940s, the average productivity of Sitka spruce has increased by up to 5% (see Horgan et al. 2004). This may be associated with a change in silvicultural practice, the introduction of genetically superior seed sources and the increased availability of better quality site types. For example, over the past decade there has been a shift away from afforestation of blanket peats with conifers, in the west of Ireland in the 1950-60s, to more productive sites characterised by fertile soils such as brown earth and gley soils (Black et al. 2009). These factors, together with the relatively short history of forest research in Ireland, make it difficult to discern any past impact of changing climate on forest growth or health. This is confounded by the lack of sustained or long term climate change mitigation, impact or adaptation research activities before the ICP monitoring network was established in Ireland and the Irish Council for Forest Research and Development (COFORD) climate change programme was initiated in 2002.

Based on the evidence presented above, or lack thereof, the only way to quantify and characterise any impacts of climate change on forest productivity is by process based modelling (Goodale et al. 1998, Black et al. 2006), analysis of large scale international experimental or monitoring data. The international literature shows that forest productivity has been increasing across Europe for some time. Although some of the increased productivity is thought to have resulted from improved silviculture and genetic improvement (Worrell and Malcolm 1990), the main cause is now considered to be nitrogen fertilisation from atmospheric pollution (Goodale et al. 1998, Magnani et al. 2007) in combination with a warming climate. Long term ICP forest monitoring trends, for Ireland, suggest there is an increase in N-deposition in the eastern half of the country (Neville pers. comm.). The extent to which N deposition may influence the productivity of forests does, however, depend on the stage of N saturation and nutrient status of forest soils (see Aber et al. 1998)

Pests and diseases
In most cases, historical trends in the epidemiology of insects and diseases in Irish forests are a direct result of forest management or afforestation history. For example, the increased outbreak of the large pine weevil in reforested stands during the re-establishment phase is associated with an increase in the area of forest clearfelled in recent decades and changed control practices, due to restrictions of pesticide use.

a) Green spruce aphid (*Elatobium abietinum*): Information from Level I ICP monitoring plots, suggest periodic peaks in needle damage may be related to aphid outbreaks (Figure 2). Aphid outbreaks occur on a 3-6 year cycle resulting in a delayed reduction in volume productivity of ca. 10% (Day 2002). Other studies, suggest a larger yield reduction of 24% in the year following an aphid outbreak (Straw et al. 2002). The population size and structure of the green spruce aphid is related to the pattern of change and the phenology of bud burst, which signifies a change in needle sap quality. Therefore, yearly differences in the winter temperature regime may affect the duration of the population growth phase and peak numbers attained in late spring (Day 2002). A combination of the population density in the summer and the number of severe cold periods below -7°C in the winter months, determine the size of the population the following year. An aphid outbreak results in significant losses of two and three year old needles during the following growing season and thus a reduction in productivity the year after peak infestation. Based on long term ecosystem flux studies in a Sitka spruce stand in the midlands, it is suggested that stand productivity is possibly associated with a 'knock-on effect' of aphid outbreaks (Straw et al. 2002, Black et al. 2007). High population densities of spruce aphid in 2002 were associated with browning and a subsequent loss of foliage, resulting in an 80 to 90% increase in litterfall in 2003 and 2004 compared to previous years (Tobin et al. 2006). Whilst a reduction in net ecosystem productivity in 2004 (18 to 23%) may have been exacerbated by the 2003 drought and self thinning, following canopy closure; these results highlight the importance of the indirect influences of climate change, such as insect outbreaks, on potential forest productivity in the future.

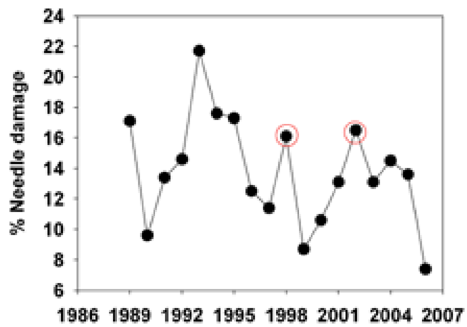

Figure 2: *The annual trends in % needle damage in Level 1 ICP plots. The red circles highlight where the occurrence of needle damage was associated with aphid outbreaks in 1998 and 2002 (Neville et al. unpublished data).*

b) Large pine weevil (*Hylobius abietis*): As mentioned, this is a particular problem in reforested stands, replanted 1 to 2 years after clearfell in warmer regions in the south and south east of the country. An increase in summer temperatures could result in greater weevil activity, particularly in combination with drought events and recent legislative policy banning the use of the insecticide Lindane (Purser et al. 2004).

c) Great spruce bark beetle (*Dendroctonus micans*): Not present in Ireland, but large areas of spruce monoculture may become vulnerable to bark beetle outbreaks, particularly in the south and south east of the country (Purser et al. 2004), where drought-induced stress may become significant (Ray et al. 2007).

d) *Phytophthora* disease of alder and larch: This species has only recently been identified in Ireland; it is possible that its expansion may be an indication of an increased planting of alder species or environmental changes (Purser et al. 2004).

e) Fomes (*Heterobasidion annosum*): Root and butt rot fungus is the most economically damaging disease affecting Irish forestry. It is suggested that fructifications are resistant to drought and moderate frost implicating a greater threat in a warmer and drier climates (Purser et al. 2004)

f) Red band needle blight (*Dothistroma septosporum*) is currently expanding its range across Europe. The disease affects many species of pine and can be transferred to other species including European larch (*Larix decidua* Mill.), Douglas fir and Sitka spruce. The fungus requires high humidity and warm spring temperatures (12-18ºC) (Brown et al. 2003). However, the predicted warmer and drier spring weather in Ireland may not provide ideal conditions for the spread of this pathogen in the future.

Extreme events

Extreme climatic events, such as drought and storms, pose the greatest climatic threat to forest productivity. Disturbances and recent extreme events in Ireland include: drought (1976 and 1995) and windstorms (1982, 1987, 1990 and 1999). Fire outbreaks are rare in Ireland, but an average of 400 ha affected by wild fires annually (NIR 2007). The largest areas burned by natural fire occurred in 2003, where numerous fire outbreaks affected some 1030 ha of plantation forests.

The location of many Irish forest plantations on exposed, windy sites with poor drainage renders them vulnerable to wind damage. In 1997, 1998 and 1998 Coillte reported 0.5, 0.85 and 1.6 M m^3 respectively of roundwood being windthrown (Purser et al. 2004). Ní Dhubháin (1998) suggests that forests on relatively exposed, ploughed sites are reaching critical heights in relation to windthrow risk and this level of damage may increase. Pre-mature felling (age of maximum mean annual increment less 20%, i.e. commercial rotation or at top heights of 18, 21 or 24 m) in high windthrow risk sites is a common practice resulting in lower site productivity and this may have a profound influence on timber sustainability or a decline in the sequestration potential of the national forest plantations, if national harvest levels are not adjusted accordingly.

Climate change projections

Regional climatic model scenarios (IPCC - A2 and B1) for Ireland have been derived using a dynamic downscaling method, published by the Community Climate Change Consortium for Ireland (C4i), and validated using back-casting techniques (McGrath et al. 2005). The simulated daily mean temperatures, daily rainfall, and daily evaporation have been compiled into mean monthly and annual values for 30-year periods. Tree physiological response to temperature may be better defined using accumulated temperature (AT), which is an index of climatic warmth, with a threshold set at 5ºC, above which both plant respiration and growth occur. AT and climatic MD (i.e. rainfall minus evapotranspiration) were calculated for the growing season (March to October, see Ray et al. 2002).

Based on the medium-high IPCC scenario (A2), the Irish climate is predicted to warm by 1.3ºC by mid century, increasing to 3.4ºC by 2100. In Ireland the mean increase in AT above 5ºC is predicted to be about 200-300 day degrees by 2100 (a 15% increase, Figure 3).

The future predictions of MD, show large increases of 40-60 mm in the south and east of the country, when compared to the climatic 30-year mean for the baseline period (Figure 4). This is partly due to predicted warmer summers and a shift in the seasonality of rainfall, with less in summer months (up to 15% decrease) and more in winter months (20% increase).

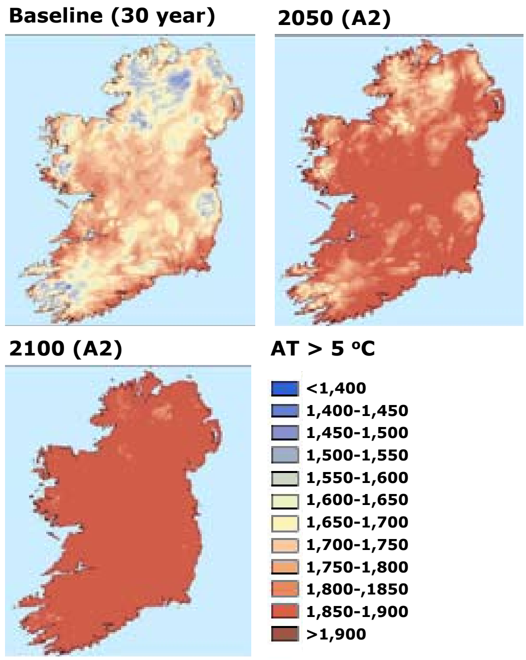

Figure 3: *Changes in warmth index for forest growth, based on accumulated day degrees above 5°C, over the next century. The current baseline data in the top left panel is the 30-year mean for 1960-1990. The projected data are means from simulations for the 30-year periods 2020-2050 (top right) and 2070-2100 (bottom) using the A2 medium-high green house gas emissions scenario.*

A frost risk assessment map has also been developed based on five topographic variables including elevation, slope, aspect, curvature and distance from the sea. Each variable was classified in three risk categories; low, medium and high based on expert knowledge and literature. Whilst it could be speculated that less hardy species could be planted in existing high frost risk areas as the climate warms, the occurrence of frost is determined by microclimatic factors. The production of frost risk maps in ESC could assist with species selection (Ray et al. 2009), particularly if a warmer future climate might tempt foresters to plant less hardy species.

Projections suggest that the climate will become more variable. Therefore, it is likely that there will be an increase in the incidence of extreme events such as dry and hot summers and intense rainfall events leading to flooding episodes in both summer and winter. One example links the projected frequency of dry summers to areas of Ireland providing a mechanism to assess the risk of drought damage to sensitive species caused by frequent dry summers. These data suggest that the frequency of water deficits above 180 mm will increase from 2 years per decade to 7 years per decade by 2080 in eastern parts of the country (Ray et al. 2008). A major scientific challenge facing the climate change modelling community is the characterisation of extreme events. Traditionally, climate change is expressed on the basis of a change in the mean over long periods. However, these projections assume no change in the statistical distribution of variables at both the spatial and temporal scale. Recent studies by Schär et al. (2004), show that in addition to a change in mean temperature, there is larger shift in the statistical distribution of higher temperatures than was previously thought. Whilst this is consistent with suggestions that the frequency of extreme events will increase, it also highlights the importance of assessing the probability distribution functions (pdf) of climate change variables. Advances in this area are primarily limited due to spatial resolution of GIS datasets. However, even if these pdfs could be generated on a fine spatial scale, there is at present no clear understanding of the relationship between the frequency and magnitude of extreme events and forest productivity. For example, we do not know how an increased frequency of drought would influence species distribution.

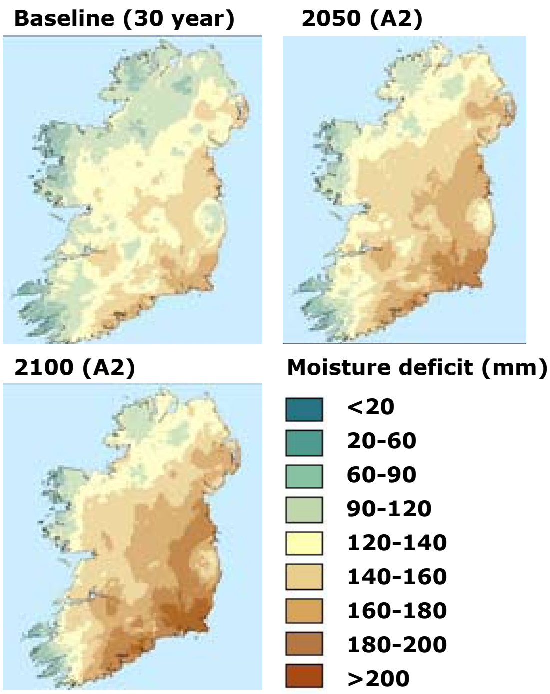

Figure 4: *Changes in average MD (mm) over the next century. The current baseline data in the top left panel is the 30-year mean for 1960-1990. The projected data are means from simulations for the 30-year periods 2020-2050 (top right) and 2070-2100 (bottom) using the A2 medium-high green house gas emissions scenario for the current baseline period.*

Potential impacts

Expected impacts are primarily determined using process based and ESC models, which describe forest processes as a function of mean changes in climatic drivers. In some cases, the models are not detailed enough to characterise the potential impacts of climate change due to a lack of scientific knowledge. In these cases, we provide a broad synopsis of the literature to infer expected impacts in Ireland.

Vegetation phenology

Based on the Irish IPG network data (see previous section), an increase of 1°C in annual average temperature may result in a 5 to 14 day extension to the length of the growing season (Donnelly et al. 2004). Assuming a linear trend in changes of phenology and temperature, these changes would translate to a 7 to 18 day increase in the length of the growing season (i.e. extended time between bud burst and leaf fall) by 2050, increasing to 17 to 48 days by 2100. However, this could potentially make some species more susceptible to early or late frost, but the occurrence of frost may be less frequent.

It is also expected that warmer temperatures during the late autumn-early winter periods could result in later bud dormancy initiation of certain species, such as ash, Sitka spruce, Norway spruce (*Picea abies* Karst.), and beech (*Fagus sylvatica* L.). These species require a certain number of chilling hours before initiation of bud set.

Species suitability

Together with the use of GIS, soil maps and future climate projections, an ESC system for Ireland has produced some predictions of future species suitability and distribution. However, the influence of potential drivers, such as CO_2 fertilisation, elevated ozone and nitrogen deposition, are not considered due to a lack of knowledge on how these variables interact with main ESC factors.

Preliminary CLIMADAPT-ESC analyses suggest that the predicted warmer and drier climate may offer the possibility of extending the range of species that are currently less common in Ireland. The warmer climate will be more suitable for southern beech (*Nothofagus nervosa* (Phil.) Krasser), Monterey pine (*Pinus radiata* D. Don), Maritime pine (*Pinus pinaster* Loud.), walnut (*Juglans regia* L. and *Juglans nigra* L.) (Anon 2000a), and more southerly provenances of conifers from the Pacific North West (D. Thompson pers. comm.). However, the increased mean MD (> 180 mm) will severely affect the suitability of a number of species or drier well drained soils. In particular, Sitka spruce, Norway spruce, Japanese larch (*Larix kaempferi* (Fortune ex Gord.)) and European beech are likely to become less suitable in a drier climate (Broadmeadow and Ray, 2005; Figure 5), and in addition downy birch (*Betula pubescens* Ehrh.), common alder (*Alnus glutinosa* L.), pendunculate oak (*Quercus robur* L.), and common ash (*Fraxinus excelsior* L.) will become less suitable on shallow freely draining soils (Pyatt et al. 2001) in the drier areas of the south and east of Ireland.

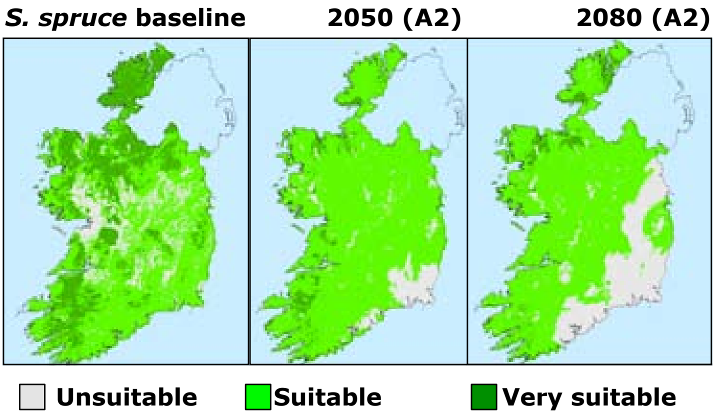

Figure 5: *Ecological site classification GIS maps showing the suitability of Sitka spruce to the current (left panel) and projected climates for 2050 (middle panel) and 2010 (right panel) assuming the IPCC A2 medium-high green house gas emission scenario. Suitability is classified on a scale from 0 to 1, where limiting factor (f) values ≥ 0.75 are very suitable (GYC > 20), ≥ 0.5 are suitable (GYC 10 to 20) and < 0.5 are unsuitable (GYC < 10).*

Strategies to introduce or replace new species, such as Monterey pine, should however, first consider suitable provenances, risks of introducing new pests or diseases, site suitability and best silvicultural practice.

It should be highlighted that there is no complete soil map for Ireland. Therefore, a GIS indicative soil map, based on satellite and vegetation models (Fealy et al. 2006), was used to characterise ESC-site variables such as SNR and SMR. The final web-based ESC system for Ireland, does, however, include a function where the soil type is determined by the end-user following a site inspection and soil classification exercise (Ray et al. 2009). It is evident that the predicted over estimation of suitability classes for Sitka spruce, particularly in areas of Donegal (see Figure 5), may be associated with either misclassification of the soil type, based on the GIS model, or poor definition of ESC soil variables, such as rooting depth and SNR, in these regions. Similarly, indication of unsuitable areas for Sitka spruce in east Galway and Westmeath (Figure 5, base-line map), may be associated with poor characterisation of soil variables or the inability of the current ESC model to deal with interactions (Xenakis et al. in review). Recent analysis using Bayesian inference and Monte Carlo Markov Chains (Xenakis et al. 2008) has provided a multi-factorial calibration framework for the ESC model, which potentially could improve yield class estimates (Xenakis et al. in review).

Productivity and timber quality

A modelling sensitivity study on Sitka spruce in Ireland, conducted by Goodale et al. (1998), indicated that site-specific conditions and management practices influence productivity to a greater extent, compared to those likely to be induced by climate change or elevated CO_2. These authors suggest the effect of climate change and CO_2 fertilization is strongly dependent on N availability. A potential 10% increase in net primary productivity (NPP) was estimated under high N inputs. This is, however, somewhat lower than recent estimates from combined free-air CO_2 enrichment (FACE) experiments (Ainsworth and Long 2005).

Where other factors important for growth are not limiting, the warmer climatic conditions will tend to increase forest productivity. However, the extent of the temperature related increase in yield is less certain. Estimates suggest that a general yield class (YC) increase of 2 to 4 m^3 $ha^{-1}yr^{-1}$ may result from an increase in mean temperature of 1ºC (Cannell 2002). Recent modelling exercise, based on ecosystem flux measurements on Sitka spruce, suggests that increases in gross primary productivity are not significant following a 1.3 ºC increase in temperature (Black et al. 2006). This is consistent with a lack of any apparent relationship between temperature and radial growth in a 70 year Sitka spruce dendroclimatology study (Tene et al. 2009).

In addition to influencing species distribution, it is plausible that an increase in the frequency and magnitude of MD events could reduce productivity in some species, such as Sitka spruce. Evidence from long-term eddy covariance studies suggest that a delayed reduction in productivity of Sitka spruce in response to water deficits is driven predominantly by increased needle turn-over rather than physiological factors in the shorter term. We hypothesise that this 'knock-on or lag' response to water deficits and interactions with insect infestations may be more important than short-term physiological factors under present and future climates (Black et al. 2007). This hypothesis is currently being tested using dendroclimatology and natural isotope abundance studies across a climatic and drought gradient (Tene et al. 2009).

The fast growth rate of Sitka spruce, under current climatic conditions, results in poor timber quality, when compared to that of species growing at slower rates. However, there are opportunities to select material (including alternative provenances) to improve timber quality for a warmer climate in a breeding programme, such that micro-fibril angle and density remain optimal. In contrast, the pines, larches and Douglas fir will grow faster without a reduction in wood density (Ray et al. 2008). The timber quality of hardwood species varies in response to increased growth in a warmer climate. Ring porous species such as oak, ash, and elm produce harder and stronger timber when grown at a faster rate. Diffuse porous species such as sycamore and birch do not respond in this way. Chestnut and beech are intermediate in response (Ray et al. 2008).

CO_2 fertilisation?

Despite a large body of experimental evidence suggesting that elevated CO_2 levels (from 280 ppm pre-industrialisation to 385 ppm at present) enhance photosynthesis at the leaf level, there is less evidence that it has a positive effect on global forest productivity. Historical trends suggest that the effects of CO_2 fertilisation (i.e. increase photosynthetic response to elevated CO_2) may be reduced due to acclimation processes, such as a relative decrease in tree leaf stomatal density since the pre-industrial era (Woodward 1987). This notion is supported by the results from a meta-analysis of mean monthly concentrations of CO_2 at the atmospheric recording station Mauna Loa in Hawaii (see Figure 6, Keeling et al. 1995). Records show considerable variation in monthly atmospheric CO_2 levels associated with a draw down of CO_2 during the period of most rapid growth and activity over the summer months in northern temperate and boreal forests. However, there is no suggestion[1] of an increased photosynthetic draw down of CO_2 from the atmosphere due to elevated CO_2 levels. The amplitude of the fluctuations in mean monthly CO_2 levels has not increased over the last 5 decades (Figure 6, Moore et al. 1996). This provides evidence from a global observation perspective, which is apparently sensitive to fluctuations in forest productivity, that the effects of elevated CO_2 on forest productivity are not as great as previously hypothesised. Therefore, projections of CO_2 fertilisation effects should be treated with caution because of current limitations in our understanding of the factors controlling CO_2 uptake with respect to acclimation processes, climatic constraints and feedbacks from interactive processes (for review see Ainsworth and Long 2005, Hyvonen et al. 2007). These reviews provide evidence suggesting that the projected increase in forest productivity as a function of elevated CO_2 may not be as large as expected due to:

a) *Physiological acclimation* such as the decrease in Rubisco activity and regeneration, stomatal density changes (Woodward 1987) and evidence of decreased N and chlorophyll content in long term FACE experiments (Ainsworth and Long 2005)
b) *Scaling errors*. In many cases, the expected magnitude of photosynthetic enhancement does not translate into a similar increase in growth due to increased maintenance respiration as temperature increases, for example.
c) *Co-limitation*. A lower CO_2 fertilisation effect may occur during non-drought years or under N limiting conditions (Norby et al. 2005, Ainsworth and Long 2004, Hyvonen et al. 2007), so the extent of any enhanced productivity would depend on the availability of other growth-limiting resources. Indeed, resources may become more limiting due to acclimation responses to elevated CO_2 (e.g. enhanced N limitation). In other cases, increases in stand productivity have been associated with an increase in leaf area index (LAI) under elevated CO_2. However, this effect is reduced after canopy closure (Norby et al. 2005, Ainsworth and Long 2005). Plantation forestry in Ireland is characterised by high LAI and co-limitation by light and CO_2 is the major limiting factor under N rich conditions (Wang and Jarvis 1993, Black et al. 2006). Therefore, the effect of elevated CO_2 in these forest types may be lower than expected.
d) *Poor experimental design*. Experiments using step-change increases in carbon dioxide concentration may cause unrealistic ecological responses. Attempts to understand ecological effects of increasing atmospheric CO_2 concentration usually involve exposing ecosystems to elevated CO_2 concentrations imposed with a one-time step-change increase of 200 ppm or more. An assumption underlying this approach is that exposing ecosystems to a single-step increase in CO_2 concentration will cause similar ecological responses, when compared to those of a gradual increase over several decades.

[1] The seasonal amplitude of CO_2 in the atmosphere in relation to the carbon cycle of northern temperate and boreal forests could be masked by seasonal changes in sea temperatures, which would act in opposition to the vegetation cycle and hence dampen these oscillations (see Moore et al. 1996).

Klironomos et al. (2005) tested this assumption on a mycorrhizal fungal community over a period of 6 years. The authors suggested that "studies may overestimate some community responses to increasing CO_2 because biota may be sensitive to ecosystem changes that occur as a result of abrupt increases".

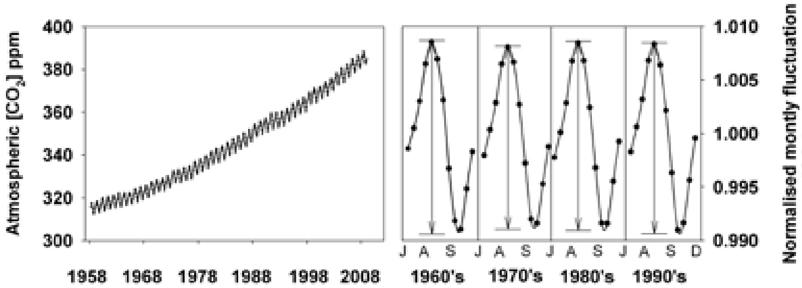

Figure 6: *Mean monthly atmospheric CO_2 levels measured at the Mauna Loa observatory since 1958 (modified form Keeling et al. 1995). The right hand side panel shows the mean decadal amplitude of the CO_2 draw-down (i.e. decrease in normalised monthly CO_2, as indicated by arrows) associated with photosynthesis in temperate and boreal forests during the northern hemisphere summers (generally from May to September).*
Source of data: http://www.cdiac.esd.ornl.gov/ftp/trends/co2/maunaloa.co2

Interactions

The magnitude of the change in forest NPP in response to changing global environmental factors depends on forest type, geographical region, degree of co-limitation of growth resources, extent of saturation of limiting resources and experimental assumptions used in deriving the data. Therefore, there is a large degree of uncertainty when assessing the impacts of individual climate change drivers on forest productivity. Meta-analysis of published data, shown in Figure 7, shows the degree of uncertainty increases and the level of understanding decreases when interactive effects of climate change are considered, when compared to simple cause and effect studies. For example, much existing evidence from long-term and large-scale (FACE) experiments does not include interactive effects of other pollutants or climatic variables. A FACE experiment with elevated CO_2 and O_3, suggest that the CO_2 fertilisation effect in *Populus tremula* L. is negated by the presence of O_3 at predicted future levels (King et al. 2005). This result reinforces the need to consider multiple factors in global-change ecosystem experiments because it can be misleading to simply "add" results from single-factor experiments.

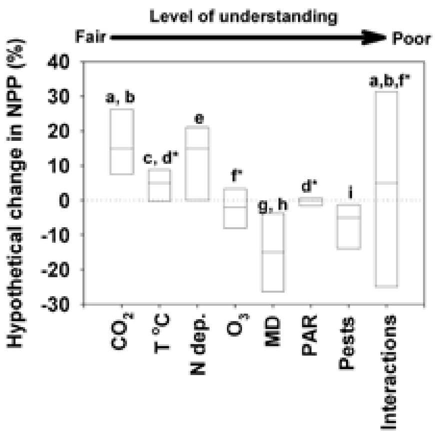

Figure 7: *Hypothetical changes in NPP of forest ecosystems in response to elevated atmospheric CO_2, temperature (T ºC), nitrogen deposition (N dep.), elevated atmospheric O_3, MDs (MD), global dimming, or reduced photosynthetically active radiation (PAR), pests and interactions of different environmental changes. The arrow indicates a reduction in the level of understanding and certainty of the magnitude of the hypothetical changes in NPP. The box plots represent a mean, minimum and maximum change based on a meta-analysis of published literature. [a]Ainsworth and Long 2005, [b]Hyvonen et al. 2007, [c]Cannell 2002, [d]Black et al. 2006, [e]Aber et al. 1998, [f]King et al. 2005, [g]Chapin et al. 2002, [h]Reichstein et al. 2007, [i]Day 2002 and Black et al. 2007. The references noted with an asterisk refer to changes in gross primary productivity. These values were converted to NPP using a GPP to NPP ratio of 0.6.*

Adaptive strategies

Newly developed computer-based spatial site classification systems can be used to as a guide for in the development of robust species choice decision tools and improved silvicultural systems to minimise the negative effects of climate change to forests, forest ecosystems, as well as other services that forests provide to society.

Some major guidelines include:

- Selection of new provenances or species for warmer climates (see section on ESC). However, species replacement options should also consider indirect consequences, such as the introduction of new diseases (e.g. red band needle blight associated with many pine species). Timber quality should also be considered in this context.
- Planting policies need to take water availability into account. It has been shown that the establishment of Sitka spruce (Tene et al. 2009, Black et al. 2007, Ray et al. 2008), under current climatic conditions, is susceptible to water deficits.
- Silvicultural practices may need to be altered to adapt to future climate change threats. For example, planting density may need to be reduced to minimise root competition for water under MD conditions.
- Rotation length may need to be reduced to take higher growth rates into account.

- Windthrow risk models have been developed for Irish forestry (Ní Dhubháin 1998), based on probability of windthrow risk using a number of stand and site variables. However these models need to be linked to future climate change scenarios to account for the higher frequency of cyclones and increased wind speed on stand stability in the future.
- Adaptive management strategies, such as reducing deadwood (i.e. fuel) load in older stands or preventative management should be considered because it is likely that fire risk would increase as the climate gets warmer. However, a shift away from the historic trend of afforesting upland peats to planting of low level marginal farm land, with vegetation which is less prone to wild fires, may reduce the occurrence of fires.
- An assessment of the effects of climate change of carbon cycling and sequestration potential of our national forest estate is also required.

Conclusions

Overall, understanding the potential impact of future climate change is key to developing adaptation and mitigation strategies. Despite much research over the past two decades, there is a still a poor understanding of the potential impacts of climate change on forest growth and productivity. Whilst the ESC system for Ireland does provide recommendations on climate change adaptation, more work is required to include multi-factorial analysis and a move away from Delphi-based models to empirical and processed-based approaches using ESC factors as the spatial framework for this work. The inclusion of more process-based drivers, such as elevated CO_2 or N deposition levels in these models, is also required, but only if interactive relationships are well defined and modelling over-simplifications are avoided.

Extreme climatic events such as storms and serve drought offer the greatest threat to forest sustainability in the future. There is a need for the climate change research community to move away from assessing long-term means for the characterisation of the statistical probabilities of extreme climatic events, and their influences on forest ecosystem function. Furthermore, risk assessments and management plans are required to provide guidelines on how these events should be managed effectively to reduce the potential negative impacts on forest productivity.

Finally, an integrated mitigation, impact and adaptation management policy is required to take advantage of opportunities arising from, and reduce risks associated with, global climate change.

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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.

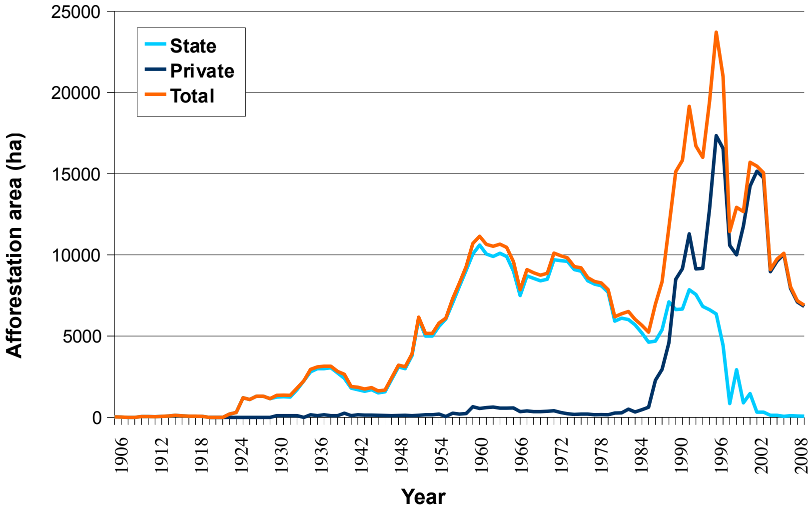

Figure 1: *Annual area of total, state and private sector afforestation in the Republic of Ireland during 1920-2008.*

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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A review of forest recreation and human health in plantation forests

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Abstract
The importance of forests, including plantations, for outdoor recreation and human health is being increasingly emphasized in numerous policy and research documents all over Europe. This paper gives a brief overview of, for example, how urban forests (and afforestation in general) can contribute to the health and well-being of the general population. In addition, the paper explores the role of forests in outdoor education and learning, and presents some ideas for the resolution of access problems. Some of the future challenges for forest planning and management are outlined. It is foreseen that more collaboration with other policy sectors is needed, and it is stressed that the many opportunities for physical exercise in (urban) forested landscapes should not be forgotten in today's political context.

Introduction

Forests and other natural areas are important for outdoor recreation. This is increasingly being emphasized in most European policy and administrative bodies (e.g. Hörnsten 2000, Jensen and Koch 2004, Bell et al. 2009). Also, society is prepared to bear relatively high costs to cater the public need for outdoor activity. In Denmark, for example, expenditures for outdoor recreation and nature interpretation constituted 10-15% of the total expenditure of the Danish Nature Agency in the late 1990's and now, 10 years later has increased to become the main activity of the Agency. Likewise, the Danish afforestation policy aims to double the forest area over the next 100 years. In accomplishing this, consideration of public outdoor activity has been very important in planning and establishing new forests (Jensen and Koch 2004).

We are now confronted with accelerating challenges, which impact upon the present and future use of the forest for recreation. These changes include:

- Changing demography: Recreational demands change with a changing, elderly and ethically more diverse society;
- Alienated urban society: Recreational demands in urban forests and plantations increase. The same for forest schools;
- New recreational technology: Recreation planners and land owners have to deal with and service a range of new activities, which in some cases are not compatible with other recreational activities;
- Health and welfare: A fast increase in health-related activities in forests and plantations, demands cooperation between sectors.

The aim of this paper is to provide a brief overview of the current use and yields of plantation forests for forest recreation and human health. Moreover, the potential

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near-future trends in the demand for activities and expectations related to public use of plantation forests are evaluated. The overall trends are supplemented by a selection of cases and examples, and the paper geographically focuses on European forests at large.

Outdoor recreation

Outdoor recreation, and specifically forest recreation has been an important leisure activity for over a century, but with significant changes in terms of transportation, societal movements, choice of recreational areas and which groups participate. The overall trend changes from organised outings by non-motorised or public transport over expeditions to individualised activities based on specialised equipment and private transport (Figure 1). Today, forest recreation holds the position as an important leisure activity. Surveys in Sweden and Denmark show that forest recreation comes very high on the list, with a visitor rate of approximately 90% (Jensen and Koch 2004, Fredman et al. 2008) (Figure 2). At the European scale, it is difficult to compare visitor numbers between countries, due to heterogeneous methodology (Sievänen et al. 2008, 2009), but in most European countries more than 2/3 of the population visit the forest yearly.

Year	*Development in transportation*	*Movement in society*	*Recreation area*	*Groups of participants*
1800				
↓	Railway system	Conservation organisations	Beach / archipelago	
	Bicycles	Tourism organisations	Mountains	Expeditions
		Skiing clubs	Forests	Organized interest groups
	Public buslines			
	Private cars	Rambling associations		Families
		Jogging movement		Special interests
2000		Equipment industry		

Figure 1: *Outdoor recreation has changed markedly course of the last two centuries, from organised outings by non-motorised or public transport to individualised activities based on specialised equipment and private transport. Based on Kardell 1979 and Jensen 1999.*

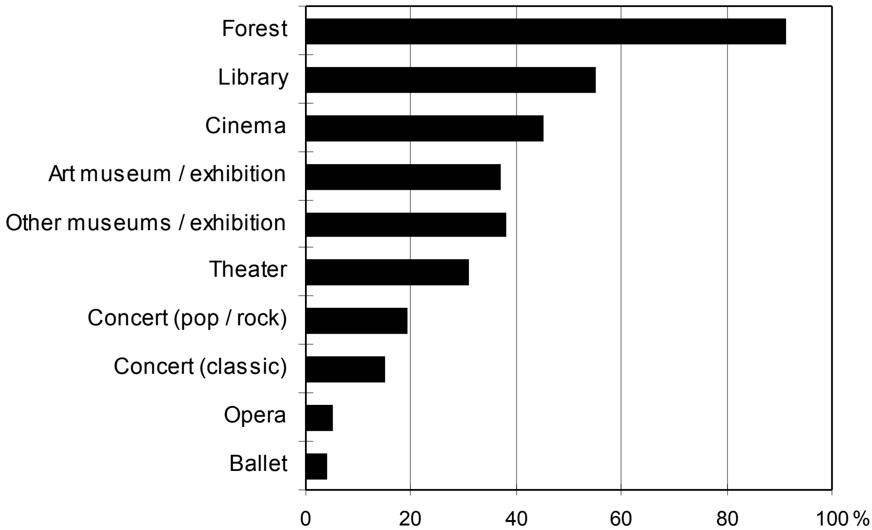

Figure 2: *Data from Danish surveys show that Danes, when asked about which leisure activities they undertake, rank forests highest on the list. Over 90% of all Danes visit the forest at one or more occasions annually (Jensen & Koch 1997).*

In Denmark, as an example, people seem to want to maintain or even increase their visitation to the forest, but research results have also revealed a change in behaviour in this respect. The main change is that to be able to manage that visitation rate in a more and more busy everyday life, the average duration of the visits has decreased (Jensen and Koch 2004). Another trend is in relation to the more traditional activities – in Sweden, as an example, wild berry picking in Swedish forests has changed significantly over the period 1977-1997. Here, a 70% decrease in the total amount of berries picked was observed (Hörnsten 2000), and the same tendency is found in Norway (Odden 2008). One probable reason for the decrease in berry picking is a decline in "traditional" Nordic forest recreation activities (such as walking in the forest, berry and mushroom picking, and cross-country skiing), where "earlier generations who were taught to appreciate these activities will be replaced by generations with a different or at least a more diversified basic attitude" (Jensen 1995). Overall, it seems that the forest has been able to hold its position as a very attractive location for leisure activities – although a number of new leisure time attractions have become available over the last decades (e.g. more television channels, computer games etc.).

Human health

The literature indicates a number of positive relationships between people's forest use and their health, e.g. reducing stress, insomnia, hypertension and consumption of medicines, as well as improved spirit, concentration and motor function, or just a general increase of well-being. A number of public forest agencies around Europe are currently focussing on the possible use of forests as "green fitness centres", especially in relation to obesity campaigns.

Obesity is a growing problem. For example, obesity levels have doubled in the last 10 years for six-year olds and trebled for 15-year olds in the UK and obesity costs the national economy £7 billion each year (Philips 2008). Combined with the fact that children are twice as likely to play outdoors where there is rich vegetation rather than on barren land (Philips 2008) it is evident that forests are important as combined playgrounds and health facilities for children. The trend towards using the forest as a "Green Fitness Centre" is seen in most European countries, e.g. the "Health Walk Project" from Natural England, "Hälsospåret" in Sweden, the "GetMoving Campaign" in Denmark and the fact that doctors now prescribe outdoor/nature exercise programmes for patients.

Another example is the exploitation of the benefits of therapeutic interactions forests present, where the long tradition of horticultural (garden) therapy (e.g. Stigsdotter and Grahn 2003) now extends into silvicultural therapy, with regular visits to nearby green spaces. Recent projects addressing this theme include "GreenSteps" in Norway and Sweden. There is a high need for further research in this subject, to answer e.g. what the health outcomes related to different settings (garden, forest) are, and how the results compare to clinical therapy (Nilsson et al. 2007). The need for further investigations has been acknowledged, e.g. the establishment of the IUFRO task force on Forests and Human Health (2007-2011).

In the future, we will see an increasing need for developing some plantation forests to serve the public health and welfare sector – together with all the other functions which are currently in demand from forests. There is no doubt, that many plantation forests can excellently fulfil welfare demands from society. However, one concern is how to do this without urbanising the more or less natural environment, maintaining the contrast between the forest and the urban environment – a contrast which is highly appreciated by most people.

There is a lack of concrete information on the best practice to be followed for handling such planning and management problems. One thing is certain, however: easy access and proximity to green space, including plantation forests, are very important for the public. For example, Danish research has concluded that the number of forest visits is more than halved if the distance from the home to the nearest forest is increased from 2 to 4 km (Jensen and Koch 2004). Therefore, with respect to recreation, human health and forests, existing local plantation forests and urban afforestation will play a key role.

In addition, it is worth mentioning that the forest also provides a number of health-related products, e.g. xylotol (dental health), sitosterol (cholesterol reducer), pycnogenol (antioxidant) and HMR lignan (inhibitor of certain cancer forms) (Nilsson et al. 2007). There is currently scant information regarding the bioactive potential of products derived from European forest ecosystems.

Outdoor education and learning

In recent years there has been an increased interest in using the outdoors, and in particular the natural environment, as a setting for education and learning. Forest School is a particular approach to outdoor learning, originating in Scandinavia, but now spread to numerous other countries. In the UK it has been used since the mid 1990s, and a UK review by Lovell and Roe (2009) concluded that outdoor education makes an important contribution to students' physical, personal and social education. This includes increased physical activity, and better mood and lower anger levels. The same benefits were found in a Danish research project (Mygind 2005, 2007, 2009). Moreover, Forest School has beneficial impacts on concentration, motivation and communication skills, but also provide opportunities for the improvement of physical motor skills. Finally, those children participating in Forest School developed more positive attitudes towards the forest environment. It is possible that this will have far reaching impacts, with the increased likelihood of the continued use of forests and woods in adulthood, for physical activity pursuits and to restore psychological wellbeing (Lovell and Roe 2009).

Access and legislation

Throughout Europe there are laws or regulations pertaining to recreational use of forests and the regulation of public access to forests is a major issue in most countries. At the European scale, there are two main approaches towards public access: private land being inaccessible or private land being subject to a "Right of Common Access". In many countries in the Nordic and Central-European region (except France) the public has, independent of public or private ownership type, a right of free access to forested areas, but must respect the environment, and the rights of landowners and other visitors. In Scandinavia, the traditional "Right of Common Access" includes berry picking, mushroom collection and free access for recreation activities. In contrast, many other countries in the Eastern and Mediterranean regions of Europe, public forests are freely accessible, while private forests have limited access (Pröbstl et al. 2009). It appears that forest recreation has an especially strong tradition in those European countries, where the abundance of forested areas is combined with a common right of access or similar access legislation.

There is a trend towards stimulating private forest owners to open up their forests to the public and it is probably not legislation that is preventing the forest from playing a more important future role in recreation and human health. On the contrary, some new forest owners like to restrict access to their newly acquired property. These new situations and attitudes towards private ownership and access to private forest land do cause problems and seems to be a growing issue. However, there is yet no scientific data on the motive, magnitude and effect of these developments.

For the forest visitor, the access legislation can be rather complicated in some situations, for instance where local ownership status is difficult to determine, and where detailed local regulations come into play for different types of activities. Therefore, with the current demand for increased public access to forests, and a strong diversification of forest recreation activities, it is necessary to plan for public access and recreation when designing new plantation forests.

Preferences for afforestation and forest management

Afforestation is high on the agenda in a number of European countries and can create multiple societal benefits (e.g. Præstholm et al. 2002), but care is needed also when planning new afforestation projects in a traditionally open landscape (O'Leary et al. 1998). Here, we focus on three aspects of afforestation; 1) the distance to a forest from the urban dwellings; 2) forest preferences; and 3) welfare economics of afforestation.

When planning for new forests and plantations, it is important to bear in mind that from a recreational perspective, the public generally appreciate the opportunity to visit a forest nearby. Urban-fringe afforestation projects therefore play an important role in providing recreational opportunities. In Denmark for example, it was found that people who live close to a forest area (< 500 m) on average visit a forest 90 times per year, and 86% of these visits are to the local forest. When the distance exceeds 3 km to the nearest forest area, the number of visits drops to 20 or fewer times of which only half are to the local forest area (Jensen and Koch 2004). Studies from the UK and Belgium show the same trend: the closer the home is to a forest, the higher is the frequency of visits (Roovers et al. 2002, Coles and Bussey 2000). Other aspects of distance to a forest area are: 1) the cost of transportation, where people with restricted budgets have possibilities for access to forests nearby; 2) preference by user groups, where local, urban forests are considered safe and thus provide access to, for example, the elderly, children, and school groups; and 3) the opportunities for volunteer projects and partnerships, which are presently very common pursuits in the USA, but also emerging in Europe, especially in the UK.

The public attitude towards afforestation is generally very positive, especially in countries with low forest cover. However, specific landscape planning control and design guidelines are needed for different landscape types, e.g. in areas with distinct and historically open landscapes like the Irish landscape (O'Leary et al. 1998) (Figure 3). The suitability of different forest types and the preferred forest management options for each type have been examined in a number of studies (e.g. Koch and Jensen 1988, Jensen 1993, Jensen 1999, Lindhagen 1996, Gundersen and Frivold 2008). Regarding forest type, the results of a Danish study showed that both broadleaved and coniferous forests received high scores, with 90% stating that new broadleaved forests are a 'good' or 'very good' idea, and 62% stating that coniferous forests are a 'good' or 'very good' idea – even Christmas tree plantations are perceived as a relative good "forest" type in former agricultural areas (50%) (Table 1). At the European level, a review study of forest preferences across Europe (entitled: "Public Preferences for Forest Attributes: Towards a European Synthesis"), conducted by the EU-funded EFORWOOD-project, is underway.

Figure 3: *Illustration of a Danish landscape today (left) and the potential forest landscape 80-100 years from now (right), as it may develop with the present afforestation policy. (Illustration by Granby).*

Table 1: *Results of a Danish survey on the public perception of three different types of afforestation (Jensen 1998).*

	Very good idea	*Good idea*	*Don't care*	*Bad idea*	*Very bad idea*
Broadleaved forest	40	50	7	3	0
Coniferous forest	13	49	17	17	4
Christmas tree plantation	9	41	22	21	7

Information is a key tool when dealing with – especially high impact or controversial – planning and management issues. The results of a number of studies have shown that the availability of relevant information for a forest can affect significantly the willingness to accept a given management practice. An example is the question of fencing: When for instance the general Danish population is asked to rank the simple statement: "a fence", the statement is placed no. 62 among 100 different issues in relation to a particular management regime for a forest. If additional information is given: "…around some young trees" the statement moves up to no. 44 and finally, if even more information is given: "… to protect them from the deer", the statement moves 14 places to no. 30 in the rankings (Jensen 2000).

The welfare economics of afforestation has become a focus area and it is well-documented that new forests have high economic value for the local communities, maybe more than was believed earlier. Moreover, the value of the forests will increase, for the benefit of generations to come (Anthon et al. 2005). The implicit price of proximity to the forest, measured as its impact on the price of a specific house, depends on the distance from the house to the forest edge (Figure 4). When more than 1000 m away from the forest edge, price impacts are likely to be negligible (Anthon 2003).

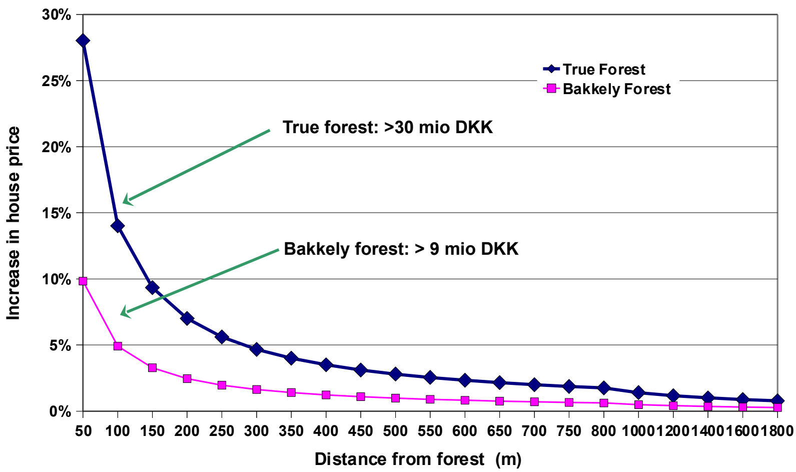

Figure 4: *New forests are worth millions to local communities, maybe even more than we believed before (Anthon 2003). All prices are in Danish Kroner (100 DKK ~ €13.42; December, 2010).*

Discussion and conclusion

We are facing accelerating challenges, for example: a changing demography, with more older people, more ethnic diversity and societies that feel alienated from their surroundings and the broader environment. Here the forest sector can play an important role in relation to future generations' nature/forest knowledge and appreciation, where for example a more close collaboration with the school system would be beneficial. In Denmark, approximately 14% of the 2000 primary schools currently are active in outdoor learning/outdoor schools (Bentsen et al. 2009). In this context urban forests are especially important.

What is the future of recreation and human health in plantation forests? The current trend of increased and diversified recreational and health-related use of forests will continue and will probably become even stronger, with higher expectations from individuals, organised groups and the public at large. In addition, there is likely to be an interest in increasing the diversity of activities and other pursuits offered in forests (i.e. the "experience economy"), including the development of more health-obesity-physical exercise programmes. There might be a risk of the forests and plantations being turned into amusement parks in a green setting. This calls for strategic planning on how to handle an increasing number of different "technology driven" activities (mountain-biking, gps/geocaching, tree-climbing, off-road (motorized) skateboards etc.) and an increasing amount of "hardware" (exercise constructions, shelters, separate horseback/mountain-bike/skiing trails, health measurement equipment, art and light installations etc.). Moreover there is a need for balance among the different types of recreational and health benefits offered by forests. To many people the forest provides a valuable contrast to the urban environment – a natural, quiet and dark environment.

We suggest that forest owners and managers – in addition to "playscapes" – also start planning for more tranquil forest landscapes, such as "soundscapes" (e.g. Manning et al. 2006) and "darkscapes", where the visitor can experience the forest without getting a feeling of being located in a green fitness room or entertainment centre.

Finally, the health/welfare/physical exercise issue provides opportunities (and needs) for the forest sector to cooperate with other administrative bodies and policy sectors, e.g. social, health, culture and sport. This however, can be a challenge, not only in communication and planning but also in relation to budget negotiations – should the forest sector or the health sector pay for health-recreational facilities in forests?

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Forest research for 21st century Ireland Meeting society's needs

Eugene Hendrick[a]

Abstract

Forest research has a solid track record in Ireland, going back to the 1950s. The scope of forest research has expanded in the intervening years, due mainly to a growing awareness of the environmental role and impact of forests. As new forest establishment is funded largely by the state, forest research needs to play a strong role in supporting and obtaining a return on national investment.

Forest research meets society's needs when it contributes to policy aims being met, insofar as the policy goals are well established and articulated. The general purpose is to provide guidance to policy makers and practitioners through scientifically-based, timely and well-communicated information.

Forest research has a significant time dimension, which needs to be recognised in funding arrangements, expertise and application of results. A weakness of project-based funding is the difficultly in providing for continuity of expertise and information transfer. To address this issue, research programmes dealing with well-defined areas could be funded on a recurring basis, subject to performance, and based in third-level or existing national research establishments.

Continuing and assured investment (state and private) in research is necessary to grow, harvest and process wood and other forest products in a sustainable and competitive way. Gross expenditure on research and development in Ireland in 2008 was €2.6 bn, or 1.68% of GNP. In the same year total investment in forest R&D was €11.2 million, or 0.57% of the GNP contribution of the sector. Investment in research and development in the forest sector, therefore, lags well behind the rest of the economy.

Effective dissemination of research findings to policy makers and practitioners is of fundamental importance to nationally-funded programmes. Meeting society's needs through the uptake of forest research outputs occurs in three main areas: policy, practice and products, and standards.

Keywords

Forest research, forest policy

Introduction

The purpose of this paper, based on a presentation made at the Scientific Seminar of the European Forest Institute (EFI) in Dublin in September 2009, is to outline approaches to ascertain the research needs of the forest sector in Ireland and wider society, and how these have and are being addressed through national research and information dissemination. COFORD – the National Council for Forest Research and Development – was the principal agent in identifying forest research needs from its establishment at the end of 1992, as well as being responsible for funding national forest research until the end of 2008. In the context of this paper it is also opportune to

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outline and review COFORD's operations, and to draw lessons and recommendations for the future.

Forest research has a solid track-record in Ireland, going back to the 1950s (see for example, Forestry Division 1967, Joyce and OCarroll 2002). Species and provenance selection, silviculture, forest management systems still in place today, as well as knowledge of nutrient, water, energy and carbon cycles in forests in Ireland, are largely a result of research carried out over the past five decades, mostly but not exclusively, in the state sector.

By the early to mid 1980s forest research had begun to expand in scope, due mainly to a growing awareness of the environmental role and impact of forests. Much of the new work on the environmental aspects of forests was based in third-level institutions, such as the Forest Ecosystem Research Group at University College Dublin and others at Trinity College Dublin and University College Cork. Work was focussed on understanding hydrological and biogeochemical cycles in plantations, and on the impact of forests and forest operations on freshwater ecosystems. This work has also made a significant contribution to forest policy and practice, mainly through standards and guidelines (for example the National Forest Standard (Forest Service 2000a), the Code of Best Forest Practice (Forest Service 2000b) and the associated environmental guidelines (Forest Service 2000c)). In a more fundamental way it has deepened the understanding of how plantation forests in temperate climates function.

The policy imperative for research on the environmental aspects of forests was given a renewed emphasis following the Earth Summit in Rio de Janeiro in 1992. Society-based issues and needs such as climate change mitigation and adaptation, biodiversity conservation, and protection of water quality increasingly influence forest policy in almost all developed countries. As has been pointed out, prior to Rio research on environmental aspects of forests had begun in Ireland, but the climate change and biodiversity conventions enacted after the Earth Summit had a significant effect on all aspects of forestry, including policy, practice and research priorities (Hendrick et al. 2002).

The purpose of forest research

Research builds on existing knowledge and expertise, by continually challenging existing findings and ways of doing things[1]. (The author recalls a protracted discussion with a forest manager on a new approach in forest establishment. Even when all the technical and cost arguments had been clearly laid out, the existing practice was clung to, on the basis "we have always done it that [the existing] way".)

As new forest establishment is funded largely by the state, forest research needs to play a strong role in supporting and obtaining a return on national investment in afforestation. It also has a role in addressing forest-relevant issues that impact on

[1] Forest research, as well as finding out new information, will by its nature disprove and reformulate assumptions, propositions and ways of doing things. This approach to research and science in general has been formulated by a number of thinkers, including Popper's work on the scientific approach to problem solving (Popper 1959, see also www.tkpw.net).

society at large, mainly climate change mitigation, biodiversity conservation, water quality and recreation – often referred to as public goods.

Ireland's forest resource is plantation-based and this is reflected in research priorities. Most plantation forests in Ireland have a 30-year+ rotation, and research projects can span part, or indeed all of the cycle of individual forests, from establishment to harvest. Forest research has therefore a significant time dimension, which needs to be recognised in funding arrangements, expertise and application of results. Long-term research is also needed to investigate the effective provision of public goods. Furthermore, data assembled over periods of several decades from field trials, permanent sample plots, and biogeochemical monitoring sites have applications across several areas, such as process-based modelling of forest growth, assessing the impact of climate change on forests and assessing their contribution to mitigating the rise of carbon dioxide concentrations in the atmosphere. A caveat should be stated here: long-term monitoring sites and field trials need clearly defined objectives and dissemination plans (which should be periodically reviewed) so as to avoid collecting data for data's sake.

Synergies in environmental and competitiveness aspects of forest research are also apparent in forest policy and practice. The competitive and sustainable production of wood resources has achieved a new importance, partly in response to climate change and related policies. Sustainable production of wood fuels, for example, is now a national priority, as Ireland takes on legally-binding targets at national level, in order to comply with the Renewable Energy Directive (2009/28/EC). Indeed, wood products in general have taken on new importance due to their low embodied energy and carbon storage role. These developments partly explain why, even in the current circumstances, roundwood demand is at an all-time high.

Continuing and assured investment (state and private) in research, is therefore necessary to grow, harvest and process wood and other forest products in a sustainable and competitive way. Forest research is needed to address knowledge gaps in the provision of public goods, and in the understanding of biogeochemical (including carbon), and hydrological cycles in forests. The general purpose is to provide guidance to policy makers and practitioners through scientifically-based, timely and well-communicated information. In Ireland, forest research by state and the third level, and more recently the COFORD forest research and dissemination programmes, have attempted to address this agenda.

Forest policy and research

National forest policy is set out in *Growing for the Future* (Department of Agriculture and Food 1996), with elaborations in the National Development Plan (2007) and Statements of Strategy (Department of Agriculture, Fisheries and Food 2008, 2010). Policy is being reviewed following on the Renewed Programme for Government (Department of An Taoiseach 2009).

Forest policy addresses both public goods provision and competitiveness. While, at a certain level, these may be seen to be competing aims, there are, as pointed out, synergies between them, for example in locating productive forest on more fertile lowland sites, while avoiding less productive upland or peatland areas, many of which have a high inherent habitat value. Or aiming to increase forest productivity, which will also speed up the rate at which CO_2 is assimilated, thereby contributing to climate change mitigation and allowing time for the development of a low emissions economy. At the same time, it is clear that in some instances, particularly in the area of water quality, there is potential for conflicting outcomes.

Research has been seeking to better understand how forests and water interact, and to bring forward solutions. For example, the proposed Programme of Measures for forestry under the Water Framework Directive (Water Framework Directive, National Programmes of Measures – Forest and Water Working Group 2009), proposes a catchment-based approach to forest location and level of operations, as well as other specific measures, which were and are being informed by scientific findings arising from the COFORD-funded research programme and earlier research.

Whatever about the dichotomy between public goods and competitiveness, and the role of research in addressing it, there can be no doubt that achieving the aims of forest policy - in the sense that it is a set of actions to be followed over a period of time - is dependent on national investment in focused, adequately resourced forest research, which must come with effective communication and dissemination of results, and a high level commitment to research-informed innovation, and to following through on promising research findings.

It can be argued at one level that forest research meets society's needs when it contributes to policy aims being met, insofar as the policy goals are well established and articulated. Ways in which forest research needs are prioritised, how it is structured, funded, carried out and disseminated, how buy-in is fostered, how it gets used in policy and practice are all critically important in achieving the policy aim.

Addressing risk of failure and achieving returns from research investment

Risk of failure of research to provide answers and new information can be addressed and reduced by having clear questions to answer, achievable objectives, adequate resources, and perhaps most importantly by having competent and committed researchers and practitioners engaged in the process. These issues can be summarised as follows:

- at the outset asking the right questions, developing testable hypothesis, and
- having competent persons and adequate resources to answer them;
- clear communication of results to policy makers and practitioners, using reports, papers, presentations and advocacy;
- openness to change among practitioners and policy makers, and their involvement in research programmes;
- developing policy support and advice, and innovation systems that take ownership of research results and exploit them (for example the COFORD wood energy advisory service, the COFORD forest growth modelling and financial appraisal system GROWFOR, modification and improvement of wood products in the boardmilling and sawmilling sectors).

Establishing and prioritising forest research needs

The main policy statement on the scope and objectives of the national forest research programme is in Chapter 12 of *Growing for the Future* which states "Policy on research will be: To promote research and development focused on the strengths of the Irish forestry sector, with particular emphasis on market demands, industrial needs, environmental concerns and cost efficiency." *Growing for the Future* drew on the COFORD programme *Pathway to Progress*[2] research programme, which had been published two years earlier in 1994: "The need to maintain forest research effort in the areas identified in 'Pathway to Progress' is accepted".

Pathway to Progress was the first formal, large-scale engagement with stakeholders and wider society in Ireland to understand and scope forest research needs: "Committees were set up to prepare the five sectoral programmes [Reproductive Material, Silviculture and Forest Management, Harvesting and Transport, Wood Processing, Socio-economic] contained in this document. Over fifty people contributed their time and energy to ensure that these sectoral programmes were presented within the short time available and to a standard that will ensure long-term economic and environmental benefits. It brought together a wide cross section of the industry, reflecting the ever changing face of Irish forestry. It included not only traditional practitioners such as foresters, sawmillers and nursery managers, but drew widely from researchers, the farming community, administrators and educationalists. The common objective was to develop a programme that was appropriate, affordable, achievable and complete."

What the scoping exercise achieved "… was a new appreciation of the importance of 'all sector' involvement in research planning" (Mulloy 1994). The research programme reviewed the strengths and weaknesses of each sector, past and ongoing research, and made recommendations on research areas and priorities on a sectoral basis. It also identified a number of new areas where research was needed, such as wood supply planning and costs, wood transport and public perceptions of forestry.

The process underlying the development of *Pathway to Progress*, and the associated research scoping, was partly a reflection of an increasing level of private sector involvement in afforestation, timber harvesting and transport, and wood processing. Private sector afforestation dramatically increased from the mid 1980s, on foot of the introduction of annual premium payments, as well as increased capital grants to cover afforestation costs (Figure 1). Forest nurseries were dealing with a wider range of species, new growers had new information needs, and harvesting and transport had not been addressed in any depth in previous research programmes. Prior to the mid 1980s, forestry was by and large (with some notable exceptions) a state undertaking, and research needs were identified within the state forest service through coordination between the Research Division and the forest management inspectorate.

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[2] *Pathway to Progress - A Programme for Forest Research and Development*. (Forest, rather than forestry, research was chosen to reflect the sector-wide nature of the programme. The name COFORD – the National Council for Forest Research and Development – was chosen for the same reason.)

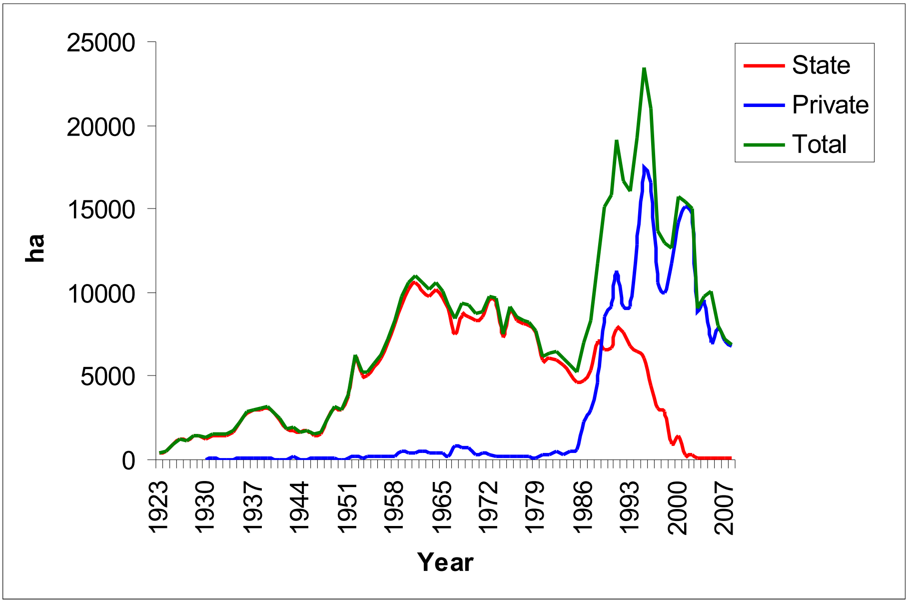

Figure 1: *Annual afforestation levels from the foundation of the Irish state in 1922 to 2007.*

Growing for the Future determined that: "… a phased and prioritised upgrading of national R&D effort will be brought forward by the end of 1996…" As a result, COFORD entered into a further period of stakeholder consultation, and developed a new programme in two documents, *Our Forest Future*, submitted to government in 1997, and then, following discussion with the Department about the need for a greater level of costing in the programme, in *A costed, phased and prioritised research and development programme for the forestry sector*, submitted in January 1998.

The 1998 document set out seven priority areas for forest research:

1. diversification of the species range in Irish plantation forestry;
2. seed sources for, and the establishment of broadleaved crops;
3. harvesting and wood transport, particularly the needs of farm forestry;
4. the effects of forests and forest operations on water yield and quality;
5. socio-economic research, including recreation and other non-market values of forests;
6. the development of new wood products;
7. information dissemination and technology transfer.

Priorities were to be addressed by a 7-year forest research programme, over the period 1998-2004. Among the measures envisaged was the recruitment of eleven permanent scientists, seven in COFORD. A building to house COFORD scientific and research programme administration staff (part of a new National Forest Institute) was envisaged. The funded national forest research programme was to continue as before, on a competitive basis to address the outlined priorities.

In the event, sanction was not obtained for the permanent scientific staff, nor for the National Forest Institute (NFI), despite endorsement by the COFORD council and protracted discussions, which lasted until 1999, with the Departments of Agriculture, Fisheries and Forestry, and Marine and Natural Resources (which had responsibility for forestry from 1997-2002). A design for the NFI building was produced and a site was earmarked at the Belfield campus of University College Dublin[3].

On foot of *Pathway to Progress*, calls for research proposals had been issued by COFORD from 1995 to address the issues indentified in the programme, on a sectoral basis. Seventy two projects were funded over the period up to 1999. These addressed traditional 'forestry' research topics such as silviculture, genetics and forest planning, as well as newer areas such biodiversity, climate change, forests and water.

From about 1998 onwards COFORD began to disseminate the outputs of funded research projects in workshops, books and reports and through the development of specific advisory services (see **Dissemination and uptake of forest research outputs**).

Forest research under National Developments Plans

National Development Plans (NDPs) were put in place at national level over the period from 1994 (COFORD was established in late 1992). The plans were focussed on capital investment to secure national development and competitiveness. Research and development formed a significant part of the investment, particularly in information and communications technology (ICT) and biotechnology (see Irish Council for Science and Technology 2000, which provides an overview of national thinking at the time in science and technology policy development).

The national forest research programme and its funding came within the framework of three successive NDPs: 1994-1999, 2000-2006, and the current programme which is running from 2007-2013. Under the first two NDPs (Department of Agriculture, Food and Forestry 1994, Department of Enterprise, Trade and Employment 2000), forest research was referenced in specific areas.

In the 1994 NDP forest R&D came under *Measure 2, Forestry Development*, and had the following aims:

a. to provide and expand research and training facilities related to the development of the timber chain;

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[3] One of the obstacles to the implementation of the plan was the lack of a formal legal status for COFORD as a stand-alone state body. This was recurring issue throughout the existence of COFORD as an executive body, and it was not resolved. Had it been, it would have strengthened the continuity and effectiveness of the national forest research and development programme, and its ability to meet the needs of wider society, particularly if it had been aligned with recruitment of the additional staff indicated. In the 2009 Budget (Department of Finance 2008), the government announced it was to proceed with the rationalisation of state agencies, based on a number of considerations set out in the budget statement. In all, 41 state bodies were involved, including COFORD. Annex D of the Summary of Policy Changes stated, under the Department of Agriculture, Fisheries and Food: "Merge COFORD, the National Council for Forest Research and Development into the Department". The forest research function was transferred to the Research Division of the department in 2009. The COFORD council was retained as an advisory body, while the COFORD development areas were retained within the executive that transferred to the Department.

b. to provide support for research and back up to afforestation and wood processing programmes including genetic research, dissemination, product development, management and marketing;
c. the continuation of COFORD's activities in the research area.

The programme also stated: "The aim will be to maximise the return on the investment in afforestation and the wood processing sector through the provision of appropriate and necessary support in the fields of research and development. This will optimise the use of resources so that forestry will become a major contributor to the economy, consistent with social, cultural and environmental needs. Action will relate to the following:

- improve the linkage between industrial needs, research, technology transfer and the financing bodies;
- strengthen research and development linkages;
- advance product development, management and marketing techniques."

While the COFORD programme led to the inclusion of research and development as a sub-measure of the *Forestry Development Measure*, the aims expressed did not capture many of the priorities for the forestry sector identified by COFORD. Furthermore, the sub-measure structure was insufficiently focussed on tangible issues and outcomes. The final objective (c above), did however give the necessary mandate to COFORD to continue its activities. As already indicated, for the period of the Operational Programme, calls for research proposals reflected the priorities of the COFORD costed programme.

Under the second NDP, 2000-2006, forest research and development was part of the Operational Programme for the Productive Sector (Department of Enterprise, Trade and Employment 2000). The research priorities were based on the COFORD report, referred to earlier - *A costed, phased and prioritised research and development programme for the forestry sector*:

1. improving the share of home-grown wood products in the home and export markets and developing innovative wood products and conversion technologies in line with market requirements and quality systems;
2. improving the cost competitiveness and underpinning the economic and environmental sustainability of the forest industry through the investigation of silvicultural techniques, wood harvesting and transport systems;
3. forest health and vitality, and environmental interactions of forests and forest operations;
4. determining the impacts of the afforestation programme on rural development,
5. community stability and the national economy;
6. investigating and developing forest products that have a local use and application;
7. developing silvicultural systems, harvesting techniques and information and communications technology appropriate to farm forestry in order to foster rural development and environmental compliance;

8. investigating and developing the genetic resource of indigenous and exotic tree species to ensure that forest plantations are diverse ecosystems;
9. developing cost-effective plant production and handling techniques in line with best environmental practice.

COFORD, in collaboration with the Department of Enterprise, Trade and Employment and the Department of Finance developed a comprehensive set of performance indicators for the four elements of the forest research programme 2000-2006 (funded research, technology transfer, researcher training and mobility, and forest research and development coordination). As well as simple output indicators, such as number of post graduate awards and the level of cofunding by industry, outcome indicators, such as number of research projects that result in products, processes or services that are taken up by the forestry sector (31 over the course of the programme), were used to better evaluate the overall impact of the programme and value-for-money achieved by state investment. In all, 57 forest research projects were funded under the Operational Programme for the Productive Sector.

An *ad-hoc* NDP Natural Resources RTDI Group was also established during the period of the Operational Programme for the Productive Sector. It met on a regular basis in order to better coordinate thematic and administrative aspects of national research funding in the natural resources area. It led to a number of jointly-funded projects with the Environmental Protection Agency in areas such as forest biodiversity (the BIOFOREST project – see http://bioforest.ucc.ie/–) and forests and water (such as the PEnrich project see: http://www.epa.ie/downloads/pubs/research/water/name,24322,en.html).

Joint funding expanded the scope of the research and enabled issues to be tackled in greater depth. Research funding collaboration as outlined, and the general coordination of the national research effort, enabled forest research to better address the needs of wider society.

The current operational programme came into effect from the beginning of 2007. Forest research comes under the Agri-Food Research Sub-Programme. Under the heading *Research in Forestry* it states: "Funding will be provided for a continuation of the COFORD Forestry competitive research programme. The future success of the forestry sector depends on it being able to produce and sell products in a highly competitive market, while at the same time providing public goods and services. Research will focus on the need to position wood production and processing as an internationally competitive sector, as well as to assess and develop the public-good benefits of forestry."

National system of forest research

Research projects funded by COFORD are generally on a 3-4 year time-frame. However some areas of forest research, such as forest genetics, crop structure and forest biodiversity, are longer term, and benefit from continuity of staffing and resources. To address this issue COFORD has begun funding projects on a 5-6 year time-frame. In addition, it has set up research programme areas, whereby projects are clustered around themes areas. Programmes are led by prominent third-level researchers; some involving two or three separate third-level institutions. To date, programmes have been established in climate change, forest biodiversity, forest management and planning, and forest policy and economics (COFORD 2010).

The COFORD research administration model was based on integrating research scoping, project selection, technical and financial administration of projects, publication of findings, dissemination and advocacy. The executive undertook the initial scoping of research areas, which involved input from the COFORD council and other stakeholders – addressing society's needs – as well as seeking input, depending on the topic, from other agencies such as the Forest Service, The National Parks and Wildlife Service, the Environmental Protection Agency and the Sustainable Energy Authority of Ireland.

In addition to the COFORD programme, Coillte (the Irish Forestry Board) and Teagasc also conduct forest research. Coillte's main area of research is in tree improvement and the development of improved Sitka spruce, the main commercial species in Irish forestry. It also conducts long-term forest monitoring studies and provides science-based services in areas such as water quality assessment and in forest protection.

Teagasc has had a growing involvement in forest research over the past two decades in areas such as broadleaf silviculture and tree improvement, as well as in more recent times in forest economics and forest growth modelling and related areas. Teagasc also provides the national forestry advisory service to private forest owners. The two functions are closely linked in the Teagasc structure which is an effective means of communicating research findings to owners.

Forest product research is now mostly conducted at company level, through research support schemes administered by Enterprise Ireland. Some projects have involved third-level institutions. The National University of Ireland, Galway (NUIG) and the School of Architecture at UCD also conduct research on wood products and timber building systems.

A weakness of project-based funding (the model that exists among national funding agencies, including the COFORD programme) is the difficultly in providing for continuity of expertise and information transfer. The model that operated from the late 1950s, whereby forest research was largely carried out in the state forest service by permanent researchers, changed after the setting-up of Coillte in 1988. While it took on the forest research area, it did not have a formal mandate (as a commercial company) to carry on the work at a national level. Over time the level of forest research in Coillte declined. In hindsight, it may have been preferable had the forest research role remained within the Forest Service, as it would probably have provided a level of funding and the continuity of effort and staffing needed to build on existing knowledge and better contribute to meeting the sector's needs.

Given that there is little scope for forest research to come directly within the ambit of the Forest Service, alternative approaches are needed to address continuity of effort and related issues. The COFORD forest research programmes in climate change and other areas provide a basis for a way forward. Programmes dealing with well-defined areas could be funded on a recurring basis, subject to performance, and based in third-level or existing national research establishments involving partnerships between third-level, Teagasc, Coillte and other research providers and industry partners. Membership of international networks, such as NOLTFOX (Northern European Database of Long-Term Forest Experiments – see http://noltfox.metla.fi/contact.htm) and Regional Offices of the European Forest Institute, would enable international collaboration, development of competence and the ability to address research questions at scale.

National and business-led investment in forest research

The level of funding envisaged for COFORD in the 1998 forest research policy document (*A costed, phased and prioritised research and development programme for the forestry sector*) was just over €2.9 m per annum, in 2009 terms[4]. By 2004, the final year of the programme, expenditure was to reach €3.8 m, again in 2009 terms. The funding target was based on achieving an annual level of investment by the state and the EU in forest and forest product research which would equate to 3% of the primary forest output value, which in 1998 was estimated as €6 million, out of €200 million.

The levels of funding envisaged in the 2000-2006 Operational Programme (Department of Enterprise, Trade and Employment 2000) for forest research was €12.7 m (£10 m) over the period of the programme, or about €2.1 m per annum (it was well into 2001 before the programme actually got underway).

The actual level of funding (in 2009 terms) of the COFORD programme was €1.9 m in 1998, by 2004 it had reached €2.7 m, and over €4 m by 2009[5] (Figure 1). Over the period from 1994 to 2009 the COFORD programme grew in real terms by an average of 5% per annum.

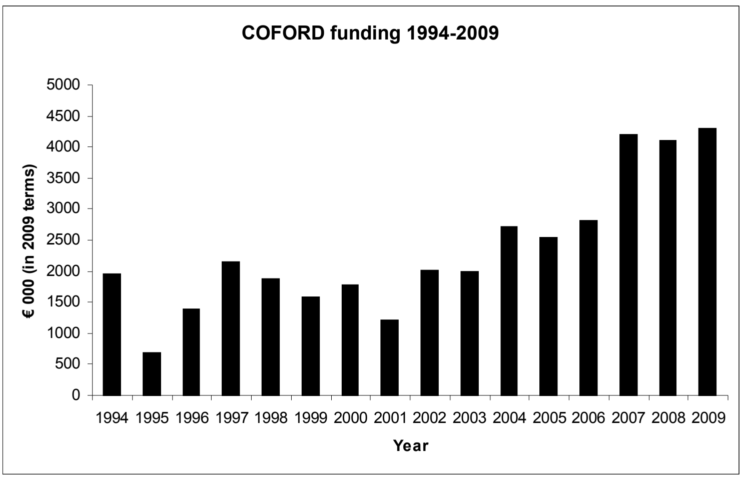

Figure 2: *Annual COFORD funding from 1994 to 2009.*

[4] Estimated using the annual Central Statistics Office (CSO) Consumer Price Index.

[5] The COFORD figure includes expenditure on research coordination and dissemination, estimated as about €0.7 m per annum over the period from 2000 (see COFORD annual reports at www.coford.ie for a detailed breakdown of expenditure).

In addition to the COFORD programme, state-led expenditure on forest research and development (including the state contribution to company-led research) includes Coillte, Enterprise Ireland and Teagasc (Table 1). Total expenditure in 2009 was €8.4 million.

Table 1: *State investment in forest research and development (including wood products) in 2009.*

Organisation	***Funding (€ million)***	***Nature of research and development***
COFORD *Department of Agriculture, Fisheries and Food*	4.3	Establishing and growing forests Harvesting and forest products Policy and public goods
Coillte *(Commercial state forestry company)*	1.0	Tree improvement Forest establishment (reforestation) Conifer silviculture Environment-related topics
Enterprise Ireland *(National business development authority)*	1.5	Business-led R&D in wood products
Teagasc *(National agriculture research and advisory service)*	1.0	Afforestation and farm forestry Broadleaf silviculture
Other Department of Agriculture, Fisheries and Food (Stimulus programme) Environmental Protection Agency	0.6	Biogeochemical cycling in forests Forests and water
Total	**8.4**	

Business-led investment in research and development, based on the level and rate of grant-aid (30%) from Enterprise Ireland (excluding Coillte) was in the region of €3.5 million in 2009 (Fitzgerald pers. comm. 2010).

The estimated[6] value of goods and services provided by the forest sector in 2009 was €1.89 bn. Investment in R&D in the same year (state and private) was €12.3 million, or 0.63% of the €1.89 bn figure. Comparable economy-wide data are only available up to the end of 2008. These show (Forfás 2009) gross expenditure on research and development investment at €2.6 bn, or 1.68% of GNP. In the same year total

[6] The contribution was estimated by bringing forward the 2003 estimate (Ní Dhubháin et al. 2006) to 2009 using the Consumer Price Index 2004-2009 (CSO).

investment in forest R&D was €11.2 million, or 0.57% of the GNP contribution of the sector. Even allowing for possible discrepancies in data collection and calculation approaches, the relative level of investment in research and development in the forest sector lags well behind that in the rest of the economy.

Part of the reason for the relatively low level of investment in research by the forest sector is the predominance of the "computers and related activities" and "chemical and chemical products" in business-led R&D investment (Forfás 2009). Intense competition, allied to frequent product turnovers, drives investment in these sectors. Data from the UK (Office for National Statistics 2006) illustrate this point. Research and development investment as a percentage of sales in manufactured products (data are for period 2003-2005), ranged from 33% in pharmaceuticals, to 0.1% in paper products, printing and wood. Unlike software development, pharmaceuticals and other rapidly developing areas the forest products sector is normally a technology taker and adopter. Furthermore, wood products tend to remain relatively unchanged for long periods: medium density fibreboard (MDF) for example was first developed in the US in the early 1960s, almost 50 years ago.

Nevertheless, indications are that the level of R&D investment in the wood products sector in Ireland is relatively high, when compared with the UK at least. Wood and wood products rank mid-table in terms of innovation activity by sector (Forfás 2009, p 49).

Whatever about the relativities of investment in forest R&D, there is a continued need for state-led investment to meet society's needs in terms of the effective provision of public goods and to build a competitive and sustainable forest sector in Ireland. Furthermore, the direct state investment in forestry, through afforestation grants and premiums and other grant-aid and supports (the 2010 budget for forestry was €119.7 million[7] (Department of Finance 2010) carries an onus to ensure value for money and effectiveness, through supportive and risk reduction measures such as forest research and development.

Dissemination and uptake of forest research outputs

Effective dissemination of research findings to policy makers and practitioners is of fundamental importance to nationally-funded programmes. Meeting society's needs through the uptake of forest research outputs occurs in three main areas: policy, practice and products, and standards.

Policy

Examples of how forest research outputs are used in forest policy include its formulation, and the ways that research can inform the provision of public goods, such as climate change mitigation. Not only does the research address policy needs (see for example the National Forest Standard, Forest Service 2000) but it can and should itself influence the direction of policy.

[7] Includes the forest research budget of €3.242 million but excludes *Bio Fuels Establishment Grants (Willow/ Myscanthus) and Bio Fuel National Top Up Grant)*.

Practice and products

Forest research outputs have more traditionally been used in forest practice. Changes in the national system of forest research referred to tend to lessen direct interaction between researchers, practitioners and policy makers. However, simply having researchers and practitioners working in the same organisation is no guarantee that effective dissemination of research outputs will take place. Indeed, the publication imperative that operates in most third-level institutions directly benefits the recording and critiquing of research outputs, whereas a significant part of the research conducted in state organisations over the past five decades has not been published. Most of this work is recorded in unpublished reports, but these are often difficult to access. Nevertheless there is a need for the state to systematically consider and foster the uptake of research results in forest practice. COFORD has addressed dissemination and uptake of forest research outputs in a number of ways. It has developed information systems and provides advice based on research outputs. COFORD has also engaged in a significant way in the publication of research outputs, drawing mainly on funded projects, but also on other national and international research.

The COFORD Connects series disseminates research findings and information of interest to practitioners and policy makers in the form of short notes, written in an accessible style. The areas covered are:

1. reproductive material;
2. silviculture and forest management;
3. harvesting and transport and forest machinery;
4. wood processing and product development;
5. socio-economic aspects of forestry;
6. forestry and the environment.

COFORD has also been active in outreach activities in areas such as wood energy and broadleaf silviculture, in collaboration with third-level and Teagasc. In the future it is desirable that Teagasc would become the main state service provider in this area, including areas such as management of conifer plantations and first thinning, given its experience and track record, and contacts with growers.

Standards

Research outputs are also taken up through the use of forest certification and forest products standards. Voluntary standards such as the PEFC Irish Forest Certification Standard (see www.pefc.ie) and the draft Forest Stewardship Council of Ireland Standard (www.fsc.org/europe_ireland.html) draw on research findings in establishing indicators for sustainable forest management. A number of forest product standards such as IS 444 *The structural use of timber in buildings*, IS 127 *Timber grading*, Irish timber fencing standards, the recent CEN (European) standards dealing with wood fuels, and the recently launched Wood Fuel Quality Assurance scheme, draw on forest research carried out in Ireland over the past three decades, as well as having a strong input from forest researchers in the drafting process. Without research information many of the standards could not have been developed. Standards are a means of protecting consumers' interests and facilitating open trade and commerce (particularly under the

Single Market of the Single European Act), and by contributing to the development and implementation of standards, research is meeting society's needs.

The COFORD council acts as a vehicle for encouraging the uptake of research results, through the members providing leadership and advocacy for research-led change. In addition, the thematic structure of the COFORD programme, which has developed the programme areas referred to earlier, enables resources to be dedicated to research dissemination and outreach. Examples include programmes such as PLANFORBIO (www.ucc.ie/en/planforbio) and CLI-MIT (www.coford.ie).

Given the recent amalgamation of COFORD with the Department of Agriculture, Fisheries and Food, the publication and dissemination activities referred to need to be put on a long-term footing, to build on what has been achieved to date.

Conclusions and recommendations

Forest research in Ireland has by and large addressed and continues to address society's needs and those of the forest sector. At the same time the increasing demands on the forest sector, in public goods provision and in providing increasing outputs of forest products in a cost-effective manner, contribute to the need for well-resourced and long-term research programmes.

Involvement of end-users and customers in scoping research priorities and in dissemination is an important part of the national forest research process. Such involvement helps to build ownership of forest research outputs, and support for investment by both the state and the private sector. The COFORD Council should therefore be continued as a consultative body on forest research and to address wider development issues (where research outputs and researchers can provide key inputs). In this context it is important that the council has a strong input from private sector forestry and industry in general.

Funding is of course a fundamental issue; without state intervention the level of research is unlikely to be sufficient to impact on long-term competitiveness, and will certainly not support the need to understand and guide public goods provision. The current level of both state and private investment runs to around €12 million per annum, a relatively modest figure, given the scale of the sector and developing information needs. Given the current state of the public finances, an increase in research expenditure is unlikely, but at the same time it is essential that levels of investment are at least maintained, not only for research to continue to support policy, practice and standards development, but to build and secure the human capital and expertise that has been developed over a long period of time.

Research themes and priorities are constantly changing, but in a sector with a long-term perspective such as forestry it is important to secure and support the extended investigations and monitoring that are essential to address many of the thematic areas that are funded under the current COFORD programme. For this reason, the national system of forest research should seek ways to establish long-term thematic programmes in a number of key areas, based in third-level and state research institutions.

Ireland has a competitive advantage in growing renewable wood fibre. The main research imperative and investment should be in this direction, as in the future oil-based products and minerals will inevitably become increasingly scarce and costly

(Campbell 2004). The provision of public goods from forestry will also continue to be an important area for forest research, which will require continued national investment.

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Forest Perspectives

Forestry in France

Matthieu Mourer

Educated as an engineer in forestry, I have worked 10 years for the French Forest Service and the French Department of Food, Agriculture and Fisheries before starting a post-MSc diploma. As part of these studies, I was invited to UCD to learn about Irish research on forest carbon storage. This internship was also an opportunity for me to make a presentation to Irish researchers on French forests and forestry practice. This article, following the presentation, is divided into three parts; history, natural diversity and economics. I would also like to share a short personal perspective of what I have seen of forestry in Ireland, however, though I still work for the French Department of Food, Agriculture and Fisheries, all opinions throughout the article are my own.
Finally, I would like to thank Dr Brian Tobin for having corrected and improved my original text and to apologise if any imperfections that remain.

History

Knowledge of historic forest area is difficult owing to the lack of serious statistics. A land registry was first set up by Napoleon I in 1807. Before this date, only royal and church forests were mapped. Many locally defined measurement units generated confusion. Three definitions of *arpent* coexisted and ranged from 3,420 to 5,100 m^2. Thus, assessments varied largely: between 7 and 15 million ha in the early 18^{th} century. No forest inventory was achieved by royal administration. The first serious study was carried out in 1788 and was based on the Cassini's map projection, the most detailed map covering all France at this time. The total area of France was assessed then as 47.8 million ha, and forest cover as 7.6 million ha (including forests in Lorraine, which had just recently been added to the French kingdom some years before). Thus forest represented 14% of the land area.

Historical studies have shown that forest cover was very extensive during the Gauls' age (peak period in 3^{rd} century BC). During the middle ages forests were cleared around abbeys and villages to develop farmlands. Despite a series of famines, population growth soared and put pressure on forest areas. In 1291, King Philippe le Bel created a specific Forest and Water Service to improve royal forest protection against unauthorised animal grazing and wood harvests (the latter especially prevalent in coal mining areas).

During the reign of Louis XIV, Minister Colbert aimed to create a strong Navy to fight against the English fleet and to further develop a maritime trade. In 1669 he issued an ordinance to define rules to protect forests and promote large-timber production. Each community was ordered to allow one quarter of its copse cutting forest to grow to maturity. Large areas were afforested with oak and sawmills were further encouraged near fir and spruce forests to take advantage of the larger dimensioned material. Oak timber was specifically needed for boat hulls and coniferous timber for masts.

During the 18th century medium-scale manufacturing, heavily dependant on timber for energy production, developed in heavily forested areas; e.g. the Baccarat crystal factory or Nicolas Ledoux's royal salt factory, set up in the Vosges and Jura mountains, respectively. These large forests could meet both the demands for timber as well as for other raw materials (sand for glass and crystal, salted water etc.).

In 1789, the revolutionary government seized royal and church lands. Forests were transferred to public estate: the majority of woodlands became state-owned and areas where inhabitants had using-rights were given to the newly created *communes* to replace former parishes. Today these state forests can still be recognized by their large areas (1,000 to 15,000 ha) and the alley ways cleared for royal hunting.

19th century forest area expansion

In 1827 Charles X created the first version of a Forest Code of Laws. This book kept many provisions from the 1669 Colbert ordinance. It defined management rules for public forests, the so called "Régime Forestier". All public forests, even community-owned, had to be managed by the National Administration for Water and Forests, which had the monopoly for public timber sales.[1] Each state or community woodland had to be clearly delimited and managed according to a long-term scheme that declared how much timber could be exploited every year. Timber was sold after standing trees were marked and a check was made subsequently to see whether the markings had been respected. The company buying timber was responsible for harvesting and had to provide a financial warranty before starting to harvest. These conditions only applied to public forests, and not to private estates.

During the second half 19th century, huge works were carried out in the mountains to limit the impact of natural hazards. Many rivers were dyked and pastures on slopes were seized for afforestation to increase stabilisation. A specific administration was created in 1861 to lead these public works. "*Service de restauration des terrains en montagne*" (Mountain Lands Re-establishment Service) still deals with protection against flood, erosion, falling rocks or avalanche hazards. This date also corresponded to the last extension of France, with the addition of the mountainous Savoie region in 1860.

A notable addition to modern French Forestry was the creation of the *Landes* Forest (Figure 1). Along the Atlantic coast, the Gascogne region's shore was formed by dunes which moved with the wind. Many witnesses reported villages being buried in sand. Natural river flows were blocked and pastures suffered flooding and became so wet and spongy that shepherds needed to walk with stilts. In the early 19th century, the Ministry of Agriculture and Water led a programme to afforest these unhealthy swamps called *"les Landes"*. Millions of Maritime pines were planted in an effort to dry the swamp areas, both to limit the spread of malaria and to provide timber and

[1] Napoleon I created the *Prefet*, who represented the national government in each department (100 throughout France). His role consisted of overseeing the work of *communes* and ensuring that their decisions were legal, preventing corruption, managing the police etc.

subsequently employment. Afforestation was funded by banks and private citizens. Community-shared grazing was sold to banking corporations and rich bourgeois living in Bordeaux or Paris. A consequence of this was that local shepherds felt betrayed. However, this programme of works lasted about 50 years, from 1860 to the First World War, and led to the creation of the largest single woodland area in France, and in doing so, one of the more controversial moves in French forestry.

Figure 1: *Trencat's dune and the Landes Maritime pine forest.*

Recent afforestation works

After the Second World War, France needed timber for reconstruction and in 1946 the government provided national forest funding to encourage the planting of fast growing trees. Funds were raised by a specific tax levied on each wood product sold, apart from heating wood. Private landowners were either directly grant-aided or offered cheap long-term loans to afforest abandoned farmland. Two million ha were planted over 50 years, mainly with Norway spruce and Douglas fir. Subsequently however, regions where large areas had been planted became isolated and young inhabitants tended to move away to larger towns. These regions became less and less attractive as populations dwindled. In the mountains even flat pastures were planted and villages felt ever increasingly isolated, surrounded by these new coniferous forests. In an attempt to promote a more traditional lifestyle and to develop rural tourism, many of these regions were classified as "Natural Parks". These extensive coniferous plantations were starting to change the traditional landscapes and experiments were begun to start to clear the forests in order to regain the original landscapes. During the 1980's, ecologically minded NGO's led several media campaigns concerning acid rain and presented the recent monospecific coniferous plantations as responsible for soil acidification. Thus the National forest fund's reputation deteriorated rapidly as trees grew taller! In the meantime, as older forests matured, trees started to be harvested and sold. Forest-owners refused to pay afforestation tax any more. Finally, this fund was cancelled in 2001 by a change in forest policy law.

The last step in recent forest policy consisted of a split of Water and Forest administration into two distinct entities in 1963. The Department of Agriculture kept control of forest policy and forest management, and the *Office National des Forêts* (ONF, National Forest Service) was created in order to manage all public forests, both state-owned and community-owned forests, according to a new Forest Code of Laws. However, no land ownership was transferred to this new company. Initially, ONF was grant-aided to cover the cost of non-commercial forest management. Conditions have changed and no aid is granted any more for this role since the 2008 national revision of public policies.

Today French forests represent an area of 15.8 million ha on the mainland. ONF manages 5 million ha, of which 1.5 million ha are state-owned.

A natural diversity

The French mainland is a 55 million hectare-wide territory, one third of which is covered by forests. Our country also covers overseas territories all over the globe, of which French Guyana with more than 7 million ha of rainforest, adds greatly to the diversity of climates, altitudes and management types. This has allowed a large diversity of ecosystems to develop and which place very different demands on management.

Natural biodiversity

Approximately two thirds of the French mainland forest area is covered with broadleaved stands. Sessile and pedunculate oak or beech can be mixed with hornbeam in the more fertile sites or with chestnut where limestone is absent. Around the Mediterranean Sea, species more adapted to hot climates grow (e.g. *Quercus ilex* L., *Pinus pinea* L., *Pinus halepensis* Mill., *Cupressus sempervirens* L.). In the mountains there is a natural succession of species as altitude increases (Figure 2). Beech occurs naturally to 1,500 m in altitude, mixed with Silver fir. The latter then become dominant until Norway spruce and finally mountain pine (*Pinus cembra* L., *Pinus mugo* Turra) appear and continue until 2,200 to 2,400 m. Higher than this, only grazing pastures can resist the arduous winter weather.

This diversity of tree stands reflects a similar diversity in ecosystems. 6.8 million ha (12.4% of total mainland area) are classified in the Natura 2000 network. A large part of preserved areas are located on sea shores and in the mountains, where biodiversity is very varied and often exceptional. Sites located in central plains represent the more common farm and woodland biodiversity. The French management system has attempted to include all stakeholders in the territories, including landowners, farmers, hunters, hikers etc., in writing together a management guide to define everybody's role and responsibility in site conservation. This approach has posed an ownership problem in that landowners in many cases do not wish to share management of their own land with other representative groups. Negotiation and some public grants remain the best way to find solutions – hopefully!

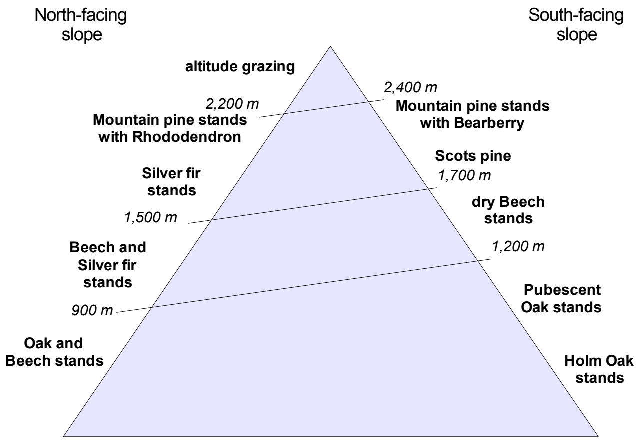

Figure 2: *Vegetation succession with altitude in the Pyrenees.*

Ownership

Forests cover over 15 million ha of the French mainland, of which private estates represent 2/3 of the area. After many inheritances, this estate has been divided into many small parcels and the mean size is often not larger than 1 ha, or less. On the contrary, state forests are still composed of huge tracts, often larger than 1,000 ha. The largest state forest, near Orleans, reaches an area of 35,000 ha, nestled in wider woodland of 50,000 ha. However, state-owned forests only represent 10% of the total mainland estate (1.5 million ha). The rest is composed of community forests which cover 4 million ha. According to the forest code of law, communities and state forests must be managed by ONF.

Relations between the state and private owners have never been easy. The former wanted to protect an estate that concerned general interest whereas the latter didn't want any constraint in managing their lands. The first idea proposed in 1913 by the Audiffred law, consisted of establishing 10-year agreements by which any private owner could let the Water and Forest Administration manage his estate. But only a few contracts have been signed to date! After World War I, the State tried to limit abuses in over cutting by reducing the maximum area which could be cut over without authorization from 10 to 4 ha.

After World War 2, though national forest funding was available, people worried about the size of afforested parcels which often appeared too small to be economically viable. Meanwhile despite a rural exodus, farmers started regrouping their lands to improve their management. This regrouping did not affect woodlands but in 1954 forest unions were created to gather small properties into larger estates which had to be larger than 30 ha. Such unions were different from joint ownership because management decisions didn't need to be approved unanimously any more. In the beginning, forest unions were granted better financial conditions for forest funding e.g. not paying back loans before the first timber sales. However, this system has experienced mixed success, and has been most successful in rural regions of the south central mountains. Today, about 3,000 forest unions are managing c. 500,000 ha.

To ensure management adheres to law, private owners of large forests (> 25 ha) have to establish a management plan composed of three parts, namely a stand analysis, management aims and a felling and hunting programme. Documents are gathered and validated by regional private forestry councils. These official associations provide technical advice to foresters and represent them when negotiating with the timber industry or administration.

Management / regeneration

For many years the main use of timber was for heating and forests were managed as coppices. In 1669, Colbert forest law enshrined the importance of large-timber production. This began the widespread planting of oak forests and their management as high forests. During 19th century, large forest areas were planted while coal and oil replaced wood as major energy sources. The 20th century has been marked by a general rural exodus and farmer numbers have dramatically decreased after World War II. Nowadays the few surviving old coppices with standards have no use any more and they are progressively converted into high forest.

Today, natural regeneration is facilitated as often as possible in order to limit management costs. This often also represents the most efficient solution. Experiments on fire-devastated Mediterranean forests have shown that, 10 years after a fire, naturally regenerated trees became larger than planted trees. Since the removal of the Forest Fund, plantings mostly consist of Maritime pine in the Landes region and poplars elsewhere. Both species have undergone genetic selection to improve wood quality and drought resistance. Other research concerns Douglas fir, European larch, ash, and cherry for occasional reforestation.

An insufficient harvest

In 2008, 21 million m^3 timber were harvested in France, of which 6 million m^3 was broadleaf and 15 million m^3 coniferous. This volume included 11 million m^3 used for panels and pulp. Heating wood harvest was estimated at more than 20 million m^3 however, the majority of this is consumed by the owners/harvesters and is largely unknown; less than 3 million m^3 are sold. Taken as a whole, commercial harvest is assessed to 35.5 million m^3, dominated by coniferous timber.

This result is a paradox since 2/3 of forest area is broadleaf. Volumes harvested in each forest vary highly according to ownership, accessibility, parcel area, slope etc. Coniferous harvested volume has increased steadily since 1950 whereas broadleaved harvest has dramatically decreased after the 1999 storm destruction. Beech forests have been seriously damaged and wood prices have not recovered even yet.

Many efforts have been made to collect more timber. The government has fixed new ONF targets to improve timber harvest in order to guarantee a steady supply to timber transformation companies and to allow the industry to further develop. In the private estate the task is more difficult owing to the huge number of land-owners. Tax shields and owners' associations have not yet been successful in rationalising private timber harvests, except in the main forest regions such as the *Landes*.

Traditionally timber is sold standing; trees are marked before the sale and the customer is free to harvest them during the following two years. The main advantage is that timber not making a sale continues growing! A disadvantage is that the buyer doesn't exactly know either the volume or the quality he buys. Important defects such as beech red heart or the presence of shell fragments[2] can not be detected before the price is proposed. Consequently the timber industry insists on developing other methods of sale. Harvesters prefer to buy wood by product units: the agreement only concerns unit prices and the final amount is known at the end of harvesting. This system is progressively used for the cheapest timber but obviously not for higher value timber, particularly broadleaves. This grade of timber can't be standardised like coniferous material and each merchant prefers his own analysis for a sale of lumber.

Foresters who prefer to control the date and method of harvesting prefer selling roadside timber. In the mountains, winter blown conifers are quickly pulled out of forests to protect standing trees from insect attacks. Harvesting is carried out as soon as the snow disappears, a few weeks before early sales in May and June. In mixed stands, this can be difficult as different species have to be separated, very often each being sold to a different merchant. In the last 10 years, a new methodology tries to preserve the advantages of roadside timber and to maintain the flexibility of standing stock. Roadside pre-selling allows an agreement on unit prices when timber is standing. Later, the trees are harvested when the customer needs them. The timber is then analysed by both and a final price based upon real volume and quality is agreed.

Hunting

The rental of hunting rights is another forest resource to be utilised. Smaller estates are managed with the rest of the community territory by the local hunting association. Any interested citizen holding a hunting licence[3] can become a member. Then, he can participate in collective shooting of tracts[4], which is the most common way of hunting in France. In larger estates, game populations can be managed independently. As soon as an area of woodland is larger than 20 ha (100 ha in mountainous regions), the owner is allowed to organize hunting and to forbid the local association from hunting his land.

These conditions apply across the whole mainland except in Alsace-Moselle. This region was annexed by Germany between 1871 and 1918, and local law still includes special provisions inherited from German law. Thus, no local hunting association

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[2] Many broadleaved species growing since before WW I still contain bullets, shell fragments or barbed wire which can break or cause damage to chainsaws and saw-blades.

[3] Like a driving licence, there is a theory exam to test knowledge regarding safety rules, species specific requirements and season dates etc. A practical exam checks that the applicant can handle a gun!

[4] A group of hunters stand at the edge of a forest tract, while other hunters, beaters and dogs flush out game from cover towards those waiting at the edge.

exists and property rights apply absolutely. Moreover, the most frequent way of hunting consists of shooting alone from a hide.

As far as large game is concerned, hunters and farmers or foresters represent opposed interests; the former expect to have as much game as possible whereas the latter want to prevent wild animals from devastating their crops or their plantations. Every year, all stakeholders are gathered by local administrations to assess game populations and to determine the allowable kill in each community territory. After a hunting plan is adopted, local associations try to kill their game quota because they are financially responsible for subsequent damage to farmlands and forests. Hunters also pay a tax for shooting each animal.

Only deer and wild boars are covered by these management plans. Bird hunting is limited by official season dates but there is no maximum bag number. Finally, a nationwide list is published of animal species which can be locally classified as "pests" (weasel, marten, polecat, rabbit, fox, crow, starling etc.) Once classified, they can be trapped and killed without any limit in number or date.

The particular case of French Guyana

North of Brazil, French Guyana covers 8.3 million ha, of which 7.5 million are covered by rainforest. The population (200,000 inhabitants) lives in a few towns along the northern seashore, whereas density in the forested region is lower than 2 persons per km^2. Access to the southern part of this territory is restricted and only natives (about 4,500 persons) are allowed to live there.

The equatorial climate is characterised by steady temperatures, between 22°C and 36°C. Humidity fluctuates around 80%, and rainfall varies from one month to the next. Biodiversity is so intense that more than 150 tree species can be found in one hectare and total tree species number identified and recorded is 1,300. Since the 1992 Rio Earth Summit, a project was initiated to create a national park in this territory to protect and study the included ecosystems. It was finally realised in February 2007 and 2 million ha were classified as national park. There is also a clause allowing neighbouring areas (1.4 million ha) to join.

In Guyana, all forests are public and managed by the national forest service. Yet, no complete inventory has been carried out and only 1 million ha has precise management rules. The ONF intends to identify suitable sites for exploitation. These places should gather enough commercial tree species to justify a single-use road to be built. Then, private corporations are licensed to work by specific concessions. Between 60,000 to 70,000 m^3 are harvested every year, though very little is exported.

The most lucrative product extracted from the rainforest is gold. Three tons are produced every year representing €36 million. The French Geological and Mining Survey (BRGM) identified deposits where extraction could be allowed and has assessed remaining reserves in the region of 120 tons. Extraction methods in the past were very polluting, releasing mercury into the environment. Today, the challenge for maintaining this gold production will be in reducing the levels of pollution.

Climate change impact

Climate change models have shown seasonal contrasts will increase during the next century, hot and dry summers becoming more frequent. Tree growth models suggest an increase northwards of the Mediterranean forest area, whereas areas suitable for beech could be reduced dramatically. Currently, foresters try to favour oak instead of beech since the former should better resist dry summers. However, no extensive planting works have been carried out. Moreover, since the 1999 storm, harvested beech volume has decreased from 1.9 to 1.1 million m^3 in line with its price reduction.

The evolution of coniferous species is more uncertain owing to their location in low mountainous areas. Snow is expected to be dramatically reduced at lower levels and winter rainfall would consequently not be stored for as long a period in spring. Contrastingly, warmer temperatures would allow plants to grow for a longer season, thereby increasing the possibilities of droughts. Global consequences could be different from one species to another, but clear consequences have yet to be understood. Concerning Maritime pine, genetic research is being carried out to select more drought-resistant varieties that could maintain timber production with less rainfall.

An important economic sector

In France forests provide 40,000 full-time jobs, split between two roughly equal pools. Half are employed in forest management and timber exploitation, of which 10,000 in the National Forest Service, and the other half in sawmills and other timber processing. Since the main part of harvested volume is coniferous, sawmills are mostly settled in the low mountain regions, such as Vosges, Jura, Central Massif, Alps, and in the *Landes* (Figure 3).

The main characteristic of the French timber industry is the small size of the companies. More than 2,000 sawmills were registered in 2007 which provide 18,000 jobs; among them 1,500 sawmills employ less than 10 persons. Harvesting companies are much smaller; 4,000 companies provide 8,000 jobs. This fragmentation makes sawmills weak, being caught between an important timber provider (ONF) and international construction, panel or paper groups. Standardisation makes competition easier, mainly with coniferous timber coming from Sweden and Finland. Scandinavian spruce timber arrives in Nantes harbour at a lower price than the export price from any sawmill in the Jura Mountains. French companies are therefore compelled to explore other markets to justify their price differences. Research endeavours are also directed at new product development and manufacturing methods. A national policy aims to incorporate more wood in traditional building methods and an agreement was signed in 2001 to reinforce links between large construction companies and timber research centres.

The furniture market is the second most valuable after construction; it represents a €9 billion turnover. For 30 years, this market has evolved greatly. Traditional rustic production has been split into two types, following domestic consumption. On one hand, useful and cheap pieces are made with panels that can and are largely imported. On the other, first grade modern-styled furniture is increasingly produced from veneered panels. Also, specialised retail shops have become scarce, replaced by general-interest shopping centres. Mechanisation and international competition put pressure on production costs and compel companies to manufacture abroad, to find

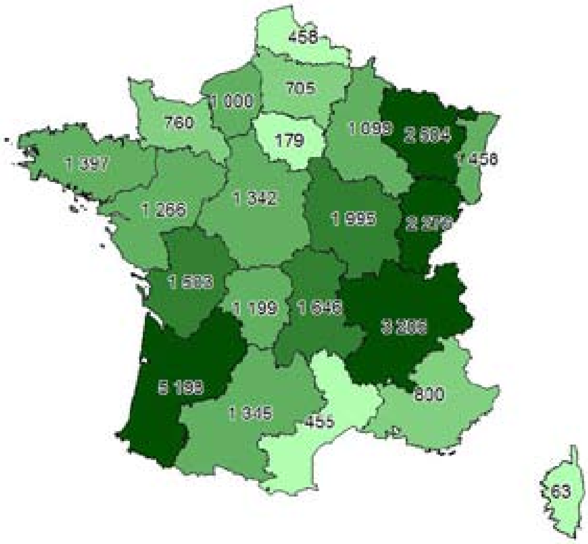

Figure 3: *Timber industry work force in each region – after Agreste, 2008.*

lower wages.

Packaging is another important outlet for low grade wood. The pallet market is mainly guided by selling prices and productivity is the master word. Thus, many companies can only compete with specialised products which exactly fit a client's needs. Health or environment standards are also useful criteria to identify specific products, e.g. material for food packaging (cheese boxes, etc.).

The pulpwood market is totally international, dominated by multinational groups. To resist competition, French foresters and woodworkers have to guarantee a regular and adapted supply of pulp grade and timber waste. Often only one, or occasionally two pulp mills are situated in each forest region and their closure would have serious consequences for the local wood industry.

For the last 20 years, low grade timber has lost traditional markets. The last iron or coal mines were closed in the 1980's and high speed railways are now built using concrete sleepers. Moreover, recycled wood can be used to produce panels or pulp. In this context, heating wood appears both as an environmentally friendly energy source and as a new outlet for wood waste. Technical innovation encourages increased wood usage in town buildings such as schools, sport halls etc. The stakes are now high with the image of logs lying by the fireplace about to change for ever!

Irish forests as seen by a French forester

My internship has given me the opportunity to learn about Irish forestry, while my weekends have been spent in travelling across the island. The most impressive aspect of Irish landscapes is the way that every small parcel of land is being used, either for grazing, for tillage, bog or forest exploitation. I've felt Irish people are deeply attached to their lands and they make strong efforts to maintain and value them.

However, at the end of my stay, I worry about two points. First, Sitka spruce monocultures appear to me hazardous given they represent over half of the Irish forest estate. A few years ago, I witnessed the remarkably quick development of bark beetle populations in Norway spruce stands damaged by the 1999 storms. Also, the *Landes* forests are increasingly subject to damage from foliage feeding caterpillars, the most serious damage occurring after trees have been weakened during a hot summer. So I wonder, what the consequences would be if continental insects find their way across the Channel and Irish Sea?

Secondly, a large area of forest has recently been planted; almost half of the total estate is younger than 25 years. So, I wonder how a wood industry can adapt to this production peak. Investments can be made if production is sustainable and steadily reliable. If such a large proportion of forest is managed with a similar growth rhythm, the production peak could be followed by a significant gap. Such quantity variations would have serious consequences on wood prices, and markets would have to find a "natural" balance. Forest-owners want/need to sell timber mainly when prices are high enough to cover costs, which if every one comes to the market at about the same time, cannot happen. Changes in thinning practice might indirectly reduce stands growth speed while a market is not yet ready to integrate the additional supply. Today, many forests are in the first rotation, stands and properties are even-aged and growing at the same rhythm. But regeneration will be an opportunity to bring more age diversity to the stands. In the meanwhile, clearfelling could be staggered from 40 to 50 or 60 years-old. Other methods of regenerating could also be experimented with, both to prevent clearfells, to save planting costs and, most of all to follow both the industry's and greater society's needs and expectations.

As a conclusion, Irish and French forests have been confronted with many of the same challenges. The main difference is linked with the period of the industrial revolution, which occurred later in France than in Northern Europe. This allowed France to preserve her forests by using coal directly instead of timber. After this period, large planting works have been carried out in both countries, mainly with conifers, to provide a ready supply to build and support a timber industry.

Today, Ireland and France have to adapt their forest estates to the international timber market. The former is developing its wood industry to transform the newly available resource. The latter tries to speed up the growth of its old rustic oaks and to find them further use beyond barrel making.

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Trees, Woods and Literature - 34

There is a curious change in the appearance of the county when one moves inland from the coast of Mayo to the congested portion of the inner edge the county. In this place there are no longer the Erris tracts of bog or the tracts of stone of Connemara; but one sees everywhere low hills and small farms of poor land that is half turf-bog, already much cut away, and half narrow plots of grass or tillage. Here and there one meets with little villages, built on the old system, with cottages closely grouped together and filled with primitive people, the women mostly in bare feet, with white handkerchiefs over the heads. On the whole, however, one soon feels that this neighbourhood is far less destitute than those we have been in hitherto. Turning out of Swinford, soon after our arrival, we were met with almost at once by a country funeral coming towards the town, with a large crowd, mostly of women, walking after it. … When the funeral was out of sight we walked on for a few miles and then turned into one of the wayside public houses, at the same time general shop and bar, which are a peculiar feature of most of the country parts of Ireland. An old one-eyed man, with a sky-blue handkerchief round his neck, was standing at the counter making up his bill with the publican, and disputing loudly about it. …

While he was talking some men who were driving cattle from a fair came in and sat about in the shop, drinking neat glasses of whisky. They called for their drinks so rapidly that the publican called in a little barefooted girl in a green dress who stood on a box beside a porter barrel rinsing glasses while he served the men, They all appeared to know the old man with the one eye, and they talked to him about some job he had been doing on the relief works in this district. Then they made him tell a story for us of a morning when he killed three wild ducks 'with one skelp of a little gun he had', and the man who was sitting on a barrel at my side told me that the old man had been the best shot in the place till he got too fond of porter and had had his gun and licence taken from him because he was shooting wild over the roads. Afterwards they began to make fun of him because his wife had run away from him and had gone over the water, and he began to lose his temper. On our way back an old man who was driving an ass with heavy panniers of turf told us that all the turf of this district will be cut away in the next twenty years and the people will be left without fuel. This is taking place in many parts of Ireland, and unless the Department of Agriculture, or the Congested Districts Board, can take steps to provide plantations for those districts there may be considerable suffering, as it is not likely that the people even then will be able to buy coal. Something has been done and great deal has been said on the subject of growing timber in Ireland, but so far there has been little result. An attempt was made to establish an extensive plantation near Carna, in Connemara, first by the Irish Government in 1890, and then by the Congested Districts Board since 1902; but the work has been a complete failure. Efforts have been made on a smaller scale to encourage planting among the people, but I have not seen much good come from them. Some turf tracts in Ireland are still of great extent, but they are not inexhaustible, and *even if turf has to be brought from them, in few years, to cottagers great distances away, the cost of it will be serious and additional hardship for the people of many poor localities.*

Extracts from *In Wicklow, West Kerry and Connemara* by J.M. Synge; first published in 1911 by Maunsel & Co Ltd., Dublin, and republished in a number of editions since the 1960s.

The playwright and poet John Millington Synge (1871-1909) was born at Rathfarnham in Dublin in April 1871. He was educated privately, and then studied at the Royal Irish Academy of Music. After graduating he travelled to Germany to continue his music studies, but changed his mind and decided to concentrate on writing. Synge was one of the founders of the Irish National Theatre (which went on to become The Abbey Theatre), along with Lady Gregory, W.B. Yeats and others. He is best known for *The Playboy of the Western World*, the drama which caused riots during its opening run in 1907 at the Abbey Theatre. His views on theatre are summed up in the quote: "I do not believe in the possibility of 'a purely fantastic, unmodern, ideal, breezy, spring-dayish, Cuchulanoid National Theatre'... no drama can grow out of anything other than the fundamental realities of life which are never fantastic, are neither modern nor unmodern and, as I see them, rarely spring-dayish, or breezy or Cuchulainoid."

As a schoolboy Synge's passion was birdwatching, along the banks of the River Dodder and in the grounds of the nearby Rathfarnham Castle (now owned by the state and open to the public). Summer holidays were spent at Greystones, near the Synge estate at Glanmore Castle, close by Ashford, Co Wicklow. His great-grandfather, Francis Synge (who built Glanmore), was one of the most prolific tree planters in Wicklow, becoming involved from the late 1700s and on into the following century (Carey 2009). Synge was, therefore, likely to have had a knowledge of forestry, and to have used it to inform his references to tree planting in the extracts reproduced here. He also spent a holiday at Avondale in 1897.

The extracts are from a series of articles Synge wrote in 1905, on commission from the *Manchester Guardian*, on the congested districts of the west of Ireland. He spent four weeks travelling through Galway and Mayo, in the company of Jack B. Yeats who provided illustrations to accompany the articles. Synge brings up forestry in the context of turf bogs being cut away, with a need for a replacement fuel. Increasing affluence, better transport and the availability of coal, and more recently oil, meant his predicted fuel shortage did not arise, and the use of wood fuel he advocates stayed at low levels throughout the 20^{th} century. Today, with rising oil prices and turf bogs increasingly off-limits, the situation has changed radically, with wood fuel use expanding rapidly, with some quantities coming from farm plantations established in areas similar to those Synge wrote about over a century ago.

An unsuccessful attempt to establish tree plantations near Carna is also described by Synge. This was the Knockboy project, described in detail by OCarroll (2004) who concludes: "More recent knowledge would leave little doubt that the primary cause of the failure of the tree crop at Knockboy was deficiency of soil phosphorus. Even with added phosphorus fertiliser the exposure would have had serious adverse effects on tree quality, and we have not enough knowledge of the effectiveness of the original drainage system to know whether it might have been adequate."

Despite the Knockboy setback, much has been learned in the intervening period, and the forest estate has expanded ten-fold since Synge wrote his articles for the *Guardian*. In a postscript he writes of possible remedies, including forestry, to improve the state of the people in the congested districts. But he warns against "… a sort of contempt for the local views of the people which seems rooted in nearly all the official workers one meets through the country." Synge may be too one-sided here, as experience suggests that there may also have been a reciprocal suspicion and mistrust of officialdom among the people. Attitudes have become less fixed, though a reticence to change still exists, which, together with subsidies, constricts the further expansion of forestry onto lands unfit for any other economic use.

Lia Coille

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Book Reviews

The Road to Avondale

Thomas Briody. Choice Publishing & Book Services, 2009
372 p. ISBN: 978-1907107-25-2
(Available from the Society of Irish Foresters. €15.00)

Today, most public figures publish a biography; politicians unusually do so when they retire from active politics and sports people see it as a fitting end to their careers. Until now, no forester in Ireland has done so. Tom Briody is the first and what a story he has to tell!

Tom was born in Mullahoran, in south west Cavan on 28th October 1913. This was one year before the outbreak of World War I and three years before the 1916 Rising. He attended national school when Ireland was ruled by Britain. At the age of 96 he published the first volume of his life story. The second volume is already written and will be published in late 2011.

Tom began recording his story in 1999 when he was in his late eighties. In all he filled 1,000 pages of "foolscap". He was assisted in his endeavours by his son Mícheál, who is a lecturer in the Language Centre of the University of Helsinki. Tom proofed the text as it was edited and checked the final draft twice. This is no mean achievement for a man at 96 years of age who retired in 1978, more than ten years before Coillte was established.

The book begins with his youth in Cavan and he tells the family story so intimately that the reader feels they are prying. His observations and clear recall of people and places are phenomenal. He was witness to a way of life that has long vanished. He describes going to Mass by a horse and trap. He describes in detail the types of timber used in thatch-roofed houses. His accounts of old farming methods are a marvellous record for future generations. But it is his reaction to and preoccupation with the Economic War in the 1930s that is a recurring theme in the book. Tom's love of our native language is evident throughout the book and his son Mícheál includes, in an appendix, a comprehensive account of the decline of the native language in Co Cavan.

Tom Briody's path to forestry was circuitous. It begins with a year in Ballyhaise Agricultural College in Co Cavan. He describes this year in great detail. It was here that he met some of his future classmates in forestry. Tom then went on to the Albert College in Glasnevin, an institution no longer in existence. Once again we get a very detailed description of life there.

The sections of the book that should be of greatest interest to foresters are Part IV and V. These chapters recount the life of a trainee forester. His account of lining out with a rope and spade is very descriptive, even somebody who never witnessed it will understand the process through the wonderful images he creates. Similarly he describes pit-planting and the importance of digging "soil pits" to ascertain which species was best suited to a particular soil type. It would appear that good workmanship was a *sine qua non* for these early foresters -as is evident in his description of laying down pole lines to ensure straight lines for planting, with the lines separated by five feet in all directions.

It is disappointing that none of this early work on the afforestation programme was ever documented. The state broadcasting service has many hours of archival material on the rural electrification scheme and peat development but none on our extensive afforestation programme. Perhaps this is something the Society of Irish Foresters should address.

Tom worked in four forest centres during his practical year; Kilsheelan, Aughrim, Kinnitty and Woodford. His account of the different treatment he received from the foresters-in-charge at these centres is a masterpiece in diplomacy –a career in which Tom would also have excelled! He was a qualified forester in Clonmel/Kilsheelan Forests and a forester-in-charge at Slievenamon Forest. He describes the difficulties encountered during the war in supplying firewood for industry. A recurring theme is the continuous moving about and the difficulty in finding suitable "digs" and houses. This story ends and the next book begins when he marries in 1943.

The reader is left with the impression that Tom Briody remains a positive and happy man despite the ups and downs in his life. As he says so often in the book, he feels he achieved a lot 'for his country' -a noble aspiration in today's world. Like his generation of foresters they achieved a lot with very little and for very little recompense. There may be a lesson in that for all of us today. I am eagerly looking forward to the second volume of his auto-biography.

John Mc Loughlin

(John Mc Loughlin is Vice-President of the Society of Irish Foresters.)

Stopping by Woods – a travel guide and history of Irish forestry

Donal Magner. Lilliput Press, Ireland, 2010.
544 p, ISBN: 9784813511700, €35 (hardback), €25 (paperback)

The author of *Stopping by Woods* will be known for his weekly column on forestry matters in the *Irish Farmers Journal*. Indeed, several of the forests included in the book were first featured in the Journal in 2004 in the series 'A Woodland near You' which marked the centenary of modern Irish forestry.

Shortly afterwards, he began compiling an account of forests and woodlands open to the public in Ireland. He has crisscrossed the country "seeking out woodlands with a story" in what must have been a fascinating journey to familiar and unfamiliar forests. The result is a book which is the first of its kind to be produced in Ireland and, as far as this reviewer is aware, the first of its kind in Europe. All the popular recreation forests are featured, but his epic journey in discovering and writing about the lesser-known woodlands makes for spellbinding reading.

He features Ireland's native and semi-natural woodlands, the mixed native and naturalised woodlands of the old estates and the forests established since the beginning of the last century. His account of the estate woodlands provides fascinating snapshots of the evolution of Irish forestry, even for foresters who will be well-informed about this aspect of our forest history. He is particularly adept at tracing the history of these estates and how they evolved into State forests, as typified in accounts of Moore Hall, Co Mayo, Coole Park, Co Galway, Curragh Chase, Co Limerick, Tomnafinnoge, Co Wicklow and lesser-known woodlands such as Ballysaggartmore Towers, Co Waterford.

He examines the role of the State in becoming directly involved in restoring the country's woodland resource when Irish forests had been radically diminished by centuries of exploitation and neglect. He explains why exotics have formed the main species mix and discusses with spirit about forests established at a time when forestry was known as "the land-use of last resort". He provides numerous case studies on the silvicultural rationale behind coniferous forestry. The book illustrates the productive and beautiful resource that has been created as foresters planted the "right trees in the right places".

In Gortin Glen in Co Tyrone, for example, he writes "there is no pretence about the silvicultural objectives" as the main aim was to "produce commercial spruce for the Irish wood-processing industry". He goes on to say: "Some of the pre-war Sitka is still standing and regardless of one's views about this species, it has a monumentality and presence that most species don't acquire until centuries old."

He delights in the diversity of Ireland's forests such as: Brackloon, Co Galway, "an echo of a distant world" when Ireland was covered in native and natural forest; Bonny Glen, Co Donegal with its "melancholic mood" where seven families of crofters lived. They sold their land during the Great Famine for the price of passage to America before "silence settled on this strange but beautiful glen".

The Green Road, Glenadlough Forest, an attractive walk through ancient sessile oak woodland. Photograph: Donal Magner

He writes knowledgeably about species selection, including the pine forest established at Raven, Co Wexford, where species choice was influenced by the famous French forests of Landes which were planted on the sand dunes around the Bay of Biscay. He is intrigued by the beech forest of Mullaghmeen, on the Westmeath-Meath border, reputedly one of the largest beech plantations in Europe.

One would have thought that in chronicling 340 forests by county, the site descriptions would become monotonous and repetitious but he manages to avoid this and maintains a freshness in the accounts. True, Sitka spruce and other fast growing conifers crop up repeatedly, but as he points out there are 53 species featured in the National Forest Inventory. These are all included, as well a many more that reflect species selection trends – "some experimental and some eccentric."

He emphasises that most of the sites are working forests where operations such as harvesting, planting and road making are essential to the livelihoods of the people who work the forests and the downstream industries that depend on timber. These are the forests featured in the State's open forest policy since the 1970s and now enshrined by Coillte and the Forest Service of Northern Ireland. In these forests he explains the rationale behind the various management operations and techniques.

He is a forester first and foremost and doesn't shirk from making the case for commercial forestry. A former technical councillor, PRO and vice-president of the Society of Irish Foresters, he is also at home in the woodlands managed by the National Parks and Wildlife Service and local authorities. His demonstrates his journalistic instincts by seeking out some fragmented woodlands in private ownership and in the hands of agencies and community groups.

The author has visited and researched every forest featured in the book, often making repeated journeys to take photographs. Though he surely cannot have been blessed with beautiful weather during the years 2007-2009, some of the photography featured is extremely beautiful.

This book should have a wide appeal and readership. Foresters will browse these pages because this is above all a celebration of their work, which the author readily acknowledges. The general reader will find much of interest in *Stopping by Woods*, as too will walkers, tourists and specialist groups, while teachers and lecturers could use this publication as a learning tool in the open classroom of the forest.

He describes the evolution of Irish forestry over the past few generations as "a quiet revolution" where "forest cover has doubled within two generations, benefiting both woodland owners and the forest industry". There are many facets to Irish forestry and commercial achievements are only part of the narrative. He writes: "Forests, however, are valued not only for their economic benefits, but for their enhancement of landscape, ecology, heritage and the soul."

Stopping by Woods is a welcome addition to the story of Irish forestry. It is also a useful book for these recessionary times as there is no charge in over 320 centres described, with only a modest fee for cars in the forest parks. It is a handsome volume and one that gives rise to the hope that private growers – mainly farmers – and the next generation of foresters will create a new wave of forests in Ireland as successfully as the previous generation.

Pat O'Sullivan

(Pat O'Sullivan is the Technical Director if the Society of Irish Foresters.)

Society of Irish Foresters Study Tour to Croatia 9 - 16 September 2009

On Wednesday, 9 September, 30 of the Society of Irish Foresters departed for Zadar, Croatia to begin the 66th Annual Study Tour. The group was welcomed at Zadar airport by our tour-leader, Ratko Matošević, of the Croatian Forest Service.

The total area of Croatia is 5.6 million (ha), of which 2.4 million ha (43%) are under forest. The State and its agencies manage 81% of the resource while 19% is privately owned. Total roundwood production in 2006 was 3.5 million m^3, with exports of 361,000 m^3. Exports of hardwood lumber typically include 50% beech, 30% oak, and 6% ash. Panels and veneer are also exported and Croatia is starting to increase its output of value-added products via foreign private joint ventures. Over 35% of timber products are exported to Italy.

Forest certification is now a major issue in Croatia. This was discussed during our visit especially in Hervatska Sume where FSC was introduced in 1991. By early 2002 approximately two million ha of Croatia's forests were FSC certified and in 2007 Croatia's certificate was renewed for a further five years.

Croatia's widespread practice of "Close to Nature Forest management" helped in securing FSC certification. Initially there was some resistance to the introduction of FSC certification from some forest districts but forest certification is less controversial now. The key driver for Croatia was its valuable export market for good quality hardwood timber, mainly to Italy with re-exports to the "IKEA" market in the UK and Benelux[1].

Under Croatia's certification scheme, 15% of the forest area must be set aside for biodiversity. Implementing these biodiversity requirements has been a problem at times e.g. in the Deluice region with mortality spreading among the fir trees, it had not been normal practice to retain decaying trees as "Dead Wood", as they became breeding sites for bark beetles.

Thursday, 10 September

The 40,000 ha Musapstan forest was planted during the Italian occupation in the early 1940s. The local forester Mislav Maršić explained that the main species are: umbrella or stone pine (*Pinus pinea* L. -34%), aleppo pine (*Pinus halepensis* Mill. -24%), Italian cypress (*Cupressus sempervirens* L. -22%), and holm oak (*Quercus ilex* L. -20%). The forest is classified as "borderline" Mediterranean. The area is very prone to forest fires and forest management regimes are dictated by forest fire protection requirements. The forest has 30 employees and a further 35 seasonal employees. An important aspect of their work is fire prevention and control.

There is very little timber harvesting – approximately 60% of the forest area is classified as degraded and no harvesting is carried out here. The remaining 40% is

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[1] The Benelux is an economic union in western-Europe comprised of three neighbouring countries, Belgium, the Netherlands and Luxembourg.

harvested. There the primary forest management objective is to remove the introduced species and plant native species under high forest. Coupes of 4–5 ha are harvested and planted with pioneer species such as aleppo pine and Crimean pine (*Pinus nigra* subsp. *palasiana* (Lamb.) Holmb.) with a view to improving conditions for native tree species. Silvicultural practice includes the removal of the pioneer species to allow native climax species to establish either through natural or artificial regeneration.

Forest fires are a major problem in this part of Mediterranean Croatia. The intensive forest roading system serves the dual purpose of facilitating speedy access and preventing the spread of forest fires. The main objective of the fire fighters is to act quickly before the fire spreads to the tree canopy where it is virtually unstoppable. Volunteer fire-fighting brigades are located in each village and are assisted by the army when tackling very large fires. In the Zadar Forest District and other regions, the spread of fires is assisted by the *bora*, a very strong, cold, north-easterly wind which can reach hurricane strength. Following severe fires, there is an increased danger of soil erosion. Normally this region receives an average of 700 mm of rainfall per annum, most of which falls in winter and there is a period of three to four months of very dry weather during the summer when forests are most at risk from careless forest users.

Approximately 60% of the forests in this region are classified as “degraded” and are typified by a very fragile ecosystem. The process of degradation is a gradual progression from high forest to scrub and seedlings, due to intense grazing, mainly by cattle and goats. With the exception of juniper (*Juniperis communis* L.) all the tree species are susceptible to grazing. Degradation is quickly followed by soil erosion and eventually only bare rocks remain. In recent years, there has been a significant drift of the local population into the towns so the extent of forest degradation is reducing. However, there are plans to build and develop recreational facilities here e.g. walking trails and mountain bicycle tracks, which will place further pressure on soil and emerging fauna, if not carefully managed.

Approximately 75% of the forests are owned by the state and the remaining 25% are privately owned. The average size of privately owned forest holdings is 0.4 ha. The land is very valuable for development because of its proximity to the city of Zadar and the Adriatic Sea. Forest land owned by the Republic of Croatia is managed by Hervatske Sume, the state forest service. During the period 1945–1947, the communist government nationalised the land and now descendants of the original owners are entitled to the return of their land or to receive compensation in lieu. To date, approximately 5% of the land area has been returned to its original owners, including almost 7,000 ha returned to the Catholic Church.

The private owner’s main sources of revenue are from the sale of fire-wood and hunting – mostly small game. The wolf population is increasing in Croatia and as the wolf is a protected species, the forest owner is fully compensated for all damage caused by wolves.

An interesting aspect of the Croatian economy is that 0.07% of all company revenues (not just profits) are “ring fenced” to finance the forest budget. This amounts to €35 million annually. In the Zadar Forest District most of it is spent on forest fire prevention measures and the restitution of unproductive forests.

Friday, 11 September

We headed north through the Karlovac area to the Slunj Forest office where we were welcomed by District Officer Zelsko Roddulie. He briefed us on aspects of forestry in this part of Croatia. While beech is the most common tree, oak (both sessile and pedunculate) is a more valuable species. Conifers make up about 15% of the forest area, comprising mainly common silver fir (*Abies alba* Mill.), Norway spruce (*Picea abies* (L.) Karst.) and Austrian pine (*Pinus nigra* Arnold.). Most of the forests are natural or semi-natural.

The State Forest Company, Hervatske Sume, has 9,000 employees and is divided into 16 Regions and 173 Forest Offices. The forest sector has an annual turnover of €300m but recently, because of the global economic downturn, has become unprofitable.

Oliver Vlawic, who is Vice President of the Society of Croatian Foresters, informed us about the Slunj forest and the surrounding area. Apparently, the population has declined from 15,000 about 100 years ago to 6,000 today. However, people have been drifting back to the area after the War of Independence (1991–1995). We then toured the nearby village of Rastoke which had mills powered by the many waterfalls in this limestone area. Our guide, Maria Jazbec, told us that the village architecture was protected and that any alterations or repairs to houses must be approved in advance by the local Council. Many of the houses and the nearby bridge were damaged during the war.

Figure 1: *The village of Rastoke.*

Having left Rastoke behind us, we visited an area that has regenerated naturally. The foresters, Zellio Simunovic and Dejan Toljan, outlined the plans for the region. An area of 133 ha was clearfelled, which is very large by Croatian standards, but the area was not worked on for some time as it was feared that there were land mines on the site. The crop removed was 160-year-old oak which was much older than the normal rotation. The regeneration period allowed was 10 years. A preparatory cut was first carried out in which 30-40% of the stems were removed, allowing more light onto the forest floor to encourage further regeneration. This thinning also resulted in a better yield of acorns. The better trees were left and when a good seed year occurred, the clearfell was completed. Where regeneration was poor acorns were imported and spread manually. On this site 80 tonnes of acorns were used.

Tending takes place for the first few years and species such as hornbeam (*Carpinus betulus* L.) are removed as they tend to suppress the oaks. In Croatia, hornbeam is rarely allowed to grow to maturity. When the young oak reach a height of approximately one metre, there is little further intervention for the next 10-15 years. Then the more poorly formed oaks are gradually removed. A small number of hornbeam are retained as an understory which helps to keep the lower boles of oak free of epicormic shoots. In Croatia, beech is generally kept separate from oak as it is too aggressive a competitor.

We then visited a beech forest and were welcomed by foresters Zvonho Piuzic and Krundoslav Biscan. The beech stand was 42 ha in extent and was 110-years-old. It had already received a thinning in 2008 when 3,100 m^3 were removed. Over the next seven years there will be up to three further thinnings. The final felling is carried out with great care to avoid damage to the regeneration; skidders are restricted to existing tracks. Following an excellent lunch we travelled east to Zagreb.

Saturday, 12 September

We visited the headquarters of the Society of Croatian Foresters in Zagreb where we were welcomed by the Secretary, Damir Delac. Founded in 1846, the Society is very proud of its long tradition. It is the third oldest society in Europe – only those in Baden-Württemberg in Germany and Switzerland are older. The building is owned by the Society and used to house the university's faculty of forestry for many years. The faculty has a renowned school of forest management which is based on natural regeneration. It has been publishing a scientific journal for 133 years, as well as many books and literature on forestry in recent times. It has 3,000 members in four sections:

- Pro-Sylva;
- Biomass;
- Ecology;
- Forest Protection.

We then proceeded to the Medvednica Mountains to the north of the city. These mountains overlook and dominate the city of Zagreb. There we were welcomed by

Hubert Krauthacker who told us that they have the same problems in Zagreb as in any city forest; mainly people-pressure and vandalism! The most contentious management issue is always harvesting. However, the park is highly regarded by the public as it is a very people-friendly forest/nature park with good signage and pathways, including some trails designed for wheelchair users.

The total area of this forest is 22,500 ha, of which 16,500 ha are forest and the remainder comprises meadows and ski slopes. The state owns 8,500 ha of the forest and the balance is privately owned, mainly by the Catholic Church. Over half the forest is composed of beech while oak, silver fir and Spanish chestnut (*Castanea sativa* Mill.) are also prominent. We visited a sawmill which was closed in 1972 but has been skilfully converted to a museum and coffee shop. This sawmill used to produce wooden wheel-barrows for the Russian market after World War II!

The Medvednica mountains rise to a little over 1,000 m in altitude. The forest is formed of a sessile oak/hornbeam mixture in the lower slopes (up to 400 m), from 400 to 700 m, beech followed by a beech/silver fir mixture becomes prominent while ash (*Fraxinus excelsior* L.), maple, Norway spruce and sycamore (*Acer pseudoplatanus* L.) mixtures dominate the forest above 700 m, with pure stands of silver fir closer to the summit.

Our final stop was at a small mountain-top church which is dedicated to Our Lady of Sljeme. Here we were welcomed by Fr Joseph who ministers in the area. The church was built in 1932 to commemorate two jubilees - 1,000 years of Croatian nationality and 1,300 years of Croatia's conversion to Christianity.

Sunday, 13 September

We headed west to Delnice, a mountainous area close to the Slovenian border. The average elevation there is 730 m. This area has 75% forest cover, the highest in Croatia. Forestry is the most important industry with 50 small sawmills in the region with an annual throughput of 40,000 m^3 of roundwood.

We were welcomed by Vlado Cure at the Golubinjal Forest Park, who told us that the region's forests comprise a mix of conifers (60%) and beech with some maple (40%). The rainfall is very high, averaging 2,000 mm per annum. The main conifers here are silver fir and Norway spruce. The silvicultural system employed here is the Selective Forest Management System, with the aim of having a continuous-cover system. Conifers are harvested throughout the year, though broadleaves only in winter. Because of the mountainous terrain, forest road density tends to be high in this region – over 23 m/ha. In this region, forest decline has been an issue for the past 15 to 20 years and consequently much of the harvesting is for sanitary purposes. Forest decline has been less severe in recent years and this is probably as a result of the demise of many heavy industries which were located in the south.

The main forest activities are:

- Harvesting;
- Hunting (brown bear, red and roe deer, wild boar);
- Nurseries;
- Tourism.

A lot of resources have been employed in developing infrastructure for tourists. We visited a nearby tree trail in the 51 ha Golubinjal Forest Park, a limestone landscape with caves and excellent examples of silver fir and beech. One of these silver firs was 226-years-old, with a height of 42 m, diameter of 1.42 m and a volume of 32 m^3. The area was designated a Forest Park in 1955 but it has been a favourite resort since the beginning of the 20^{th} century.

We then headed west to the Istrian peninsula for the remainder of our tour.

Monday, 14 September

The tour party left Opatija early on Monday morning to begin the long journey to catch the ferry to the Brijuni Island National Park. On the journey we observed extensive excavation for road construction and bridge building. The soil, known locally as "*terra rosa*", has a pronounced red colour due to its high iron content.

There were numerous small groves of olive trees (*Olea europaea* L.) growing throughout the countryside. A noticeable feature of the locality were the small, circular, stone-roofed houses which were used by shepherds in the past when sheep-farming was an important farm industry. Animals once played an important role in the economy and in the lives of the Istrian people. The donkey was used mainly for transport of goods and people. Because of the Karst terrain with poor paths, fragmented cultivable areas and a lack of food, the donkey made a reliable working animal.

The arrival of the Romans on the archipelago of Brijuni led to significant economic, social and cultural changes and eventually, to a new way of life on the islands. Today, there are many excavated villas and temples to be seen. Venetian rule commenced in 1337. During the next four and a half centuries, Brijuni was subjected to repeated exploitation of natural resources - mainly stone and firewood. When Venetian rule came to an end in 1797 the islands were totally devastated and were abandoned.

In the eighteenth and nineteenth centuries the area was infested with plague. Paul Kupelwieser, an Austrian industrialist bought the island in 1893. Kupelwieser, with the help of experts in the fields of health and estate management, began to restore the island to its former splendour. World Wars I and II impacted severely on the island and led to renewed decline. From 1947 to 1980, President Tito of Yugoslavia had a residence on Brijuni, where he entertained many world leaders. In 1983, Brijuni was designated a national park and now attracts more than two million visitors annually.

The park superintendent, Milos Uarad, informed us that because of its economic, cultural, religious and mythological significance, the olive tree is the most important tree on the island. Milos then brought the party to the "old olive tree", which is the oldest tree on the island and probably one of the oldest olive trees in the entire Mediterranean area. It is about 1,600-years-old according to carbon-14 dating analysis, though it still produces about 30 kg fruit every year (which is pressed to produce the finest quality oil!).

The party then boarded the ferry for the mainland and then on to Poreč.

Tuesday, 15 September

The day commenced with a guided tour of Poreč, a popular tourist location, which has a population of 12,000. The town was established around 100 BC and contains many fine remains of Roman buildings. Poreč had many rulers from medieval times to the present. Some residents, like the grandfather of our guide, Cedomir Krizmanic, have over the course of their lifetimes been citizens of four different states while remaining in the same house.

The party proceeded to a holm oak forest, developed from a stand which was coppiced 30 years ago. Forests in the area are intensively managed and after 60 – 80 years are left to regenerate naturally. The abundant light that has been allowed in by the thinning assists the regeneration. The absence of rain for up to two months during the summer and the risk of fire are the main problems encountered when trying to regenerate an area.

Black pine (*Pinus nigra* Arnold.) is considered a suitable species in this location as it can survive periods of drought. Approximately 46% of the forests are state owned with the balance in private ownership. Private ownership has increased in recent years and a free forestry advisory service is now available to growers. When planning and designing forest plantations here, it appears that greater emphasis is put on soil protection and shelter than on securing direct economic benefits.

The party then visited the Boredine cave, which contains distinctive reddish coloured stalagmites and stalactites due to the presence of iron oxide. The caves descend to a depth of 120 m. where a miniature and transparent crayfish (*Prateus anguinus*) can be found.

Our next stop was at a mixed oak and ash forest in the vicinity of the hill-top town of Motovun. This is a very untypical plantation in a Mediterranean region. The species selection was influenced by the soil of the Mirna river valley which is very fertile. The area has always been a state forest and in the past it was used to provide timber for shipyards.

The forest is extensively used during the truffle hunting season, which begins in September and continues into late autumn. It is regarded as one of the best truffle sites in the world. The truffle is a highly prized delicacy and locals use specially trained dogs to sniff out the truffles which look like small tubers and are found at the roots of oak trees. Truffles are an important source of income for the local population and the truffle hunting season has been compared to an annual gold rush over the 1,200 ha forest.

The party returned to Poreč for the final night of the tour.

Wednesday, 16 September

Krasno was the first Forest District in Croatia and was established in 1765, it was instituted as the Royal Inspectorate for the Afforestation of Karst land in 1878. Most of this district is classified as “Nature Park”. However, it has a low level of protection so some economic activity is permitted, but all forest operations must secure prior approval. The main species are beech, silver fir and juniper. The average elevation is 1,100 m.

The Forestry Museum at Krasno occupies a 130 m^2 building and contains 360 exhibits and a library of 560 books. It houses documents relating to forest management practices in the 18^{th} and 19^{th} centuries, old land-surveying instruments and maps, log marking stamps, nursery production and silvicultural tools and chain saws. It provides a fascinating glimpse of early forestry in Croatia. The records of forest harvesting, dating to the 13^{th} century, along with other documents and memorabilia demonstrate the rich tradition of forestry in this beautiful country which will serve it well as it grows and develops its forest industry.

Date	***Recorder***	***Accommodation***
Wednesday, 9 September	Travel to Croatia.	Hotel Porto, Zagreb
Thursday, 10 September	Pat O'Sullivan	Hotel Jezero, Plitvice
Friday, 11 September	John McLoughlin	Hotel Jadran, Zagreb
Saturday, 12 September	John McLoughlin	Hotel Jadran, Zagreb
Sunday, 13 September	John McLoughlin	Hotel Opatija, Opatija
Monday, 14 September	Frank Nugent	Hotel Neptune, Poreč
Tuesday, 15 September	Frank Nugent	Hotel Neptune, Poreč
Wednesday, 16 September	Tour end. Return to Dublin	

Tour Participants

Marie Aherne, P.J. Bruton, Richard Clear, John Conneff, John Connolly, Jim Crowley, Ken Ellis, Pat Farrington, Jerry Fleming, Brigid Flynn, Tony Gallinagh, Eugene Griffin, Kevin Kenny, P.J. Morrissey, Liam Murphy, Tom McDonald, P.J. McElroy, Willie McKenna, Jim McHugh, John McLoughlin, Jim Neilan, Frank Nugent, Benny O'Brien, Michael O'Brien, Liam O'Flanagan, Paddy O'Kelly, Denis O'Sullivan, Pat O'Sullivan, Tim O'Regan, Trevor Wilson.

Figure 2: *The tour group at Plitvice Waterfall.*

Obituaries

Kathleen Clear
1913 - 2010

Kathleen Clear (nee Mitten) was born in Wexford town on April 4th 1913. The eldest of 5 children, her father died when she was 6-years-old. When she was 19-years-old, Kathleen left for Gibraltar and taught English at the Loreto Convent there (having herself been a Loreto girl in Wexford).

On returning to Ireland, and while visiting a cousin who was married to a forester in Gort, Co Galway, she met her future husband. This man, Tom Clear, was later to become not only the longest serving Professor of Forestry in University College Dublin, but also an iconic figure in Irish forestry. Kathleen and Tom were married on September 5th 1939 and were blessed with a large family. One of their sons, Richard, followed in his father's footsteps by pursuing a career as a professional forester.

When the Society of Irish Foresters (SIF) was founded in 1942, Tom Clear was the leading mover behind this development. During those early years, when he acted as both secretary and treasurer, Kathleen was widely recognised as being a huge support to her husband in these roles and in fact did most of the secretarial work of the Society. Her work for the SIF, though behind the scenes, was both diligent and comprehensive.

Kathleen was a constant companion to her husband on his many forestry trips, both at home and abroad. These included numerous SIF field days and other events as well as a 'Kelloggs Foundation' funded tour to New Zealand to study the forestry of that country. These activities eventually led to Kathleen becoming an Associate Member of the SIF, something which she continued until her death on August 24th 2010. She was 97-years-old.

The Society recognised her contribution to its work when, in 2009, she was presented with a framed copy of the letter which her husband Tom circulated in September 1942, calling the inaugural meeting of the SIF. I had the pleasure of meeting Kathleen on that occasion and found her to be a warm and charming person and still keenly interested in forestry matters.

Kathleen is predeceased by her husband and sons, Martin and Declan.

To Michael, Judith, Mary, Aidan, Colman, Eoghan, Simon and Richard, we offer our deepest sympathy.

Kevin J. Hutchinson

Elizabeth Furlong
1922 - 2010

Elizabeth (Lily) Furlong, who died on 26th October, was one of the most widely known staff members of the state Forest Service, formerly the forestry Division of the Department of Lands.

Born in Dublin in April 1922 of Wexford parents, she went to school in the Loreto College in North Great George's Street, and having attended a secretarial course, entered the Civil Service in 1942.

In the course of her career she worked closely with two Chief Inspectors: Seán O'Sullivan (1948 - 64) and Tim MacEvoy (1973 - 82) but was for a long time quietly influential in the background. She also acted as informal and unofficial 'welfare officer' for all members of the technical staff, both Foresters and Inspectors. I clearly remember shortly after my recruitment being brought to her small office in the top floor of Upper Merrion Street by 'Mister Mooney' and introduced to 'Miss Furlong' (things were more formal in those days) and told 'this is where you come with all your troubles'. She was fond of quoting a former senior officer in the Forestry Division who complained about the quality of typing in a letter he was given to sign. 'But it's only going to so-and-so' said the typist. 'It doesn't matter where it's going to' he replied; 'what is important is where it's coming from'.

Lily joined the Society of Irish Foresters as an associate member in 1951. She was first elected as an Associate Councilor in 1958 and was a near constant in that position until 1996.

Her contribution to the running of the Society, mostly behind the scenes, as a council member and as an ordinary member was immense, among other things working with Miss O'Glynn's Secretarial Service to see that relevant notices and circulars went out on time. That service was acknowledged by her election to Honorary Membership in 1999, one of only three non-foresters elected to that position.

The Journal did not until recently record the names of all those attending Annual Study Tours, but I know from personal knowledge that she attended the Black Forest Tour in 1956 and all such tours that I attended since then. On Study Tours she was on constant alert to ensure that everything went smoothly and to plan.

Lily died on 26th October 2010. She is survived by her sisters Peg, Kathleen (Fahy) and Joan (Green). To them we extend our deepest sympathy.

Niall OCarroll