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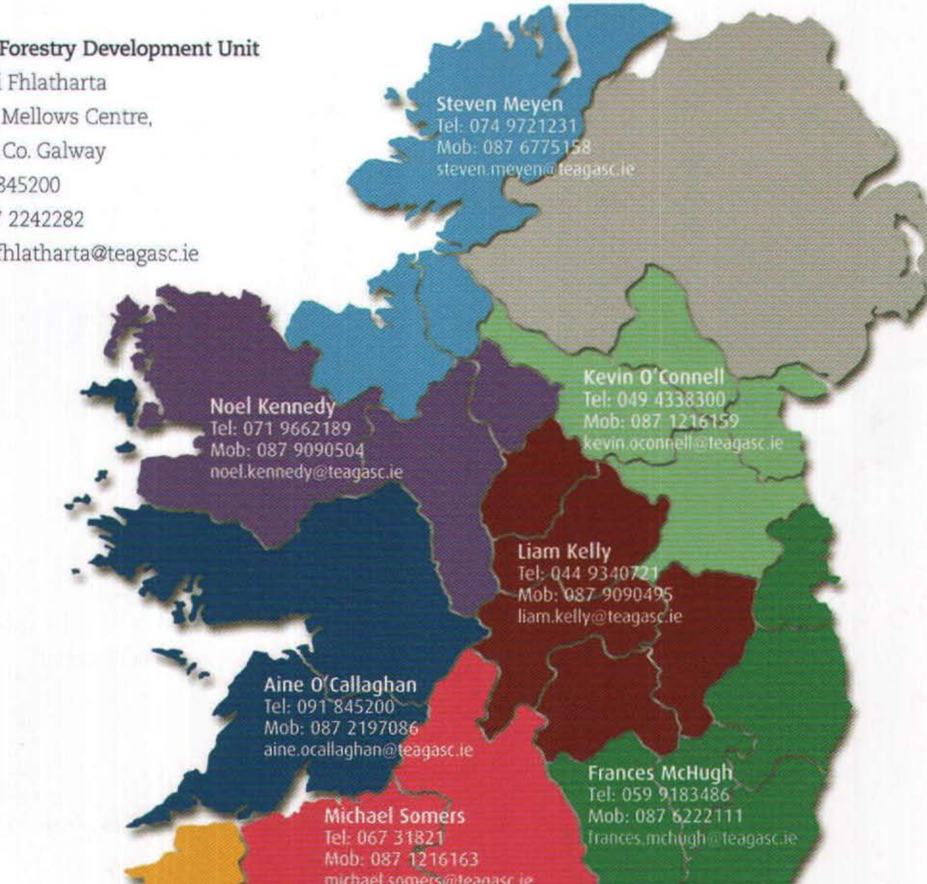

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3. Correct spelling, grammar and punctuation are expected. Nomenclature, symbols and abbreviations should follow established conventions, with the metric system used throughout. Dimensions should follow units with one full space between them, for example 10 kg.
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EDITORIAL

Protecting our forests

Ireland's forests are remarkably healthy and free of many insect pests and diseases that cause catastrophic damage abroad. Lodgepole pine, for example, is currently being devastated by mountain pine beetle attack in western Canada. Such is the level of attack that the decay of dead and dying trees is predicted to release 270 million tonnes of carbon dioxide into the atmosphere - four times Ireland's annual level of greenhouse gas emissions.

The healthy state of our forests is down to good species selection practice, allied to geographic isolation and the effective implementation of plant health regulations by the Forest Service.

Success in keeping out harmful insects and fungi has not however been matched in dealing with deer and grey squirrel, which have decimated significant areas of young forest, particularly broadleaves. Such is the level of damage that some stands have been reduced to firewood quality. And the problem is not going away; the paper on the Wicklow deer herd in this issue shows the fecundity of sika deer and its ability to expand almost at will. Recent work has also shown the grey squirrel population is rapidly expanding – as is the level of damage in young broadleaf stands.

What then is to be done? First of all the excellent work that the grey squirrel project, funded by the Forest Service, should be continued, particularly in raising awareness among the public and preparing the way for a concerted programme of control. Second, the two main agencies concerned with the issue: the Forest Service and the National Parks and Wildlife Service should implement joint, long-term control programmes for deer and grey squirrel, in priority areas and in cooperation with landowners and hunters. Much can be done through mobilising and targeting existing resources, in the framework of an agreed plan. Third, landowners considering forestry should be made fully aware of the risks inherent in planting certain species and the likely need for future control measures.

Education of landowners and the public, allied to long-term national control programmes will go a long way towards dealing with the mammal problem. Developments in control systems, such as immunocontraception may also, in time, offer a sustainable solution, and there are signs that natural predators are impacting on grey squirrel numbers. In the meantime, there is an urgent need for concerted action at the national level to protect our forests from deer and grey squirrel damage.

Environmental and social enhancement of forest plantations on western peatlands - a case study

Dermot Tiernan[a]

Abstract

A case study was carried out on future management scenarios for Western Peatland Forests (WPFs) along the Western Seaboard. It indicates a change in emphasis from wood production alone to a broader ecosystem management approach with increased emphasis on environmental and social objectives. Productive and financial potentials of typical WPFs were examined, and redesign plans were developed, consistent with an ecosystem management approach. Both the productive and financial potential of WPFs were found to be challenging under current conditions; options to improve this situation are presented and discussed. The impact of redesign planning was quantified in terms of biodiversity enhancement, bog restoration and protection, enhanced watercourse protection and visual landscape improvement. Impacts were projected to a national level to indicate future management scenarios for WPFs.

Keywords

Peatland forests, redesign plans, sustainable forest management, financial appraisal.

Introduction

The first attempt at afforestation of western peatland dates to 1892, on an exposed impoverished blanket bog at Knockboy, near Carna in Co Galway. It ended in failure due to the unsuitability of the site for tree growth (Durand 1998). However, experimentation from the 1950s, on drainage and nutrition methods, enabled the establishment of forest plantations on peatland (OCarroll 1962, Farrell and McAleese 1972, Dickson and Savill 1974, Gallagher, 1974, Galvin 1976, Farrell and Mullen 1979, Gleeson 1985, Farrell and Boyle 1990).

The extent of afforested peatland has been estimated as 200,000 ha, with the greater part occurring in the west of Ireland (Farrell 1990). Since 1990, a further 22,633 ha of unenclosed land has been planted along the western seaboard (Forest Service 2006), bringing the total to over 223,000 ha. Overall ownership of Irish forests is 58% public (Coillte – The Irish Forestry Board), with the balance privately owned (Forest Service 2003).

Western Peatland Forests (WPFs) occur along the length of the western seaboard, from Donegal in the north to Kerry in the south. Peatlands in the region consist mainly of low-level and high-level blanket bog. The majority of WPFs were established between the early 1960s to the late 1980s, and served an important social function, whereby afforestation provided a means of employment in disadvantaged areas (Tiernan 2004). Today, afforestation of western peats has declined (Renou and Farrell 2005), largely due to the designation of peatland Special Areas of

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Conservation (SACs) – under the EU Habitats Directive - and as Natural Heritage Areas (NHAs), and the movement to better quality forest land.

At the time when most forests were being established on peatland, it was regarded as 'waste land', mainly because it was unsuitable for agriculture. Today, many peatlands are regarded as rare and endangered habitats with high ecological value. This is of particular importance as Ireland now retains one of the largest areas of peatlands remaining in Western Europe (The Heritage Council 1992).

Forests on western peatland are mainly first rotation. All were planted with the twin objectives of providing employment and adding to national wood production (Farrell 1997). As the forests mature it is clear that a single focus on wood production is not attainable from an economic, environmental or social perspective. There is a need to adopt a multi-objective management approach, with the view to redesign during reforestation to provide a greater range of services in the future.

The case study reported here sampled WPFs in the Coillte estate, in order to develop a range of redesign plans, with the view to balancing environmental and social benefits with future forests. The impact of the plans was analysed, and the results extrapolated to the full Coillte estate, to provide a basis for sustainable management of these areas into the future.

Objectives

The objectives of the case study were:

- to quantify the wood production potential of WPFs,
- to redesign WPFs for the second rotation so as to balance economic, environmental and social objectives,
- to analyse the possible impacts of redesign plans on the future management of WPFs and
- to conduct a financial appraisal of forestry on western peatlands.

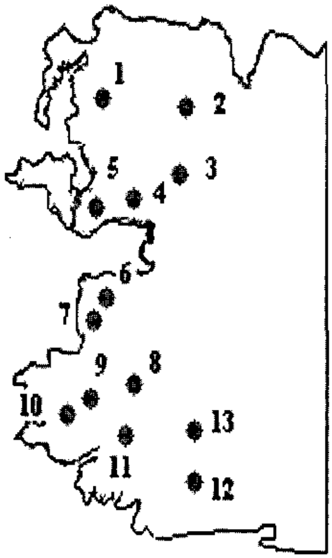
Materials and methods

Management redesign plans

A total of 13 forest properties in the Coillte estate was examined in counties Mayo (7) and Galway (6), covering an area of 7,926 ha (Figure 1). They represented a 3.9% sample of the total estimated area of afforested blanket peatland in the Republic of Ireland. The properties ranged from 42 ha to 3,008 ha, with an average of 610 ha. Each property was visited, assessed and mapped.

Redesign plans were drafted for each site using a standard approach, in order to address environmental and social issues, as well as future wood production (Table 1). The approach was developed by Coillte in 2003/2004 as part of an internal company project that investigated possible future management strategies for low production plantations on western peatlands (Tiernan 2004).

Redesign required both field visits and utilisation of Coillte's IT forest management tools. Comprehensive, long-term management plans were developed for each of the 13 properties. Planning consisted of five steps (Table 1):



	Coillte property name	*County*	*Inventory area (including open space) ha*
1	Drumanaffrin	Mayo	80
2	Corrovokeen	Mayo	376
3	Coolnabinnia	Mayo	183
4	Glendahurk & Glenamong	Mayo	724
5	Cartron	Mayo	957
6	Loughnamucka	Mayo	523
7	Tawnydoogan	Mayo	318
8	Shannaunnafeola	Galway	73
9	Finnisglin	Galway	52
10	Derrylea	Galway	42
11	Cappahoosh	Galway	1,241
12	Finnaun	Galway	3,008
13	Derreen	Galway	351

Figure 1: Coillte properties in counties Mayo and Galway that formed the sampling frame for the case study.

1. Forest details (before/after plan),
2. Planning considerations,
3. Assessment of wood production potential,
4. Redesign management prescriptions and
5. Management redesign plan.

Step 1: Forest details (before/after plan)

Forest areas in each property were allocated to one of 16 categories (Table 1). Areas were calculated before and after the redesign plan, using a combination of the Coillte GIS system and manual methods. Area-wise comparisons were made for each category.

Step 2: Planning considerations

A total of 26 planning considerations were applied to each redesign plan (Table 1). These considerations were broadly classified under wood production, statutory designation, environmental and social and visual. These considerations were evaluated for each property during the redesign process.

Step 3: Assessment of wood production potential

Yield class[2] was assessed for all crops in each property (Table 1) and was mapped using three colour-codes:

[1] Defined as potential maximum mean annual volume increment (to 7 cm top diameter), in units $m^3 ha^{-1} y^{-1}$.

Table 1: Overview of the methodology used in the redesign of western peatland forests (WPFs).

Step 1: Forest details (before/after plan)				
Total area	*Forest cover*	*Coniferous forest*	*Broadleaf forest*	*Extend to MMAI*
Inaccessible	Unsuitable for forestry	Unplantable	Water/Swamp	Turbary
Long term retention				
Buffer zones	Open space	Roads/ridelines	Undeveloped (stunted crops)	Bog restoration
Straight edge redesign				
Step 2: Planning considerations				
Timber production	*Statutory designations*	*Environmental*	*Social*	*Visual*
Wood production	SAC	Fisheries	Recreation	Improvement of visual appearance
Wood production potential	NHA	Avian	Archaeology heritage	Landscape sensitivity
Access roads	SPA	Wildlife	Adjacent residences	Landscape
Windthrow risk	National park	Forest health		Public view points
Exposure	Nature reserves	Climatic factors		Landform analysis
Soils	Freshwater pearl mussel catchments	Acid sensitive areas		
Step 3: Assessment of timber production potential				
Green (good) YC $\geq$ 16	Amber (intermediate) YC 12-14	Red (poor) YC $\leq$ 10		
Step 4: Redesign management prescriptions				
Retention of existing open space	Creation of extra wide buffer zones	Long term retention	Bog restoration & protection	Straight edge redesign
Step 5: Management redesign plans				
Forest details summary (before/after plan)	Main planning considerations	Assessment of wood production potential	Biodiversity plan	Water protection plan
Reforestation plan	Landscape design plan	Non-wood benefits plan		

1. Green (good): yield class ≥ 16
2. Amber (intermediate): yield class 12-14
3. Red (poor): yield class ≤ 10.

Step 4: Redesign management prescriptions

Five redesign management prescriptions were considered for each property (Table 1):

1. retention of existing open space,
2. creation of extra wide buffer zones,
3. long term forest retention,
4. bog restoration and protection,
5. straight plantation edge redesign.

Open space occurred in all properties, corresponding to infertile areas left unplanted; these areas were retained. The creation of extra wide buffer zones was determined by the sensitivity of the adjoining watercourse and local topography. Current guidelines require widths of between 10 and 25 m, depending on slope. In comparison, the extra wide buffer zones varied in width from 50 up to 100 m, involving the creation of new buffer zones and the extension of existing ones. Long-term forest retention was determined solely by inaccessibility for harvesting. Bog restoration and protection were selected for areas on the basis of ecological reports (where available), areas with a physical or hydrological link to adjoining peatlands with statutory protection, areas containing swamps, and areas where the vegetation present suggested good potential for successful restoration. Straight edges were removed by designating boundary areas to be left unplanted at reforestation.

For all properties, bog restoration and protection and straight edge redesign occurred once the crop was felled, as did the installation of extra wide buffer zones. Retention of open space and long term forest retention could clearly be carried forward in the absence of felling, once the plan was in place.

Step 5: Management redesign plan

Each property had its own management redesign plan that contained eight key features (see also Table 1):

1. forest summary (before/after plan),
2. main planning considerations,
3. assessment of wood production potential,
4. biodiversity plan,
5. surface water protection plan,
6. reforestation plan,
7. landscape design plan and
8. non-wood benefits plan.

Financial appraisal of forestry on WPFs

A model was developed to guide financial appraisal of forestry on WPFs. The scope was limited to pure lodgepole pine crops, where the harvestable material was exclusively pulpwood. Other permutations, such as pine crops with additional pallet and/or small sawlog assortments, or crops containing other species or mixes were not considered. Therefore, the results from the model should be viewed with caution and only within the context of WPFs which contain pure lodgepole pine pulpwood crops.

Using current costs and revenues, a Microsoft Excel-based model was developed to calculate discounted revenue over a rotation for pure lodgepole pine, for yield classes 6-18. The discounted revenues provided an indication of the maximum amount of revenue potentially available for reforestation of typical WPFs. The model was:

$$\textit{Discounted revenue (€/ha)} = (\textit{Volume/ha} \times \textit{Stumpage€/ha})/(1.0p)^n$$

volume/ha was obtained from a lodgepole pine (south coastal) yield model (Forest and Wildlife Service 1975),
stumpage was calculated as sales price (€/m^3) - harvesting cost (€/m^3) - transport cost (€/m^3), expressed on a hectare basis,
p was the discount rate, chosen at 5%,
n was the age at clearfelling.

Volumes (m^3/ha) were based on a no-thinning regime, at 2.0 m spacing. A stumpage of €6/m^3 was calculated, based on a typical price €32/m^3 for pulp, €19/m^3 harvesting costs and €7/m^3 haulage costs (assumed haulage to a local mill within an 80 km radius). A discount rate of 5% was chosen at it is the one commonly used for forestry financial appraisal. Output from the model is presented in Figure 2.

The impact on discounted revenue of changes in roundwood price was also assessed. For ease of analysis, only discounted revenues at MMAI were considered (Figure 3). The assessment indicated the expected roundwood revenues (per m^3) required for

- harvest and transport operations to break-even and
- harvest, transport and subsequent restocking operations to break-even.

Results

Assessment of wood production potential

Results (Table 2) indicated that 650 ha (11%) of the 6,257 ha sampled had good wood production potential (YC 16+), 3,031 ha (48%) were intermediate (YC 12-14), while 2,578 ha (41%) had poor wood production potential (YC $\leq$ 10). As expected, the range differed significantly between properties. Of the properties examined, those with good wood production potential ranged from 0-47%, while the corresponding ranges for the intermediate and poor categories were from 0-79% and 5-100%, respectively. Of the 13 properties examined only nine contained all categories (good, intermediate and poor wood production potential). Four properties did not have any areas with good wood production potential (YC $\geq$ 16); of these, only two (Derrylea & Drumanaffrin) were categorised as having only poor wood production potential (YC $\leq$ 10).

Table 2: Assessment of wood production potential by property.

Property	*Wood production potential*						
	Forest area	*Good (YC ≥ 16)*		*Intermediate (YC 12-14)*		*Poor (YC ≤ 10)*	
	ha	*ha*	*%*	*ha*	*%*	*ha*	*%*
Cartron	459.0	-	0	128.5	28	330.5	72
Coolnabinnia	135.7	12.2	9	10.9	8	112.6	83
Corrovokeen	341.6	68.3	20	194.7	57	78.6	23
Glendahurk & Glenamong	685.3	41.1	6	294.7	43	349.5	51
Loughnamucka	499.1	79.9	16	394.3	79	25.0	5
Tawnydoogan	264.3	44.9	17	23.8	9	195.6	74
Cappahoosh	926.0	9.3	1	518.6	56	398.2	43
Derreen	320.5	73.7	23	192.3	60	54.5	17
Derrylea	32.7	-	0	-	0	32.7	100
Drumanaffrin	75.6	-	0	-	0	75.6	100
Finnaun	2,408.6	289.0	12	1,228.4	51	891.2	37
Finnisglin	44.5	-	0	17.8	40	26.7	60
Shannaunnafeola	67.1	31.5	47	27.5	41	8.1	12
Total	6,257.3	650.0	11	3,031.4	48	2,578.6	41

Management plans by redesign management prescriptions

Of the total area of 7,926.1 ha (including open space), 21% (1,666.1 ha) consisted of unplanted open space, with the remaining 79% comprising the forest area. Following redesign, the forest area was subdivided as follows:

- 13% (842.9 ha) suitable for long term retention,
- 8% (500.1 ha) for the creation of extra wide buffer zones,
- 8% (487.4 ha) suitable for bog restoration and protection and
- 1% (62.8 ha) for straight edge redesign.

Existing open space ranged between properties from 4-52%. Ranges for long term retention areas were from 0-96%. Areas for extra wide buffer zones ranged from 0-27%, while areas suitable for bog restoration and protection ranged from 0-13%. Finally, areas used for straight edge redesign ranged from 0-4%.

Financial appraisal of forestry on WPFs

Despite favourable price assumptions, discounted revenues were low and would place a limitation on revenue available for reforestation on typical WPFs (Table 3). Using the stumpage discounted revenue criterion, the maximum available spend for reforestation ranged from €170 and €658/ha, for the range of yield classes from 6 to 18 (Table 3).

Table 3: Available spend for reforestation on WPFs based on discounted revenue.

Yield class $m^3\ ha^{-1}\ y^{-1}$	*Rotation years*	*Discounted revenue €/ha*
6	37	170
8	35	246
10	33	327
12	30	409
14	30	482
16	29	590
18	28	658

For all yield classes observed, the maximum discounted revenues had rotation lengths of between 28 and 37 years for yield classes between 6 and 18 (Figure 2).

The sensitivity analysis (Figure 3) showed that the discounted revenues for lodgepole pine crops were directly proportional to increases in roundwood prices, with greater values associated with the higher yielding crops. The break-even roundwood price for the cost of harvest operations, including transportation to a local mill but excluding subsequent restocking, for all yield classes was 26 €/m^3. When the cost of restocking was included, the price required to break-even was dependent on yield class, with lower yield classes requiring higher roundwood prices to break-even. For example, assuming a restocking cost of €2,500/ha, the roundwood price

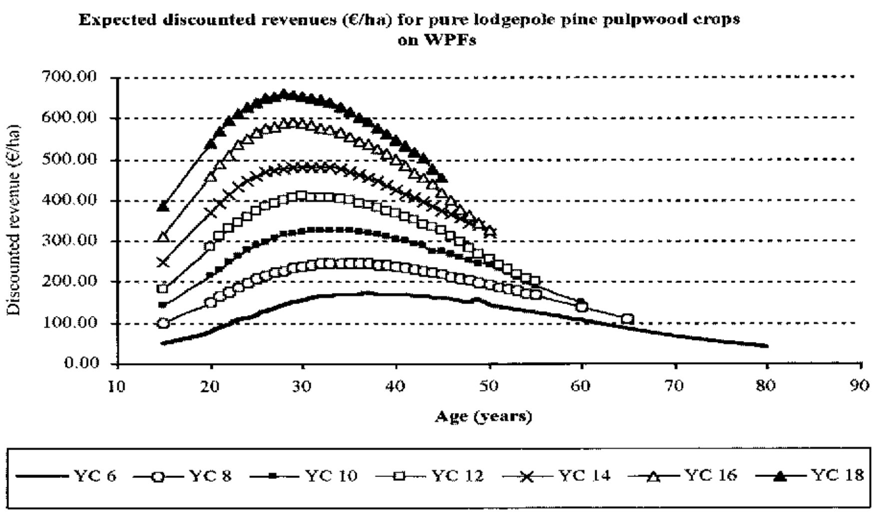


Figure 2: Effect of yield class and rotation length on the discounted revenue of pure lodgepole pine pulpwood crops on WPFs.

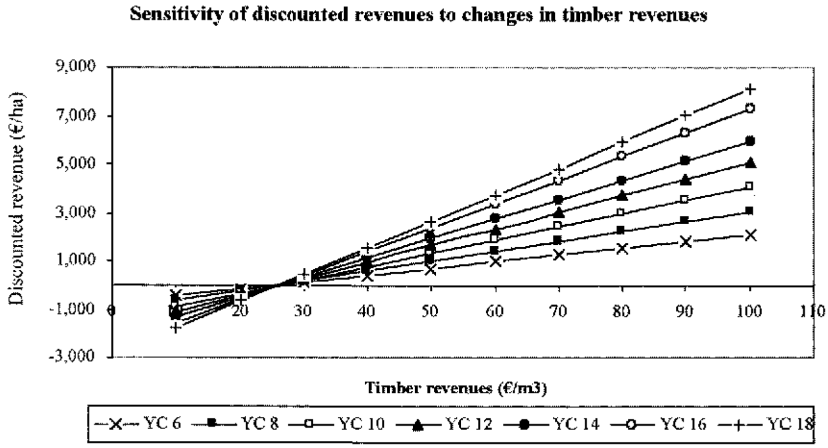


Figure 3: Sensitivity of discounted revenue at maximum mean annual increment (MMAI) in lodgepole pine crops (YC 6- 18) to roundwood price.

required to break-even was in the range of 49-115 €/ m^3 for yield classes 18 and 6 respectively.

Discussion

Over 40% of WPFs were found to have poor commercial potential, with the remainder having good or intermediate potential. Achieving future commercial investment (reforestation) in these areas will be challenging, with break-even costs limited to between €170-658/ha. However, the 1946 Forestry Act requires all forests that are felled to be replanted. A possible solution consistent with the Act would be to reforest using reduced stocking densities (1,000–1,500 stems/ha), with no ground preparation and minimal management. This could be justified economically, as the cost would be within the break-even range indicated. However, the role of these forests would change from a commercial function to the provision of a biomass crop and the retention of carbon stocks.

WPFs occur in a part of Ireland that has some of the best fishing rivers in the country; in a landscape that is dominated by extensive blanket peatlands and in a local economy that is increasingly reliant on tourism. For these reasons, adopting an ecosystem management approach for WPFs is wholly appropriate. In addition, the social and environmental contribution of forestry to the national economy is currently estimated at between €88 to €97 m per year (Bacon 2004, Fitzpatrick Associates 2005). Adopting an ecosystem management approach for WPFs would improve the environmental contribution by providing a variety of additional environmental services such as bog restoration, protection of watercourses and biodiversity and enhanced visual landscapes.

Bog restoration

Peatlands are unique and endangered habitats worldwide. After Finland, Ireland has the largest proportion of peat cover of any EU country (Hammond 1981). Yet despite this, 94% of raised bogs and 86% of blanket bogs have been damaged or destroyed in Ireland. As a result, less than 112,000 ha of blanket bog and 18,000 ha of raised bog remain relatively intact in Ireland (The Heritage Council 1992). Recent EU LIFE projects have restored 1,212 ha of blanket bog and 571 ha of raised bog of formerly forested peatlands to a peatland habitat (Donnellan 2006). Based on the case study reported here, 8% of WPFs have the potential to be restored to their original peatland habitat, representing a potential total area at the national level of 12,640 ha (Table 4).

Table 4: A possible national scenario for land-use allocation and management of WPFs based on case study.

Scenario	*ha*	*% of total inventory area*	*% of total forest area*
Retain existing open space	*42,000*	*21*	-
Forest cover (excluding open space)	158,000	-	100
Wood production (economically justifiable)	17,380	-	11
Wood production (economically questionable)	75,840	-	48
Wood production (economically unjustifiable)	17,380	-	11
Extra wide buffer zones	12,640	-	8
Bog restoration & protection	12,640	-	8
Long term retention	20,540	-	13
Straight edge redesign	1,580	-	1
Total inventory area (including open space)	200,000		

Protection of watercourses

Unlike many other European countries most large Irish rivers still support salmonid populations, with the best of these occurring along the western seaboard (The Heritage Council 1992). Salmonids and the freshwater pearl mussel (*Margaritifera margaritifera*) are water quality indicators; most rivers in WPFs still support these species. In the case study, 8% of the area was designated as extra wide buffer zones, in recognition of the importance of protecting water quality. Replicating this practice for all WPFs would result in an additional 12,640 ha being devoted to riparian management (Table 4).

Protection of biodiversity

Biodiversity in WPFs is of significant value, and is often understated. In this survey 21% of the area was classified as open space, most of which adjoined statutory designated areas. They were deemed to be too poor to plant and often comprised valuable wetland and/or peatland habitats. Extrapolating the survey to the national level suggests that 42,000 ha of WPFs contain open space that is contributing to national biodiversity. In the survey 13% of the area was designated for long term retention. This was based solely on their inaccessibility for harvesting. At a national level, this suggests that approximately 20,540 ha of WPFs may not be harvestable. While these areas contribute to structural age diversity, their overall biodiversity contribution is uncertain and further research is required on how best to manage them.

Enhanced visual landscapes

There are strong demands to improve the visual impact of forest plantations and integrate them with the surrounding landscape, especially in sensitive landscapes (Price 1997). One of the added benefits of the ecosystem management approach is that is caters to a large degree for visual aspects of forests. However, plantations with highly visible straight edges may not be fully catered for, and this study suggests that the removal of 1% of areas, or 1,580 ha nationally (Table 4) is required to redesign plantation edges in WPFs.

Future scenarios for WPFs

Forest management in WPFs should, in the future, place more emphasis on the provision of environmental goods. Forestry will continue on western peatlands but within a context that takes account of environmental, social and wood production – sustainable forest management. In the majority of cases environmental and social values will take precedence. Forest redesign should occur in a manner that enhances the environmental and social dimension, in the context of a national land use policy for western peatlands. Table 4 summarises these conjectures by presenting a future management scenario for WPFs, based on the findings presented here.

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Estimating the amenity value of Irish woodlands

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Abstract

During the last decade, as the population of Ireland has become increasingly urbanised, there has been an increase in demand for outdoor recreational pursuits. Increased affluence, mobility and changing values have also brought new demands with respect to landscape, conservation, heritage and urban land use. Forests in Ireland are seen by the general public as potential destinations to fulfil their outdoor recreation requirements. We estimate an urban fringe forest recreation demand function and use it to investigate the value of urban woodland space, in terms of public-good provision to local residents. Through the estimation of a travel cost model, the study derives the mean willingness to pay of the average outdoors enthusiast using two urban fringe forests in Co Galway as €12.33, of which the travel cost comprised €7.36, with the balance the consumer surplus of €4.97. The results indicate a high value of urban woodland in Ireland from a recreational perspective.

Keywords

Recreation, urban woodland, travel cost model, negative binomial distribution.

Introduction

It has been well established (Tyrväinen et al. 2005) that urban forests greatly improve the local landscape and environment, provide a wide variety of recreational and educational activities for all ages, play a role in improving air quality and in carbon sequestration, provide a buffer to integrate mixed development and land uses and help to create an attractive green landscape, which encourages inward investment, employment and tourism.

In an Irish context, as a result of the growth in the urban population, significant increases have taken place in outdoor recreation participation throughout the 1990s and into the early 2000s. The widely documented Celtic tiger has brought increased wealth and disposable income to a greater proportion of the Irish population, giving rise to increased car ownership and extended leisure time, enabling people to partake in a range of outdoor recreational pursuits (Fitzpatrick and Associates 2005).

With over 60% of the Irish population now living in cities and in towns with populations in excess of 10,000, urban forests can provide important opportunities for people to recreate. In a review of forest research of non wood benefits of Irish forestry, Cregan and Murphy (2006) point out that urban forestry has the potential to provide green space for active and passive recreation. The authors also highlight the fact that urban forests may provide an increased level of social cohesion in the community, and can be important in terms of maintaining natural functions and biodiversity in urban areas.

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Urban forests have also been found to add value to house prices (Morales et al. 1980, Anthon et al. 2005).

To date, few studies have explored whether urban forests in Ireland contribute to the well-being of nearby communities. However, a number of studies have been carried out in Europe and elsewhere in this regard (Bennett et al. 1995, Lockwood and Tracy 1995, Tyrväinen and Miettinen 2000, Tyrväinen 2001, Anthon et al. 2005, Chaudhury 2006).

Urban forestry in Ireland

The importance of urban forestry[1] in Ireland has been highlighted for many decades, although according to Johnston (1997) it was not until the beginning of the 1990s that it began to be properly recognised in Ireland[2]. A 12-month project initiated by the NGO Crann, during 1988 - *Crann sa Chathair* - had the objective to establish woodland in city areas. One thousand trees were planted in each of ten areas of Dublin City, with the impetus coming from local communities (Crann 2008).

More recent urban woodland initiatives include the Forest of Limerick project established in 1991[3], the Terryland Forest Park initiative in Galway City (begun in 2000 and still expanding) and the urban forestry programmes of ECO, ECO UNESCO[4] and the Tree Council of Ireland. According to Johnston (1997) not only did ECO develop the beginnings of a national urban forestry network, it also did much to gain international recognition for developments in the Republic of Ireland. The interest in urban forest research is also evident from the fact that there were three national urban forestry conferences during the 1990s (1991, 1996 and 1998). The year 2000 also saw the holding in Dublin of the research seminar *Planting the Idea, The role of Education in Urban Forestry* by COST Action E12[5].

As the importance of urban forestry grew in Ireland, grant aid became available for its development. In 1995 the Forest Service launched the Urban Woodland Scheme. Its main aim was to support the establishment or development of urban woodland by local authorities, for the specific purpose of recreational use by the public (DAFF 2007). The scheme was co-funded by the EU under the Operational Programme for Agriculture, Rural Development and Forestry.

[1] According to international definitions (COST E12, IUFRO) the urban forest is the entire tree and woodland population within an urban area (including street trees, trees in public spaces, private gardens and woodland), and urban forestry is the multi-disciplined integrated approach towards the management of this overall resource. This study focuses on the urban woodland component of the overall urban forest resource.

[2] Having said this, Massey Woods near Killakee in the Dublin mountains was laid out primarily as an urban recreational woodland in the 1930s under the guidance of the then Director of the Forestry Division, Otto Reinhardt.

[3] A pilot project initiated by the Forest Service, it led to the establishment of the first state grant aid scheme for urban woodland

[4] ECO-UNESCO is Ireland's national environmental organisation for young people specialising in environmental education.

[5] See Collins (1996), Collins (1998) and Collins and Konijnendijk (2000) for further information on these conferences.

The Urban Woodland Scheme ceased in late 1999, and was replaced by the NeighbourWood Scheme. The NeighbourWood Scheme offers support to local authorities, community groups, environmental NGOs and private woodland owners to work in partnership to develop woodland amenities in and around villages, towns and cities, and has led to many new projects being developed. It is administered by the Forest Service, Department of Agriculture, Fisheries and Food and until recently was co-funded under the Regional Operational Programmes of the National Development Plan by the State and the EU. The NeighbourWood Scheme, involving public, private and voluntary sector organisations, continues to contribute to the development of urban forestry[6]. Local authorities and the Office of Public Works own and provide much of the urban woodland available for recreation in Ireland. Coillte, The Irish Forestry Board is the largest owner of urban (and peri-urban) woodland in Ireland, particularly in and around the fastest growing towns.

With the expansion of city suburbs into rural areas, some former rural woodlands can now be considered as urban green spaces. The two sites used in this study are two such examples: Barna Woods and Renville forest park were 20 years ago in rural locations, but with the growth of Galway City and Oranmore village, they now lie on the edge of these settlements, respectively.

The valuation of pubic good provision in Irish forestry

There have been a number of valuation studies of Irish forestry, using both stated and revealed preference techniques, but none relating specifically to non-market goods provision in urban forestry[7]. Work was undertaken by Ní Dhubháin et al. (1994), as part of a larger study to determine the social and economic impacts of forestry on rural development in the Republic of Ireland, Northern Ireland and Scotland. Forest recreation was valued using both the travel cost method (TCM) and the contingent valuation method (CVM). The work showed that the willingness to pay (WTP) for a single day-visit to a forest, varied from €1.02 to €2.73 (1992 prices) and estimated the value of recreational activities associated with forests at €15.9 million annually.

Clinch and Convery (1995) carried out an extensive review of the levels and trends of forest recreation in Ireland using existing data at that time. Clinch (1999) expanded this work by carrying out a public goods valuation study on Irish forestry; estimating that there were 8.5 million visits made to Irish forests annually. Clinch (1999) used a contingent valuation method (CVM) approach to account for the willingness to pay for landscape, wildlife and recreational benefits from Irish forests.

[6] For a discussion relating to the development of urban forestry in Northern Ireland see Johnston (1998).

[7] Economic valuation techniques usually fall into two distinct categories: stated preference (SP) techniques (e.g. the contingent valuation method (CVM)) and revealed preference (RP) techniques (e.g. the hedonic price method and the travel cost method). The stated preference method asks users directly to state their WTP for the opportunity to use an environmental amenity (Hanley et al. 2000). The revealed preference technique aims to deduce WTP from observed evidence of how users behave in the face of real market choices, so as inferences can be drawn on a related non-market good (Pearce and Ozdemiroglu 2002).

Results indicated that in 1999 the net present value of Irish forests amounted to £129 million.

Bacon and Associates (2004) updated Clinch's visitor estimates, presuming a growth rate of 3% per year, indicating a total of 11 million visitors in 2004. Adopting a model used in the UK, Bacon and Associates (2004) were able to calibrate a model for Irish forests and estimate a willingness to pay of €3.34 per visitor based on 2003 prices.

A more recent report (Fitzpatrick and Associates 2005), commissioned by Coillte, used primary data from 640 on-site interviews and 3,000 household surveys, in a contingent valuation study, to measure the non-market value of forest recreation in Ireland. Value was estimated at €97 million per year, a substantial increase from the €16 million estimated in 1990 when Coillte carried out a similar valuation exercise (Fitzpatrick & Associates 2005). This Fitzpatrick & Associates study also highlighted the importance of proximity to home in terms of use and the popularity of general recreational pursuits that are typical of urban woodland.

In another study, Scarpa et al. (2000) used the CVM approach to calculate the WTP of users of forest attributes in Irish forests. The study found that the presence of a nature reserve in a forest significantly increased visitors WTP. A random utility model was used to calculate the welfare gains from the presence of a nature reserve. A new nature reserve was found to generate almost half a million pounds of welfare per year accruing to visitors. Thus, provision of forest attributes and facilities, such as nature reserves, have been shown to significantly increase the returns from forest sites to the recreational users. In a study dealing with similar issues, Mill et al. (2007), calculated the personal and social mean willingness to pay (MWTP) for conservation of an Irish forest. The study found a positive correlation between the personal MWTP and the rankings of forest types by forest managers, suggesting that public use forests have been reasonably efficient in providing facilities that reflect visitor MWTP.

Research into the non-market valuation of urban forestry in Ireland is limited. Collins (1994) conducted a study that examined the potential to develop woodland in West Dublin. This study undertook a review of urban forestry and its development in Ireland and set out a case study of the development of an urban forest in the Finglas suburb of Dublin, based on a detailed community survey and site evaluation.

Johnston (1997, 1999) contains an in-depth review of the development of urban forestry in the Republic and Northern Ireland. The 1997 paper reviewed the organisations primarily responsible for the development of urban forestry in Ireland and criticised the Department of the Environment and Local Government for not playing any significant role in this development process; Johnston speculated that it may have been due to "continuing misconceptions regarding the broad scope of urban forestry and a lack of awareness that it is primarily a local authority function."

In a recent review of forest recreation research needs in Ireland, Cregan and Murphy (2006) highlighted the fact that there is "a limited understanding of the role and value of woodlands in urban settings in Ireland." Who uses urban woodland in

Ireland and what value do they bring to urban communities are two areas of research that Cregan and Murphy (2006) believed required particular attention.

This study addressed these issues by having the overall objective of estimating the recreational value of urban woodland by assessing recreational activity of local residents in two urban woodlands in Co Galway.

To put the work reported here in context, much research evaluating other benefits of urban forests is being conducted abroad, examining aspects such as urban regeneration, public health, tourism, sustainable urban planning/development, sustainable transport corridors, as well as direct environmental benefits such as cooling effects and savings in air conditioning.

Materials and methods

On-site, in-person interviews were undertaken at two urban forest sites in Ireland, between June and August 2006. Both forests are managed by Galway County Council and are in close proximity to residential populations. Barna Wood is located in the western suburbs of Galway city, and covers 10.5 ha, while Renville Forest Park is located on the outskirts of Galway City, adjacent to Oranmore village, and has a forested area of 18.5 ha. Barna Wood, just 5 km from the city centre, comprises native oak woodland with walks, trails and picnic facilities. Renville Forest Park meanwhile has walks, a playground and picnic and barbeque facilities. There are many other examples of urban fringe woodland across Ireland, Brackloon near Westport, Co. Mayo and Trespan Rock Park on the outskirts of Wexford Town being just two others.

The two forest sites in this study are not tourist destinations in their own right but nevertheless are used heavily by the local urban communities as recreational amenities. The frequency of visits is quite high, with a significant number of people visiting the sites on a daily basis. The forests cater for a wide range of uses, from walking, nature walking, dog walking, cycling and picnicking. A breakdown of the main activities pursued by the sample of visitors at the two forests is provided in Table 1.

On-site interviews were conducted during both week and weekend days, as well as during all daylight hours. The format of the survey questionnaire followed

Table 1: Main reasons given for visiting the forests in the study.

Activity	*Renville Forest*	*Barna Wood*	*Total*
Walking	120	46	166
Dog Walking	39	15	54
Cycling	4	3	7
Picnic/Barbeque	15	0	15
Other	25	2	27
Total	203	66	269

standard guidelines for the design of valuation survey instruments (Bateman et al. 1996). Survey respondents were provided with some background information on the study and were then asked to outline how they use the forests for recreation. Finally, socio-economic, demographic and attitudinal data was collected from respondents.

Model specification and empirical estimation

Valuation of recreation or environmental goods attempts to estimate the economic value, in monetary terms, which members of society receive from the use of natural resources. Due to their public good characteristics, such as being non-rival and non-excludable, they cannot be efficiently allocated through markets Yet, walking in a forest or on upland commonage or kayaking on a river can provide an economic benefit to the individual even if a formal market does not exist to recognise this. It is a benefit for which the consumer would, if he/she had to, pay (perhaps a parking or access fee). The fact that they do not have to pay (in most cases), results in the recreationalist retaining, therefore, a consumer surplus as extra income.

Methods of valuing non-market goods (recreation or environment) are usually categorised as stated or revealed preference approaches. In the former, respondents are asked to directly state their willingness to pay for recreational opportunities in the context of hypothetical changes in the supply or quantity of these opportunities. The Contingent Valuation Method (CVM) is an example of a stated preference approach and its use in the valuation of urban forestry can be seen in Bennett et al. (1995) and Tyrväinen (2001). Revealed Preference (RP) models are the main alternative to Stated Preference (SP) techniques for modelling recreation. The RP methods of valuation are based upon data drawn from observations of behaviour in real markets from which inferences may be drawn on the value of a related non-market good. Previous studies that have used the Hedonic Price RP method for urban forest valuation include Tyrväinen and Miettinen (2000) and Anthon et al. (2005), while Lockwood and Tracy (1995) and Chaudhury (2006) have used the Travel Cost Method (TCM) to estimate the value of urban forest resources from a recreational viewpoint.

The travel cost model (TCM) is widely used by economists to estimate user benefits from visits to recreational areas. There have been problems with using the TCM in urban areas because travel costs may not be a major determinant of visitation (Curtis 2002), as travel time is not a key factor in determining recreation demand. Tyrväinen et al. (2005) describe how the TCM is problematic in urban settings because there are usually no, or only small costs involved in travelling to the site. However, in our case the two sites can be considered a regional recreation resource, with a significant number of people travelling between 10 and 45 minutes to visit them, with the majority of visitors travelling by car.

Tyrväinen et al. (2005) say: *the TCM method is useful in a setting where large urban forests within city limits are scarce and people have to travel further to reach the areas*. There is at present no large urban forest within the city of Galway (although Terryland Forest Park is under development) or in Oranmore. Residents of both areas have to travel to the outskirts of the suburbs of each area, usually by car, to reach Barna Woods and Renville forest. Therefore there are time costs involved that make the TCM an appropriate valuation option.

Chaudhury (2006) used the TCM to estimate the recreational value of an urban woodland site as the author had previously found that respondents in CVM studies had a tendency not to reveal actual income on record which led to poor results in using CVM analysis.

TCM is, therefore, an indirect valuation technique which uses expenditure in travelling to a site as a surrogate measure for the price paid by an individual visitor. The price faced by recreationalists is the cost of access to the urban forest site (mainly the time and money costs of travel from home to site), while the quantity demanded per year is the number of recreational trips made to the (urban forest) site. A demand equation can then be estimated, from which consumer surplus can be derived. Economic value (consumer surplus) of a particular output of a public good such as urban forest site recreation can be found by estimating the consumer demand curve for that output. It is important to note that the consumer surplus figure is a measure of the user value of the urban forest site only, and does not measure the site's environmental or intrinsic value (McKean and Walsh 1986).

Travel cost should reveal itself as being the critical driving factor behind the demand for trips to the urban forest area. Demographic factors such as gender and age generally have less dramatic impacts on demand, but can be important in explaining why different groups respond differently to changes in price or income (McKean and Taylor 2000). Variation among recreationalists in travel cost from home to the urban forest sites (i.e. price variation) creates the urban forest recreation demand function.

Travel Cost Count Data models are typically estimated based on either the Poisson or negative binomial distributions. Such an approach is consistent with the discrete nature of the dependent variable, that is, the annual number of trips. The number of trips taken in any given year is reported as a discrete, non-negative integer value. Thus, application of the standard distributional assumptions (e.g. normality) is inappropriate because the dependent variable in the TCM cannot take on a continuous range of values. This is evident from the histogram in Figure 1 where it can be seen that a discrete probability distribution would result in a better model specification.

The Poisson model has been criticised because of its implicit assumption that the conditional mean of T (in this study T is the expected number of trips to the urban forest area demanded) equals the variance of T (Greene 1993). Therefore, if a Poisson model is fitted to the urban forest data, a mean-variance equality restriction is imposed on the estimation; effectively requiring the variance to be less than it really is. As a result, the true variability of the data is underestimated. This leads to underestimation of standard errors, and so the overestimation of the level of precision of the coefficients (Cameron and Trivedi 1986).

This mean-variance equality has proven problematic since data frequently exhibit over-dispersion: where the conditional variance is greater than the conditional mean. Take recreationalists at an urban forest site for example; the average number of trips

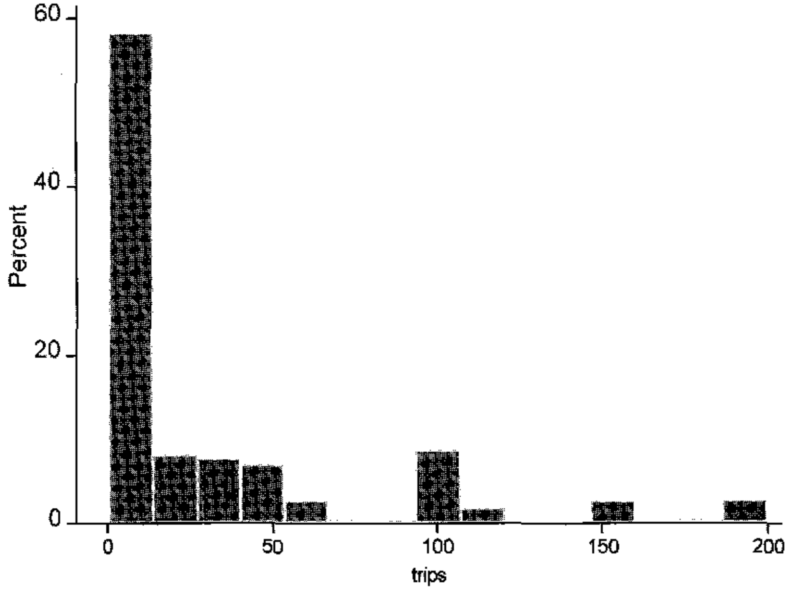

Figure 1: Frequency distribution of recreational trips to forests in the study.

taken to the urban forest in one year was 32.5 but the variance was over 68 times that at 2,228. Following the work of Creel and Loomis (1990) and Grogger and Carson (1991), however, the Poisson distribution can be generalised to take over-dispersion into account. The generalisation most often used in the literature is the negative binomial probability distribution (Grogger and Carson 1991, Englin and Shonkwiler 1995, Curtis 2002) where an individual, unobserved effect is introduced into the conditional mean.

Having taken into account the foregoing, one remaining issue needed to be addressed: there were no observations for individuals who made no trips to urban forest sites. The survey dataset only reflected the behaviour of individuals who took at least one trip to the study areas. This has important implications for the empirical specification of the TCM. Exclusion of individuals who chose not to make a trip implies that the data were systematically truncated. If not recognised, the resulting parameter estimates will be biased in terms of inferences drawn about the population of potential beneficiaries of urban forest recreation in the future. Bias will extend to the estimates of consumer surplus that are derived from these parameters. To address this issue the negative binomial distribution was modified to reflect the fact that T_i is only observed when $T_i > 0$. Following Grogger and Carson (1991), the negative binomial probability distribution was adjusted for truncated counts. The revised probability model can be written as:

$$\Pr(T_i) = f(T_i) = \frac{\Gamma(T_i + 1/\alpha)}{\Gamma(T_i + 1)\Gamma(1/\alpha)}(\alpha\lambda_i)^{T_i}(1+\alpha\lambda_i)^{-(T_i+1/\alpha)}[1 - f(0)]^{-1} \qquad (1)$$

where there are $i = 1, 2, \ldots, n$ observations, Ti is the number of trips to the forest for individual i and λi is some underlying rate at which the number of trips occur, such that we expect some number of trips in a particular year, i.e. the mean of the random variable T_i, $(E(T_i|X_i))$ is given by λ_i and $\lambda_i = \exp(X_i'\beta)$. The variance of y_i $(\mathrm{var}(T_i|X_i))$ is given by $\lambda_i(1 + \alpha\lambda_i)$. The vector X_i represents the set of explanatory variables reported for each individual i. It is a 1 by k vector of observed covariates and β is a k by 1 vector of unknown parameters to be estimated. The scalar α and the vector β are parameters to be estimated from the observed sample. Γ in equation (1) indicates the gamma function that distributes λ_i as a gamma random variable. Finally, α is a nuisance parameter to be estimated along with β. α is a measure of the ratio of the mean to the variance of the number of trips to the forest site. Larger values of a correspond to greater amounts of over-dispersion. The model reduces to the Poisson when $\alpha = 0$, as $E(T_i \mid X_i)$ is again equal to $\mathrm{var}(T_i \mid X_i)$). The truncated probability function differs from the standard probability function by the factor $[1 - f(0)]^{-1}$. Since $f(0)<1$, multiplication of the usual probabilities by $[1 - f(0)]^{-1}$ inflates them, accounting for the unobserved zeros. Estimation of the resulting truncated negative binomial model relies on standard maximum likelihood techniques. The log-likelihood function for the truncated model can be written as follows:

$$\ln L = \sum_{i=0}^{N} \ln\Gamma(T_i + 1/\alpha) - \ln\Gamma(1/\alpha) + T_i \ln(\alpha\lambda_i) - (T_i + 1/\alpha)\ln(1 + \alpha\lambda_i)$$
$$- \ln[1 - (1 + \alpha\lambda_i)^{-1/\alpha}] \qquad (2)$$

where N corresponds to the size of the truncated sample. The conditional mean and variance of this model is given by:

$$E(T_i \mid X_i, T_i > 0) = \lambda_i[1 - f(0)]^{-1} \qquad (3)$$

and

$$\mathrm{var}\,(T_i \mid X_i, T_i > 0) = \frac{E(T_i|X_i, T_i > 0)}{f(0)^{\alpha}}\{1 - [f(0)]^{1+\alpha} E(T_i|X_i, T_i > 0)\} \qquad (4)$$

For comparison purposes, the demand model was also estimated under the less restrictive assumptions imposed by use of the untruncated negative binomial distribution. A truncated Poisson distribution is also used to model the data generating process that underlies the discrete, nonzero values observed in the sample. Although this model can be somewhat easier to estimate, it once again imposes the restriction that the conditional mean of the dependent variable λ, is equal to the conditional variance.

Results

During the course of this study, 269 on-site personal interviews were carried out in Barna Wood and Renville Forest Park. In order to correct for respondents who replied with a very high number of trips taken, the approach taken by Morey et al.

(1993) was followed and the analysis was confined to respondents who stated that they had made 200 or less trips in the previous year. This reduced the sample to 235 observations, of which 62% were female, 64% were in full-time employment and 60% had third level education. Renville Forest accounted for 75% of the sample.

The average annual number of visits to the forest sites was 32, one-way distance travelled was 9.6 km and time spent at the site was just under an hour (53 minutes). The short average distance travelled and the high average frequency of trips taken, indicate the level of usage of the facilities by local residents in particular. Indeed, the furthest distance travelled was 145 km. Table 2 provides a detailed summary of some of the key variables for the sample.

Table 2: Summary urban forest visit statistics.

Variable	*Mean*	*Std. dev.*	*Min*	*Max*
Annual number of trips	32.5	47.2	1	200
Distance travelled from home to forest site (km)	5.95	9.36	0.5	90
Travel cost (€)	67.02	68.03	0.5	321.75
Income (€)	46,979	26,726	0	120,000
Travel time from home to forest site (minutes)	13.0	15.8	1	150

Parameter estimates for the urban forestry TCM are presented in Table 3. Four alternative specifications of the demand equation were estimated: the Poisson, the negative binomial model, the truncated Poisson and the truncated negative binomial model. Although these alternative models gave results similar in magnitude (and with the same signs), the Poisson was rejected in favour of the negative binomial model. The value of the maximized log-likelihood was -933 for the chosen truncated negative binomial model, whereas it was -4476 for the truncated Poisson model indicating that the truncated negative binomial model is a better fitting model for our data.

In the chosen truncated negative binomial model[8] α, the over-dispersion parameter is 3.15. It is positive and significant, indicating that the data were over-dispersed. In order to test the hypothesis that $\alpha = 0$ (and therefore indicating that the Poisson model would be more appropriate) a likelihood ratio-test is performed. The χ^2value of 7985 asserts that the probability that one would observe these data conditional on $\alpha = 0$ is virtually zero, i.e. conditional on the process being Poisson. This indicates that the negative binomial distribution is more appropriate. The model's estimate of the mean number of urban forest recreational trips demanded is 24.8. This is slightly lower than the actual mean of 32.5 trips observed in the sample.

[8] All results discussed in this section are based on the parameters from the truncated negative binomial model (column 4 in Table 3).

Table 3: Model parameter estimates.

	Poisson	*Negative binomial*	*Truncated Poisson*	*Truncated negative binomial*
Travel cost	-0.272	-0.142	-0.281	-0.201
	(-19.65)**	(-3.84)**	(-19.95)**	(-3.81)**
Travel cost to substitute site	-0.32	-0.254	-0.33	-0.299
	(-15.36)**	(-4.34)**	(-15.03)**	(-4.01)**
Forest code (Renville = 0, Barna = 1)	-0.748	-0.645	-0.753	-0.784
	(-24.15)**	(-3.22)**	(-24.31)**	(-2.77)**
Dog walking	0.831	0.882	0.83	0.97
	(31.93)**	(3.86)**	(31.85)**	(2.99)**
Cycling	-0.975	-0.758	-0.982	-0.856
	(-8.58)**	(-1.6)	(-8.64)**	(-1.34)
Picnic/barbeque	-1.68	-1.713	-1.69	-2.134
	(-14.78)**	(-4.69)**	(-14.56)**	(4.46)**
Other forest activity	-1.234	-1.114	-1.255	-1.425
	(-17.97)**	(-3.79)**	(-17.97)**	(-3.69)**
Gender (1=female)	0.102	0.236	0.102	0.323
	(3.94)**	(1.31)	(3.93)**	(1.29)
Married	-0.186	-0.266	-0.184	-0.28
	(-6.23)**	(-1.17)	(-6.16)**	(-0.89)
Retired	0.773	0.772	0.774	0.912
	(17.74)**	(2.35)*	(17.71)**	(2.06)*
Income	0.00002	0 .00003	0 .00002	0 .00003
	(19.90)**	(3.32)**	(20.19)**	(3.34)**
Age greater than 34	0.287	0.145	0.288	0.064
	(9.24)**	(0.67)	(9.24)**	(0.22)
Constant	4.502	4.27	4.519	4.209
	(77.24)**	(10.95)**	(77.34)**	(7.46)**
α (over dispersion parameter)		1.36		3.15
Log-likelihood	-4484	-973	-4475	-933

(Absolute value of z statistics in parenthesis)

*** significant at the $p \leq 0.05$ level*

** significant at the $p \leq 0.01$ level*

The marginal effect of covariates on mean urban forest trips taken is given by:

$$\frac{\partial E(T \mid X)}{\partial x_i} = (1+\alpha)\lambda_i \beta_j \tag{5}$$

where λi is the predicted number of trips taken (24.8), β are parameters estimated from the observed sample and α is the over-dispersion parameter.

For every €0.50 increase in the travel cost of a trip, the number of trips per year demanded fell by 13. This suggests that the demand for recreational pursuits at urban forests is extremely elastic. This may be due to availability of a number of substitute recreational options close to both sites.

The estimated coefficients for both travel costs and income are negative and are significant at the $p \leq 0.05$ level. The income coefficient is significant and positive but is very small at 0.0000255. While this result is unexpected, it is not uncommon to encounter small (and in some cases counter-intuitively negative) income effects in recreational travel cost demand models (Chakraborty and Keith 2000, Curtis 2002).

Whether an individual was retired or not also had a significant impact on the demand for urban forest recreation. Retired individuals were likely to make 94 more trips per year than their working counterparts. Compared to the base case of walkers, dog walkers made significantly more trips per year to the forest sites, while cyclists, individuals who used the forests for picnic/barbeque activities and other forest users made significantly less trips. Women were likely to make 33 more visits per year than men. Individuals older than 34 were more likely to partake in recreational activities in urban forests, compared to those under the age of 34.

As stated, the overall aim of the study was to use the urban forest travel cost model to calculate the economic value of urban forest recreation. Consumers' surplus (estimated following McKean and Taylor (2000) and Hellerstein and Mendelsohn (1993), was used to calculate consumer utility (satisfaction), subject to an income constraint, and where trips were a nonnegative integer. Hellerstein and Mendelsohn show that the conventional formula to find consumer surplus for a semi-log model also holds for the case of the integer-constrained quantity demanded variable. They show that the expected value of consumer surplus, E(CS), derived from count models can be calculated as $E(CS) = E(T_i|x_i)/\beta_p) = \hat{\lambda}_i|(\beta_p)$ where $\hat{\lambda}_i$ is the expected number of trips, and β_p is the price (travel cost) coefficient. Consumers' surplus per-trip (*E(CS)*) is simply equal to $1/\text{-}\beta_p$.

Using the truncated negative binomial regression, the travel distance was multiplied by €0.42 per km per person, to which was added 25% of the individual's gross hourly wage (taken to represent the opportunity cost of leisure time), to give an estimated travel cost coefficient of -0.201[9]. Consumer surplus (CS) per individual per trip is the reciprocal or €4.97. The population estimate of per-trip consumer surplus is estimated with 95% confidence to be between €3.23 and €10.24. Average trips per

[9] Much of the travel cost literature has argued that the cost of leisure time is below the hourly wage rate. Cesario and Knetsch (1976) are credited with first having suggested approximating the opportunity cost (value) of time as a fraction of an individual's wage rate. The appropriate fraction to choose however is the subject of much debate. According to Parsons and Massey (2003) the recreation demand literature has more or less accepted 25% as the lower bound and the full wage (100%) as the upper bound. Following the literature review, 25% of the hourly wage was chosen, as we believe that individuals could possibly receive disutility from work and more importantly, the 'transit time' in getting to the recreational site produces many joint products. For instance, if the drive is scenic, one derives benefit from this. Such additional benefits or products suggest that using some fraction of the marginal wage rate may be more appropriate.

year in the full 235-person sample were found to be 32.47, giving a total consumer surplus per individual, per year of €161.38.

Conclusions

The mean willingness to pay (mean WTP) of the average recreationalist using urban forest sites in Co Galway was €12.33. The travel cost comprised €7.36, with the balance the consumer surplus of €4.97. This suggests that individuals received a considerable benefit from urban forest recreation.

Mean WTP was more than twice the estimate of €3.53 in Bacon and Associates (2004). In a more recent survey, Fitzpatrick and Associates (2005) estimated the typical value placed by a user on a visit to a trail or forest site was €5.42. This estimate is still lower than our estimate of €12.33 but given the high frequency of visits of urban residents to urban fringe forestry this is not an unexpected finding. Fitzpatrick and Associates (2005) estimated that there were 18 million visits to Irish forests annually, providing a value of €97 million for the total non-market annual value of forest and trail recreation on the Coillte estate[10]. Comparisons between valuation reports are however, difficult to interpret, since methodologies and context vary. Nevertheless, it can be argued that urban forests generate higher welfare estimates than larger forests which are not frequented as often by local residents. However, site value may be overestimated for Renville forest, as it links up with a one mile coastal walk. For some individuals, the forest and the coastal walk may be joint products and not all of the value of the visit is attributable to the forest, and the consumer surplus estimates may have been overestimated.

This study is also limited in the sense that the sample size was quite small. While the results indicate that the value of Irish urban forest recreation is high, further research is necessary on a larger sample. The preferences of recreationalists for alternative forest sites as a function of site characteristics and individual characteristics should also be explored. It would also be interesting to investigate the impacts on welfare and trips of alternative rationing mechanisms, such as the imposition of car-parking fees and measures to increase public access (see for example Shaw and Ozog 1999 and Hanley et al. 2002).

Our estimates of recreationalists' welfare also suffer from many of the generic drawbacks of the travel cost model; for instance, that they do not include non-use values of the urban forest site, and that our values depend on assumptions made about the value of leisure time and what should constitute the marginal cost of visiting. Omission of non-use values may be particularly important for urban forest sites with unique scenic qualities or for sites of high cultural significance and will certainly bias any cost-benefit analysis based solely on recreation use values.

The work has, however, confirmed findings by Clinch and Convery (1995) and Hutchinson and Chilton (1994) that urban woodlands have a high value for local

[10] This study was unable to estimate the total annual usage of the forest sites in question, thus we are unable to calculate a total annual non-market recreational value, for comparison with Fitzpatrick and Associates (2005).

populations. The high welfare estimates for the usage of urban forests combined with their small catchment areas provides a strong case for more resources to be devoted to this land use in the hinterland of Irish cities and towns. Urban residents derive considerable benefit from urban and community-owned forests that are managed by Local County Councils and Local Authorities.

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Reproduction and potential rate of increase of the sika deer herd in Co Wicklow

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Abstract

All three deer species in Ireland mainly inhabit forests, where they can cause significant economic and ecological damage through browsing and bark stripping of trees. Sika deer and sika x red hybrids are currently the most numerous deer. Their expansion through Co Wicklow and beyond was associated with afforestation. Deer must be managed, and to do this effectively, knowledge of their reproductive potential is needed. We investigated the reproduction of female sika-like deer harvested in the Co Wicklow area during the hunting seasons from 1995/1996 to 1997/1998. Fifteen percent of calves, 87% of yearlings and 84% of adult females were pregnant. One female was found with twin foetuses. Seventy-two percent of adults were lactating and 71% had a calf-at-foot. Eighty-five percent of calves survived to six months of age. The deer herd has a yearly potential rate of increase of 28%. Pregnancy and survival rates are very high for sika deer in Ireland and in line with other populations elsewhere. It is likely that our estimate of 15% of calves becoming pregnant and raising offspring is low. This high fertility is despite the high densities at which sika-like deer are found in Co Wicklow. Deer are increasing in numbers because insufficient numbers are harvested compared with their rate of increase. This trend could cause a serious increase in tree damage levels. We recommend that the harvest be increased to at least 30% of the female population and reproduction be continuously monitored, with an emphasis on assessing for pregnancy in calves and checking for twins.

Keywords

Sika deer, reproduction, survival, rate of increase.

Introduction

The three species of deer found in Ireland: fallow, red and sika are all associated with forests. Red is the least numerous, with a population estimated at 3,000 in 1988 (Guerin 1989), centred around the national park areas in Kerry, Donegal and some special red deer parks. Fallow are widely distributed; their numbers were estimated in 1988 at several thousand (Guerin 1989). Sika deer and their hybrids with red deer are found in areas around former deer parks where they have escaped to form feral herds. These herds have spread extensively (Harrington 1973, Hurley 1996) and this species is now the most numerous in the country (Hayden 1997). In 1988 the total number of deer in the country was estimated at 20,000 (Guerin 1989). Since then, the population of sika deer and their hybrids in Co Wicklow alone has been estimated at 16,200 in 1994 and 19,215 in 2000 (Lowe 1994, O'Brien 2000). Sika have spread

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from Co Wicklow into other counties: they were recorded in Co Wexford in 1980 and are also currently in Cos Kildare and Carlow (Hurley 1996).

Fallow, red and sika deer are all intermediate or opportunistic feeders, and will both graze and browse (Ratcliffe 1987, Takatsuki 1988, Geist 1999). Red deer cause economically significant damage in commercial forests (Wolfe and v. Berg 1988, Welch et al. 1991, Gill 1992a, 1992b). They are considered to be more damaging than roe deer due to their large size and efficient digestive system, which allows them to subsist on forage of low nutritional quality, and their resultant bark stripping activities (Wolfe and v. Berg 1988). Browsing by roe can, however, be as costly because they reach higher densities (Wolfe and v. Berg 1988, Mayle 1996). Sika have a better capacity for digesting poor quality food than reds (Hoffman 1982), have higher reproductive rates and reach higher densities than red and often roe deer in commercial forests (Mayle 1996). In their natural range, sika feed on a variety of vegetation including bark (Asada and Ochiai 1996, Yokojama et al.1996). In Ireland, grass can make up more than 50% of the diet (Quirke 1991) but heather, gorse, holly and other trees, including saplings and bark are also eaten (Kelly 1981). Outside their natural range, sika have become important pests in managed forests (Rose 1991). In Co Wicklow, sika damage is estimated in 45-50% of young stands, (Coillte 1995, cited in Hurley 1996). At some sites, over 60% of trees are damaged (Lowe 1994), with browsing the most common type of damage (Hannan and Whelan 1989). Fallow deer also bark strip (Gill 1992a), though fewer studies have been conducted.

The spread of sika-like hybrid deer through Wicklow was associated with the afforestation of the county over the period from the 1930s to the 1950s. Young forests are ideal habitats for sika deer (Ratcliffe 1987, Mayle 1996) and the increase in sika deer numbers in Scotland is considered a direct consequence of commercial afforestation (Ratcliffe 1987, 1989).

Deer must be actively managed in both natural/old-growth and commercial forests where they occur, to control populations and to minimize damage to commercial trees and other important plants, especially in the absence of natural predators, as is the case in Ireland and much of western Europe. In order to achieve forest certification a management plan must be created for deer, if present (Rooney and Hayden 2002). Control is usually achieved by means of harvesting a proportion of the population, with targets set for removing a certain number of individuals in an area. This number will vary depending on the local density and rate of increase of the herd. To investigate population dynamics and develop a management strategy for a deer herd, knowledge of reproductive patterns and capacities is essential. Sika, red and fallow deer are all seasonally polyestrous. In autumn, females come into oestrus, which can be cyclically repeated about every 22 days through the winter until they conceive (Chapman 1974, Moore 1995). Most females conceive during first oestrus, so that sika and red calves are generally born during May and June (Mitchell et al. 1976), with fallow fawns born a little later, in June (Moore 1995).

The age at which female deer first conceive varies widely between and within species, in relation to environmental conditions (Mitchell and Lincoln 1973, Woolf and Harder 1979, Thomas 1982, Clutton-Brock et al. 1987). A threshold level of body condition, best indicated by body weight, must be reached in order for a female to be capable of full gestation. This occurs at different ages depending on the particular conditions under which deer are living. In general, fewer yearlings than adults in a population breed (Thomas 1982, Boyce 1989, Gaillard et al. 1992). This is related to the lower body weights of yearlings compared to adults (Putman and Clifton-Bligh 1997). Yearlings also tend to breed later in the year than adults, as they may only reach sufficient condition late in the year (Clutton-Brock et al. 1982, Feldhamer and Marcus 1994, Putman and Clifton-Bligh 1997), as is the case for adults in poor condition (Mitchell and Lincoln 1973). Pregnancy in sika and red calves is not the norm in most populations, though in some British sika populations it is becoming common (approaching 30%; Ratcliffe 1987, Mayle 1996). Females in most sika populations reach sexual maturity as yearlings (Chapman 1974, Davidson 1973, O'Donoghue 1991, Feldhamer and Marcus 1994).

In favourable conditions, females, once reaching sexual maturity, normally bear offspring every year until old age (Davidson 1973, Ratcliffe 1987, Boyce 1989, O'Donoghue 1991. Gailard et al. 1992, Ouellet et al. 1997; Putman and Clifton-Bligh 1997), while in less favourable situations females take longer to regain condition after rearing a calf, and may not conceive the following year (Mitchell 1973, Mitchell et al. 1976, Guinness et al. 1978, Gerhart et al. 1996). Females may take longer than one year to reach their threshold weight where conditions are extremely harsh (Thomas 1982), and the threshold itself can be higher in high density populations (Albon et al. 1983).

The reproductive performance of female deer in the Co Wicklow region was examined to discover whether the reported high density (Lowe 1994; Coad pers. comm.) adversely affected age at first conception and subsequent pregnancy rate, and to determine the potential rate of increase of the population. Also, since the most important aspect of reproduction is the proportion of calves born which survive to become independent and reproduce, determining recruitment to the population, the early survival of calves was investigated.

Materials and methods

Data on female reproduction were collected during a study of deer harvests in the Wicklow region during the three open hunting seasons (September to February inclusive for males, November to February inclusive for females) of 1995/1996 to 1997/1998. Of 1,388 deer for which data were provided, stalkers[1] classified 15 as fallow, seven were classified as red, 87 hybrid and 1,231 as sika. For the purpose of this study, fallow were omitted and all other deer were pooled as sika-like deer, due to the dubious genetic integrity of both species in the Wicklow region. Stalkers were asked to check if harvested females were pregnant and/or lactating when they were gralloching the carcass, and to record whether the female had a calf-at-foot when it was shot. Pregnancy was assessed by the obvious presence of an identifiable foetus in the uterus, while lactation was assessed on the basis of milk being readily

[1] Deer hunting in Ireland is conducted by stalking; using high-calibre rifles, without the use of dogs.

squeezed from the teats. Data sheets that had no data entered under the pregnancy and lactation categories were excluded as unchecked deer. Only positive and negative assessments of reproductive status were included in analysis. Pregnancy rates were calculated only for females which were harvested from December to February, to avoid under-reporting due to difficulty in assessing early pregnancy, while lactation rates were calculated only for hinds harvested before January, to avoid problems of later cessation (un-shown data).

The percentages of females that were pregnant, lactating and with a calf-at-foot in each year were calculated to determine both the age at which females in the population first become pregnant and the age-related reproductive potential, including any evidence of reproductive senescence. The proportions of females in all years combined which were pregnant, lactating and with a calf-at-foot were calculated for each age class from 0 to 18. The proportions of females lactating and with a calf-at-foot were compared with pregnancy rates to determine the early survival rate. The proportional contribution of each age class to the following year's offspring was calculated using the age-related reproductive (pregnancy) rates and the proportion of the female population made up from each age class. The products of these two for each age class were tabulated as a percentage of the total contributions.

Results

Eighty-seven percent of yearlings and 84% of adult females were pregnant when all seasons are combined. Eighty-two percent of yearlings were pregnant in 1995/1996, 79% in 1996/1997 and 91% in 1997/1998. Eighty-eight percent of adults in 1995/1996 were pregnant, with adult pregnancy rates at 74% and 87% 1996/1997 and 1997/1998 respectively. Adult lactation rates were 72% overall: 73%, 67% and 76% in 1995/1996, 1996/1997 and 1997/1998, respectively. Seventy-one percent of females had a calf-at-foot overall: 75% during 1995/1996, 63% in 1996/1997, and 72% in 1997/1998. The survival rate of calves to 6 months of age, calculated from the proportion of females pregnant and those with a calf-at-foot was 85%.

Few calves (15%) were pregnant but the proportion rose to 87% of yearlings and was similar in age classes until age eight, after which a decrease to 50% in 11 year olds is seen (Table 1). However, 82% of females aged 12 or older were pregnant. The proportions of females with a calf-at-foot and lactating were similar in most age classes; rising from 26 and 20% respectively in yearlings, to 67 and 68% in 2 year olds and staying between 60 and 80% for the most part in all older age groups. The only age group with a decrease in the percentage of hinds with a calf-at-foot was 11 year olds, with just 20%, though the single hind checked was lactating. In females aged 12 or older, 82% had a calf, and 75% were lactating (Table 1).

There was one case reported of a hind being pregnant with twins. Two hundred and two uteri were reported to have been opened, producing a twinning rate of 0.5%

Table 2 shows the proportional contribution of each age class to the numbers of calves born the following year, based on pregnancy rates and the number of young born to each age group in a hypothetical population of 100 females. The largest contributors were 2-year-olds, producing 22% of all calves. Animals up to 4 years old

Table 1: Age specific reproductive status of hinds.

	Pregnant			Calf- at- foot			Lactating		
Age	*Total*	*N*	*%*	*Total*	*N*	*%*	*Total*	*N*	*%*
0	27	4	15						
1	46	40	87	54	14	26	44	9	20
2	61	53	87	76	51	67	40	27	68
3	31	27	87	44	32	73	38	28	74
4	30	24	80	38	29	76	20	14	70
5	14	12	86	22	15	68	14	9	64
6	12	11	92	15	11	73	8	7	88
7	12	11	92	12	8	67	5	3	60
8	8	7	88	14	11	79	11	8	73
9	8	6	75	12	9	75	6	4	67
10	7	4	57	11	9	82	8	6	75
11	6	3	50	5	1	20	1	1	100
12	3	3	100	4	4	100	3	2	67
13	2	2	100	3	2	67	2	2	100
14	1	1	100						
15	2	2	100	2	2	100	1	1	100
16	2	0	0	2	1	50	2	1	50
17									
18	1	1	100						
(12-18)	11	9	82	11	9	82	8	6	75

produced nearly half of all calves (47.5%). Using lactation rates, 3-year-olds and 4-year-olds reared more calves than did yearlings. Age classes from 4 to 8 years each produced around 5% of offspring, while calves themselves contributed 6% to the next generation. Individual age classes older than 8 contributed very little: 2% or less. For every 100 female deer, 66 offspring were produced, 56 of which survived to weaning. This gives a yearly potential rate of increase of 28% for the deer herd.

Discussion

Pregnancy rates of adult sika-like deer in Wicklow were very high, with 84% of adults overall being pregnant after November. Pregnancy rates of Wicklow yearlings were equally high at 87%. This shows that females in the population reach the threshold body condition for conception in their second year, and generally conceive at the same time as older females, since pregnancy was easily detected by stalkers after November.

It was unexpected to find that calves would be pregnant in the Wicklow area. That only a small number were discovered is probably because the majority of stalkers did

Table 2: The proportional contribution of each female age class to the total numbers of calves produced in the following years and the number of young born to each age class per 100 females of the herd, based on the proportion of the female population made up by each age class and the pregnancy rate of that age class.

Age	*Proportion of pop.* %	*Pregnancy rate* %	*Proportional Contribution*	*Number of young born per 100 females*
0	27.40	15	6.18	4.1
1	13.09	87	17.33	11.4
2	16.93	87	22.39	14.7
3	11.69	87	15.51	10.2
4	8.90	80	10.84	7.1
5	3.14	86	4.10	2.7
6	3.84	92	5.36	3.5
7	3.32	92	4.63	3.1
8	3.14	88	4.18	2.8
9	2.27	75	2.59	1.7
10	2.27	57	1.97	1.3
11	1.22	50	0.93	0.6
12	1.22	100	1.86	1.2
13	0.52	100	0.80	0.5
14	0.17	100	0.27	0.2
15	0.52	100	0.80	0.5
16	0.17	0	0.00	0.0
17	0.00		0.00	0.0
18	0.17	100	0.27	0.2

not check for signs of pregnancy in harvested calves, presuming it unnecessary. Only 27 calves were checked, four of which were pregnant. In some of those checked, it is possible that pregnancy was not detected because of late conception. The one pregnant calf examined by the first author, in February, had a small foetus weighing 4.67 g which was estimated to be approximately 66 days old, using the equation expressing the relationship between the cube root of fetal weight (y) and length of gestation (x) given for sika in Killarney by O'Donoghue (1991): $y = 3.945 + 0.085x$. Thus, the calf is likely to have become pregnant in late December, nearly two months after the rut. If other calves similarly became pregnant late in the year, due to the time required to attain sufficient body weight and fat reserves as seen in white-tailed deer fawns (Scanlon 1978), signs of pregnancy would still not be obvious late in the season. Therefore, calves that did not appear to be pregnant when harvested may have been.

O'Donoghue (1991) reported one pregnant sika calf out of 45 examined in Killarney. It had conceived in early January, again considered due to only attaining sufficient weight late in the season. The author considered the foetus unlikely to have survived and the 2% pregnancy rate of calves therefore deemed negligible in terms of contributing to the overall reproductive performance of the herd. No yearlings were reported as lactating, indicating that the offspring of any calves that conceive do not survive until autumn. In Wicklow, the 15% calf pregnancy rate was superseded by the lactation rate of yearlings (20%), indicating not only that pregnancies had been successful and that offspring born to hinds giving birth as yearlings survive as well as those born to older hinds, but also that the pregnancy rate of calves is somewhat higher than 15%. Calves in Wicklow, therefore, do contribute in part to the reproductive performance of the herd (6%). Yearlings in Wicklow also seem to contribute more to the herd's reproductive performance than do yearlings in Killarney, with a pregnancy rate of 85% compared to 60%.

Overall pregnancy rates of sika and sika-like deer in Ireland are similar to other populations of sika: 85% and 80% for adults and yearlings respectively in a New Zealand population where no calves were pregnant (Davidson 1973); 90% for adults and 72% for yearlings in Dorset, Britain, (Putman and Clifton-Bligh 1997); 80% for adults and yearling pregnancy described as common in other British populations (Ratcliffe 1987); and 94% based on *corpora lutea*, 74% based on visible foetuses for adults and 100% and 56% for yearlings using the same criteria in a Maryland herd, where 8/15 calves had ovulated, and four had a blastocyst-stage embryo (Feldhamer and Marcus 1994).

O'Donoghue (1991) considered the high pregnancy rates of yearlings in Killarney indicative of good quality range and lack of density-related limiting factors which have been shown in red deer (Clutton-Brock et al. 1985). The number of adults breeding is also closely related to habitat. Female sika-like deer in Wicklow have few problems regaining body weight and reserves after rearing a calf. The same was true of sika in Killarney (O'Donoghue 1991), while sika deer in Hokkaido, Japan generally produce their first calf as two year olds and will have a calf every year until age 8 or 9, which is the life expectancy for most females there (Kaji et al. 1984). Hinds of up to 18 years were shot in Wicklow. However, the present study found no evidence for reproductive senescence, with reproductive performance of females aged 12 or older similar to that of younger (1-9 years) hinds (χ^2 =0.001, p=0.979).

Twinning in red and sika females is rare. MacNally (1985) stated that five undisputed births of red deer twins were recorded in Scotland between 1970 and 1984, with one stillborn set of twins, and one report of twin foetuses. Courtier (1971) reported a captive sika hind bearing twins. A culled sika female in Maryland had two healthy foetuses (Feldhamer and Marcus 1994). Clinton et al. (1992) found a female sika pregnant with twins during routine culling in Co Wicklow, and cite twinning rates of less than 0.01% for most Old World (Pleisometacarpalian) deer, including the genus *Cervus*. During this study, one case was reported by a park ranger who verified that the uterus was opened, giving a rate of 0.05%. It is possible that there were more, but which were unidentified because rupturing of the uterus is often unnecessary to positively identify pregnancy, meaning there could have been two foetuses, but only one pregnancy was recorded.

Overall, survival of sika-like calves born in Wicklow was 85%. This is higher than recorded from lactation data from Killarney (O'Donoghue 1991) and from Japan (75%: Kaji et al. 1980 cited in Ratcliffe 1987). This very high survival rate for young sika-like deer in Wicklow is probably the result of excellent dam condition, also indicated by their longevity compared to sika in their native range (Kaji et al. 1984) and lack of reproductive senescence, giving high quality milk, and the absence of large predators in Ireland, where only red foxes (*Vulpes vulpes*) and domestic dogs (*Canis familiaris*) can attack wild deer, and then only in the first few weeks after birth, as is the case in other species of deer (Nelson and Woolf 1987). Predation of sika by dogs has never been documented, but is unlikely to be important, as it is insignificant in other species of deer where it has been examined (Scott and Causey 1973, Causey and Cude 1980). The only account of a fox attacking a deer in Ireland was a female sika calf killed in Killarney (Nowlan 1988). The high survival rate of offspring, added to the high pregnancy rate of adults and yearlings, and the pregnancy of some calves, means that for every 100 females in the population, 56 calves will be reared to weaning. If, as it seems, the foetal sex ratio is parity (un-shown data), then 28 females are added to the population every year. Therefore, in order to maintain the Wicklow sika-like deer herd at current numbers, it is necessary to harvest 28% of females.

The exact number of sika-like deer in the county is unknown, but 1994 it was estimated at 16,200 deer (Lowe 1994), and in 2000 at 19,215 (O'Brien 2000). Afforestation continues today at more than twice the yearly rate of the mid 80s with much greater areas planted privately than by the state (Department of Agriculture, Food and Forestry 1996, Coillte 1999, Irish Timber Growers Association 2002) due to grant-aid schemes for afforestation (Forest Service 2003). As suitable habitat has increased during recent years, the populations of all species, especially of fallow and sika, have presumably increased in density and/or geographical range, and are likely to continue to do so. Recent work in Co Wicklow using dung counts confirms that densities, at 40 deer/100 ha in some areas (Coad, pers. comm.), are indeed at the higher end of the spectrum recorded for sika deer, compared with densities of 11.9/100 ha in Dorset (Putman and Clifton-Bligh 1997) and 36.5/100 ha recorded for an island population at Lake Toya, Japan (Kaji et al. 1984). These high densities are currently having no ill effects on the reproductive output of females. Table 3 shows the total number of red, sika and red/sika hybrid harvested in Co Wicklow each year from 1995 to 2002 (calculated from figures returned to Dúchas by hunters when applying for a new hunting licence). Most of these deer were termed sika, (yearly mean of 14.5 male and 15.5 female red deer, and 139.75 male and 138.25 female hybrid deer). The number of females harvested has more than doubled in eight years, while that of males has almost done so. While this is due in part to a request from some landowners for hunters to harvest more deer because of damage (Coad, pers. comm.) it is most probably mainly due to the result of increasing numbers of deer. Deer are increasing in numbers because too few (females) are harvested each year to counteract their high rate of increase. If there were 16,200 sika-like deer in 1994, half of which were females (an uncertain fact given the widely-reported tendency to cull more males than females prior to then), 2,268 hinds would have needed to be culled to maintain that number of deer. As seen in Table 3, fewer than half that number were culled in 1995. By the same token, if 19,215 sika-like deer were present in the county in 2000, 2,690 hinds would need to be harvested to maintain a static population. In 2002, the number of hinds harvested still had not reached that figure. Thus, even using quite conservative estimates of deer numbers, it is clear that the potential rate of increase of the Wicklow sika-like deer population requires that more deer be harvested than at present. The numbers of fallow deer shot in Co Wicklow each year is also increasing, evidence that the population of that species is also expanding.

Tree damage is linked to deer density, though the correlation is weak (Putman and Langbein 2000). Thus as deer numbers increase, so too will tree damage. In the Wicklow area, Sitka spruce damage has been estimated at 45-60% of trees browsed, with 20-25% of trees damaged to an economically significant level (leaders eaten leading to malformed stems producing split trunks) in some forests (Lowe 1994, Coillte 1995, cited in Hurley 1996, Hayden 1997). In order to protect forests from deer damage, it will be necessary to keep population densities at or below a level where damage levels are acceptable to forest managers. This study has shown that given current damage levels, density of deer and deer reproductive potential, an increase in the deer harvest in the Co Wicklow region is required.

Management recommendations

As described above, the densities of sika-like deer in some parts of the Wicklow area are currently at the highest levels recorded for sika deer. The reproductive output of hinds is presently apparently unaffected by these high densities, but this may occur in the future. It is recommended that the reproduction of hinds be continuously monitored to assess any future changes that occur. If densities increase, the proportions of hinds that become pregnant and/or successfully rear offspring may decrease, while contrastingly, if deer numbers are reduced, reproductive output might further increase.

It was unexpected that calves in this population would be fertile. In a study of sika deer in Killarney, while the majority of yearlings became pregnant, just one calf did

Table 3: Total number of male and female red, sika and red/sika hybrids harvested in Co Wicklow from 1995 to 2002 (data provided by Dúchas).

Year	*Male*	*Female*
1995	1,257	1,164
1996	1,374	1,430
1997	1,106	665
1998	1,312	1,315
1999	1,565	1,694
2000	1,940	2,109
2001	2,284	2,522
2002	2,252	2,583

so. It is probable that many stalkers in the present study did not check whether calves were pregnant because of an assumption that it was unnecessary given its improbability. Lessees and stalkers using a forest should be made aware of the need to assess all females for pregnancy, regardless of age. Foetuses in calves may be very small and difficult to see, even during January and February. However, if pregnancy in this age group is not accurately assessed, it may lead to large errors in calculating the potential rate of increase and thus the appropriate target harvest level during the hunting season. Stalkers should be encouraged to check every uterus, or, if unwilling and pregnancy is not obvious, then the uterus should be collected and passed on to professionals for examination. Similarly, stalkers should be encouraged to open uteri to check for twin foetuses, so that a more accurate twinning rate may be ascertained. It is possible that twinning may be more common than presently thought, further increasing the potential rate of increase of the population.

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The elms of Co Cork- a survey of species, varieties and forms

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Abstract
In a survey of the elms in County Cork, Ireland, some 50 single trees, groups of trees and populations were examined. Four main taxa were recognised, these being wych elm, Cornish elm, Coritanian elm and Dutch elm plus a number of ambiguous hybrids. While a large overall number of elms were found, the number of mature or even ancient elms is relatively small. Still, there are sufficient numbers of elms in the county to base a future elm protection programme on.

Keywords
Ulmus, wych elm, field elm, hybrid elm, Dutch elm disease.

Introduction
Elm taxonomy is known to be notoriously difficult. For the British Isles there are many different concepts, varying between just two elm species and more than one hundred so-called microspecies (Richens 1983, Armstrong 1992, Armstrong and Sell 1996).

The main reason for the difficulty with elm taxonomy lies in the fact that the variability within the genus is extreme. This is especially true for the group of elms we know under the name field elm. As a result, there is no generally accepted system for classification of the elms of the world. Some British researchers claim to host up to eight elm species in their country (Melville 1975, Clapham et al. 1987, Stace 1997).

The approach taken here follows the lines being drawn by Richard H. Richens (1983) who followed a fairly simple strategy. He assumed that there are just two species of elms present in the British Isles, the native wych elm, *Ulmus glabra* and the introduced field elm, *U. minor*. According to Richens the latter has a number of varieties, five in total, and both species hybridise to form the hybrid elm, *U. x hollandica*. Up to this point this is a practical concept. Unfortunately, for taxonomists, every individual within the *U. minor – U. x hollandica – U. glabra* group is able to hybridise again with every other member of the group, which results in a great range of morphological forms.

Based on studies on biochemical and genetic variation, modern researchers propose that wych and field elm are not two separate species at all (Machon et al 1995, 1997, Goodall-Copestake et al 2005). Evidence from several studies showed a continuity in variation for the respective features investigated. Consequently, these two forms, wych elm, *U. glabra* and field elm, *U. minor* may be considered as being at the extreme and opposite ends of a very variable single species – probably to be called *Ulmus campestris* L. We are not able to find the discontinuity of characters

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that would sufficiently define a species (Mackenthun 2003, Goodall-Copestake et al. 2005).

This study undertakes the task to shed some light onto the various forms of elms that may be found in Co Cork. Not every finding may be in line with current taxonomic knowledge but the study aims to give an idea of the scope of elms in the area. Considering the complicated taxonomy of elms one might expect an impenetrable jumble of elm populations in Co Cork. This is not so. The clearer forms can be defined and those individuals that bridge the gaps between one form and the other can be identified.

Materials and methods

As already pointed out the overall objective of this study was not to produce a map of elm distribution in Co Cork. Rather, it seeks to give an impression of the range of species, varieties and forms of elms in the County.

Therefore, it was not necessary to scan the whole area but to go to places were the occurrence of elms was most likely: Natural and semi-natural woodlands, the wider river valleys (Rivers Bandon, Blackwater and Lee), the coastline, cemeteries and the gardens of stately homes. Furthermore, the knowledge of local people was utilised, for example employees of the Heritage department of Cork County Council. And while travelling through the County every elm of at least some importance was noted.

The identification of elms is based on two key sets of data.

First, pictures were taken of all trees under investigation in late spring 2006. They document their growth habit and their silhouette. Many British researchers base their system of elm species and varieties on the overall shape of the tree, especially its crown (e.g. Jobling and Mitchell 1974). In Co Cork, however, we find that many elms are not solitary, mature, well-shaped individuals but very often grow in hedgerows, in little woods where their growth may be suppressed by other trees. So, while the silhouette of a single tree is of good diagnostic value, it may not be clearly visible in every case. In some cases – like the majestic Castletownbere elm – it was used to identify a tree.

Second, during the following summer, leaf samples were collected from every elm that had been visited before. An additional excursion to the Gearagh was made by Chris Eisele in June 2007 to count elms and to collect leaf samples as described below. There is now a collection of leaf samples of nearly 50 trees which form the base for elm identification in this study.

Other characters which may provide useful hints to the designation of an elm are the flowers and fruits, for example. Characters of the bark are of good diagnostic value as long as trees of the same girth are compared. The bark varies a lot during the lifetime of a tree and only with luck a pair with similar dimensions may be found to allow for proper description and identification.

One particular character is indeed very helpful for the identification of elms: corky ridges on young twigs – so called 'winged twigs'. This is a clear hint towards field elm. But missing ridges may not lead to the conclusion that the tree in question is not a field elm.

Leaf characters were the main tools used for the identification of the elms in this study. When comparing elms, only mature leaves from the mature tree crown should be used. Leaves from shoots, suckers, from young individuals or from stumps are of little diagnostic value. It is best practice to use only the second leaf of a short shoot from the mature tree crown. Very often, however, these leaves are not available and the researcher has to work with what is at hand. For this study fairly uniform leaf samples which showed consistent characters were collected so that comparisons between elm populations could be made more feasible.

Elm leaves generally share a set characters as follows:

- they are simple (as opposed to compound leaves) and they are not lobed (like maple);
- the leaf margin is serrate (as opposed to entire), each larger tooth has 1 to 3 smaller teeth – so the margin is in fact doubly serrate;
- the lowest part of the lamina where the leaf margins join the petiole is usually asymmetric.

But the specific formation of leaf characters may disclose fine distinctions:

- the leaves can have many different overall forms from nearly round to very narrow;
- the leaves can be large (8 to 14 cm long), intermediate (6 to 10 cm) or small (4 to 6 cm);
- the leaf lamina can be wide (5 to 8 cm across) or narrow (2 to 3 cm);
- the tips of the teeth of the serrate leaf margins may be acuminate (Figure 1 (a)) or blunt (Figure 1 (b)).

The asymmetry of the leaf may express itself in different ways:

- both leaf margins join the petiole at the same point but the larger half of the lamina forms a lobe covering a part of the petiole (Figure 1 (c));
- both leaf margins join the petiole at the same point and the two halves of the lamina are just of different size (Figure 1 (d));
- both leaf margins join the petiole at different points but the distance between these two points is relatively short (Figure 1(e));
- both leaf margins join the petiole at different points and the distance between these two points is relatively long (Figure 1 (f));
- the petiole and the midrib of the leaf is not straight but bent, leading to an extreme asymmetry in the lower part of the leaf (Figure 1 (g)).

This set of characters should be sufficient to identify the elms of Co Cork. But, as was said before, a wide range of intermediate forms occur.

Results

Species, varieties, cultivars and types of elms

In the course of the study four more or less distinct taxa were found: *Ulmus glabra* (wych elm), *U. minor* var. *cornubiensis* (Cornish elm), *U. minor* var. *coritana* (Coritanian elm) and *U. x hollandica* (Dutch elm). All four taxa display various forms of variability in leaf characters so that the overall number of discernible entities is 13. The taxonomical status of each of these entities needs to be discussed.

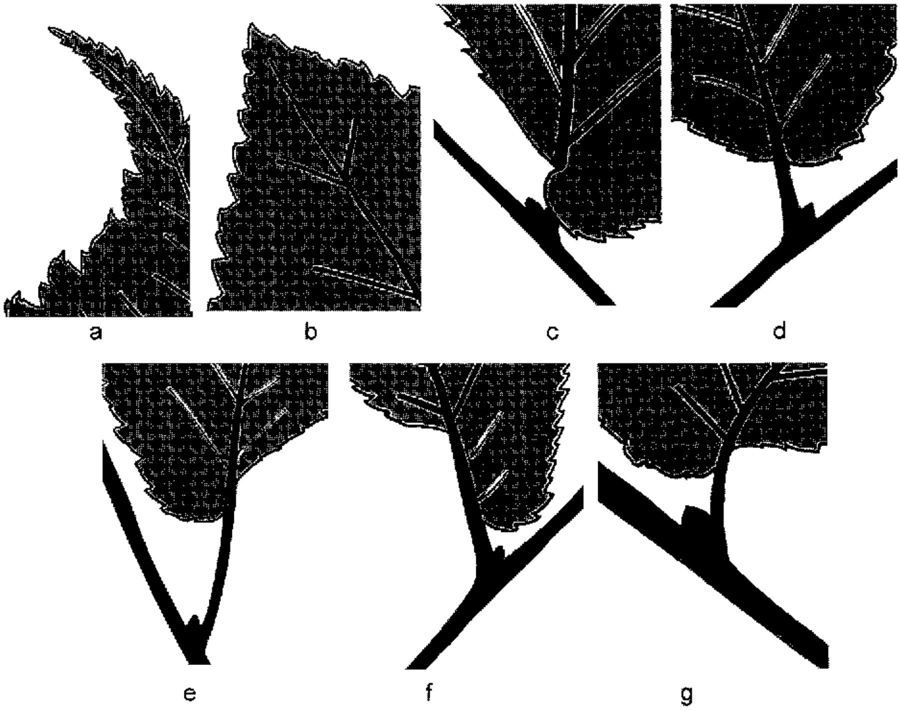

Figure 1: Leaf characteristics of elm species - (a): acuminate teeth at the leaf margin, (b): blunt teeth at the leaf margin, (c): lobe covering the petiole, (d) leaf margins join the petiole at the same point, (e) leaf margins join the petiole at different points (short distance between points), (f) leaf margins join the petiole at different points (long distance between points), (g) bent petiole and midrib.

Ulmus glabra (wych elm)

The leaves of *U. glabra* are large, 8 to 14 cm long, 5 to 8 cm wide (the product of length x width being > 28), their form is ovate, the widest part of the leaf is shifted towards the tip, the upper surface of the leaf is very rough, the leaf margin is sharply serrate, some leaves tend to have multiple leaf tips, the vein-pits are densely pubescent, the lowest part of the lamina is normally nearly symmetrical – but very asymmetrical variants occur – the larger half forms a lobe covering the petiole.

The typical form with a fairly symmetrical base of the leaf-blade occurs at relatively few locations (Figure 2): Ahakista (mid-town), Ballineen (western part of town), Ballyally (coastguard station), Baltimore (Glebe Garden), Glengarriff (near Lady Bantry Bridge), Macroom (Crow Wood – three examples, each with a girth of around 100 cm at breast height, were found here).

An atypical form with a distinct asymmetrical lower part of the leaf-blade was found at Baltimore (Glebe Garden) and Letter Lower (Figure 3). Multiple tips of the leaf may or may not occur in both forms.

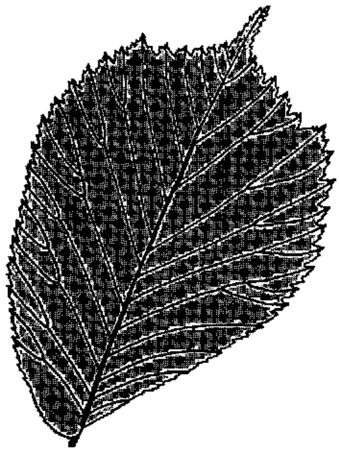

Figure 2: Leaf form of wych elm – typical form, approximately half natural size.

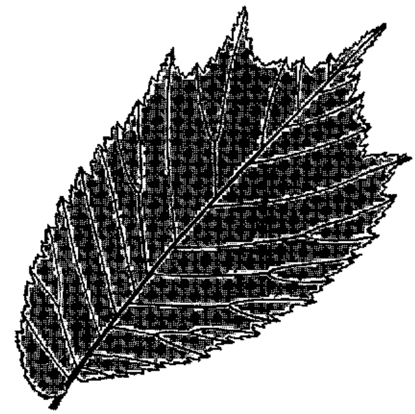

Figure 3: Leaf form of wych elm – atypical form, approximately half natural size.

Ulmus minor (field elm)

Traditionally, this elm species is sub-divided into five different varieties, one of them is found in Co Cork. Additionally, a second form of *U. minor* seems to be present.

Ulmus minor var. cornubiensis (Cornish elm)

The leaves are small, 4 to 6 cm long, 2 to 3 cm wide (the product of length x width being < 28), the leaves are ovate to rhombic, the lower part of the leaf-blade is rather symmetrical – variants with a very asymmetrical lower part of the leaf-blade occur, both leaf-margins join the petiole at the same point, the upper leaf surface is normally smooth, the leaf-margins are pointedly serrate.

The typical form with a rather symmetric leaf and a smooth upper leaf surface (Figure 4) was found at the following locations: Ahakista (western part of village), Ahakista (near the coast), Ardnagashel (eastern part of village), Bandon River (near Gurteen crossing), Bantry (near the road to Careagh), Bantry (Clashduff House), Castletownbere (cemetery, the champion tree with a girth of 450 cm), Castletownbere (cemetery, several other individuals of smaller size), Crookhaven (coast line opposite town), Dunbeacon (Carberry Home), Goleen (cemetery), Gurteen (Bandon River), Innishannon (River Bandon bridge), Kilcrohane (glebe land near the church), Lissarda (near Macroom), Macroom (Mill Road), roadside of the N71 near Clonakilty (near 'Shalom' B&B), roadside between Toomore and Goleen.

A type with a rather symmetrical leaf-blade but with a rough upper leaf surface was found in the Convent precinct of Castletownbere and at the Gearagh. Another type with a smooth upper leaf surface but a very asymmetrical lower part of the leaf occurs at the Blarney Crossing in Cork city and again in the Convent precinct of

Figure 4: Leaf form of Cornish elm, approximately natural size.

Castletownbere. A fourth type with a rough upper leaf surface and a very asymmetrical leaf was encountered at Drumkeen (the Gearagh), Cork city (Blarney crossing) and in Kealkil (Ballingeary Road, opposite 'Future Forests').

Elm tree at Castletownbere cemetery.

Ulmus minor var. *coritana* (Coritanian elm)

For practical reasons discussed below there was a need to re-introduce the former species *U. coritana* as a sixth variety of *U. minor*. The leaves of the proposed *U. minor* var. *coritana* are larger than those of the other varieties of field elm, 7 to 9 cm long, 4 to 5 cm wide, the leaf margin is bluntly serrate, the petiole and parts of the leaf-blade are extremely asymmetrical (Figure 5).

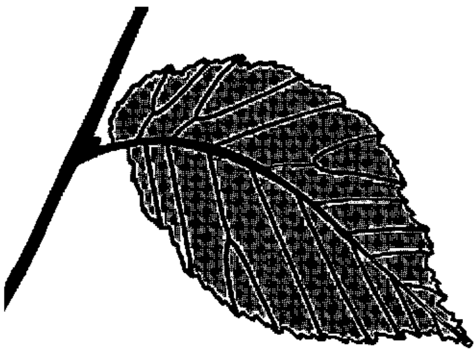

Figure 5: Leaf form of Coritanian elm, approximately three-quarters natural size.

This form was found near Barley Cove, at Lissagriffin and at Toomore. In the farm-yard at Lissagriffin stand the two finest examples of 160 and 170 cm girth at breast height.

Ulmus x *hollandica* (Dutch elm and hybrid elm)

In Co Cork five different forms of *U. x hollandica* occur, only one may be recognised as a cultivar. The others can be considered as spontaneous hybrids between various forms of elms, the result of continuous hybridisation.

Ulmus x hollandica 'Major' (Dutch elm); putative first generation hybrid

The leaves are mid-sized, 8 to 10 cm long, 5 to 7 cm wide (the product of length x width being > 28), the leaf-blade is ovate to cordate, the upper surface is smooth, the leaf margin sharply serrate, the lower part of the leaf is rather symmetrical to very asymmetrical (Figure 6).

U. x hollandica 'Major' grows at: Ballineen (western part of town), Durrus (Friendly Cove), Innishannon (banks of the River Bandon), Inchigeelagh (eastern exit of the village), Kilountain (banks of the River Bandon), Letter Lower (farm yard), Letter Lower (garden), Toomsbridge (the Gearagh, south lake road). The largest example is the tree at Kilountain, with a girth of 105 cm.

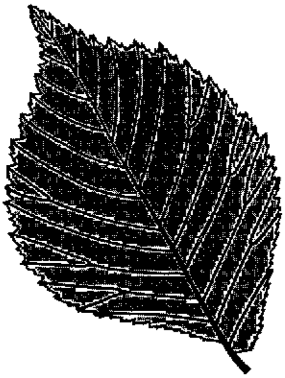

Figure 6: Leaf form of Dutch elm, approximately half natural size.

Ulmus x hollandica (hybrid elm); ambiguous hybrids

Five discernible types of hybrid elms – other than the cultivar 'Major' – can be found in Co Cork.

Type 'A' seems to be another hybrid *U. minor x U. glabra.* Its leaves are big, up to 14 cm long and up to 9 cm wide, the leaf margin is sharply serrate, the upper surface of the leaf is smooth. It occurs at Ardnagashel, Ballineen (western part of town), Bandon River (near Gurteen crossing), Bantry House (upper garden), Castletownbere (near 'Fast Fish' company – with a girth of 335 cm this was the second largest elm found), Cork city (Blarney crossing) and Mallow (western part of town).

Very similar in form is type 'B', another *U. minor x U. glabra.* As above, the leaves are big, up to 14 cm long and up to 9 cm wide, the leaf margin is sharply serrate, but the upper surface of the leaf is rough. It grows in the lower garden of Bantry House and two individuals of this type were found in the Gearagh.

In type 'C', also a putative hybrid of *U. x hollandica and U. glabra*, the lower part of the leaf is very asymmetrical, a lobe is covering the petiole, the leaf margin is sharply serrate. It was found near Barley Cove, at Kilcrohane (eastern and western parts of town) and at Macroom (Mill Road). The biggest tree of this type is the one at Kilcrohane with a girth of 125 cm.

The fourth form, type 'D' may be a hybrid of *U. x hollandica* and *U. minor* var. *coritana*. The leaf is very similar to type 'C', but the leaf margin is bluntly serrate. There are examples at Ballycotton, Ballymaloe Estate and Cork city (Blarney crossing).

Finally, type 'E' resembles an old Dutch cultivar (cf *U. x hollandica* 'Belgica'). The leaves are 8 to 12 cm long, only 4 to 5 cm wide, thus quite narrow, the base of the lamina is extremely asymmetrical (Figure 7). It occurs at only one location, Killavullen.

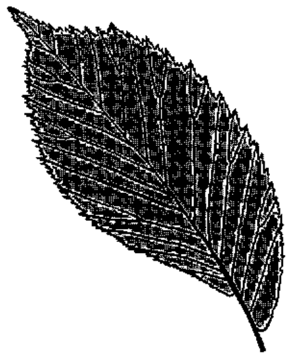

Figure 7: Leaf form of type 'E' hybrid elm, approximately half natural size.

The question whether or not the various individuals of the hybrid elm cluster are of clonal origin or are the product of sexual reproduction cannot be answered within the limits of this study. The definition of the five types was based solely on leaf characters which resemble more or less closely the features of their possible parents.

Mature elms

In total 28 elms with a girth of 80 cm or more at breast height – translating into a bole diameter of 25 cm or more – were found during the study. Table 1 gives an overview of the trees in question with their respective locations and dimensions.

Of the 28 largest elms, 13 grow on the three southwestern peninsulas, seven in the Bandon River valley, five in the Lee River valley and one in the valley of the river Blackwater. Towns and cities were not particularly investigated, so only one larger tree each were noted in Bantry and in Cork.

Whether or not any conclusions may be drawn from this distribution remains to be discussed.

Discussion

A couple of assumptions need to be made to reduce the number of elm species one may be likely to encounter in Co Cork.

First, it is highly improbable to find *Ulmus laevis* in southwestern Ireland. The species is predominantly distributed in central and eastern Europe.

Second, it is highly improbable that modern cultivars were planted in rural Ireland during the last two or three decades without people knowing. Only three nurseries are known to have sold or to still sell modern cultivars (like the Dutch *Ulmus* 'Columella' or the American *Ulmus* 'New Horizon'). During the research for this study only one of these plantings was encountered (on private premises at Friendly Cove near Durrus).

Table 1: Mature elms of Co Cork.

Location	*Species, Variety, Cultivar, Type*	*Girth cm*	*dbh cm*
Ballineen	*Ulmus glabra*	80	25
Castletownbere, Cemetery	*U. minor* var. *cornubiensis*	80	25
Glengarriff	*Ulmus glabra*	80	25
Ballineen	hybrid *U. minor & U. glabra* (type 'A')	85	27
Gurteen	hybrid *U. minor & U. glabra (*type 'A')	85	27
Inchigeelagh	*Ulmus x hollandica* 'Major'	90	29
Macroom, Mill Road	hybrid *U. x hollandica & U. glabra (*type 'C')	90	29
Innishannon	*Ulmus x hollandica* 'Major'	95	30
Macroom, Crow Wood	*Ulmus glabra*	100	32
Macroom, Crow Wood	*Ulmus glabra*	100	32
Macroom, Crow Wood	*Ulmus glabra*	100	32
Bantry, road to Carcagh	*U. minor* var. *cornubiensis*	105	33
Kilountain	*Ulmus x hollandica* 'Major'	105	33
Mallow	hybrid *U. minor & U. glabra* (type 'A')	105	33
Ballineen	hybrid *U. minor & U. glabra* (type 'A')	110	35
Gurteen	*U. minor* var. *cornubiensis*	110	35
Cork, Blarney crossing	hybrid *U. minor & U. glabra (*type 'A')	115	37
Ahakista, near coast	*U. minor* var. *cornubiensis*	120	38
Kilcrohane	hybrid *U. minor & U. glabra* (type 'C')	125	40
Lissagriffin	*Ulmus minor* var. *coritana*	160	51
Lissagriffin	*Ulmus minor* var. *coritana*	170	54
Castletownbere, Cemetery	*U. minor* var. *cornubiensis*	230	73
Castletownbere, Cemetery	*U. minor* var. *cornubiensis*	240	76
Castletownbere, Cemetery	*U. minor* var. *cornubiensis*	245	78
Castletownbere, Cemetery	*U. minor* var. *cornubiensis*	245	78
Castletownbere, Cemetery	*U. minor* var. *cornubiensis*	290	92
Castletownbere, 'Fast Fish'	hybrid *U. minor & U. glabra* (type 'A')	335	107
Castletownbere, Cemetery	*U. minor* var. *cornubiensis*	450	143

Third, it is also not very probable that exotic forms of elms from other continents were introduced into rural Ireland. For example, this would rule out *Ulmus pumila*, an Asian elm widely planted in the southern countries of Europe.

On the other hand, we can assume that some English influence should be reflected in today's elm population, especially near estates and manors. We may find older English cultivars like *Ulmus x hollandica* 'Major' or *Ulmus x hollandica* 'Vegeta'. The English impact may have diminished after political independence in1922. Under both English and Irish rule, plantings were made so that today it must be assumed that there is a mixed population of native elms plus introduced elms plus any hybrids which arose among and between them. In addition, some elms (*U. minor* and hybrids), which showed useful traits such as straight stems, and which readily produced suckers were probably lifted and transplanted quite widely.

Though these assumptions are all quite plausible and reflect the recent history of the Irish countryside, one has always to be open for surprises and unexpected encounters when dealing with elms in any given area.

As already mentioned, elms tend to make their taxonomy even more complicated by hybridising freely among each other. This happens naturally where the areas of *U. minor* and *U. glabra* overlap. One such result is *Ulmus x hollandica*, which is considered to be a natural first generation hybrid of *U. glabra* and *U. minor.* The cultivated form of this elm is *Ulmus x hollandica* 'Major'. In our study, elms with key leaf characters intermediate between those of the two parent species are considered to belong to this taxon.

And also, man took his chance in producing cultivars consisting of natural hybrids plus other parents (Hiemstra et al 2005). Since all of the hybrid offspring are fertile they hybridise again with the original parent species or with other natural hybrids or with cultivars. The result is called a cluster of hybrids with any number of entities with no clear delimitation between them (Endtmann 1980, Rothmaler 1990). This does not only show in morphological data (Mackenthun 2003) but also in the genetic make-up (Goodall-Copestake et al 2005). It was suggested that the *U. glabra – U. x hollandica – U. minor* group should be treated as one single species (Machon et al. 1995, 1997). Those hollandica-elms that cannot be put into the taxon 'Major' are regarded as possible second generation hybrids. They all do not show intermediate leaf characters of the parent species but lean to either the field elm or the wych elm side of the spectrum.

But the single species approach would blur distinctions between some of the entities within the group. For example, it is known that *U. minor* is more susceptible to Dutch elm disease than *U. glabr*a (Mackenthun 2004). This is in an important fact for the future treatment of elms in the countryside.

To avoid both over-simplification and over-splintering a middle path for considering the classification of elms was conceived. It follows mainly the concept by Richens (1983) with just two species and a number of hybrids.

Wych elm

Notwithstanding the difficulties of elm taxonomy, one distinct entity is *Ulmus glabra*, the wych elm or Scotch elm (Mackenthun 2001). This species is the common elm of many uplands, hills and mountains in most parts of Europe. Its distribution reaches from the Atlantic to the Urals and from Italy to Norway. In natural environments *U. glabra* is the elm of rich soils with a good supply of water.

Some researchers claim that it is the only elm native to the British Isles (e. g. Mackay 1836, Richens 1983, Preston et al. 2002). It is quite likely that wych elm was in the country before man. Later, it was important enough to receive several mentions in early Irish literature (Richens 1983).

We find a number of good wych elms in Co Cork which all show the typical leaf characters. In two locations we found examples with a somewhat atypical leaf but the differences between these two groups are too small to constitute separate taxa.

Field elm

On the other end of the spectrum we find *Ulmus minor* (invalid synonym: *U. carpinifolia*), the field elm, smooth-leaved elm or narrow-leaved elm (Mittempergher 1996). It is the typical elm of river floodplains in all parts of Europe, except in the north. Covering a wide ecological range it can also populate the dry slopes of floodplain margins. The species was widely planted in many countries, most notably in England in the form of Ulmus minor var. vulgaris (English elm, '*Ulmus procera*') as well as in Spain and Italy (Mackenthun 2005).

There are good reasons to consider field elm to be a non-native species. It was suggested that it was brought to the British Isles during the Bronze Age some 3500 years ago. The English elm in particular might have been introduced in Roman times as a recent study claims (Gil et al. 2004).

Being most susceptible to Dutch elm disease, field elm vanished from most parts of Europe as a mature tree during the last century, but survives as root suckers in many places.

Ulmus minor as a species is subdivided in five varieties (Richens 1983):

- *U. minor var. cornubiensis* (Cornish elm): an elm restricted to the westernmost parts of Britain, today considered to be a single clone, not a variety (Coleman 2002);
- *U. minor var. lockii* (Lock's elm): today considered to be a single clone, not a variety (Coleman 2002);
- *U. minor var. minor* (small-leaved elm): today the commonest type of field elm in continental Europe – probably formerly '*U. suberosa*' (e. g. in Mackay 1836);
- *U. minor var. sarniensis* (Jersey elm): a cultivar from south-west England, today only used as amenity tree, most likely to be a single clone (Coleman 2002);
- *U. minor var. vulgaris* ('*U. procera*', English elm): formerly the commonest elm in southern Great Britain, again, it is now seen as a single clone (Gil et al 2004, Mackenthun 2005).

Of these varieties or clones only one, the Cornish elm, appears in Co Cork. Within this taxon leaf characters vary a lot. Still, the various types seem to have a sufficient set of features in common and the differences do not appear to be great enough to allow for separate taxa and individual names. As already pointed out, *U. minor* in particular is one of the most polymorphic species in the flora of the British Isles (Stace 1997).

The decision to create a larger group of cornubiensis elms was based on leaf characters as well as on the growth habit of the trees in the cemetery in Castletownbere. As opposed to other forms of elms, *U. minor* var. *cornubiensis* has a straight and strong trunk with the main branches steeply ascending, forming a fanshaped crown (Jobling and Mitchell 1974, Blamey and Grey-Wilson 1989, Coleman 2002). Dutch elm expert Hans Heybroek (formerly of the Dorschkamp research institute in Wageningen, pers. comm.) helped with the identification of this elm variety. The pictures of elm silhouettes in Blamey and Grey-Wilson (1989) were useful, plus their remark that *U. minor* var. *cornubiensis* occurs – besides mainland Britain – "also in SW Ireland". The Cornish elm has a somewhat 'Celtic' distribution, covering Brittany in France, Cornwall in England and the southwestern counties of Ireland. One may or may not assume that the variety was brought to these parts of Europe by Celtic people.

It seems that *U. minor* var. *lockii*, *U. minor* var. *minor*, *U. minor* var. *sarniensis* and *U. minor* var. *vulgaris* do not occur in Co Cork (the latter has a similar growth habit to the cornubiensis variety but the leaves are entirely different). It is surprising that English elm was not encountered during the study. One reason may be that we simply overlooked it. One has to keep in mind, however, that it is the most susceptible of all European elms and tens of millions succumbed to Dutch elm disease in the British Isles.

There is one distinct elm in Co Cork which clearly belongs to the field elm group but does not fit into the pattern of the five traditional varieties (Richens 1983). However, there is a description of this taxon by Melville (1949). More than 50 years ago he postulated an elm he called *Ulmus coritana* or Coritanian elm. It was named after an old British tribe living in ancient times in the Leicestershire region, the Coritanea. His species was later discarded by nearly all authors, most notably by Richens (1983). He considered *U. coritana* and *U. minor* var. *minor* to belong to the same entity.

However, there are three elms in Co Cork fitting very neatly the description by Melville (1949). One prominent feature is that both the petiole and the midrib are not straight as in *U. minor* var. *minor* we know from continental Europe but that they are more or less distinctly bent. Therefore, it was decided to revive the long gone species as a variety – even if it may only be a preliminary solution until a more sophisticated arrangement of the elms of Co Cork is devised.

The current authoritative flora of the British Isles (Preston et al. 2002) states both *U. glabra* and *U. minor* to be widely distributed in Co Cork. No differentiation is made between varieties, var. *vulgaris* is treated as a separate species ('*U. procera*').

Elm hybrids

The putative natural first generation hybrid between *U. glabra* and *U. minor* is *U. x hollandica*, the hybrid elm. This type of elm was given the name 'Major' or Dutch elm when it was selected for propagation by early nursery men and thus became a cultivar. It was probably chosen for its growth performance (major being Latin for big) at some unknown point of time in history. It is well known, however, that this cultivar was widely planted in Britain after the Dutch prince William of Orange became king of England in 1688 (Hiemstra et al 2005). It would be no surprise that English influence brought this elm also to Ireland.

In continental Europe, the 'Major' elm appears in some outdated publications but it is hard to find a living specimen in nature. It is quite surprising that there are individuals in Co Cork which neatly fit the description given in More & White (2003).

There can only be guesses concerning the possible origin of other types of hybrids. It is only clear that they diverge in a number of leaf characters from the 'Major' elm. There is no point in giving names to these types since they do not establish separate entities that can be defined in a satisfactory taxonomic way. They must rather be considered as representatives of many forms of ambiguous hybrids occurring in Co Cork. It would be entirely sufficient for practical reasons to lump them all together in one taxon as there is a haphazard element in subdividing this group of elms. Still, it might be useful to describe separate entities for future researchers to decide whether or not they want to follow the concept presented here.

Most of these types 'A' through 'E' of the ambiguous hybrid elms occur in locations where also other forms of elms exist, e.g. in Bantry, Cork and Castletownbere. One might suggest that the various sample trees belong to the same genotype and that the differences in leaf characters are differences between individuals (triggered by ecological factors) or that indeed hybridisation takes place within the population and two leaf samples from two trees represent two different genotypes. Without an analysis of the genetic make-up no answer can be given.

Distribution and size

Considering the elms of Co Cork, three facts are perhaps worth mentioning.

Elms next to the shore

Elm trees were always valued for the many practical purposes they could be used for. But also, elm trees were valued for their toughness in nearly all environments. Both the physiological and the ecological amplitudes are rather wide in this genus. They can withstand flooding and drought, poor soils and rich soils, limestone and granite, storm, snow, rain, hail, cold and heat as well as sea water spray. So, it is little wonder that in Co Cork elms are quite often found in places where they face the sea directly. The spray blown inland by strong westerly winds carries aggressive salts few plant species can cope with. Elm seems to flourish under these conditions.

Vast numbers of elms

There are enormous numbers of elms in Co Cork. We visited some 50 locations and encountered hundreds if not thousands of elms. There are still miles and miles of hedgerows that quite often contain elms. This is especially true in the Bandon valley. With every cutting of the hedgerow elms re-sprout from the stump and thus give life to a clonal group of new elms. There are thousands of individual trunks and some of them may have the chance to grow into a mature tree. There is no shortage of elms in the county.

Big elms

With Dutch elm disease present in nearly every place where elms exist in the northern hemisphere one does not expect to find very many big and mature elms. This, generally, is also true in Co Cork. But surprisingly there are a larger number of at least moderately sized elms than could have been foreseen.

At 50 locations visited for the study we found 28 elms with a girth at breast height of 75 cm or more. By Mitchell's Rule (1 inch of girth equals 1 year of age) these elms are older than 30 years – this means they survived the second, most destructive pandemic of Dutch elm disease from the 1970s onwards. Out of those 28 trees, 7 have a girth of 225 cm or more, translating into an age of nearly 90 years and more. These are the survivors of the first and the second Dutch elm disease pandemic. All of them stand in Castletownbere, one in the town centre and six in the cemetery. The biggest of this group of elms, a giant of 600 cm girth and more than 200 years of age, was unfortunately felled by a storm in 2005 (its trunk was rotten inside, there was no trace of Dutch elm disease). The huge tree lay in the far corner of the cemetery for a while and was removed early in 2007. Next to it stands the current elm champion of Co Cork with a girth of 450 cm, translating into an age of some 175 years, a height of 25 m and a crown diameter of 20 m. The mighty bole branches only 1 m above ground level into two big trunks so that from a distance it looks as if it were two trees growing in close proximity.

The big trees are more or less evenly distributed between the southwestern peninsulas and the valleys of the three major rivers in Co Cork.

Dutch elm disease

The Dutch elm disease pandemic was described and analysed in thousands of books, scientific papers, newspaper articles, broadcasts and internet publications (an extensive overview is given in Buchel and Cornelissen 2002). Of course the elm populations on the island of Ireland were strongly affected by the disease. Some forms of elm today only occur as shrubs and little trees. This is especially true for the English elm in Britain.

Without the slightest doubt Dutch elm disease made its impact on the elms of Co Cork too. Some forms of elms may have vanished from the county altogether, other forms may exist only in hedgerows, undetected and unidentified, again other forms may be the sole survivors of a much larger and probably much more diverse population. It may be no coincidence that the largest elms occur on the peninsulas and in the river valleys. The disease came from the east. Near the coast with its strong westerly winds the elm bark beetle, the vector of Dutch elm disease, had little chance to travel any further. Thus, the disease came probably to a standstill when the vector and the fungus were not able to maintain a sufficient level of infection pressure. In the floodplains of the wide river valleys, elm is one of the major species that constitute the natural riparian wildwood. Before the cultivation of the floodplains huge numbers of elms must have existed. Many were lost due to habitat destruction. A large portion of what was left fell victim to Dutch elm disease. But since there were still comparatively great numbers of elms, the number of survivors also was relatively high. However, no exact mapping of elm trees was included in this study and so the remarks on the distribution of the larger trees may only be regarded as hypothesis.

All in all, we know little about the course of Dutch elm disease in the county. What we can say, however, is that the disease is still present and constitutes a permanent threat to the remaining elms.

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Zusammenfassung

In einer Untersuchung der Ulmen im County Cork im Südwesten Irlands wurden 50 Standorte näher betrachtet. Vier Sippen konnten unterschieden werden, nämlich die Berg-, Cornwall-, Coritanische und Holländische Ulme. Hinzu kommen einige unklare Hybriden. Die Gesamtzahl der Ulmen ist hoch, die der großen und alten Ulmen jedoch vergleichsweise gering. Trotzdem sind im County hinreichende viele Ulmen für ein zukünftiges Ulmenschutzprogramm vorhanden.

Schlagworte

Ulmus, Bergulme, Feldulme, Holländische Ulme, Holländische Ulmenkrankheit.

The impact of Sitka spruce log dimensions on recovery

Ian Browne[a], Traolach Layton[b] and Maarten Nieuwenhuis[c]

Abstract

The successful running of a sawmill is dependent on the ability to achieve the most profitable combination of throughput and value recovery. Analysis of log type in terms of volume/value recovery and product out-turn are important aspects of the development of optimisation techniques in the sawmill. Typically the breakdown of a stem into sawn products consists of a three-dimensional optimisation process. In the shortwood (or cut-to-length) system, this decision process is spatially and temporally divided into two stages. Based on batch data from 244 daily production runs of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) logs, highly significant relationships were found between dependent variables *output volume* and *output value* and independent variables mean batch *diameter*, mean *batch diameter squared, number of logs* in the batch and *log length* of the batch, for some of the length classes but not for others. The mean batch log diameter had no significant influence on recovery rate, probably indicating that the mix of individual log diameters in the batch, combined with the sawing pattern selection, determines recovery, not the mean batch log diameter value. Further study should focus on an investigation into the relationship between sawing patterns, log size, and product volume and value recovery.

Keywords

Sitka spruce, input/output modelling, wood volume recovery, wood value recovery.

Introduction

The successful running of a sawmill is dependent, *inter alia*, on the ability to achieve a profitable combination of throughput and value recovery. Analysis of volume/value recovery and product out-turns as influenced by log size is an important aspect of the profitable operation. Optimisation of the sawing process, however, cannot be examined in isolation of the cross-cutting process (Reinders 1989). Typically the breakdown of a stem into sawn products consists of a three-dimensional optimisation process. In the shortwood (or cut-to-length) system, this decision process is spatially and temporally divided into two stages: the crosscutting decision and processing at the stump; and the selection of a sawing pattern for each log in the sawmill. In order to move the overall process towards the financial optimum, these two decisions have to be integrated, as the most profitable result will be dependent on the optimal combination of the two.

An integrated optimal cross-cutting and sawing pattern selection strategy has to be selected for each tree. The value and demand for the end-products in the mill

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determine the value and priority of the log sizes that should be considered as part of the log mix during harvesting operations. In the mill, for each log size a number of sawing patterns can be used. Depending on the demand for certain end-products and the availability of the different log sizes in the log yard, a pattern should be selected from those available that are suitable for the specific log/end-product combination. On a day-to-day basis, demand for certain end-products, their availability in inventory, and restrictions on the supply of logs of different sizes to the log yard, may make it necessary to deviate from the optimal sawing pattern in order to produce the required output of specific products.

The sawmilling sector in Ireland

Until the 1960s, the wood-processing sector consisted primarily of a large number of small sawmills, producing non-standardised products. Because production from these plants had difficulty in competing with imported sawnwood, and in the light of forecasted increases in domestic wood supplies, government grant aid was provided for modernisation of the wood processing industry. Over the past 20 years, plantations established just before or after the Second World War have matured and the quantity of wood processed has been rapidly increasing (Gardiner 1991). In 2001 Irish mills processed 2.2 million m^3 of roundwood and this is expected to rise to 3.4 million m^3 by 2015 (Gallagher and O'Carroll 2001). Achievement of the level of processing to date is on foot of an investment programme by the sawmilling industry (ITC 2001).

Recovery

Sawmills can be characterised by the roundwood resource they process, by their size, by the type of machinery used to break down the logs and by the degree of automation (Walker 1983).

Williston (1981) identified a number of factors that determine mill profitability: throughput, volume conversion and grade recovery. Value recovery is maximised where each log is processed such that the greatest volume of the highest value items is recovered at the lowest cost. Steele (1984) pointed out that recovery is determined by the interaction of many variables. These include: log diameter, length, taper and grade, kerf width, product mix, decisions taken by sawmill personnel, the condition of equipment in use in the sawmill, and sawing method. Sawing accuracy is an additional factor influencing recovery (Stern et al. 1979).

Today, most sawmills use optimisation techniques to maximise yield from logs (Todoroki and Rönnqvist 2002). These can have a significant effect on profitability. Todoroki and Rönnqvist (2001) noted that throughout the forest-to-mill supply chain, there are many instances where provision of accurate data can enhance decision-making and profitability. To this end, many software tools have been developed to aid in decision-making, in recovery and ultimately in maximisation of profitability. For example, Barbour et al. (2003) showed in a study using AUTOSAW software, that the financial recovery from small dimension logs could be higher by focusing more on the (high-speed) production of less-valuable 'commercial' and 'factory' lumber than trying to maximise the recovery of high-value 'dimension' lumber, resulting in a slowing down of the production process.

Objectives

The research presented in this paper forms the second phase of a COFORD-funded research project (OptiVal) based at University College Dublin and carried out in conjunction with Palfab Ltd. (Nieuwenhuis et al. 1999). It follows work by Malone (1998) and McHugh (1999), which had the aim to develop a decision support system, incorporating pre-harvest measurement and analysis procedures, that would provide a timber procurer with estimates of the volume, number and diameter class breakdown of log assortments that could potentially be cut from standing lots of mature Sitka spruce (*Picea sitchensis* (Bong.) Carr.) (Nieuwenhuis 2002). Work done by Dooley (2005), investigating the accuracy of harvester head measurements, was also part of the project, aimed at linking all steps in the production chain through a parallel information chain (Nieuwenhuis and Dooley 2006, Dooley et al. 2007). This paper presents the results of a continuation of the project work, focusing on the decision making process in the mill (Browne 2003). The research involved saw pattern selection and value optimisation procedures within the sawmill. The ultimate objective is to develop an integrated decision support system, through the linkage of the in-forest and the in-mill decision making processes into an information chain.

Materials and methods

All data used in this study were collected at Palfab Ltd., Lissarda, Co Cork, and in the surrounding forests. Palfab is a medium-sized softwood sawmill, which purchases over 90% of the logs it processes from standing sales. Logs bought for processing have a small-end diameter (SED) range from 10 to 50 cm. Logs with a SED greater than 50 cm are too large for processing at this mill. Logs enter the yard as shortwood, having been cross-cut in the forest during harvesting. Four log lengths are sawn in the mill: 3.7, 4.3, 4.9, and 5.5 m. Logs of 4.9 m length are the most commonly processed. The mill produces 41 sawn timber sizes in each of the four lengths (Table 1). Timber boards range in size from 3700 x 100 x 14 mm to 5500 x 93 x 229 mm. Large sizes are rarely sawn; smaller sizes make up most of the production. Pallet boards are also sawn to two sizes: 1400 x 140 x 14 mm and 1400 x 95 x 14 mm.

Primary breakdown, re-sawing and sorting

Roundwood is delivered to the mill by truck where it is first weighed. It is then stacked in the yard, with designated areas for different length classes. Production runs typically last a half to a full day, comprising logs of one length. Logs are fed into the mill, one at a time, passing first through a butt reducer and then a debarker. Logs then pass through a scanner and onto a log angle rotator, which positions them for sawing.

The sawing line setup in the mill was as follows: logs passed through the first saw twice, removing sideboards to produce rectangular cants, which were broken down

Table 1: Product codes by width and thickness. Sawn and notional sale dimensions are shown.

Product code	Width	Thickness	Product code	Width	Thickness
	mm			mm	
1	102/100	14/14	22	229/225	22/22
2	36/35		23	36/35	
3	45/44		24	45/44	
4	75/75		25	75/75	
5	117/115	36/35	26	102/100	22/22
7	127/125	36/35	28	127/125	50/50
8	45/44		29	117/115	55/55
9	75/75		30	152/150	57/55
10	152/150	14/14	31	162/160	63/62
11	22/22		32	192/190	63/62
12	30/30		33	302/300	75/75
13	36/35		34	102/100	102/100
14	45/44		35	106/105	102/100
15	75/75		36	127/125	127/125
16	177/175	22/22	37	152/150	152/150
17	36/35		38	156/155	152/150
18	45/44		39	202/200	202/200
19	75/75		40	132/130	36/35
20	202/200	45/44	41	229/225	92/90
21	75/75	75/75			

into boards, these were then trimmed to a set length. Boards were automatically sorted into pre-assigned sizes. Sideboards were processed into pallet wood, which was also trimmed and sorted.

Data collection, storage, retrieval and analysis

In order to carry out the analysis of log size in terms of end-products and volume/value recovery, a number of preliminary studies had to be carried out. First, the reporting capabilities of the production control computer had to be examined. After establishing and analysing the range of report formats available, the accuracy of the reporting process was established by comparing manually collected data sets with those produced by the computer. Data from the production control computer could not be transferred to another computer electronically and had to be printed and manually entered into a spreadsheet.

It was decided that one year's production data were needed to produce accurate statistical results. This was on the basis that within the space of one year all log and end-product sizes would be covered. A year's data also covered differences in log quality and/or mill procedures between summer and winter. Data were in the form of computer-generated production reports for each day the mill was in operation. Pallet wood production data were produced manually at the stacking line. Reports contained information on the product dimensions, the number of boards per batch, the number of batches and the total volume of pallet wood produced during the day. All diameter values are based on under-bark measurements.

A spreadsheet was developed to facilitate data entry and validation. It comprised details of all logs processed and boards produced. A completed and validated data set was used for statistical analysis, using a General Linear Model (GLM) SAS procedure for variance and regression analyses.

The overall hypothesis tested was that the output volume and value of a batch were functions of a range of input parameters such as the mean diameter of the trees in the batch, the mean cross section of the trees, the log length of the batch and the number of logs in the batch. A range of models was analysed; in all of these models, batches of logs (as opposed to individual logs) were the units analysed. In the first set of models, relationships between the dependent variable *output volume* (m^3) and *output value* (€) for the batch, and independent variables mean *diameter* of the logs in the batch, *number of logs* in the batch and *log length* of the batch were investigated for batches of all log lengths combined. In the second set of models, these relationships were analysed for each length class separately. Output volume was calculated by summing the volumes of all products produced from the batch, while output value was calculated by summing the monetary values of these products.

Results

Log dimensions

The overall production period covered was 244 days, which represents the 1-year duration that the data set covers. The 4.9 m log length dominated production, with 153 days (Table 2).

A large number of product sizes was produced, with different products arising from combinations of different lengths and dimensions. Product codes were used to represent specific dimensions (see Table 1). An analysis of the length and diameter distribution of the logs processed revealed that logs in the SED class 180 mm were the most frequently processed log size for all log lengths, except for the 5.5 m length class, where logs in the SED class 250 mm were most frequent.

Table 2: Number of days and percentage of total time during which different log lengths were cut.

Log length *m*	*Number of days*	*% of total number of days*
3.7	39	15
4.3	24	10
4.9	153	63
5.5	28	11
Total number of days	244	100

The average SED of all logs sawn over the 1-year period was 21.4 cm. The average SEDs for each length class are presented in Table 3. A much wider range in SEDs was present in the 4.9 m length class than for the remainder of the length classes.

Table 3: Average small end diameter (SED) and SED range for each length class.

Log length *m*	*Average SED* *cm*	*Range* *cm*
3.7	20.6	19.0 – 23.8
4.3	20.9	19.0 – 22.2
4.9	21.5	18.6 – 33.6
5.5	23.5	19.5 – 26.2

Volume recovery

Based on the full data set, daily percentage recoveries were determined by dividing daily volume production by daily roundwood volume consumption. All recoveries are based on under-bark volumes. Analysis of batch recoveries on a length class basis indicated a very constant recovery rate for each length class, independent of the mean SED value. After omitting four outliers, average recovery percentages for each length class were as follows: for 3.7 m 55%, for 4.3 m 57%, for 4.9 m 60% and for the 5.5 m length class 58%.

Product dimensions

Following analysis of the numbers and dimensions of the logs processed and the recovery rates obtained, the number of products cut in each product code (see Table 1) and length class were analysed (Figure 1). Products 3 (102 x 45 mm), 13 (152 x 36 mm) and 24 (229 x 45 mm) were the most commonly cut, with a large proportion of 4.9 m logs processed into these sizes. Products 14 (152 x 45 mm) and 24 (229 x 45 mm) were frequently cut from 5.5 m logs, while 3.7 m logs were most often converted into product 2 (102 x 36 mm). Products 2 (102 x 36 mm), 3 (102 x 45 mm), 7 (127 x 36 mm) and 14 (152 x 45 mm) were cut most often from 4.3 m logs.

Analysis of the log input/recovery relationships

Based on the batch data for 244 days, relationships were examined between two dependent variables, output volume and output value, and a number of independent variables, namely diameter, diameter squared, number of logs, log length, and product dimensions produced. Where statistically significant relationships were found, regression coefficients are presented.

<u>Output volume and output value, as functions of number of logs, length and diameter</u>

In the first models, the relationship between the dependent variables output volume and output value and the independent variables, number of logs processed, diameter and log length was investigated for the full data set. A highly significant relationship

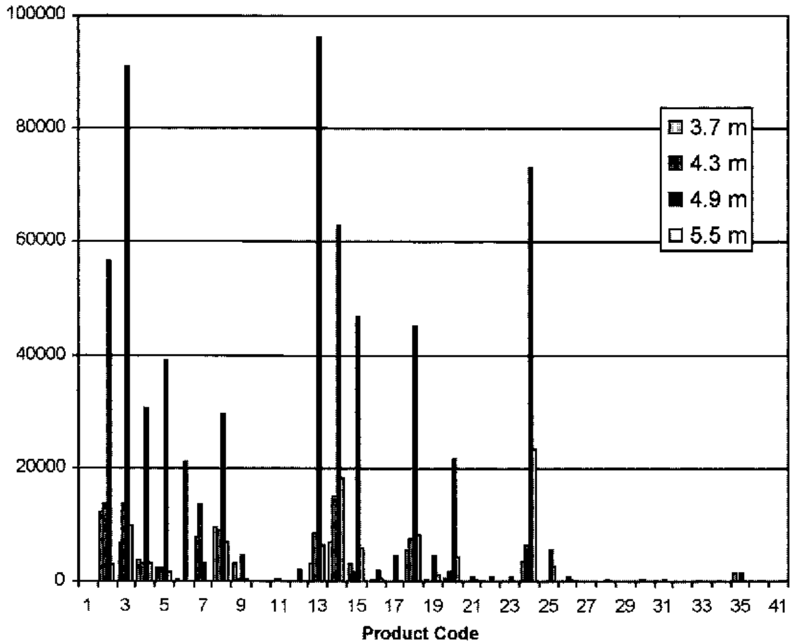

Figure 1: Number of products, by length class (3.7, 4.3, 4.9 and 5.5 m) and product code (see Table 1).

was found between the dependent and independent variables, both for output volume and for output value with $p \leq 0.01$ (Table 4).

<u>Output volume and output value, as functions of diameter, diameter², and number of logs</u>

Having analysed the relationships between *output volume* and *output value* and the independent variables for all the length classes combined, these relationships were investigated for each length class separately. The data set was sorted by log length and the analysis was repeated for each of the data subsets with the independent variable *log length* (L) removed from the models (Tables 5 and 6).

Table 4: Regression statistics for the relationship between dependent variables output volume and output value and independent variables diameter, number of logs and log length, for the full data set. Standard errors of estimates in brackets.

Model	*F value*	R^2	*Intercept*	*Diameter mm*	*Number of logs*	*Length m*
Output volume m^3	1266.9*	0.94	-346.17* (13.87)	0.83* (0.072)	0.13* (0.0037)	40.59* (2.60)
Output value €	1047.8*	0.93	-59358.86* (2426.1)	143.85* (12.57)	20.06* (0.65)	6987.19* (454.3)

* significant at $p \leq 0.01$ level

All models were highly significant. In the *output volume* models for the 3.7 m and 4.9 m length classes very high R^2-values were obtained and the regression coefficients were highly significant (Table 5). In the *output volume* model for the 4.3 m length class a very high R^2-value was obtained but only the independent variable *number of logs* was highly significant. In the *output volume* model for the 5.5 m length class a lower R^2-value was obtained than in the other models and only the independent variable number of logs was highly significant. Similar trends were found for the *output value* models (Table 6) as for the *output volume* models presented above.

It should be noted that the coefficients for the *output volume* (Table 5) and *output value* (Table 6) models for the 3.7 m length class are distinctly different (i.e. a change of sign for the intercept and the coefficients for *diameter* and *diameter^2*) from the comparable coefficients in the models for the other length classes.

Table 5: Regression statistics for the relationship between dependent variable output volume (m^3) and independent variables diameter, diameter^2 and number of logs, for each length class separately. Standard errors of estimates in brackets.

Length class m	*F value*	R^2	*Intercept*	*Diameter* mm	*Diameter^2* mm^2	*Number of logs*
3.7	797.9*	0.98	744.666*	-7.788*	0.019*	0.112*
			(170.20)	(1.62)	(0.004)	(0.003)
4.3	333.9*	0.98	-721.457	5.454	-0.009	0.116*
			(643.57)	(6.29)	(0.015)	(0.007)
4.9	528.2*	0.91	-764.031*	5.913*	-0.010*	0.142*
			(52.53)	(0.44)	(0.001)	(0.004)
5.5	10.8*	0.57	-375.164	2.427	-0.002	0.159*
			(736.91)	(6.40)	(0.014)	(0.031)

* * significant at p≤0.01 level

Table 6: Regression statistics for the relationship between dependent variable output value (€) and independent variables diameter, diameter^2 and number of logs, for each length class separately. Standard errors of estimates in brackets.

Length class m	*F value*	R^2	*Intercept*	*Diameter* mm	*Diameter^2* mm^2	*Number of logs*
3.7	691.1*	0.98	133526.3*	-1384.5*	3.525*	17.455*
			(28637.7)	(271.9)	(0.64)	(0.50)
4.3	245.6*	0.97	-117411.2	881.2	-1.481	17.657*
			(118127.9)	(1155.2)	(2.80)	(1.34)
4.9	476.8*	0.90	-132734.0*	1025.8*	-1.825*	22.180*
			(8660.9)	(71.9)	(0.15)	(0.69)
5.5	8.9*	0.52	-69794.839	460.271	-0.543	25.100*
			(132157.2)	(1147.1)	(2.49)	(5.61)

* : significant at (Pr>F) <0.01

Discussion

The reporting capabilities of the production control system in the sawmill were investigated and a test on the accuracy of the reporting process was carried out in order to ensure that the data collected from the production control system was suitable for use as part of the main analysis stage.

As the accuracy of the data produced by the production control system was tested and found to be acceptable (Browne 2003), data were obtained from the system. Recovery from each length class was on average over 55%. The recoveries are in line with recovery percentages in other mills, which ranged between 55 and 60 % (Williston 1988). In a study of a pallet mill by Dooley (2003) the average recovery was 50.6 %. This lower value was judged to be the result of the small diameter of the logs processed.

Recovery increased with increasing log length but fell slightly for the 5.5 m length class. The most likely reason for this reduction is the combined effect of log length and taper. Steele (1984) found a strong correlation between increasing log length and decreasing recovery, especially for logs longer than 17 feet (5.1 m). Steele also found a close relationship between increasing taper rate and reduced recovery for logs of similar small end diameter. Both these findings are likely explanations for the reduction in recovery to 58% for the 5.5 m log class as compared to the 60% rate for the 4.9 m length class.

A highly significant relationship between the dependent variables *output volume* and *output value* and the independent variables *number of logs*, *diameter* and *length* was found. Analyses of the relationship between *output volume* and *output value* and independent variables *diameter*, *diameter*^{2} and *number of logs* were carried out. The 3.7 m and 4.9 m length classes produced highly significant relationships and very high R-squares. As regards the 4.3 m length class, a high R^2 was found but the parameters were not significant. The 5.5 m length class produced a lower R^2 result. A number of possible reasons may explain the findings in the 4.3 m length class and the 5.5 m length class. For both these length classes small data sets were available consisting of only 24 observations for the 4.3 m length class and 28 for the 5.5 m length class. It may also have been the case that a narrower or wider range of sawing patterns was used for these length classes. Future analysis of sawing pattern selection may confirm this.

The above models will form the basis for a decision support system for the mill. However, during the course of the research reported in this paper, it was not possible to analyse the impact of individual sawing patterns on volume and value recovery due to limitations in data collection opportunities and the specific processes used in the mill. In Palfab, timber entering the mill is unsorted by diameter and the saws are reset for every log. This means that a different sawing pattern was used for each log and, with the computer system not recording individual sawing patterns, it was impossible to collect the necessary data and to analyse the impact of pattern selection on volume and value recovery at this stage of the study. However, it is envisaged that this analysis will have to be carried out in the future in order to finalise the decision support system as set out in the objectives of the study. In addition, the effect of factors such as taper, sweep and ovality, on the recovery in the sawmill need to be investigated.

Conclusion

The research reported was directed at investigating the impact of size (log length and diameter) of Sitka spruce logs on product volume/value recovery. Based on the analysis carried out, it can be concluded that output volume and output value are functionally related to a range of independent parameters for the 3.7 and 4.9 m length classes. Volume recovery rates were similar to rates found in other sawmills. The highest rate (60%) was associated with the 4.9 m length class.

The models developed in this study will form the basis for the decision support system for the mill as set out in the objectives of this study. This will allow the sawmill manager to predict potential volume and value out-turn for a range of log sizes. Work should be carried out on the relationships between sawing pattern, log size, and volume and value recovery.

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SHORT COMMUNICATION

The collective responsibility for seedling quality

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Abstract
The target seedling concept is based on the idea that seedling stock quality is a predictor of field growth and survival. Good operating practice relating to the production, selection and delivery of good quality seedling stock does not stop at the nursery gate. The potential link between seedling quality and field performance was examined in this study, based on data collected from a nursery trial and under operational field conditions. Guidelines relating to the selection of seedling characteristics best suited to specific sites are also discussed.

Keywords: Seedling quality, field performance, establishment

Introduction
Poor establishment and seedling production techniques can often result in unnecessary replanting and/or post-planting activities, which substantially increase establishment costs and decrease subsequent stand productivity (in this case caused by a delay in the time taken for a stand to reach merchantable size). The national annual costs associated with filling-in (or beating-up) have been estimated to be in the region of €0.22 to 0.75 million per year (Black 2007).

A seedling is considered of high quality ('fitness for purpose', Richie 1984) if it meets the standards of performance at a particular planting site. This implies that both nursery and establishment practices define seedling quality. It is generally recognised that plants of good quality are better able to withstand transplant shock and adverse post-planting climatic conditions, resulting in increased survival and faster early growth. Numerous techniques have been developed to test the quality of nursery stock. However, no individual tests, or combinations thereof, have been developed that fully indicate field growth and survival under operational conditions (see Mattsson 1996). In this paper, we report on the development of a quality index classification system based on a range of morphological and physiological tests. In addition, we suggest that some of these quality measures can be used to pre-select seedling stock best suited to specific site conditions.

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How do we measure good quality?

Morphological assessment

Morphological measurements (physical and structural characteristics) such as shoot height and root collar diameter measurements provide a useful assessment of plant quality. However, shoot height may not always be correlated with field performance because of site or species-specific factors (O'Reilly and Keane 2002). For example, taller seedlings may perform better at sites where there is considerable competition from weeds. Alternatively, shorter seedlings may outperform taller seedlings in exposed sites, where water or nutrients limit performance or where weeds do not pose a problem.

The ratio of shoot to root biomass (S:R) is an excellent indicator of how seedlings may respond when planted under conditions where performance may be limited by water or nutrients. In terms of water stress, S:R provides a measure of the balance between water loss area, via evapotranspiration, and water absorbing area. A useful and more practical surrogate measure for S:R is sturdiness ratio (height (cm)/collar diameter (mm)). However, this is a less robust predictor of seedling performance following out-planting.

Physiological based assessment

There is a wide range of physiological indicators for assessing seedling performance; none, however, are rapid, robust or cheap enough to be used as a routine screening tool. Root electrolyte leakage (REL) is a measure of membrane function and high values indicate that seedlings are either damaged or highly active. Benchmark REL assessments have been developed to provide indicators of dormancy status and for assessing post-storage quality (O'Reilly et al. 2000, 2001, Ritchie 1984, Black 2007).

Photosynthetic performance is a good indicator of plant responses to environmental conditions, since photosynthesis is sensitive to changes in temperature, water availability and nutrient content of leaves. Chlorophyll fluorescence is one of the increasingly used methods for assessing the 'integrity' of the photosynthetic apparatus in conifer seedlings (Perks et al. 2002, Black et al. 2005). For healthy leaves or needles, maximum potential quantum efficiency (Fv/Fm) is usually 0.8. Values below 0.5 usually indicate damage to the photosynthetic apparatus of leaves, which in most cases in non-recoverable (Black et al. 2005). The advantage of the Fv/Fm assessment is that it is non-destructive, quick (30 min) and cheap (once the equipment has been purchased). Another advantage of the fluorescence method is that it can be used to assess the response of seedlings to treatment by herbicides or pesticides.

Development of an integrated quality indicator

An integrated quality index (Q_I) was developed, based on a combination of % REL, Fv/Fm (conifers only) and S:R measurements and threshold values, to categorize the combined physiological and morphological status of seedlings.

$$if \frac{REL\%}{REL\%_{threshold}} > 1, then \rightarrow R_I = \frac{1}{\left(\frac{REL\%}{REL\%_{threshold}}\right)} \times 100 \quad (1)$$

$$if \frac{REL\%}{REL\%_{threshold}} < 1, then \rightarrow R_I = 100\%$$

where R_I is the REL index and $REL\%_{threshold}$ is the published species-specific benchmark REL value (see Black 2007, O'Reilly et al. 2001, Ritchie 1984).

An additional fluorescence index was used for scoring conifer seedlings:

$$F_I = \frac{Fv/Fm}{0.83} \times 100 \quad (2)$$

where F_I is the fluorescence index, 0.83 is the maximum Fv/Fm and Fv/Fm is the measured value. The F_I of needles with measured Fv/Fm values below 0.5 are scored as 0%.

A shoot to root index (S:RI) score was also included:

$$if \frac{S:R}{S:R_{threshold}} > 1, then \rightarrow S:R_I = \frac{1}{\left(\frac{S:R}{S:R_{threshold}}\right)} \times 100$$

$$if \frac{S:R}{S:R_{threshold}} < 1, then \rightarrow S:R_I = 100\% \quad (3)$$

The following a priori $S:R_{threshold}$ values were selected as a benchmark:

a) all spruces < 3,

b) other conifers (excluding larch) < 5,

c) oak and ash < 1,

d) other broadleaves (and larch) < 2.

Additional morphological penalty scores (MPS) were deducted from the combined quality index, where 5% was deducted from the physiological indices for bud break, broken leaders or needle yellowing, and 2% for storage mould or poor form.

Quality indices for all conifers excluding larch (QIC) and broadleaves including larch (QIB) were calculated as:

$$Q_{IC} = \frac{R_I + F_I + SR_I}{3} - MPS \quad (4)$$

$$Q_{IB} = \frac{R_I + SR_I}{2} - MPS \quad (5)$$

How does QI relate to field performance?

Nursery plot experiments

Bareroot seedlings from a total of 1378 sample bags were obtained at regular intervals from the two main Irish nurseries and some European nurseries over the period December 2005 to May 2007. An average of 15 sample trees per bag were assessed for shoot:root ratio, root electrolyte leakage and chlorophyll fluorescence (conifers only). QI values were then calculated as described.

A sub-sample of tested Sitka spruce seedling batches (42 in total) were planted out in a nursery trial at Ballintemple Nursery, Co Carlow. Seedling batches, from cold storage with a varying Q_{IC} (55 to 100%) were planted out at different times of the year to determine the influence of climatic conditions and Q_{IC} on seedling survival.

Potential soil water deficit was measured at Ballintemple to see if it had an effect on seedling survival in a demonstration nursery plot. Potential soil water deficit provides a measure of available water in the soil, based on precipitation and potential evapotranspiration. When soil water deficits (precipitation - evapotranspiration) are negative, the soil moisture content decreases. This could decline beyond permanent wilting point once the 10-day deficit reaches ~ 40 mm, depending on soil type.

The effect of planting poor quality nursery stock under ideal conditions

Poor field performance of good quality stock can be due to unsuitable weather following out-planting. The dry conditions of May/June 2006 provided a good opportunity to test the impact of such weather on field performance.

The results from this trial demonstrated poor field performance of good quality nursery stock (Q_{IC} > 85%) when planted in dry conditions. It was also evident from the nursery trial that bareroot Sitka spruce seedlings should not be out-planted when soil moisture deficits exceed -25mm (Figure 1), which had occurred by the end of May 2006 and April 2007 at Ballintemple nursery.

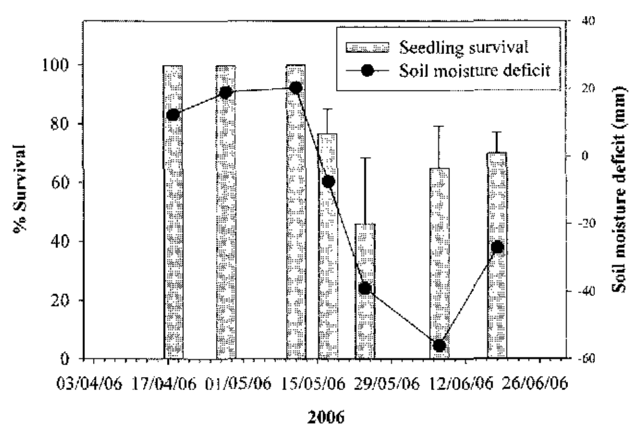

Figure 1: The effect of out-planting date and soil moisture deficit on seedling survival in a demonstration plot at Ballintemple in 2006. (All seedlings were cold-stored prior to quality assessments and out-planting).

The effect of planting poor quality stock under ideal conditions

In a separate analysis we attempted to asses how survival was related to quality (Q_{IC}) under ideal conditions for seedling establishment following good practice planting procedures. A sub-sample of tested Sitka spruce batches (Q_{IC} of 55 to 100 %) were out-planted when there was a low likelihood of subsequent water deficit (> -20 mm). Batches of 20 seedlings were planted in single rows 0.5 m apart. Seedling performance was monitored and survival was assessed after 1 year. There was a significant correlation between Q_I and survival following out planting (Figure 2). The result suggests that the survival of seedlings declines to below 50 % if the Q_I is below 70%.

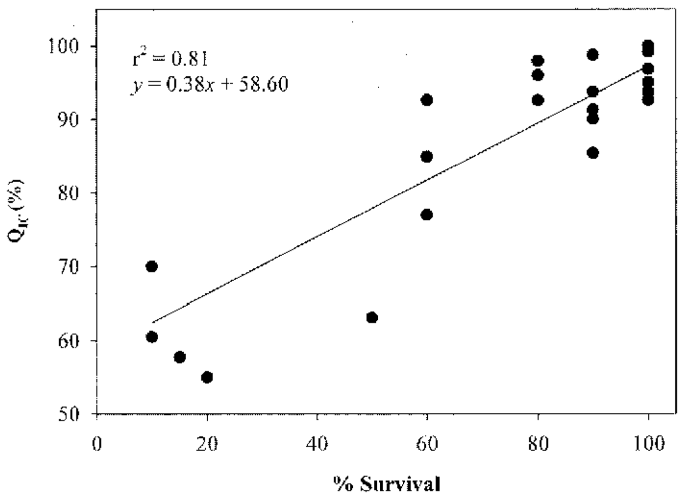

Figure 2: Correlation between quality index Q_{IC} and Sitka spruce seedling survival following out-planting under ideal climatic conditions. (All seedlings were cold- stored prior to quality assessments and out-planting).

Field performance

Field trial evidence for the detrimental effect of planting poor quality stock was hindered by the simultaneous reduction in post plant survival and vigour due to combined effects of adverse climatic conditions, variable seedling QIC and weevil damage. In April 2006, seedling survival of good quality bare root Sitka spruce stock (Q_{IC} > 85%) was 88 ± 3%, based on an analysis of 24 sites (81 plots). Survival declined to 72 ± 8%, when planted out in June when water deficits were higher. However, it is important to note that the ability of seedlings to survive weevil damage or dry conditions increased when:

a) seedling quality was good, particularly a balanced shoot to root ratio and a low sturdiness value;
b) bareroot stock were not planted under dry conditions or on exposed sites after April or May 2006.

Conclusions and recommendations

The implementation of a routine seedling quality testing service in nurseries and screening of stock, using an integrated Q_I system, prior to dispatch, can, if screening avoids poor stock going to the field, improve field performance and thereby reduce overall establishment costs. However, we estimated that fewer than 4% of the 1378 bare root stock batches sampled over the 2005/6 and 2006/7 were not suitable for out-planting (Black 2007). In addition, most of these batches were withdrawn before dispatch to the field. This highlights the importance of the implementation of a third-party seedling screening service for bare root nurseries. This should be seen as an added value service to nursery managers, as the information can be used as a marketing and quality assurance tool, providing a competitive advantage. Test results can also be used in quality control and in evaluating the effects of cultural practices (e.g. the effect of treating seedlings with insecticide to protect against pine weevil damage).

The low frequency of poor quality stock in nurseries does, however, suggest that seedling handling, planting quality, climate and selection of seedlings suitable for specific sites may also be an important issue in securing high survival and initial growth rates. This supports the concept of collective responsibility for seedling quality. Based on the evidence presented here, it is clear that field performance following out-planting is influenced by both nursery stock quality and establishment procedures/timing. We have demonstrated that field performance of good quality nursery stock is reduced when out-planted when soil moisture deficit is high.

It has been suggested that global climate change will result in more erratic climate and drier summers in Ireland, particularly in the south and east (Ray et al. 2007). Therefore, it is possible that periods of extended soil moisture deficit may occur earlier than April or May and more frequently in the future. This may result in a shorter planting season and highlights the need for selecting fit for purpose seedlings, specific to individual sites, soils or climatic regions. The use of seedlings with a low S:R for planting on freely drained soils, particularly in the south and east of the country could be a prerequisite in the future.

In conclusion, establishment systems have traditionally been a one-way system where seedlings are simply passed on to establishment teams. A key component of an integrated establishment system is the target seedling concept (Landis and Dumroese 2005). Quality assurance systems, such as quality index assessments presented here, can facilitate the definition and selection of fit-for-purpose seedlings for specific site and environmental conditions. This should lead to well defined standard operating practices along the chain from nursery to plantation establishment.

Acknowledgements

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Forest Perspectives

Times Past

Woodland management and resources in Co Fermanagh in the 18th century feature in a recent publication from the Four Courts Press: *Castle Caldwell, County Fermanagh Life on a west Ulster estate, 1750-1800* by Mervyn Busteed. The extract reproduced here, by permission of the author, shows that the concept of multi-functional use of forest was understood and practised by at least some estate owners in Ireland during the late eighteenth century.

Sustainable management of forest resources within the estate is a recurring theme, with the use of natural regeneration implicit in a letter to the estate owner, Sir James Caldwell, from one of his tenants ... "I will cut down the woods at Inisheen this winter ... I will not do any prejudice to the young growth that can be possibly be avoided..."

Ed.

Author's preface to extract

Until the mid sixteenth century Ireland was renowned for the density of its woodlands, but by the early eighteenth century it was one of the least forested countries in Europe. The transformation was due to warfare and colonisation. Throughout the late middle ages Irish chieftains had skilfully exploited woodland cover in their campaigns against the Dublin authorities. The reassertion of central government authority during the sixteenth century led to the steady clearance of woodland strongholds. Subsequently, settlers from Britain completed the process as they felled woodland for building material, cooperage, charcoal and timber exports.

Growing political security from the late seventeenth century encouraged landowners to build unfortified country houses and refashion the landscape of the demesne around the house. By the mid eighteenth century there was a strong trend in favour of open rolling greensward with carefully positioned water bodies and extensive tree plantations. Many landlords took advantage of Ireland's high humidity, lush growth of natural vegetation and frequent juxtaposition of mountain, lough and seashore and adopted the style on their estates. The result was that by the early nineteenth century approximately 6% of the country's land area was taken up in demesne land heavily planted not only with native species but also with exotic trees and shrubs introduced by returning explorers and colonial administrators.

Extract

A key aspect of improvement was the planting of woodland. It carried multiple significance. It was simultaneously an economic resource, an aesthetic embellishment, an aid to fox hunting, a gesture of confidence in the family future, a gesture of confidence in the family future, a symbol of permanence and commitment, and if oak were included, a patriotic act in supplying naval timber.[1] In comparison with England, Irish landowners were slow to take up tree planting and visitors frequently remarked on the relative absence of tree cover.[2] Between 1698 and 1791 the Irish parliament passed 17 Acts to encourage tree planting and the Dublin Society offered yearly premiums for planting and nursery stocking from 1740 to 1807. The repetition of the legislation is in itself revealing, but the growing popularity of the new 'parkland' style of demesne layout boosted tree planting since woodland was an integral part of the fashion.

Sir James Caldwell's correspondence shows that he needed no such prompting. From the outset he was a careful steward of the estate woodlands, and the rent toll of 1770 reveals that just over 11 per cent of his estate was wooded (Table 1). He took great care over the planting of trees, writing on one occasion to an employee to specify that new trees should be 60 feet from each other.[3] The felling of timber was carried out with great care. Late in 1768 one of Sir James's employees wrote a reassuring letter 'I will cut down the wood of Inisheen this winter & you may rely on it I will not do any prejudice to the young growth that can be possible avoided & I will give particular directions to take care of it lest it be hurted'.[4] Such decisions could bring to the surface the tension between aesthetic and economic considerations. On at least two occasions there is evidence that they strained family relationships. In early 1745, scarcely a year after he had become head of the family and when he was still in Austria, Sir James was involved in a dispute with his mother about the sale of timber. This led to his relative Sir James Cooke to write hat he was about to receive a visit from the formidable Dowager and he hoped to raise the mater: 'I shall in ye most tender manner talk to her about the woods that are sold and hope ye mater shall be in ye most amicable way made up between ye.'[5] Thirty-two yeas later, when his son John requested money to buy his army commission as lieutenant, Sir James wrote 'Your mother and I have been thinking, how we could raise the money. I could, t is true, sell the ornamental timber in and about this place and in the domain, which would bring in at least a thousand pounds; this would be so much loss to you, and at the same time ruin the beauty of the place'.[6] Just under a year later, when his wife had died and he was encouraging John to come and view the estate,

[1] Stephen Daniels, 'The political iconography of woodland in later Georgian England.', in D. Cosgrave and S. Daniels (eds) *The iconography of landscape: essays on the symbolic representation, design ad use of past environments* (Cambridge 1988), p. 48.

[2] T. Reeves-Smyth, 'Demesnes', in *Atlas of the Irish rural landscape*, p.552.

[3] John Johnston to Lady Elizabeth Caldwell, 3 March 1755. John Rylands University Library, Manchester, Bagshawe Muniments, 3/20/209.

[4] William Hassard to Sir James Caldwell, 16 Nov. 1768 John Rylands University Library, Manchester, Bagshawe Muniments, 3/20/168.

[5] Sir James Cooke to Sir James Caldwell, 18 Feb. 1745 John Rylands University Library, Manchester, Bagshawe Muniments, 3/14/26.

[6] Sir James Caldwell to John Caldwell, 9 Nov. 1777 John Rylands University Library, Manchester, Bagshawe Muniments, 3/13/113.

he revealed the lengths he would go to preserve the woodlands: 'I have ... preserved most valuable and ornamental woods ... I am determined to run all risks even the seizing of my stock and furniture than to sell from you the beautiful and ornamental woods of Rossmore and Castle Caldwell which would bring a great deal of money'

Table 1: Land use on the Castle Caldwell estate in 1770.

Land use	*Percentages*
Arable	49.1
Arable & pasture	17.0
Pasture	8.2
Wood	11.1
Bog	9.3
Moor	3.0
Mountain	2.3

and he declared he would pay any debts 'without touching the woods'.[7]

The request for money and the death of his mother clearly provoked an awkward phase in what seems to have been a close relationship between father and son. Just over a yea later John confessed that his absence on the American frontier meant that he had 'very trifling knowledge ... in respect of entitlements, leases or anything else that may regard the right of heritage' but, going to great pains to reassure Sir James, he went on: 'my dear father did ever I give the smallest hints that such great improvements as are carried out at Castle Caldwell, were agreeable to me, because, perhaps, I should one day or other be the possessor of them? No, so long as they pleased you they were pleasing to me.[8] By late 1782, when there were signs that his father's health was faltering, John was clearly taking a greater inertest in the running of the estate. In December he wrote to warn of false economies: 'A gardener was lately recommended ... as a perfect master of his profession and from his discharge [references] an excellent character. He was brought up in England under the care of the great nursery men. He asks 25 pounds a year and says he will not come for less, let me know your determination. In my opinion it is cheaper to give a few pounds more & have a man who can be depended upon.[9] He too now realised realized the value of tree planting, to the extent where he was specifying tree types and planting

[7] Sir James Caldwell to John Caldwell, 18 Oct. 1778 John Rylands University Library, Manchester, Bagshawe Muniments, 3/13/114.

[8] John Caldwell to Sir James Caldwell, 24 Sept. 1779 John Rylands University Library, Manchester, Bagshawe Muniments, 3/13/115.

[9] John Caldwell to Sir James Caldwell, 6 Dec. 1782 John Rylands University Library, Manchester, Bagshawe Muniments, 3/13/123.

sites. In early 1783 he wrote: 'I hope all the trees &c. have arrived safe. I beg a piece of ground may be prepared for some timber seeds I will send down, especially of evergreens, which are much wanting around C[astle] C[aldwell] the angle in the bog near J. Mulhearns would answer very well for al finds of ever greens'.[10] Exploration and military service abroad meant that Europeans in the 18th century were encountering new species of plants and trees, and it is quite possible that John's interest in evergreens was sparked by his time in the woodlands of North America.

It is hardly surprising, therefore that wood stealing could ring heavy punishment, a Justice of the Peace having the power to award the victim 'treble damages, also to fine the person any sum not exceeding ten shillings for the poor of the parish'.[11] Sir James clearly acquired some expertise in timber management. In 1779 his relative Lady Coghill wrote:

> I must beg a little instruction from you in respect of felling and disposal of trees. We have found out in a few cuttings & corners some old oaks that are beginning to decay to the number of abut forty or so. I know you have had some experience of business & can there fore give me your advice about the timber and bark ... will the lesser branches do for charcoal. Sir John is determined not to sell off trees standing, which would certainly be improvident.[12]

The results of these years of care were visible in the extensive woodlands recorded on the demesne in by the Ordnance survey in 1834 (Figure 1). In all, by late 1778 Sir James estimated that on the demesne he had 'laid above sixteen thousand pounds ... so as to make it almost three times as much as what it was'.[13] In his will drawn up two years later he had revalued his improvements at £25,000 and they were still incomplete.[14]

10John Caldwell to Sir James Caldwell, 29 March 1783 John Rylands University Library, Manchester, Bagshawe Muniments, 3/13/128.

[11] Frederick French to Sir James Caldwell, 23 Oct. 1750 John Rylands University Library, Manchester, Bagshawe Muniments, 3/14/138.

[12] Lady Coghill to Sir James Caldwell, 28 Feb. 1779 John Rylands University Library, Manchester, Bagshawe Muniments, 3/14/26.

[13] Sir James Caldwell to John Caldwell, 18 Oct. 1778 John Rylands University Library, Manchester, Bagshawe Muniments, 3/13/114.

[14] Bagshawe, *Bagshawes of Ford*, p. 349.

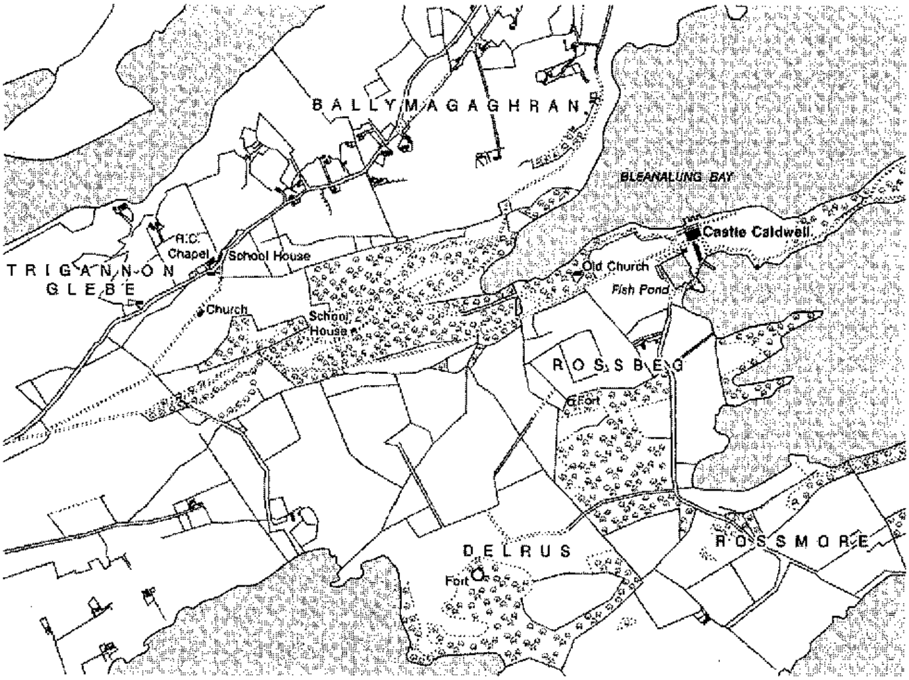

Figure 1: The Castle Caldwell demense in 1834. Adapted from the Six Inch Ordnance Survey for Co Fermanagh, sheet 8. The extensive areas of woodland are noteable. (Copied from Castle Caldwell, County Fermanagh. Life on a west Ulster estate, 1750-1800 by Mervyn Busteed. 2006. Four Courts Press Ltd.

Trees, Woods and Literature – 31

For three days we went out and climbed the hillside, planting the hundreds of seedlings out of the pail, and finally, with some help, six thousand of them. Inge, ... carefully set roots in the slits I was cutting with a flat spade. From the middle of Europe she has brought this reverence for the consecration of such moments in life when the consciousness of time's flow is supreme. And twenty-five years later our ankle-high seedlings are dense sixty-foot trees with stems thicker than telegraph poles...

I have lived more than half my life in the Connecticut countryside, all the time expecting to get some play or book finished so I can spend more time in the city, where everything is happening. There is something about his forty-year temporary residence that strikes me funny now. If only we could stop murdering one another we could be a wonderfully humorous species. My contentment discontents me when I know that little happens here that I don't make happen, except the sun coming up and going down and the leaves emerging and dropping off and an occasional surprise like the recent appearance of coyotes in the woods. There is more unbroken forest from Canada down to here than there was even in Lincoln's youth, the farms having gradually vanished, and here is even the odd bear, they say, a wanderer down from the north, and now those coyotes. I have seen them. They have a fixed smug grin, as though they just stole something. And they cannot be mistaken for dogs, whom they otherwise resemble, because of their eyes, which look at you with a blue guilt but no conscience, a mixture of calculation and defensive distrust that domestication cured in dogs thousands of years ago.

And so the coyotes are out here earnestly trying to arrange their lives to make more coyotes possible, not knowing that it is my forest, of course. And I am in this room from which I can sometimes look out at dusk and see them warily moving through the barren winter trees, and I am, I suppose, doing what they are doing, making myself possible and those who come after me. At such moments I do not know whose land this is that I own, or whose bed I sleep in. In the darkness out there they see my light and pause, muzzles lifted, wondering who I am and what I am doing here in this cabin under my light. I am mystery to them until they tire of it and move on, but the truth, the first truth probably, is that we are all connected, watching one another. Even the trees.

From the autobiography *TIMEBENDS A Life* by Arthur Miller (pp 598-599), Grove Press New York, 1987.

Arthur Miller was born in Manhattan in 1915. He came of age during the Great Depression and had to work his way through college at the University of Michigan, from whence he graduated in 1938 with a bachelor's degree in English. He worked at a variety of writing and other jobs, before building a studio in Roxbury, Connecticut, in 1948. It was there he wrote his famous play *Death of a Salesman,* which premiered on Broadway in early 1949. It was acclaimed by the critics, became a huge commercial success (running for 742 performances) and won many awards.

Miller's next play - *The Crucible* – subsequently to become his most famous - was first performed in early 1953 on Broadway. It is based on the 1692 Salem witch trials in the US, and was influenced by the blacklisting of colleagues by the House Un-American Activities Committee (HUAC) during the McCarthy era. Miller was himself questioned by HUAC in 1956 and was convicted of contempt of Congress for refusing to name names. He was fined $500, sentenced to thirty days in prison, blacklisted, and disallowed a US passport. The conviction was lifted shortly afterwards by the court of appeals.

In 1965 Miller was elected the first American president of International PEN, a position he held for four years. He continued writing plays and other work, up his death at Roxbury, beside the plantation he describes in the extract, in early 2005.

Arthur Miller is widely considered to be one of the greatest dramatists of the twentieth century, among the likes of Eugene O'Neill, Luigi Pirandello, Samuel Beckett, Bertolt Brecht, and Tennessee Williams.

His interest in trees and forestry is evident from the extract, as well as in the caption to a photograph in TIMEBENDS: *Preparing to plant six thousand pines and firs on a barren Connecticut hillside,* which sees him seated atop a John Deere tractor, ready for action. Apparently Miller received advice on the planting from a state forester and explained in an interview: *There is a hillside within sight of the house, a swampy area with hummocks and a lot of stone. It's not very handsome to look at. The farmer who owned the land before me and the farmer's forebears turned their backs on this impossible land, which was not even good enough for grazing. We decided to plant the trees, basically for aesthetic reasons. We got the seedlings from a state nursery and planted them on 8- to 10-foot centers.*

(Selection and note by *Lia Coille*)

Book review

Choice of Sitka spruce seed origins for use in British forests. C.J.A. Samuel, A.M. Fletcher and R. Lines (2007). Forestry Commission Bulletin 127. ISBN 978-0-85538-727-3.

This Bulletin is highly specialised in that its subject is confined to one species – Sitka spruce, nevertheless a most important species for forestry in Britain. The publication is an exhaustive study of the performance of the species in Britain over the period from its introduction in 1831 to the present day.

The authors have spent most of their working lives studying the early growth and performance of Sitka spruce throughout Great Britain, in its natural range in Canada and the US, as well as in other parts of Europe. Between them they bring together this unrivalled knowledge, complemented by results from scientific field trials undertaken in Britain. Overall, the study is one of the most comprehensive undertaken.

Taking as their starting point the year of introduction, 1831, the authors highlight the fact that since it was introduced by David Douglas, Sitka spruce has become the most important commercial timber producer in upland forestry in Great Britain, while accounting for 36% of the total forest area in 2004.

The natural range of the species is the greatest of the world's spruces, some 3,000 km, occurring along a narrow coastal belt from Kodiak Island in Alaska to northern California, and covers significant variation in climatic conditions. Provenance variation has evolved, and the authors highlight the need to determine by means of comprehensive provenance experiments the most suitable seed origins for use in Great Britain. Also highlighted is a comparison between the British climate and that of north-western America, with a clear focus on the many similarities, especially the fact that the general climate throughout the range of the species is predominantly maritime, strongly influenced by the prevailing westerly winds from the Pacific Ocean.

The publication addresses the evaluation of Sitka spruce seed sources, through the process of obtaining and testing various seed lots during the early phases of seed origin research, which eventually leads on to the development of the IUFRO (International Union of Forest Research Organisations) source authenticated seed collections throughout the species natural range. This culminated in the establishment of two main series of experiments, one in 1960/61 and the other in 1974/75. The authors suggest that the latter was the most comprehensive as it was based on the IUFRO 1968/70 collections and had 62 seed origins represented. Results from these experiments, both from the nursery and field stages, have shown the adaptability of several of the seed origins for a range of site types. Variation in date of flushing between origins is small and therefore cannot be used as a defining factor in selecting seed sources which might be used to avoid spring frost damage. However, date of growth cessation and therefore susceptibility to damage by un-seasonal autumn frosts is much greater and has to be considered during the nursery and early forest stage. The authors highlight the fact that the more southerly origins in which growth cessation is late in the year, are very susceptible to autumn frosts and also produce the greatest numbers of lammas shoots.

In Britain there is a general cline in increasing vigour with decreasing latitude, with origins from northern Oregon proving to be the most vigorous, especially on southern sites. Poorer growth is found in origins from the Skeena River, mainland and lower coastal British Columbia and the Puget Sound area in Washington. In contrast, seed origins from the Queen Charlotte Islands of British Columbia produce better than expected growth, although there is some variation within the Queen Charlotte Islands origins, with the low elevation seed sources from the northern and eastern parts of Graham Island having higher than average production. These origins proved to be well adapted and productive over a wide range of sites in Britain.

The Bulletin points out that Sitka spruce is also an important species in Ireland, in both Northern Ireland and the Republic of Ireland, and points out that because plantations of the commonly used Queen Charlotte Islands origins grew well in the early days, investigations in Ireland of the more southerly origins did not commence until 1960, when ten origins – the same as in the British 1960/61 series – were planted at Killarney. Here the results showed the clear superiority of the Washington provenances. In 1972 a meeting of the IUFRO Working Party on Sitka spruce met in Ireland; thirteen countries agreed to establish an international provenance experiment in Sitka spruce. The experiments, called the IUFRO Sitka Spruce International Ten Provenance Experiments were established to last for a maximum of ten years after planting, and were designed to provide data on variation in the species during the nursery and field establishment phase. This series acted as a complement to the main IUFRO series of experiments established with a much larger but not common selection of seed sources and with larger plots to allow growth measurements to be made for up to half the rotation length.

In an Irish context the Bulletin presents the International Ten Provenance Experiment as described by the late John O'Driscoll, with results at the nursery stage in 1976 and again with further results presented after three growing seasons in the forest covering three different sites. The pattern of height growth was similar at all sites with the tallest seed lot from Necanicum (Oregon). There were also significant differences in flushing, growth cessation and frost damage. The overall pattern of flushing on all the field sites was similar to that in the nursery, with the southern provenances first to flush but with only a maximum of seven days difference between the provenances. The pattern of growth cessation was also similar to that in the nursery but the range was far larger, with a maximum of 64 days recorded between sources at the Kenmare (Co Kerry) site. There was also a strong clinal pattern in growth cessation, with the most southerly provenances the last to cease growth.

In addition to these experiments, the authors report that the main IUFRO collection of 67 provenances was planted in Ireland across nine sites covering a wide range of site conditions. As with the International Ten Provenance Experiments, results from these also showed that the pattern for height growth after nine years was similar to that at the end of the nursery stage. Height at both ages was closely correlated with latitude of seed origin. Southern Oregon and northern Californian provenances were the fastest growing, decreasing progressively to Alaska, except for the Nass and Skeena Rivers (British Columbia) provenances, whose height was lower than expected for that latitude. Provenances from mid-Oregon southwards all had autumn frost damage in the nursery but all were hardy in the field, once past the tender seedling stage. Damage due to late spring frost was experienced at one field site but there were no differences in its effect on the different provenances due to the small range in flushing date.

The Bulletin also reports results for wood density and branching characteristics for Ireland, measured in six selected provenances at four of the most contrasting sites, when the material was 12 years old. The results showed that wood density is negatively correlated with growth rate but positively correlated with latitude of seed origin. However, site type had a greater influence on wood density than seed origin, but seed origin had a greater influence on branch size and number than site type, with the slow-growing origins from Alaska and British Columbia having larger sized branches in relation to stem diameter than those from Washington and Oregon.

Six of the Irish sites were re-measured after 19 growing seasons for top height. The results continued to show that height growth increased from north (Queen Charlotte Island provenances) to south (Washington and Oregon provenances) until it began to decrease in the Northern Californian provenances. An increase of two or even three yield classes could be achieved by planting southern Washington provenances (yield class 24) and Oregon (yield class 26) provenances rather than Queen Charlotte Island provenances (yield class 18). Earlier growth studies also demonstrated that the southern provenances produced fewer and smaller branches, thus adding to the advantage these provenances have, especially when planted in sheltered sites. On colder, more exposed sites the northerly provenances of Queen Charlotte Island and Vancouver Island performed better.

Sitka spruce is and continues to be the most important species in Irish forestry with the recent National Forest Inventory showing that it presently represents 56% of the forest estate.

While this Bulletin provides results of the performance of an extensive range of seed source studies of Sitka spruce in Britain, it also compiles results on provenance studies in Sitka spruce from many other European countries, especially Ireland. For anyone involved in the establishment and management of Sitka spruce as a forest crop this publication is both timely and relevant and it is recommend as necessary reading for all those who have an interest in Sitka spruce and its role in Irish forestry. For forest owners and managers, as well as forestry students it is very useful reading, especially for those who wish to extend their knowledge of the potential and performance of the species, based on results from field experiments carried out over a prolonged period.

John Fennessy

(John Fennessy is Research Programme Manager, Tree Improvement in COFORD.)

Sixty-third Annual Study Tour Galicia 10-16 September 2006

Thirty Nine Society members assembled on Sunday 10 September 2006 at Dublin Airport to begin the 63rd study tour to Galicia in North West Spain. The flight was to Oporto in Portugal.

Dr Marina Amurrio, our guide for the week welcomed us at Oporto. Marina was assisted for part of the tour by Dr Almudena Pérez. They worked tirelessly and efficiently to look after the needs of the group and the Society is deeply indebted to them. The Society is also indebted to Dr Agustín Merino for putting together such an interesting and varied programme for the week. Our host for the week was the University of Santiago de Compostella (USC) at their Lugo Campus. All the staff of the forestry faculty that we met did a wonderful job during our stay there

As we drove north to our first night's accommodation in Ponteverda we were able to see first hand the devastation of the large number of fires that occurred during August. All through the week we saw the enormous damage with 80,000 ha or 6 million cubic metres - the total annual production - burned.

Over the next six days the group visited Galicia, which has an area of three million ha, about half the size of the Republic of Ireland. There was surprise among the group to find that almost 70% of the land area of Galicia is forested. There was also surprise at the greenness of the landscape; the reason becoming apparent during the week as the rain began to fall.

Galicia is an autonomous region of Spain and, like Ireland, has Celtic influences. The language is Galician, which is similar to Portuguese. The tour overnighted at the Galicia Palace Hotel, Ponteverda.

John Mc Loughlin, Tour Convenor

Monday 11 September

The group made the short journey from the Hotel Galicia Palace in Ponteverda to the Forest Research Centre and Botanic Gardens, Lourizán. The visit to Lourizán provided the group with an opportunity to receive an overview of forestry in Galicia and to assess the performance of a range of tree species growing in the Botanic Gardens. Our guide was Francisco J. Falez de Ana Magán, President of the Associatión Forestal de Galicia (AFG), a body that represents private individual growers and private communes.

Virtually all of Galicia's forests are owned by either private growers or communes. While foresters in Ireland often bemoan the problems of harvesting and managing privately owned forests because of their small average size (around 10 ha), the average size of private forests in Galicia is only 2 ha. Nobody knows for sure how

Galicia study tour group.

many owners there are, but it is believed that the 1,385,000 ha of private forest is owned by between 400,000 and 600,000 individuals. About 1,070,000 ha are classed as productive forests. On the other hand, the average size of communal forests is over 200 ha, although little over half are categorised as wooded area.

AFG represents private and communal owners and promotes a range of educational and research projects both in Galicia and internationally. It established the Selga Galician Forestry Company Ltd in 2002, which allows AFG members to be more commercially focused in relation to timber sales, processing and renewable energy projects. Selga sells the timber for the owners at prices that are subject to annual reviews. Close to 90% of Selga's capital belongs to AFG. Given the huge land base, Galicia's forest owners are exploring wood energy, but are also using the land resource to maximise solar and wind energy. They are currently evaluating the potential of residues and biomass with other partners in the 'Atlantic area' including Portugal, Galicia, northern Spain and south-west France.

Like Ireland a wide range of species grow well in Galicia, especially exotics. Francisco de Ana Magán outlined the species that perform well commercially and later during a guided tour of the nearby forest research centre and botanic gardens. Here, there are over 400 tree species and a further 100 species of ornamental shrubs. The gardens were founded in 1942. Originally a farm that supported grain and orange production, the soil is an acid brown earth, over a granite base and is ideal for tree growth.

The two main species grown in Galicia are well represented in the gardens.. Two thirds of the forest area in Galicia comprises either *Eucalyptus globulus* or maritime pine (*Pinus pinaster*). All in all there are 56 eucalypt species growing in the gardens, including *E. globulus*. It was introduced to Galicia at the beginning of the last century. Research is being carried out on other eucalyptus species including *E. regnans*, which is resistant to frost, and is ideal raw material for fibre board manufacture.

While the performance of over 60 pine species is being monitored, Galician foresters are likely to persist with maritime pine, although Radiata pine (*P. radiata*) is growing in popularity and Scots pine (*P. sylvestris*) is also planted, albeit in small lots. Norway spruce (*Picea abies*) performs well in Lourizán but it is dwarfed by *E. regnans* and other eucalypts.

Native broadleaves are also well represented in Galician forestry. Close to 27% of the forest area comprises pedunculate and rebollo oak (*Q. robur* and *Q. pyrenaica*) – and Spanish chestnut (*Castanea sativa*). Cultivated hybrids of *Castanea* have been developed for fruit production.

The group was introduced to other species, including rimu (*Dacrydium cupressinum*) with its beautiful weeping foliage and kauri (*Agathis australis*), both native to New Zealand, and coast redwood (*Sequoia sempervirens*) planted in 1954.

After lunch in the Botanic Gardens the group went south to visit the Communal Forest of Tuy or Tui, where we were met by our guide Julio Ruiz Cagigal, AFG.

The forest has an area of 580 ha and is 'owned' by 600 people living in the area. The concept of ownership of communal forests is similar in some ways to commonage ownership, except that each communal forest is run professionally, with an administrative and accounting system. The commune elects its own officials who decide policy. The administration carries out the operations, including planting, coppicing, maintenance, forest protection and harvesting which are outlined in a management plan. Profits are reinvested to administer the forest or to improve the local community. For example, the impressive community hall we stopped off in for coffee was built from the profits of the forest.

The species mainly comprised *Eucalyptus globulus* – to produce fibre for either pulp or panel board - maritime pine and Spanish chestnut, with smaller areas of Douglas fir (*Pseudotsuga menziesii*) and oak (including red oak (*Q. rubra*)).

E. globulus coppices freely after clearfelling, which takes places at about age 15; the best stems are selected for final crop production very early on in the rotation. To maximise natural regeneration harvesting must be carried out before the summer. After the fourth rotation, (every 60 years) regeneration is carried out by planting 1,250 stems/ha, at a spacing of 2 x 4 m.

The forest is 500 m above sea level, and while the main objective is wood production, strong emphasis is placed on provision of recreation. The fire risk is high and water reservoirs are strategically positioned in the forest. We stopped at one reservoir near a recreation area, it was normally full of water in September but was almost empty - it had been months since there was any significant rainfall.

Unlike the rest of Spain, Galicia is green and it rains throughout the year, but not in 2006. The summer had been the driest in memory, and the inevitable fires that followed in August destroyed close to 100,000 ha of forest. Eucalyptus and pine forests were ravaged by fire and between six and seven million cubic metres had been destroyed, equal to the total annual harvest for Galicia, or half of Spain's annual cut.

Donal Magner

Tuesday 12 September

In the morning the party departed Ourense, the capital of the province of the same name. Ourense is a major route centre and gateway to Galicia.

The first stop of the day was the wood research centre – CIS Madeira, which is state owned. It is engaged in developing technologies, with the intention of promoting innovation in the wood industry. The centre works on its own research programmes, and in cooperation with other forest centres. One of the areas under investigation is the determination of wood quality using non-destructive testing.

Fernando Sanz Infante and Manuel Touza Vazquez took the party on a guided tour of the centre and explained the various processes involved in the research work. The main area of research in recent years has been the study of stresses in logs; this work is carried out through various projects.

The impact of the introduction of Eucalyptus to the Galicia area, over one hundred years ago, is causing some anxiety to silviculturalists and environmentalists, the centre is researching the species under the 'Eucalyptus in a changing world' project. Results of the research will influence the future position of the species in Galician silviculture. To date, the research shows it to be a good strong timber which grows in a short time. The environmental drawback is the almost complete absence of vegetation on the forest floor, and negligible leaf-fall.

The party travelled to the Douglas fir plantation owned by Tino Moneiras. The land has been in the Moneiras family since 1848, it was farmed until 1960 when the family began to establish forests comprising mainly of chestnut and maritime pine. In 1970 30 ha were planted with Douglas fir at a stocking of 800/ha. Establishment was successful and the trees now have a fine cylindrical form. Different growth rates were apparent due to changing soil conditions over the site. Due to the wide spacing branching is very strong.

Elaborate fire precautions are in place in event of an outbreak. Several water-traps were set up throughout the plantation. On average, there is a 2-3 month dry period each summer.

The owner does not intend to fell the plantation, he intends to allow it to grow on indefinitely, because, as the English-speaking guide informed the party, 'he does not need money and loves his trees'.

The final stop of the day was at Tragsa Viveros Nursery at Ourence. Tragsa is a company specialising in rural development and nature conservation. Operations are mechanised and concentrated over a relatively small area, comprising greenhouses (3.2 ha), mobile shade covering (2.5 ha) and hardening areas (11.0 ha).

The Agro-Environmental Development and Improvement Centre (CEMDA) are located beside the nursery. The facilities have been designed to enable technology to assist with in-vitro culture, grafting, softwood cutting and acclimation. The intricate nature of the nursery operations and the laboratory techniques were explained by Beatriz Cuenca, Blanca Lopez and Juan Antonio Gomez.

Following the nursery visit the party set off to overnight in Lugo, Galicia's oldest provincial capital, which retains an intact Roman wall.

Frank Nugent

Wednesday 13 September

We drove to Begonte, Lugo and were met by our leaders for the morning, Professors Roque Soalleiro, Agustin Merino and Martin Santalla (Forest administration, Galicia).

First stop was a thinning trial in Radiata pine which had the aim was of improving knowledge of thinning effects, and of encouraging private growers to thin their plantations.

The thinning trial was established on a high quality, community owned wood, planted in 1990 at a spacing of 3 x 2 m. A local seed source and a New Zealand source were also being compared, to determine qualitative and quantitative differences between the different genotypes.

Four separate thinning treatments were employed with three replications:

1. Heavy from below– 80% basal area retained, with selection aimed at removing crooked and diseased stems.
2. Heavy with crop tree designation – 80% basal area retained final crop trees identified and marked in advance, with thinning aimed at favouring them.
3. Light – 90% basal area retained.
4. Control – no thinning.

Next a harvesting site was visited where a mechanical harvester was seen carrying out a first thinning of Radiata pine. One line in twelve was being removed, with selective thinning in the remaining lines (selection was by machine operator). A volume of 50 m3/ha was being removed (not considered to be unduly heavy by local managers). A standing price of €40/ m3 per was being obtained. As a general rule, first thinning is at 12-14 years, second at 22-25 years, followed by clearfelling at 30-35 years.

The next stand visited was established using natural regeneration, using two techniques: mechanical brush control and fire control. To date, fire control has proved to be better, with a stocking of 2000 stems/ha compared with 1000/ha for mechanical control. The low stocking associated with mechanical preparation will require expensive remedial work in the future.

In the afternoon we visited a Finsa MDF mill which employs three hundred people, producing the following products:

- MDF boards
- Flooring
- Profiled boards
- Melamine boards

The mill has two separate lines to cope with the different properties of pine and eucalyptus. In the log yard, both species are stored separately. All logs are chipped to the specified size, and clean chips are cooked (pine bark is burned for energy) to break up the fibre, which is then compressed to remove excess water. When the fibre is ready, it is fed on to a belt at different thicknesses, depending on the end product required, and travels to a chamber which compresses it to the required dimension. The board is quite hot at this stage and cooling machines are used to cool it evenly and efficiently. After cooling, the board is sanded and cross cut and edged to achieve final dimensions. The mill has a capacity to produce approximately 600 m^3 of product per day.

Paddy O'Kelly

Thursday 14 September

Pedunculate oak in Galicia

Pedunculate oak is distributed throughout most of Europe and is the dominant tree species in the native forests of northwest Spain. At present there are 188,000 ha in pure stands in Galicia. In terms of area, the species is second only to maritime pine, while annual roundwood production, at 0.069 million m^3, puts it in fourth place behind eucalyptus (2.450 million m^3), maritime pine (2.032 million m^3) and radiata pine (0.505 million m^3).

Historically, pedunculate oak forests were subjected to selective exploitation felling to supply ship building timber for the Spanish Navy, and as a source of charcoal. The species has had a low priority in modern Galician silviculture, which has concentrated on fast growing species such as *Eucalyptus globulus*, maritime pine and radiata. This combination probably explains the poor quality of stands, with very few good stems. Most oak stands (85%) are coppice-with-standards, only 12% are high forest - 3% are coppice. The species has had a low priority in reforestation: only 400 ha were planted during the period 1998-2003, mainly on moist sites, through plantations of fast growing species.

Pure stands of oak are only found on poor soils, the better quality sites are used for agriculture or have been planted with fast growing conifers or eucalyptus. It is considered that growing oak for quality wood production is only possible on the best sites that have deep, rich soils where rotations of 100 years are possible. The mean annual increment of oak in Galicia varies from 1.9 to 5.7 m^3/ha/year.

Recent years, however, have seen increasing interest in the management of broadleaves such as pedunculate oak. The stimulus is the current emphasis on biodiversity conservation. Although it is forbidden by law, replacement of oak by eucalyptus still occurs in Galicia. Pedunculate oak forest is mainly in private ownership (86%).

The hill-fort of Viladonga

The hill-fort (*Castro*) of Viladonga is situated 70 km from Lugo on national route 640 to Vegadeo, in the municipality of Castro de Rei. It consists of ramparts and ditches enclosing two terraces, on which the remains of houses, enclosures, and other buildings have been excavated, beginning in 1971. The houses are of two distinct types: round houses that were thatched, and rectangular houses with tiles, which point to Roman influence in their design.

The earliest occupation of the site dates from the Bronze Age between the seventh and the fifth centuries BC. The hill-fort culture continued at Viladonga to about the middle of the first century AD, by which time Galicia was part of the Roman Empire.

The Roman conquest did not lead to the immediate abandonment of the hill-fort culture, but rather to a process of gradual change. By the end of the first century BC many hill-forts were abandoned and a large part of the population had settled in the valleys. Some hill-forts such as Viladonga were reoccupied from the third to the fifth centuries AD.

The economy of the Viladonga hill-fort was based on cereal crops, cattle, pigs and horses.

There is an interpretive museum at Viladonga and a selection of the many and varied finds uncovered by the archaeological excavation are on display. These include tools, weapons, pottery, gold jewellery, coins, games, glass and decorative items of harness wear. An impressive model of the hill-fort is on display.

Souto de Retorta

There are sixty six reserves, one national park, six natural parks and four natural monuments included in the Galician conservation of biodiversity programme. Souto de Retorta is one of the four natural monuments. It comprises 3.2 ha of mature eucalyptus forest, located immediately adjacent to the town of Chavin de Viveiro. It is 45 m above sea level, about 5 km inland. The mean annual temperature is 15°C, with an annual rainfall of 960 mm.

Eucalyptus globulus became popular in Galician forestry from about 1950 because of its high growth rate. Rotation length is 12-16 years depending on site quality. Planting of the species is confined to areas up to 400 m above sea level, as it is susceptible to frost damage. It is easy to establish. Second rotation crops are often established from coppice shoots. Some of the eucalypts at Souto de Retorta are among the tallest trees in Europe. The tallest tree in the reserve stands at 66 m, with a volume of 28.6 m3. The tree with the greatest volume - 76 m^3 - is '*El Abuelo*'; it reaches 62 m in height. When a branch fell from the tree in 1998 it was measured at 18 m^3! The tree with the greatest girth is 188 cm at breast height, is some 53 m tall, and has a volume of 47 m^3.

Bob Dagg

Friday 15 September

The group was devastated on Friday morning with news of Joe Tracey's passing during the night. The programme for the remainder of the day was cancelled and the group attended a special mass for Joe at the Cathedral of Santiago de Compostela at 7.30 in the evening. This mass was kindly arranged by the staff of the University of Santiago de Compostela.

Overnight Hotel Universal, Santiago de Compostela

John Mc Loughlin

Saturday 16 September

In the morning the tour headed south to Oporto Airport for the journey home.

John Mc Loughlin

Participants

Marie Aherne, Peter Alley, John Brady, PJ Bruton, Michael Bulfin, (President), John Conneff, John Connelly, Jim Crowley, Bob Dagg, Ken Ellis, Pat Farrington, Jerry Fleming, Brigid Flynn, Eugene Griffin, Christy Hanley, George Hipwell, Kevin Kenny, PJ Lyons, Donal Magner, Tony Mannion, Pat McCloskey, Kevin McDonald, Tom McDonald, John Mc Loughlin, (Convenor), PJ Morrissey, Liam Murphy, Jim Neilan, Frank Nugent, Dermot O'Brien, Michael O'Brien, Pat O'Callaghan, Liam O'Flanagan, Paddy O'Kelly, Tim O'Regan, Denis O'Sullivan, Joe Tracey, Trevor Wilson, Coleman Young.

Obituary

Robert Tottenham
1925 – 2007

Robert Tottenham who died in April 2007 was a champion of Irish private sector forestry. His forest at Mount Callan, near Inagh in Co Clare, which he and his family established almost entirely on wet farmland and mountain, became and remains a symbol of the transfer of emphasis from state to privately-owned forest in Ireland. He believed passionately in forestry and its potential to deliver economic benefits to owners and the wider rural community.

Robert was instrumental in the formation of the Irish Timber Growers Association, and served on its executive and as chairman for many years. A long term member of the council of the Society of Irish Foresters, he strongly advocated its expansion to attract more members from the private sector, especially forest owning farmers, forest workers and forestry contractors.

He loved to share his experiences and knowledge of forestry. Through his generosity of time, Mount Callan became a regular stop on student tours, visits from foreign forestry organisations, field days and study tours. He was always available to discuss his ideas on forest management and to pass on his experience. A mentor to many farm forest owners in his native Clare and beyond, those who sought his advice continued to seek out his company, as Robert had a gift of finding fun and sometimes devilment in all matters, no matter how serious.

Robert became renowned in Irish forestry for his policy of early, intensive and frequent thinning which he practised at Mount Callan, and which resulted in rapid volume increment of the remaining stems. He used this practice in conjunction with deep drainage as a means of engendering stability in stands where windthrow would otherwise be expected.

It is likely that Robert's most enduring legacy to Irish forestry will be his discovery of the European Pro Silva movement, and its advocacy of continuous cover forestry. He was subsequently instrumental in the formation of Pro Silva Ireland, of which he was the founding chairman. In an almost Pauline conversion to continuous cover, he sought out experts in the area throughout Europe, and assembled groups from Ireland to visit them and their forests. Experts were invited back to Ireland to advise on how best Irish forests might be transformed from monoculture plantations to permanent forests.

Irish forestry is poorer for the loss of Robert Tottenham, his mistrust of authority, his love of people, his cheeky smile, his inquisitive eye, the open shirt, the dog whistle around his neck and springer spaniel at his side. Robert is survived by his wife Jane and sons Robin, Fred and George.

Paddy Purser

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