Irish Forestry

JOURNAL OF THE SOCIETY OF IRISH FORESTERS

Volume 71, No. 1&2, 2014

Contents

IRISH FORESTRY

VOL. 71 NOS. 1&2 2014

IRISH FORESTRY

JOURNAL OF THE SOCIETY OF IRISH FORESTERS

VOL. 71 NOS. 1&2 2014

Irish Forestry
JOURNAL OF THE SOCIETY OF IRISH FORESTERS
Volume 71, No. 1&2, 2014

Contents

World Forestry Center

World Forest Institute

Forestry Fellowships Available:
Spend 6-12 Months in Portland, Oregon USA

The World Forest Institute is accepting applications from forestry and other natural resource professionals for 6-12-month Fellowships involving networking, research, and cultural exchange.

Eligibility Requirements:
- Residents of any country may apply
- Proficiency in the English language
- Bachelor's degree in forestry, natural resources or related field.
- Relevant project proposal
- Proof of financial support

Applications are accepted year-round

To apply, please follow the instructions at our website: **wfi.worldforestry.org**

For more information please contact:

Sara Wu
World Forest Institute
503-488-2130
swu@worldforestry.org
wfi.worldforestry.org
4033 SW Canyon Rd.
Portland, OR 97221 USA

Mt Hood National Forest, Oregon

Looking for a fresh perspective on forestry?

Come experience the beauty of the famous forested landscape of Oregon and the Pacific Northwest. Make connections with the region's forest sector and learn the trends impacting this industry and community. This land has always been a landscape in constant motion. It is also where the shifting currents of globalization, trade, environmental concerns and land stewardship clash, producing many of forestry's iconic images: old-growth forests, spotted owls, spectacular fires, economic boom and bust cycles, forest fragmentation, and the new sustainability ethic. Come learn how these factors have impacted the people who depend on the forestry sector, and hear their stories of struggle, adaptation and survival. Because in spite of everything, Oregon is still America's timber basket.

Fellowship benefits include:

- Opportunity to develop the contacts and skills necessary to advance your professional career
- Conducting a project on a forestry or related natural resource topic of your choice
- Visits and field tours to public and private forestry organizations each week, including forestland, harvesting sites, public management and research agencies, local, state and national parks, manufacturing facilities, and non-government organizations.
- Working with forestry colleagues from around the world
- The Harry A. Merlo Foundation provides a matching grant that covers 50% of the Fellowship fee (applicants are responsible for the other 50% plus additional visa and travel costs)
- Monthly stipend ~ $1000/month (net taxes)
- Public transportation pass provided

Why Portland, Oregon?

- Portland is a green, livable city of 1.8 million
- Half of the state is forestland
- Oregon is the largest producer of forest products among the 50 US states
- The Pacific Northwest is abundant with natural beauty and outdoor recreation: Portland is only one hour from mountains, beaches, forests, and desert

For more information about the program and how to apply, please visit: http://wfi.worldforestry.org


Husqvarna
T 540 XP
TechLite
Husqvarna
Husqvarna
Some things are
worth waiting for.


Husqvarna
TechLite


European
Business
Awards™
Winner
2012/13
At the recent European Business Awards, Coillte was the outright winner for Environmental and Corporate Sustainability, beating off competition from over 15,000 European companies.
Coillte. Trees are just the start of it.
It's official – Coillte is No.1 in Europe for Sustainability
Natural resources, responsibly managed.
www.coillte.ie
coillte

Department of Agriculture, Food and the Marine
An Roinn Talmhaíochta, Bia agus Mara

Forest Service

NDP
National Development Plan 2007 - 2013

Green Belt
CELEBRATING 30 YEARS OF SOLID GROWTH
Planting since 1982
Get Professional Advice From Your Local Experts
• Forest Establishment & Maintenance
• Forest Management & Insurance
• Forest Road Consultants
• Thinning, Harvesting & Timber Sales
• Forest Aquisition and Sales
Contact Green Belt Ltd.
Virginia, Co. Cavan
Freephone: 1800 200 233
www.greenbelt.ie
Green Belt
CELEBRATING 30 YEARS OF SOLID GROWTH
Planting since 1982

Wood is...

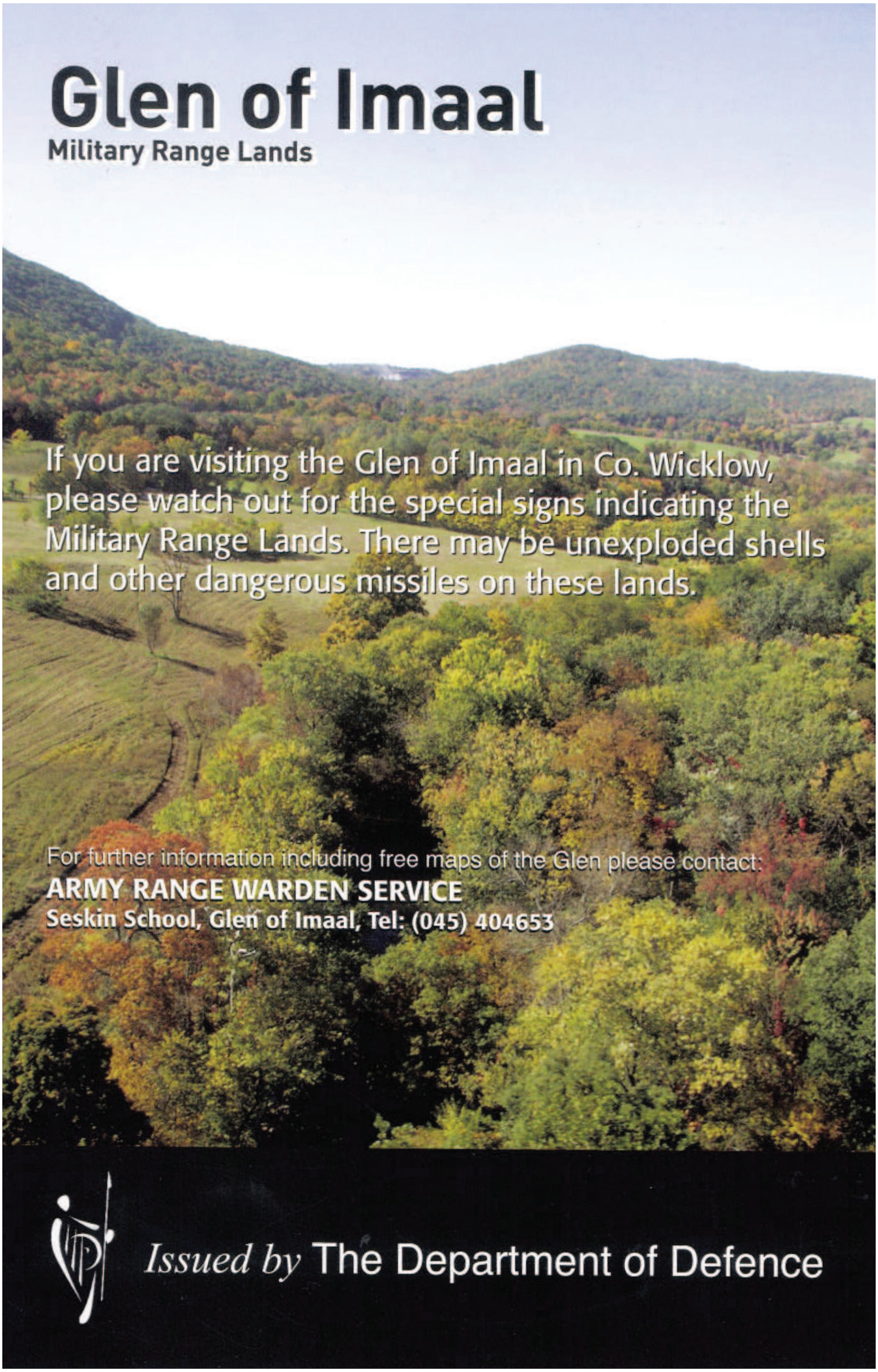
The Wood Marketing Federation is a non-profit making organisation, founded in 1989 to promote wood as a renewable, sustainable and versatile natural material.

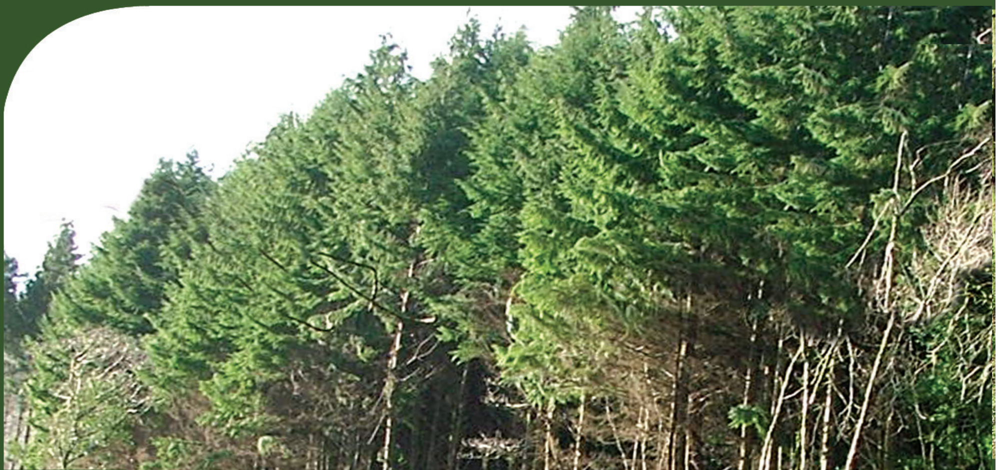
WMF carries out projects which are either generic or relate to members own businesses, including:

- Publication of *Woodspec – A Guide to Designing, Detailing and Specifying Timber in Ireland*. The guide, which is the first of its kind in Europe, is aimed at architects, engineers, designers and other specifiers.
- Wood Design Award aimed at third level students of architecture, engineering and design.
- Wood promotional and educational literature including *Talking Timber* a series of guidelines on wood products, sustainable forestry, wood energy, construction and timber treatment.
- Exhibitions, seminars and workshops.
- Lobbying Government, State agencies, EU and other organisations.

WOOD MARKETING FEDERATION

www.wood.ie


Glen of Imaal
Military Range Lands
If you are visiting the Glen of Imaal in Co. Wicklow, please watch out for the special signs indicating the Military Range Lands. There may be unexploded shells and other dangerous missiles on these lands.
For further information including free maps of the Glen please contact:
ARMY RANGE WARDEN SERVICE
Seskin School, Glen of Imaal, Tel: (045) 404653
Issued by The Department of Defence



Advertiser's Index

The Society of Irish Foresters would like to thank the
following advertisers for their support of *Irish Forestry*

Contents

Book Reviews

Obituaries

The Society of Irish Foresters

Comann Foraoiseorl na nEireann

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

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

Submissions of articles to Irish Forestry

Submissions

1. Original material only, unpublished elsewhere, will be considered for publication in *Irish Forestry*. Where material has been submitted for publication elsewhere, authors must indicate the journal and the date of submission.
2. All submissions must be in MS Word, submitted electronically to the Editor, *Irish Forestry* at sif@eircom.net (see Guidelines). Authors are requested to keep papers as concise as possible and no more than 12 pages in length (including tables and figures).
3. Submissions will be acknowledged by the Editor. Authors will be informed if the paper is to be sent for peer review. If peer review is not envisaged an explanation will be provided to authors.
4. On submission, authors should indicate up to three potential referees for their paper (providing full contact details for each referee). Choice of peer reviewer rests in all cases with the Editor.
5. Peer reviews will be communicated to authors by the Editor. Changes suggested by the reviewer must be considered and responded to. It is expected that co-authors should be informed of, and in agreement with, such changes and responses. The decision to publish will be taken by the Editor, whose decision is final.
6. Guidelines for authors on *Irish Forestry* house style and layout can be downloaded as an MS Word template from http://societyofirishforesters.ie/lrishForestry.

Front cover: Ireland's Oldest Oak Tree at Abbeyleix Estate. *Photograph by Kevin J. Hutchinson for the book* Heritage Trees of Ireland *published by The Collins Press in association with the Tree Council of Ireland.* **Insets:** *Past and present Professors and Heads of Forestry, covering over a century of education at UCD.*

Acknowledgements
The Editors would like to acknowledge the work of Dr Stefanie Duesberg in editing and laying out the content of this issue. The assistance of Ann Luke was invaluable in sourcing images for articles in this issue. Kevin Hutchinson and John Mc Loughlin also contributed to this task as well as playing a key role in organising many of the book reviews. We also thank the anonymous reviewers who have contributed to maintaining the quality of the scientific and other articles published in this journal..

Irish Forestry
Volume 71, Nos 1&2, 2014
ISSN 0021-1192
Published by the
Society of Irish Foresters © 2014.

Designed and printed in Ireland for
Arrow Print Management.

Annual subscription €50.
Subscription enquiries:
Society of Irish Foresters,
Glenealy,
Co. Wicklow,
Ireland.
Email: sif@eircom.net
Website: www.societyofirishforesters.ie

Society of Irish Foresters
Council 2014 – 2016

President	Pacelli Breathnach
Vice-President	Conor O'Reilly
Secretary	Tara Ryan
Treasurer	Tim O'Regan
Editors	Conor O'Reilly / Brian Tobin
Business Editor	John Mc Loughlin
Public Relations Officer	Kevin Hutchinson
Technical Councillors	Hugh Cawley Joe Codd Niall Farrelly Gerry Murphy Alistair Pfeifer Vincent Upton
Associate Councillors	Gordon Knaggs Toddy Radford
Northern Region Group Rep	Ken Ellis
Belfield Region Group Rep	Edwin Corrigan
AIFC Representative	Daragh Little

Technical Director	Pat O'Sullivan
Editorial Management Board	Conor O'Reilly (Convenor) Edward P. Farrell Gerhardt Gallagher Eugene Hendrick Alistair Pfeifer Brian Tobin (Co-Editor)

EDITORIAL

Funding the Scouts

Money spent on research pays dividends in the longer term, ensuring that the best decisions are made and reduces the likelihood that costly errors will occur. Fergal Mulloy, the first director of COFORD, likened forestry researchers to military scouts, sent out in advance to identify potential problems and then suggest possible solutions. For example, the research trials into species and provenance performance have provided (and in some cases continue to provide) invaluable information to Irish forestry – an excellent return from investing in the scouts. Unfortunately however, forest research in Ireland has been in some disarray in recent times, exacerbated by the loss of key expertise through retirements. The low level of investment in forest research is also a worry, at only 0.63% of the sector's contribution to the economy, compared with an average spend of 1.68% in other sectors.

COFORD was established in 1993 to develop a strategic direction for forest research and provide funding for competitive research programmes. This stimulated the involvement of the third-level institutions, which greatly expanded the scope, expertise and capacity of forestry research and development. In addition, collaboration between research and industry was fostered through participation in joint projects. This investment also helped to build research capacity, facilitating involvement in other research (e.g. EU) programmes. In response to rationalisation during the recession period, COFORD was subsumed in 2010 into the Department of Agriculture Food and the Marine (DAFM). The COFORD research programme (now known as the Competitive Forest Research for Development programme) is currently the responsibility of the Research Division of DAFM and is one of its three main R&D funding programmes. Most of the research funding is short term in nature, which is an ideal approach for addressing some forestry problems. However, long-term studies are needed to address many other problems. Field trials, sometimes involving data collection over decades, are the backbone of many long-term research projects. Field trials are expensive and require on-going maintenance. A mechanism to fund long-term research is needed. In addition, extension activities declined greatly following the demise of COFORD in 2010.

The recent policy document (see Book Reviews section) calls for the setting up of "an overarching forest sector body" to guide and coordinate forest research and development, which appears to be an attempt to reincarnate the old COFORD. This document also calls for the development and maintenance of research competence, without specifying how this might be done. In addition, the document recommends that the feasibility of setting up a long-term research programme should be examined.

The 2014 DAFM research call is interesting, showing that DAFM has followed up with actions to address some of the policy recommendations, which is a very welcome development. The Long Term Forestry Research Initiative has been unveiled as part of this research call, which could involve the establishment of a virtual centre for research (partnership among a number of forest research providers led by one institute) or a structured and coordinated programme for long-term research (set of inter-dependent projects each led by one existing research institution, but also involving strong cross-institution collaboration). The first option may be the better one since it is more likely to ensure more effective coordination and implementation of research strategies. The Food for Health Ireland (FHI) research centre, a multi-location, multi-partnered, multi-disciplinary research centre may be a model for the development of such a centre. It is recognised that no single institution in Ireland has the capacity to deliver a comprehensive long-term programme of forest research without the input of other institutions. Therefore, it makes sense to harness the capacity of this scattered expertise into a virtual centre. In addition to the older more experienced researchers, there are already many very talented young researchers working in forestry, so this bodes well for the future. However, most of these young researchers work on short-term contracts and see little prospect of a career in forest research. The DAFM goal of developing and maintaining research competence is unlikely to be achieved in the absence of measures to address this issue. Many of the sentiments expressed above have been echoed in the Society's Policy Position Paper *A Revised Structure for Forest Research*, published in 2013. The Long Term Forestry Research Initiative may have been, at least in part, a response to that document.

This year's issue of *Irish Forestry* contains the usual broad diversity or mix of papers that perhaps readers are beginning to get accustomed to (since many of the papers are research ones, this also reflects well on past investment in research). However, there is also a bumper Book Review section, which indicates that interest in forestry books has not waned despite the more widespread reliance these days on information obtained over the internet. However, the centenary celebration of Forestry education in UCD must be mentioned. The 2013 Sean Mac Bride lecture on this topic was given by Prof. (Emeritus) Gardiner on 26th November, 2013 at UCD. The lecture was both entertaining and enlightening, but in particular for those who missed it, the main contents of the talk are published in this issue (with Prof. Maarten Nieuwenhuis as co-author). The historical and political background to the origins of the programme at UCD are fascinating. The paper mentions research, stating: "It is only in relatively recent decades that Forestry as a scientific/commercial activity has begun to be recognised as a subject worthy of serious research and study." Let's hope that this research philosophy is maintained, but this cannot be done in the absence of investment.

The impact of plot numbers and plot configuration on the accuracy of pre-harvest stand estimates obtained by terrestrial laser scanning

Taye Mengesha[a], Michael Hawkins[b]
and Maarten Nieuwenhuis[a*]

Abstract

Estimation of merchantable timber volume in a stand, based on pre-harvest inventories, requires accurate measurements of parameters such as diameter, height, taper and stocking, and appropriate sampling. Data were collected using terrestrial laser scanning with a multi-scan mode, in a stand of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) scheduled for clearfelling. The stand was divided into four blocks. Two to five plots per block were established in the stand and were scanned. For a number of sample trees in each plot, detailed manual measurements of diameter were taken at half-metre intervals along the stem, for comparison with parameters derived from multi-scanning. Pre-sale measurements were also carried out in each block, based on Coillte's (The Irish Forestry Board) Standard Operational Procedures (SOPs), a standard methodology for pre-sale inventories in Ireland, based on the tariff system. The mean diameter at breast height (DBH) values derived from the point cloud data from the three scan positions in each plot were in good agreement with the manually measured DBH values (i.e. root mean square error (RMSE) of 1.72 cm and a bias of 0.3 cm). The volumes derived after adjusting the height values obtained from multi-scan point cloud data with plot-based DBH-height regression models showed the closest match with those produced by the segment method of calculating individual tree volume. The estimated stand volume using data from the three scan positions after correcting for occlusion, and the stand volume estimated based on the use of multi-scan data from the intersecting areas of the scan circles, resulted in volumes within 6.9% and 8.5%, respectively, of the volume of the stand as measured using Coillte's SOPs.

Keywords: *Multi-scanning, forest inventory, occlusion, plot configuration, stand volume, pre-sale measurements.*

Introduction

In Ireland, currently no standard system is in place for the recording or reporting of pre-harvest volume estimates from the private forest sector (Casey and Ryan 2012). At present, this information is mostly obtained by manual, ground-based methods. The use of historic data for volume estimation, forecasting and modelling is constrained because of uncertainties about the inventory methods used and the accuracies achieved. Increased requirements for up-to-date, efficient and reproducible methods for obtaining high quality data make it necessary to investigate new inventory systems. These systems

[a] UCD Forestry, UCD School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4.
[b] Roodubo Limited, Dublin.
[*] Corresponding author: maarten.nieuwenhuis@ucd.ie

should be based on efficient, economic and objective procedures that produce multi-purpose datasets and application software that will transform the data into information relevant to forest planning and sustainable forest management.

International competition has forced commercial timber companies to seek ways to reduce timber production costs. One of the areas where cost can be reduced is in forest inventory. Modern technology has made it possible to maintain measurement accuracy while reducing the cost associated with traditional inventory methods (McRoberts et al. 2010). A promising new technology in multi-purpose forest inventories is terrestrial laser scanning (TLS). This type of scanning is used in a variety of applications where accurate three-dimensional (3D) models are useful, including architectural, industrial and medical measurements, coastal erosion studies and heritage preservation (Alexsson 1999, Hetzel et al. 2001, Henning and Radtke 2006a, van Leeuwen and Nieuwenhuis 2010). The basic principles behind the operation and measurement methods of TLS appear to make the technology suitable for highly automated, multi-purpose forest inventories (Dassot et al. 2011).

Acquiring accurate estimates of forest timber volume from pre-harvesting inventories requires accurate measurements of parameters such as diameter, height and taper. Estimating stand density (number of trees per hectare), basal area, timber volume and total biomass is also important in understanding the overall structure and the dynamics of a forest stand. With recent advances in ground-based terrestrial laser scanning technology, accurate estimation of these forest inventory parameters is becoming possible (Maas et al. 2008, Dassot et al. 2011). Terrestrial laser scanning data have been used to estimate stand densities in different types of forest, ranging from low-density stands (up to 600 stems ha^{-1}) (Watt and Donoghue 2005), to stands with more than 1,000 stems ha^{-1} (Tansey et al. 2009, Liang et al. 2012). They found that stand density is the most difficult forest parameter to estimate using remote sensing technology, including TLS, due to occlusion of stems (Heurich and Thoma 2008).

When acquiring data in forests, TLS data will be lacking from zones that are obscured from the scanner, which means that some trees will be completely hidden and some others will be partially hidden. One possible approach to mitigate this effect is the use of multi-scans (Thies and Spiecker 2004, Thomas et al. 2006, Maas et al. 2008). Multi-scanning is a scanning protocol where at least three positions around the centre of a sample plot are chosen and each is scanned, so that overlapping scanning regions are guaranteed. Compared to the single scan mode, the rate of tree detection in multi-scan mode has been found to be higher (Thies and Spiecker 2004, Maas et al. 2008).

This study investigated the use of TLS single scan and multi-scan modes for a pre-clearfell inventory and analysed the impact of the number of sample plots and the plot configuration on the accuracy and precision of volume estimates, when compared with results based on Coillte's (The Irish Forestry Board) Standard Operational Procedures (SOPs).

Objectives

The objectives of this study were:

- to collect pre-clearfell forest inventory data using TLS and to compare single scan and multiple scan estimates of volume, etc. with those derived using Coillte's standard operating procedures (SOPs);
- to investigate the occurrence of occlusion and to assess the benefits of multiple scanning in reducing it, and;
- to analyse the impact of the number of sample plots and the plot configuration on the accuracy of pre-clearfell TLS inventories.

Materials and Methods

Study site

The forest stand was located in a Coillte-owned forest at Thomastown, Co. Kilkenny, Ireland (52°3'18" N and 7°2'6" W). The stand of Sitka spruce (*Picea sitchensis* Bong. (Carr.)) was planted in 1966. The area of the Sales Proposal (SP) (which is the term used to identify an area scheduled for pre-sale measurements or to advertise timber for sale) was 9.4 ha. The SP was stratified into four blocks for separate volume assessments. Summary statistics for mean diameter at breast height (DBH), stand density, timber volume and area of the blocks, based on an Abbreviated Tariff (see the pre-sale measurement based on Coillte's SOPs), are presented in Table 1.

Plot set-up and data collection

During the summer of 2011, circular plots were located by overlaying the forest area in the SP with a 40 × 40 m grid. From the overlaid grid, 25 potential grid centres were identified as potential sample plot locations. From these 25 potential plot locations, 15 grid centres were selected randomly for the establishment of sample plots for scanning and plot-level DBH and height data collection (Figure 1). Three scan positions, which were separated by 7 m from each other, were included in each plot, as indicated in Figure 1. The spacing of the scan positions was chosen because the accuracy of

Table 1: *Summary of manually measured pre-sales volume parameters in the study area.*

Block	Area (ha)	Mean DBH (cm)	Mean stocking (stems ha^{-1})	Volume (m^3 ha^{-1})	Volume per tree (m^3 $tree^{-1}$)
1	2.9	31.5	526	479	0.91
2	1.8	27.7	609	311	0.51
3	2.2	27.1	651	365	0.56
4	2.5	28.4	536	332	0.62

diameter estimation decreases as the distance from the scanner increases, due to the effects of the scanner's beam divergence and laser spot size. The centre of the first scan circle was fixed at the centre of the square grid at a position at least 3 m away from any nearby tree. The centres of the second and the third scan positions were fixed at the vertices of the equilateral triangle with 7 m sides, with the second scan position located due north of the first one. If either of the two vertices fell within 3 m of a tree, the new scan centres were determined by moving in a clockwise direction until satisfactory positions were obtained, without changing the first scan position. The radius of each scan circle was 15 m, giving an area of 0.0701 ha. The intersection of the three scan circles covered an area of 0.0414 ha (Figure 1).

Trees in the 15 m radius scan circles in the plots were numbered. A Haglöf Vertex IV Electronic Hypsometer with Sonar Rangefinder (Haglöf, Sweden) was used to determine if trees were inside the 15 m circle. Numbering started in the first scan circle from the north and moved clockwise, using the same method in the second and third scan circles. Any tree in the second or third scan circles not numbered in the previous circles was given a subsequent number. During tree numbering, a dot was put on the tree (under the number) each time it was included in a scan circle (so that it was clear which trees were included in one, two or three scan circles).

At each plot location, six trees in the common area of the three scans (i.e. from trees with three dots) were selected for DBH and height measurements to be used as an input by Autostem™ software for adjusting tree height. Two of these trees were from the top half of the DBH distribution, three from around the mean and one from the bottom half of the distribution. Three of these trees were selected randomly as volume sample trees.

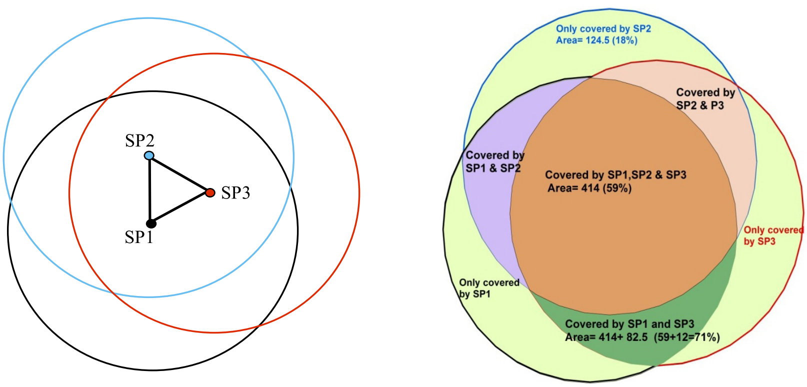


Figure 1: *Plot configurations with multi-scan positions located at the vertices of an equilateral triangle with 7 m long sides (left) and intersections of common areas (m^2) of scan positions (right). The scan circle radius is 15 m.*

(SP1, SP2 and SP3)-Data collection using TLS

The laser-scanning instrument used in this study was a FARO LS 800 HE80. The scanner has a field of view of 360° horizontal and 320° vertical, and a range of up to 80 m, with a distance accuracy of ± 3 mm, and a data collection rate of 120,000 points per second. Point clouds with more than a million accurate measured surface points can be obtained with a wavelength of 785 nm (FARO Technologies, Inc., Lake Mary, FL). The FARO LS 800 HE80 employs range determination technology using the phase-based principle, where a mirror rotates and directs the laser pulses. The FARO scanner's integrated computer is an important advantage in the scanning process. The scanner was mounted on a tripod with a built-in spirit level. The start direction was aligned to magnetic north to calculate azimuths without an offset.

Measurements and analysis based on TLS data

The TLS data acquisition for the estimation of standing timber volume was carried out based on predefined field protocols designed to overcome some of the limitations of this technology. One of the objectives of the study was to investigate the effects of vertical occlusion by branches and horizontal occlusion by stems on volume estimates, and on developing ways to overcome these limitations. The method we examined to reduce the impact of vertical occlusion was to support the TLS derived data by height measurements of trees taken in the blocks and plots where the scanning was carried out. For horizontal occlusion, the use of multiple scan positions was investigated.

Scanning was carried out from the three established scan positions in each of the plots. The height and DBH of individual trees were obtained from the single scan position per plot. The occluded trees in the first scan were, where possible, obtained from the second scan position and, if necessary, from the third scan position. In this way, most of the trees in the plot were included in at least one of the scans from the three scan positions. After estimating the total number of trees per plot using data from the three scan positions, the plot level parameters such as volume and stocking per plot were scaled up to block level and then to stand level estimates. Based on different numbers of scans (i.e. one scan, two scans or three scans per plot), the estimated block volumes were compared to those obtained using Coillte's SOPs.

Trees found in the overlapping scan area were identified in the scan data prior to processing their volume using Autostem™ software (Treemetrics, Ireland). The volumes of trees located in this part of the plot were first derived, where possible, from the single scan data, then from combined data from two scan positions, and finally from combined data from all three scan positions. The volume of the occluded trees in the single scan was determined, where possible, based on the point cloud data from the second scan position. Occluded trees in the first and second scan were identified, and the volume of these trees was obtained, where possible, from the point cloud data from the third scan position.

Measurements of tree parameters (DBH, height and volume)
Three trees per plot were felled for comparison with the stem profiles and individual tree volumes of the scanned trees. The stem profiles and volumes of the felled trees were derived from diameter measurement at 50 cm intervals along the stem. These trees were identified visually and selected in the plots by considering their assumed visibility from all scan positions. However, when analysing the scan data, two out of a total of 45 felled trees could not be detected by the Autostem™ software from all three scan positions due to (partial) occlusion.

Volumes from three individual trees in each plot, derived using four different methods, were compared to each other. The four tree-volume-*per-tree* methods used were:

1. The manual method. Each 50 cm stem section was assumed to have the shape of a frustum:
$$SEG\_V = \frac{\pi h}{12}(D^2 + Dd + d^2) \tag{1}$$
where *SEG V* is the segment volume (m^3), h is the length (m) of the segment, D is the large-end diameter (m) and d is the small-end diameter (m) of the segment.

2. The automated Autostem™ method. To deal with vertical occlusion in the upper portions of the stem, a generic taper function is incorporated in the Autostem™ software, to automatically estimate diameters for stem sections that were not seen by the TLS. Autostem™ will switch from a circumference fitting process to the taper function if the pre-set (fixed) circumference fitting reliability factor falls beyond a threshold value. In this study, the reliability factor used was set at 70%, which is similar to the one used in Bienert et al. (2007). The taper function used by Autostem™ was a modified Kozak equation for Sitka spruce (Kozak 1988).

Point cloud data from terrestrial laser scanning often do not contain an adequate amount of data points for the top part of the trees, due to occlusion by branches. As a result, heights estimated by Autostem™ using method 2 were, after an initial analysis, corrected using regression models of local DBH-height data obtained from sample trees. The models consisted of two types, resulting in methods 3 and 4.

3. The block regression method. DBH-height regression models were developed using data from all sample trees in each block. The height estimates resulting from this model were used to correct the Autostem™ heights in each block.

4. The plot regression method. DBH-height regression models were developed using data from sample trees in each plot. The height estimates resulting from this model were used to correct the Autostem™ heights in each plot.

Volume estimates from TLS data *per plot* were obtained based on:

a. The single-scan plus occlusion correction method. A horizontal occlusion correction factor for single scan data, calculated for each plot separately.

b. The multi-scan-method. The use of multi-scan data (combined data) in the intersection area of the scan circles.

Forest block volumes were obtained based on the extrapolation of plot volumes to block areas.

Pre-sale measurement using Coillte's SOPs

Estimates of standing volume per block were compiled using Coillte's Pre-Sale Measurement (PSM) Standard Operating Procedures (Purser 1999). These Procedures are based on an adaptation of the Forestry Commission (GB) Abbreviated Tariff system (Matthews et al. 2006).

Coillte's SOPs require locating lines through the stand that are representative of the diameter distribution, and measuring the DBH and height of stems along the lines. The minimum number of DBH and height samples per Sales Proposal is dependent on the extent of the harvest area and the prescribed measurement intensity. A minimum of 110 DBH measurements were taken in each block, and the height measurements in the scan plots were used as the height sample in the abbreviated tariff. Based on Edwards (1983), this results in approximate confidence intervals for the volume estimate of ±12%.

Results

Manual DBH versus Autostem™ DBH obtained from three scan positions

The DBH of the sample trees which were scanned from three different scan positions were analysed. The result (Figure 2) indicated that there are differences in the DBH estimates of some individual trees as a result of measuring from different directions.

The standard deviation of the differences in DBH between the manual measurement and the mean of three scan measurements was 1.7 cm. The range of the differences was -4.9 to 3.2 cm, with a mean of -0.3 cm. There was no clear trend of either overestimation or underestimation, but the mean difference over all felled trees indicated underestimation of DBH as the value was negative. These differences were probably due to the non-cylindrical shape of these trees, and to the presence of small stems and shrubs in the stand, which affected the DBH estimation, either by blocking the laser beam or by confusing the software, which occasionally considered the main tree stem and some of these small stems as a single tree (Figure 3).

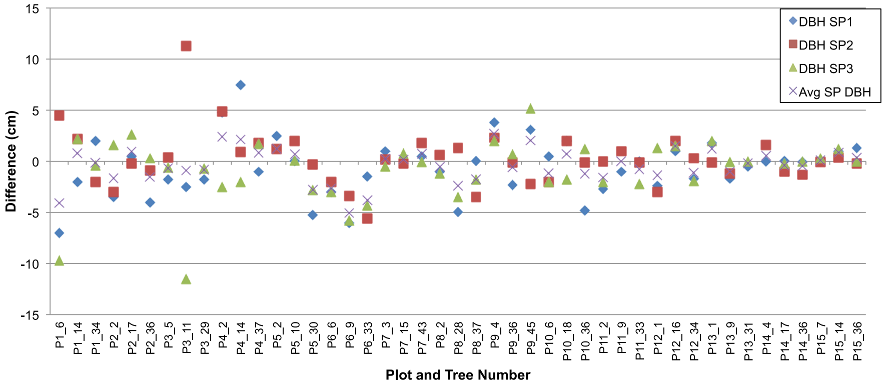


Figure 2: *Differences between manually measured DBH and Autostem™ derived DBH for the three sample trees per plot; DBH SP1, DBH SP2, DBH SP3 and Avg SP DBH refer to DBH derived using data from scan positions 1, 2, 3 and mean DBH derived using data from three scan positions, respectively. P1_6 is used to represent tree number 6 in Plot 1, etc.*

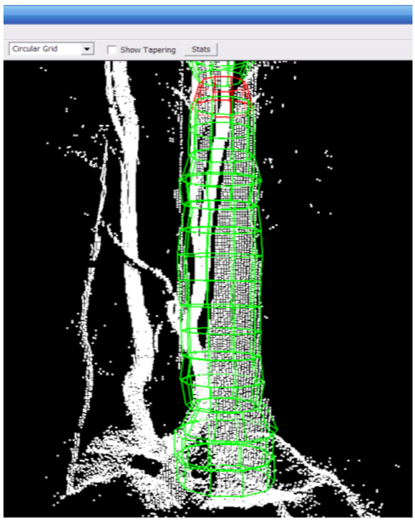


Figure 3: *A tree with overestimated DBH due to the presence of adjacent small stems.*

Mean DBH

The improvement in the DBH estimate as a result of using the mean scan values was substantial, except in a few plots. The root mean square error (RMSE) of mean DBH ranged from 1.2 to 3.0 cm, with bias ranging from -0.1 to +1.9 cm for the sample trees measured in the four blocks (Table 2). The high bias value for block 2 can be attributed to the small number of plots in this block, combined with a number of outliers in the scan data.

Height estimates

Heights of sample trees derived automatically by Autostem™ without the use of DBH-height regression models displayed large differences depending on the scan position, and resulted in large discrepancies when compared with the manually measured heights. Using the mean value of the two or three Autostem™ measurements did not resolve this issue, which led to the use of height data from the DBH-height models. Tree heights derived by Autostem™ using plot-based DBH-height regression models showed smaller differences with manually measured tree heights than those derived by Autostem™ using the block-based DBH-height regression model (Figure 4). The mean heights from the three scan positions were in good agreement with the manually measured heights, except for three trees whose heights were less than those obtained using the DBH-height model.

Volume of individual trees determined from three scans positions

The volumes of the individual trees, determined by the four methods, displayed considerable differences. The volumes estimated using method 2 showed the largest deviations for individual sample trees compared to the volumes derived by method 1. Method 3 resulted in reduced volume differences with method 1 compared to the volume differences between methods 2 and 1. The volumes derived using method 4 showed the closest match to those produced by method 1. The mean volumes calculated based on the tree parameter values from the three scan positions showed reduced differences with the method 1 volumes, compared to the variation in the volume estimates from the individual scan positions with method 1 (Figure 5).

Table 2: *DBH, root mean square error (RMSE) and bias per block, based on sample tree measurements.*

Block	No. of plots	Mean manual DBH (cm)	Mean multi-scan DBH (cm)	RMSE (cm)	bias (cm)
1	5	36.1	36.2	1.6	0.1
2	2	33.3	35.1	3.0	1.8
3	3	31.8	31.7	1.5	-0.1
4	5	29.9	30.0	1.2	0.1

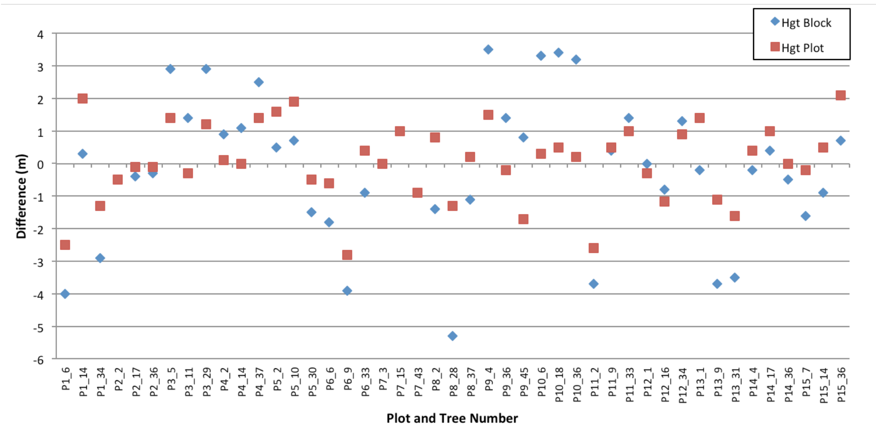


Figure 4: *Differences between tree heights measured using the manual method and tree heights derived using plot- and block–based DBH-regression models, for the three sample trees per plot. Hgt Block refers to height data derived by Autostem™ using block-based DBH-height regression models, and Hgt Plot refers to height data derived by Autostem™ using plot-based DBH-height regression models. P1_6 is used to represent tree number 6 in Plot 1, etc.*

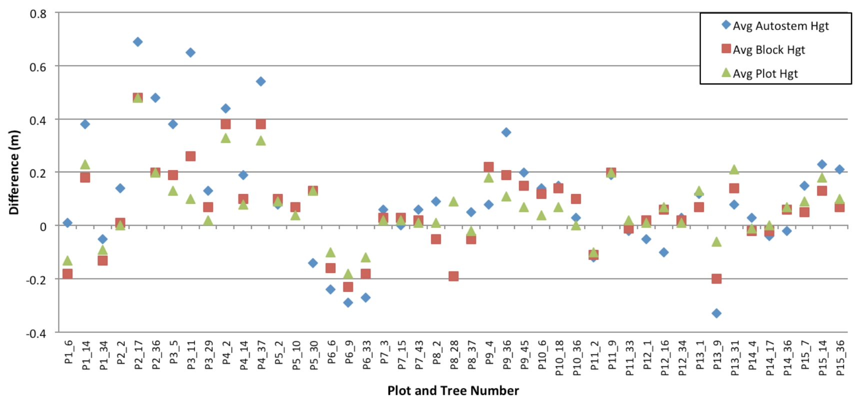


Figure 5: *Differences between tree volume measured using the segment method and tree volumes based on default Autostem height, adjusted height using block and plot-based DBH-height regression models, for the three sample trees per plot. Avg Autostem Hgt, Avg Block Hgt and Avg Plot Hgt represent volume data derived using average default heights of Autostem™, volume derived from heights obtained from block-based DBH-height regression models and plot-based DBH-height regression models, respectively. P1_6 is used to represent tree number 6 in Plot 1, etc.*

Volume per plot – based on single multi-scan

One of the objectives of this study was to investigate if there was an improvement in the accuracy of volume estimation derived using the three scan positions (multi-scan mode) compared to the single-scan mode, and to investigate the combining of scans and its possible advantage in volume estimation compared to single-scan modes. Data derived from the three scan positions were therefore processed in two different ways. The first method was based on occlusion correction factors and the second method was based on the use of combined scans.

Stand volume estimation based on correction factors (Method a)

This work showed that on average 18% of stems were occluded in all plots, based on the analysis of data from single scan positions (Table 3). The occlusion was corrected at every scan position, and the mean volumes, estimated from data from the three scan positions, were used to estimate the volumes per block (Table 4). The stand volume estimate, based on weighted block values and using method a, was 3,780.4 m^3, while the volume based on Coillte's SOPs was 3,581.9 m^3.

Table 3: *Number (#) of trees and occlusion (occl.) percent, per scan position (SP1, SP2 and SP3). B1P2 refers to Plot 2 in Block 1, etc.*

Plot	# trees in SP1	# trees in SP2	# trees in SP3	# occl. trees in SP1	# occl. trees in SP2	# occl. trees in SP3	Occl. % SP1	Occl. % SP2	Occl. % SP3
B1P1	36	35	34	7	2	6	19	6	18
B1P2	37	37	35	3	5	7	8	14	20
B1P3	37	35	35	4	3	5	11	9	14
B1P4	42	42	37	12	7	6	29	17	16
B1P5	41	40	37	6	4	5	15	10	14
B2P6	42	41	42	8	5	9	19	12	21
B2P7	41	43	43	10	10	4	24	23	9
B3P8	50	51	47	8	16	14	16	31	30
B3P9	45	48	43	14	8	9	31	17	21
B3P10	46	45	44	3	9	6	7	20	14
B4P11	42	39	36	7	3	6	17	8	17
B4P12	41	35	40	9	4	3	22	11	8
B4P13	38	37	39	9	6	6	24	16	15
B4P14	36	33	36	9	7	6	25	21	17
B4P15	38	39	42	4	8	15	11	21	36

Table 4: *Estimates of volume (m^3) before and after occlusion correction per plot (P), hectare (ha), and block (B), using three scan positions (SP). The confidence intervals (CI) for the SOPs-volumes are based on Edwards (1983). B1P2 refers to Plot 2 in Block 1, etc.*

Plot	Volume before occlusion correction (m^3)			Volume after occlusion correction								
				Per Plot			Per ha				***Block mean* (95% CI)**	**SOPs Volume (95% CI)**
	SP1	**SP2**	**SP3**	**SP1**	**SP2**	**SP3**	**SP1**	**SP2**	**SP3**	**Mean**	**(m^3 ha^{-1})**	**(m^3 ha^{-1})**
B1P1	28.10	33.25	27.07	34.88	35.27	32.87	498	503	469	490	516 (456-576)	479 (428-537)
B1P2	34.63	32.89	28.79	37.69	38.03	35.98	538	543	513	531		
B1P3	37.63	36.44	31.39	42.19	39.85	36.62	602	568	522	564		
B1P4	29.03	38.14	31.02	40.64	45.77	37.02	580	653	528	587		
B1P5	26.12	26.61	22.53	30.59	29.56	26.05	436	422	372	410		
B2P6	20.14	21.58	23.10	24.88	24.58	29.39	355	351	419	375	327 (249-405)	311 (278-348)
B2P7	13.06	16.05	18.44	17.28	20.92	20.33	246	298	290	278		
B3P8	25.61	16.45	20.81	30.49	23.97	29.64	435	342	423	400	402 (331-473)	365 (325-409)
B3P9	15.87	19.64	19.42	23.04	23.56	24.56	329	336	350	338		
B3P10	29.08	25.49	30.64	31.11	31.86	35.48	444	454	506	468		
B4P11	23.23	25.01	22.23	27.87	27.09	26.67	398	387	380	388	317 (275-359)	332 (296-372)
B4P12	18.80	15.38	18.17	24.08	17.36	19.64	344	248	280	290		
B4P13	16.49	18.94	20.36	21.61	22.61	24.06	308	323	343	325		
B4P14	13.48	15.49	14.25	17.97	19.66	17.10	256	280	244	260		
B4P15	18.99	17.19	16.01	21.22	21.63	24.90	303	308	355	322		

Volume estimation using different numbers of plots and scan positions

Different combinations of plots and scan positions were used to investigate the best scenario for obtaining accurate volume estimates from TLS. As the number of plots increases, the precision of the volume estimate increases. In addition, as the number of combined scan positions increased, more precise volume estimates were produced (Figure 6).

Stand volume based on data from combined scans (method b)

The use of multi-scanning plots to account for occlusion was investigated and the results have shown the benefit of having more than one scan in the plot. The maximum increase in volume, as a result of using multi-scan mode compared with a single scan, was recorded in Block 2 (Table 5), with a mean value of 18.9% of the volume in the scan intersection area collected from the second scan position. On average, the mean volume added as the result of using multi-scanning in the stand was 13.6% going from single-scan to double-scan, and a further increase of 1.15% was obtained when a third scan position was added.

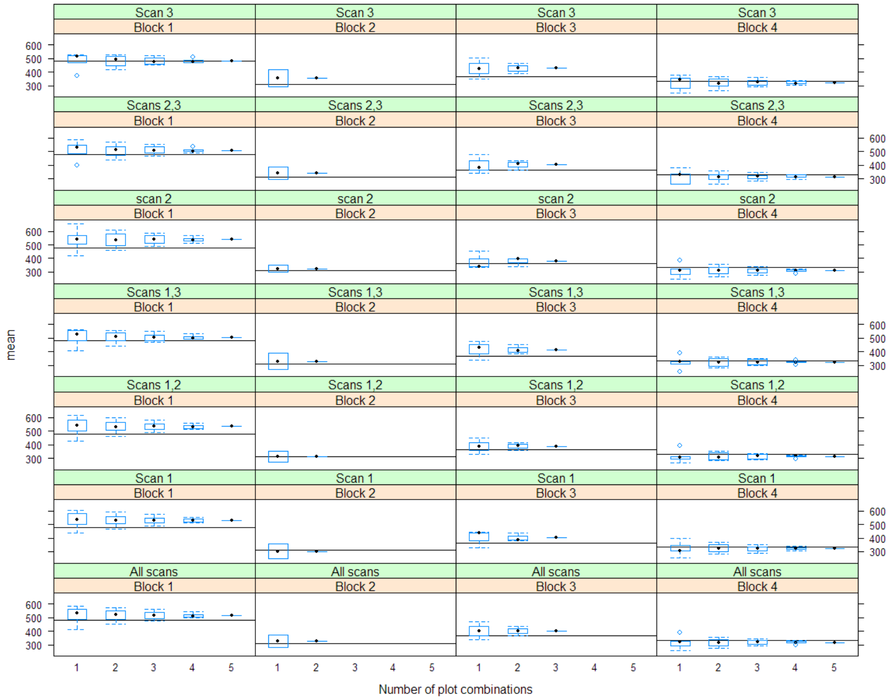


Figure 6: *The effect of different combinations of numbers of plots and scan positions, per block, on volume (m³) estimation, after correcting for occlusion. The black horizontal lines are estimates of volume obtained using Coillte's SOPs.*

The expansion of the volume of the trees in the intersection area (414 m^2), based on three scan positions (method b), to block level resulted in an estimate of 518 m^3 ha^{-1} for block 1 (Table 5). The stand volume estimate using method b, based on the weighted block values, was 3,761.2 m^3, while the SOPs' stand volume estimate was 3,581.9 m^3.

Discussion

Diameter

The comparison of the manually measured DBH of the felled trees with the laser scanning estimates indicated that the variation in the scan estimates might be due to three factors. First, the angle from which the trees are scanned will affect the diameter values. Even though the stem sections of Sitka spruce tend to be circular, some trees and tree sections are non-circular, possibly due to lean, reaction wood and wind loading. Second, some trees were occluded from the TLS at one or more of the scan positions, due to the presence of branches and shrubs at breast height. Third, some trees were partially occluded from the TLS at breast height by being partly hidden behind other trees. In addition to the factors mentioned, the over-estimation or under-estimation

Table 5: *Stand volume in the intersection area of the three scan positions and percentage of volume gained using method b. B1P1 stands for block 1, Plot 1, etc.*

Plot	Volume (m^3) SP1	Volume (m^3) SP1+2	Volume (m^3) SP1,2+3	Volume added by SP2 (%)	Volume added by SP3 (%)	Mean volume added by SP2 (%)	Volume (m^3 ha^{-1}) SP1,2+3
B1P1	18.0	20.0	20.0	9.7	0.0		
B1P2	21.1	21.5	22.0	1.9	2.3		
B1P3	20.2	22.3	22.3	9.4	0.0	10.8	518
B1P4	16.8	22.5	22.5	25.2	0.0		
B1P5	19.0	20.6	20.6	7.6	0.0		
B2P6	15.1	16.9	17.2	10.5	1.8	18.9	341
B2P7	7.6	10.4	11.1	27.2	5.8		
B3P8	16.1	17.1	17.8	5.8	3.8		
B3P9	10.3	14.0	14.5	26.4	3.6	16.0	402
B3P10	14.9	17.7	17.7	15.8	0.0		
B4P11	13.9	14.9	14.9	6.4	0.0		
B4P12	9.7	10.8	10.8	10.3	0.0		
B4P13	10.9	13.7	13.7	21.0	0.0	12.9	312
B4P14	8.7	10.7	10.7	18.9	0.0		
B4P15	13.2	14.4	14.4	8.0	0.0		

ofthe DBH of a given tree scanned from different scan positions could also have been related to the incident angle and distance from the scanner (Lovell et al. 2011). The reflectance of a target varies according to the angle it subtends the illuminating beam. Maximum reflectance occurs from a perpendicular target and decreases according to the cosine of the angle of incidence. The reason for achieving more accurate and precise DBH estimates from the mean of the estimates from the three scan positions results from compensating for one or more of the factors mentioned above.

The finding of this study resulted in a root mean square error (RMSE) of 2.9 cm (8.8%) for the DBH estimate from single scan mode data. The multi-scan mode produced a RMSE of 1.7 cm (5.2%) for the whole stand area, while biases ranging from -0.6 to 3.0 cm and from 0.0 to 1.9 cm were obtained from the analysis of DBH measurements using single scan and multi-scan modes, respectively. A TLS-study by Lindberg et al. (2012), in Norway spruce (*Picea abies* (L.) Karst) dominated stand with 600 stems ha^{-1} and 26.8 cm mean DBH, resulted in an estimation of DBH with RMSE of 3.80 cm (13.1%), and a bias of 0.16 cm (0.5%). Watt and Donoghue (2005) derived 12 DBH measurements using a Reigl LPM-300VHS scanner in a stand of mature Sitka spruce with 600 stems ha^{-1} in northern England and, compared to manual measurements, reported an average difference of 1.5 cm and an R^2 of 0.92 with RMSE of 2.3 cm, based on data collected using two scan positions. Henning and Radtke (2006b) derived 28 DBH measurements using TLS with a mean difference of ~5 cm compared to standard inventory methods. Tansey et al. (2009) determined DBHs of Corsican pine (*Pinus nigra* var *maritama* (Ait.) Melv.) in a stand with 1,031 stems ha^{-1}, with mean errors between 1.9 and 3.7 cm. The estimates of bias found in the studies quoted are similar or larger than those found in the present study. Results from the analysis of upper-stem diameters (not presented here) indicated large differences between manual measurements and those obtained using Autostem™, especially when the taper equation was used due to occlusion.

Height

Height was the most difficult parameter to derive from the TLS data. Other studies have also reported that height is difficult to be accurately determined using TLS point cloud data (Tansey et al. 2009, Liang et al. 2012). Antonarakis (2011) attributed the difficulty of deriving tree heights from ground scanners to pulse reflection; because the scanner is on the ground shooting upwards, there can be obstruction from foliage intervening in the LiDAR's view of the tree stem. This results in more points being returned from below the canopy, with less retuning from the top part of the tree. Therefore, taller trees and denser canopies will lower the probability of determining the height to the crown tip. Hopkinson et al. (2004) reported an underestimation of tree heights of 7–8% using ground laser scanning.

In this study, large differences were observed between the height values derived from Autostem™ and the actual heights of trees felled and measured manually. The mean tree height obtained by TLS was 1.4 m less than that manually measured, with an RMSE of 4.9 m. These results are similar to those found by Maas et al. (2008) who reported an underestimation of tree height by TLS of 0.64 m, with a RMSE of 4.55 m. The use of TLS height data to estimate volume is unlikely to provide sufficiently accurate estimates for sale purposes where there is upper stem occlusion due to branches. However, when used in conjunction with locally derived DBH-height regression models, TLS can provide sufficiently accurate estimates.

The study showed that plot-based height sample trees provided a more accurate method to correct Austostem™ heights than using all sample trees amalgamated at block level. Using fewer than six height sample trees per plot resulted in less precise DBH-height models.

Volume

Volume based on individual trees

Analysis of the errors of the method 2 TLS volume estimates for individual trees showed that they were due to errors in both DBH and height estimation. For one tree, the error in volume estimation from Autostem™ software was as large as 0.99 m^3, compared with the manually derived estimate. In particular, the propagation of height estimation errors led to errors in the volume estimation, and it was necessary to provide the Autostem™ software with more accurate height information. As has been shown, the best estimate of tree volume, based on individual scan position data, was achieved when height was adjusted using plot-based DBH-height regression models (method 4).

All of the estimated individual tree volumes in four of the plots in block 1, derived using Methods 2, 3 and 4, were less than the corresponding method 1 volumes. This indicates that the Autostem™ method underestimated the volumes of the trees in block 1, which contained bigger trees than the rest of the blocks (Table 2 and Fig. 5). In the other blocks, Autostem™ produced both under- and over-estimates. These findings indicate that Autostem™ may underestimate the volume of large trees. A possible explanation is that for taller trees Autostem™ relies to a greater extent on the taper equation to estimate upper stem diameters, as a larger part of such stems will be vertically occluded.

Dassot et al. (2012) conducted a study on 42 trees of various species and size classes to evaluate the potential of multi-scan mode TLS to assess their main stem volume. They found the relative difference between TLS and manually measured volume estimates to be within ± 10%. Tansey et al. (2009) attempted to extract stem volume from TLS data but without success. They attributed this to the uncertainty of stem height estimation from TLS data.

Stand volume based on the use of an occlusion correction factor (method a)

Block 1 contained the highest volume per hectare. Based on data from the first scan position, the smallest estimated volume per plot in block 1 was in Plot 1: 16.8 m^3 (Table 5), which was due to the large number of trees occluded from the first scan position in the plot. The single scan volume for the whole stand, using weighted block volumes adjusted with occlusion correction factors, differed from the SOPs volume by +13.3%.

Autostem™ was also used by Murphy (2008) to determine the volume and value of three stands (comprising large, medium and small DBH trees) of Douglas fir (*Pseudotsuga manziesii* (Mirb.) Franco) in Oregon, USA. He processed point clouds provided by a FARO LS800 HE80 scanner with Autostem™ with the fully automated profiling procedure. Total and merchantable wood volumes were underestimated by 22% compared with standard inventory methods. The semi-automated procedure, when tree heights were obtained separately and entered into the Autostem™ software, resulted in the underestimation of 5% of total volume. Murphy et al. (2010) carried out a study at two locations in plantations of radiata pine (*Pinus radiata* D. Don) plantations in Australia with average stockings of 400 and 250 stems ha^{-1}, respectively. Mean tree volume estimates based on TLS measurements were within 3% of estimates based on manual measurements for four of the six stands. On large area plots with a high stocking, up to half of the trees were occluded.

Volume based on scan intersection area (combined area) (method b)

The result of the analysis of the combined scans in the intersection area showed that the use of the second scan position added significantly to the accuracy of the volume estimates. Furthermore, these combined-scan estimates of volume per hectare were very close to those based on the mean volume estimates from the three separate scan positions corrected for occlusion. The largest difference was observed in block 2 at 14 m^3 ha^{-1}. As there were just two sample plots in block 2, this may be the reason for the relatively larger difference in volume estimates between these two methods.

Limitations on volume comparisons

The only data used to compare the block and stand volumes derived from the laser scanner data in our study were the data collected based on Coillte's SOPs. Only approximate error estimation is provided for this method (Edwards 1983). However, as it represents an industry approach, comparison of the scan results with those from the SOPs make sense, to identify areas where differences may occur if TLS is used more widely for stand volume estimation. The need exists, however, to compare the scanning results with data from (calibrated) harvester heads or sawmill in-feed scanners.

Conclusions and recommendations

Terrestrial laser scanning can provide an accurate volume estimate for an entire stand based on plot-level scan data, using two or more intersecting scanning circles (method b), and after the height measurement estimation is adjusted (methods 3 and 4). Without height estimation adjustment and the use of overlapping scanning circles, TLS standing volume estimation should be used with caution. In relation to the number of intersecting scans needed, even after most of the occluded trees in the intersecting area of the scan circles were identified from the second scan, the use of a third intersecting scan further improved the accuracy of the volume estimate, albeit by a proportionately far smaller amount (1.15%) than the addition by a second scan (13.6%). The increase in accuracy as a result of using the second and third scan positions is likely to be less in plots with smaller radii, as occlusion in smaller areas tends to decrease due to reduced interference by the smaller number of trees between the scanner and the targets. Therefore, it could be beneficial to use smaller scan circles; however, in order to capture the same overall sample area, more scans would be required, adding to cost.

The estimation of stand volume using the multi-scan method (b) showed that it resulted in comparable accuracy as the volumes obtained from single scans after adjusting for occlusion using correction factors (method a), that were obtained by counting the trees in the plot. The multi-scan method is therefore a reliable and quick method, which avoids the need for tree counting and for the establishment and marking of plot boundaries, while significantly increasing the accuracy compared to single scan results.

As indicated in this study, in addition to horizontal occlusion, the other limitation of TLS was a weakness of providing accurate measurements of tree height and upper stem diameters (i.e. vertical occlusion). Providing manually measured height data to improve the tree height estimation of TLS (methods 3 and 4) can be time consuming and costly, especially for large-scale (national or global) forest inventory purposes. The combination of TLS with airborne laser scanning, for tree height (and tree number) estimates, is one possible way to address this limitation.

Acknowledgements

This research was funded by the COFORD national forest research programme of the Department of Agriculture, Food and the Marine. The input by Treemetrics and Purser Tarleton Russell (PTR) is gratefully acknowledged, as is the access given by Coillte to its forest.

References

Antonarakis, A.S. 2011. Evaluating forest biometrics obtained from ground lidar in complex riparian forests. *Remote Sensing Letters* 2: 61-70.

Axelsson, P. 1999. Processing of laser scanner data Algorithms and applications. *Isprs Journal of Photogrammetry and Remote Sensing* 54: 138-147.

Bienert, A., Scheller, S., Keane, E., Mohan, F. and Nugent, C. 2007. Tree detection and diameter estimations by analysis of forest terrestrial laserscanner point clouds. ISPRS workshop on Laser Scanning 2007 and SilviLaser 2007, Espoo, Finland, pp 50-55.

Casey, J. and Ryan, M. 2012. *Situation and Outlook for Forestry 2011/2012*. Forestry Development Department, Teagasc, Athenry, Galway.

Dassot, M., Constant, T. and Fournier, M. 2011. The use of terrestrial LiDAR technology in forest science: application fields, benefits and challenges. *Annals of Forest Science* 68: 959-974.

Edwards, P. 1983. Timber measurement – a field guide. *Forestry Commission Booklet,* 49. Her Majesty's Stationery Office, London.

Henning, J.G. and Radtke, P.J. 2006a. Detailed stem measurements of standing trees from ground-based scanning lidar. *Forest Science* 52: 67-80.

Henning, J.G. and Radtke, P.J. 2006b. Ground-based laser imaging for assessing three-dimensional forest canopy structure. *Photogrammetric Engineering and Remote Sensing* 72: 1349-1358.

Hetzel, G., Leibe, B., Levi, P. and Schiele, B. 2001. 3D object recognition from range images using local feature histograms, Computer Vision and Pattern Recognition, 2001. CVPR 2001. In *Proceedings of the 2001 IEEE Computer Society Conference on Computer Vision and Pattern Recognition*, vol. 2: II-394-II-399.

Heurich, M. and Thoma, F. 2008. Estimation of forestry stand parameters using laser scanning data in temperate, structurally rich natural European beech (Fagus sylvatica) and Norway spruce (*Picea abies*) forests. *Forestry* 81: 645-661.

Hopkinson, C., Chasmer, L., Young-Pow, C. and Treitz, P. 2004. Assessing forest metrics with a ground-based scanning lidar. *Canadian Journal of Forest Research* 34: 573-583.

Kozak, A. 1988. Avariable-exponent taper equation. *Canadian Journal of Forest Research* 18: 1363-1368.

Liang, X.L., Litkey, P., Hyyppä, J., Kaartinen, H., Vastaranta, M. and Holopainen, M. 2012. Automatic stem mapping using single-scan terrestrial laser scanning. *IEEE Transactions on Geoscience and Remote Sensing* 50: 661-670.

Lindberg, E., Holmgren, J., Olofsson, K. and Olsson, H. 2012. Estimation of stem attributes using a combination of terrestrial and airborne laser scanning. *European Journal of Forest Research* 131: 1917-1931.

Lovell, J.L., Jupp, D.L.B., Newnham, G.J. and Culvenor, D.S. 2011. Measuring tree stem diameters using intensity profiles from ground-based scanning lidar from a fixed viewpoint. *Isprs Journal of Photogrammetry and Remote Sensing* 66: 46-55.

Maas, H.-G., Bienert, A., Scheller, S. and Keane, E. 2008. Automatic forest inventory parameter determination from terrestrial laser scanner data. *International Journal of Remote Sensing* 29: 1579-1593.

Matthews, R.W. and Mackie, E.D. 2006. *Forest Mensuration: A Handbook for Practitioners*. Forestry Commission, Edinburgh.

McRoberts, R.E., Cohen, W.B., Næsset, E., Stehman, S.V. and Tomppo, E.O. 2010. Using remotely sensed data to construct and assess forest attribute maps and related spatial products. *Scandinavian Journal of Forest Research* 25: 340-367.

Murphy, G. 2008. Determining stand value and log product yields using terrestrial lidar and optimal bucking: a case study. *Journal of Forestry* 106: 317-324.

Murphy, G.E., Acuna, M.A. and Dumbrell, I. 2010. Tree value and log product yield determination in radiata pine (*Pinus radiata*) plantations in Australia: comparisons of terrestrial laser scanning with a forest inventory system and manual measurements. *Canadian Journal of Forest Research* 40: 2223-2233.

Purser, P. 1999. *Timber Measurement Manual: Standard Procedures for the Measurement of Round Timber for Sale Purposes in Ireland*. COFORD, Dublin.

Tansey, K., Selmes, N., Anstee, A., Tate, N.J. and Denniss, A. 2009. Estimating tree and stand variables in a Corsican Pine woodland from terrestrial laser scanner data. *International Journal of Remote Sensing* 30: 5195-5209.

Thies, M. and Spiecker, H. 2004. Evaluation and future prospects of terrestrial laser scanning for standardized forest inventories. *International Archive of Photogrammetry, Remote Sensing and Spatial Information Sciences* 192-197.

Thomas, V., Treitz, P., McCaughey, J.H. and Morrison, I. 2006. Mapping stand-level forest biophysical variables for a mixedwood boreal forest using lidar: an examination of scanning density. *Canadian Journal of Forest Research* 36: 34-47.

van Leeuwen, M. and Nieuwenhuis, M. 2010. Retrieval of forest structural parameters using LiDAR remote sensing. *European Journal of Forest Research* 129: 749-770.

Watt, P.J. and Donoghue, D.N.M. 2005. Measuring forest structure with terrestrial laser scanning. *International Journal of Remote Sensing* 26: 1437-1446.

An analysis of habitat-use patterns of fallow and sika deer based on culling data from two estates in Co. Wicklow

Yan Liu[a]* and Maarten Nieuwenhuis[a]

Abstract
Deer harvest data are commonly used to reconstruct deer-forest dynamics and predict trends in relative abundance and potential damage. This study investigated the spatial distribution of deer harvest locations for two adjacent estates, Ballycurry and Cloragh, in Co. Wicklow, Ireland. The purpose of this study was to determine if and how spatial factors (e.g. habitat types and distributions) affect the frequency and locations of culling events. Particularly, we tested the role of spatial heterogeneity in determining the occurrence of culling events; factors analysed were land use, forest type and forest age. A nearest neighbour analysis was applied first, followed by a kernel density analysis and a multi-ring buffer analysis, for fallow deer (*Dama dama*) and sika deer (*Cervus nippon*) separately, to determine the factors that attracted the two deer species to specific locations. Finally, the hunting effort (hours per deer) in each season and the degree to which different deer species avoid areas of public disturbance (main roads) were examined.

Keywords: Dama dama, Cervus nippon, *harvest data, deer-forest dynamics, spatial heterogeneity, culling locations*.

Introduction
In Ireland, the populations of the three main deer species, red deer (*Cervus elaphus*), fallow deer (*Dama dama*) and sika deer (*Cervus nippon*), experienced exceptional growth between 1978 and 2008 (Carden et al. 2011). Many factors have contributed to the great increase in deer population in Ireland: translocations and secondary releases of animals by man, high reproductive rates and the substantially increased forest cover (Genovesi and Putman 2006, Carden et al. 2011). Many threats to forests have resulted from these exploding deer populations, including bark striping and browsing, which have caused serious economic loss (Côté et al. 2004). As only sika and fallow deer were present at the study site, some background on these two species is provided below.

Fallow deer
Fallow deer originated in the eastern Mediterranean region. Over the centuries, they were introduced to areas of northern and western Europe as a source of food and as a decorative animal (Chapman and Chapman 1980). Fallow deer were the first non-native species to dwell in Ireland; presumably, they were introduced to Ireland by the

[a] UCD Forestry, UCD School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4.
* Corresponding author: yan.liu.1@ucdconnect.ie

Anglo-Normans during the medieval period (McCormick 1999). In Ballycurry, the fallow deer population originates from the deer park on the estate, which was founded in 1878 and contained over 200 deer in 1944 (Whitehead 1950). The deer park was abandoned later and the deer escaped.

Fallow deer prefer deciduous and mixed woodland habitats with a developed understorey as well as open pastures. Some populations thrive in habitats predominated by agricultural land but incorporating small woods and shrubs (Nugent 1990). Fallow deer are most active at dawn and dusk, but frequent disturbance may result in deer making more use of open spaces during the night (Caldwell et al. 1983). They are grazers or non-selective bulk feeders, supplementing their diet with acorns, fruits, nuts, bramble and fungi, when available (Purser et al. 2010). Fallow deer are the most geographically widespread species in the country and the second most numerous, with an estimated population size of 124,390 or 41.1% of the total deer population in the country (Inter-agency Deer Policy Group 2011).

Adult female deer (does) spend most of their time in family groups with subadults and fawns. These groups are very stable in time and space (Apollonio et al. 1998). However, they select significantly different habitat during the three main annual stages: the breeding season, calving season and the remainder of the year (McElligott et al. 2001, Ciuti et al. 2006). The breeding season (pre-rut and rut) for fallow deer runs from late August to November, with mating occurring from mid-October to the start of November (McElligott et al. 1998). During the breeding season, female fallow deer prefer to live in open pasture, with adjacent shrubs and open woodland (McElligott et al. 2001). They give birth to a single fawn generally during the first two weeks of June (San José and Braza 1992). The habitat choices of calving does differ from those of non-calving does, from May (late pregnancy), through parturition, until the next breeding season. In particular, the ungulate mothers prefer marshes (providing good concealment for fawns) and avoid meadows (open areas) to reduce any potential dangers (Ciuti et al. 2006). Therefore, in this study the calving season is defined from May to late August from the perspective of habitat selection. In the remainder of the year, fallow deer prefer open grasslands, small clearings, woods and marshes, so there is a trade-off between selection of food and cover depending on the specific living conditions (Apollonio et al. 1998, Mysterud and Østbye 1999).

Male deer are sedentary in all seasons, except in the rutting period (mid October to the start of November), when they remain at the rutting sites (Apollonio et al. 1992).

Sika deer

Originating from Japan, sika deer spread through the southern Ussuri, Korea, Manchuria, and Eastern China to Vietnam, and sika deer were first introduced to

Europe ca. 150 years ago (Barančeková et al. 2012). Sika deer were first introduced to Ireland in 1860 by Viscount Lord Powerscourt of Co. Wicklow for ornamental purposes (Powerscourt 1884).

Sika deer can be found in areas with open glades and dense thickets; as they have a preference for acid soils, they will quickly establish in young conifer plantations (Swanson and Putman 2009). Generally, sika deer are crepuscular in their movement patterns, visiting feeding areas at dawn and dusk. They are intermediate feeders (grazers-browsers), feeding upon grasses, heather, broadleaf buds and twigs, fruits, fungi and acorns (Purser et al. 2010). They are the most numerous deer species in Ireland with an estimated population size of 142,460 deer or 47.1% of the total deer population in the country (Inter-agency Deer Policy Group 2011).

Sika deer prefer to inhabit dense coniferous forest in spring, mainly open grassland and dense coniferous forests in summer and autumn, while their winter habitat selection depends on the severity of the weather (Maeji et al. 1999). A rumen content analysis by Yokoyama et al. (2000) concluded that no major differences were detected between males and females. Compared with fallow deer, sika deer are more sedentary and show limited movement in their summer and winter range (Genovesi and Putman 2006). In Europe, the rutting season for sika is generally in the autumn (September to November) and females will normally give birth to one calf between April and June (Baiwy et al. 2013).

To make comparisons between fallow and sika deer, the same annual stages were adopted: breeding season (from 20th August to 10th November), calving season (1st May to 19th August), and the remainder of the year.

Study objectives

The purpose of this study was to determine if and how spatial factors (e.g. habitat types and distributions) affect the frequency and location of deer culling events. The hunting records, together with the local geographical and land use data, were analysed with a series of spatial analysis methods, to decide the spatial distribution patterns of both deer species and the factors that contributed to these distributions. The hypotheses were: 1) deer culling would occur mainly at the boundary between forests and fields, as well as in young forest stands before canopy closure; 2) a high proportion of sika deer culls would be in conifer forests; 3) a high proportion of fallow deer culls would occur in agricultural fields; 4) both deer species would stay away from human disturbances.

Materials and methods

Site description

The study area comprises two adjacent estates, Cloragh Estate (53°1' N, 6°8' W) and Ballycurry Estate (53°1' N, 6°7' W). Both estates were categorised into two land-use types: forest and field. The forests were then subdivided into broadleaf high forest (BHF), coniferous high forest (CHF) and mixed high forest (MHF). The high forest system is defined as a silvicultural system in which the stands are managed on rotations long enough to produce trees large enough for timber production (Nieuwenhuis 2010). The first estate, Ballycurry, covers approximately 224 ha and consists of 148 ha of agricultural land and 76 ha of forests, comprising less complex woodland types that include coniferous plantations, MHF and small broadleaved stands. The second estate, Cloragh, is 314 ha in size, of which 198 ha is forest consisting of a range of woodland types, including recently planted (grant-aided) coniferous woodland, old native woodland and plantations on old woodland sites now in the form of CHF and MHF. The remaining areas (116 ha) are agricultural lands, mainly distributed in the northwest corner and southeast corner. CHF makes up the largest proportion of the forests in both estates: 27% and 48% of the total area in Ballycurry and Cloragh, respectively (Table 1). Ballycurry has more MHF (4%) but less broadleaf high forest (BHF) (3%) compared with 3% of MHF and 11% of BHF in Cloragh. A total of 264 ha in the two estates are used for agriculture, mainly sheep farming.

In this study, the two estates were combined to perform the spatial analyses, since no barriers exist between the two sites and both deer species can move freely from one estate to the other.

Deer culling management plan

The overall aim of the deer harvest programme in the study area was to cull as many animals as possible. However, the owners of the two estates had different reasons to initiate this culling programme: in Cloragh, the objective was to reduce deer numbers to allow for natural regeneration of the forest to occur; in Ballycurry, to reduce deer numbers to minimise the potential for deer infecting agricultural animals with TB. The culling programme started in 2000 in Cloragh and in 2006

Table 1: *Forest areas (Conifer High Forest (CHF), Broadleaf High Forest (BHF), Mixed High Forest (MHF) and scrub) and agricultural lands in Ballycurry and Cloragh, in 2006.*

		Forest areas					Agricultural lands	Total
		CHF	**BHF**	**MHF**	**SCRUB**	**Total**		
Ballycurry	Area (ha)	59.94	5.92	8.63	1.63	76.11	148.39	224.50
	Proportion (%)	*26.70*	*2.64*	*3.85*	*0.72*	*33.90*	*66.10*	*100.00*
Cloragh	Area (ha)	149.53	35.04	7.93	5.41	197.90	115.80	313.70
	Proportion (%)	*47.67*	*11.17*	*2.53*	*1.72*	*63.09*	*36.91*	*100.00*
Total	Area (ha)	209.47	40.96	16.56	7.03	274.02	264.18	538.20
	Proportion (%)	*38.92*	*7.61*	*3.08*	*1.31*	*50.91*	*49.09*	*100.00*

in Ballycurry. The hunter used various makes of riffle, with calibres from 56 x 57 to 270, and a normal shooting range of 50 to 100 m, with a maximum of 200 m. He was not paid for his efforts, and he covered the whole area of both estates to reduce the overall numbers, instead of focusing on specific areas.

Almost all stalking was "still stalking" done on foot, both on roads and tracks and in the forest stands. The high seats present on the estates were used very infrequently, with fewer than 5% of the deer harvested shot from these seats. A number of locations where he had culled and had observed deer frequently in the past were visited more often for a period afterwards. However, this approach was successful for a short period only; the deer appeared to change their behaviour over time and eventually stayed away from these locations. If only one animal was spotted, it would be shot, unless it was a particularly good fallow buck. If more animals were observed, the aim was to shoot female animals. The hunter did not adopt different shooting strategies during annual stages, and the territorial behaviour of the deer did not affect the hunting style.

Data collection

Two datasets were used in this study: the culling data from 2000 to 2012 and the geographical and forestry data. The culling data were collected by the sole hunter, in Cloragh Estate and Ballycurry Estate, from 2000 to 2012 and 2006 to 2012, respectively. The deer harvest data contained valuable information such as harvest locations, weather conditions, conditions of the harvested deer (e.g. species, ages, sex, foetus sex, health conditions and weight), time of a day and general observations. For this study, the hunter marked all the harvest locations on copies of printed maps of Ballycurry and Cloragh, based on his recorded information. The harvest locations, together with the corresponding characteristics of the harvested deer such as age and sex, were then geo-coded separately by species using ArcGIS software. A shooting season in this study was defined as running from the 1st September to 31st August next.

The basic geographical information of Ballycurry and Cloragh were obtained from a forest management consultant involved in the management planning on both estates. This information included the boundaries of the two estates, roads and other infrastructure information, and the sub-division of the forest areas with detailed stand and habitat information for each sub-compartment.

Landscape classification

Generally, the landscape can be categorised into four types following the deer habitat rating system in PractiSFM (Barrett et al. 2005): providing food (forage), providing shelter (cover), providing both food and shelter (both) and providing no habitat (neutral). Based on the land-use types, the study areas were classified as field, scrub and forest, and the forest was then sub-divided into sub-compartments and these were allocated to 5-year age classes, from 1 to 70 years old, or to forest older than 70 years. The 5-year age classes were adopted because forest stands, especially conifer plantations, undergo significant structural and habitat changes over these short periods (Botkin et al. 1972) and longer age classes would not allow to capture this. Scrub was defined as stands consisting of small or stunted trees with inferior growth and shrubs, which are generally un-merchantable (Nieuwenhuis 2010). As deer culling was conducted over a 12-year period, the age of every forest stand was calculated on an event-by-event basis, i.e. for each culling event, the age of the relevant forest stand was calculated relative to the year of the event.

In addition to the age class classification, a forest type classification was used (i.e. CHF, BHF and MHF; see Site Description). The combination of forest type and age class determined the habitat provision of forest stands.

Spatial analysis

<u>Nearest neighbour analysis</u>

To determine whether the culling locations were randomly distributed or not, the nearest neighbour analysis method was applied. Nearest neighbour analysis creates an index based on the distance of each feature to its closest neighbouring feature (Scott and Tout 1989). Nearest-neighbour statistics on culling events were compared in this study to identify the distribution patterns, a method previously used to explore relative dune development (Bishop 2010). In ArcGIS, the average nearest neighbour tool measures the distance between each feature centroid and its nearest neighbour's centroid location; it then averages all these nearest neighbour distances. If the average distance is less than the average for a hypothetical random distribution, the distribution of the features being analysed is considered clustered. If the average distance is greater than a hypothetical random distribution, the features are considered dispersed (McCoy and Johnston 2001). The outcome of nearest-neighbour analysis was expressed as an index of the ratio of the observed distances between harvest locations divided by the expected distances (for a hypothetical random distribution). The index was standardized into Z-scores for tests of significance.

To verify that the nearest neighbour results were sound, 102 points (representing 102 sika deer) and 420 points (representing 420 fallow deer) were generated separately using a random-point generator in ArcGIS and these procedures were repeated 10 times (Gonser et al. 2009). Nearest-neighbour analysis was performed on these sets of points and the values of the ratio Observed Mean Distance/Expected Mean Distance and the Z-scores of the deer harvest locations of sika deer and fallow deer were compared with those of the ten sets of generated random points using the one-sample t-test in SPSS.

Kernel density analysis

Kernel density estimation (KDE) techniques can be applied, as part of a geospatial analysis, to point datasets with spatially extensive attributes (Nakaya and Yano 2010). In this study, the distribution patterns of the harvest locations were explored with the Spatial Analyst extension in ArcGIS, and the expectation was that harvest locations formed clusters (known as "hotspots") in some areas. The objective was to find all hotspots and to use them for further analysis.

Nearest feature analysis

Based on the assumption that there are interactions between the occurrence of harvest events and landscape types, the distance from each harvest location to the nearest landscape features was considered. In ArcGIS, the Near Tool determines the distances from each selected features (i.e. the input features) to one or more nearby features (i.e. the near features), within the search radius (Kulikowski and Bejleri 2006). In this study, the boundaries between forest stands and agricultural fields were deployed as the near features to measure the shortest distance from each harvest location (the input features) to them.

Buffering analysis

For each harvest location, a series of concentric circular buffers were constructed, with radii of 50, 100, 150 and 200 m, using ArcGIS 10, and all geographic information system (GIS) layers were then clipped to these buffers (Ross et al. 2005). Subsequently, the areas of different land uses and forest types and age classes in each buffer were calculated, which were classified into four different categories according to a deer-habitat suitability model developed by Barrett et al. (2005) (Table 2). By comparing the land use and forest characteristics in all circular buffers for each deer species, the species' preference for particular site characteristics was investigated, and the role that scale (i.e. buffer width) may have in characterising the harvest locations was assessed.

In the same way, a range of concentric buffers was created along the main roads (black lines in Figure 1), which were considered the main source of human disturbance in the study area. The same series of buffer widths were used, and all the culling locations were then spatially joined with these buffers. On finishing the spatial joining process, the culling events falling into each buffer were determined and the distribution patterns were examined for both species.

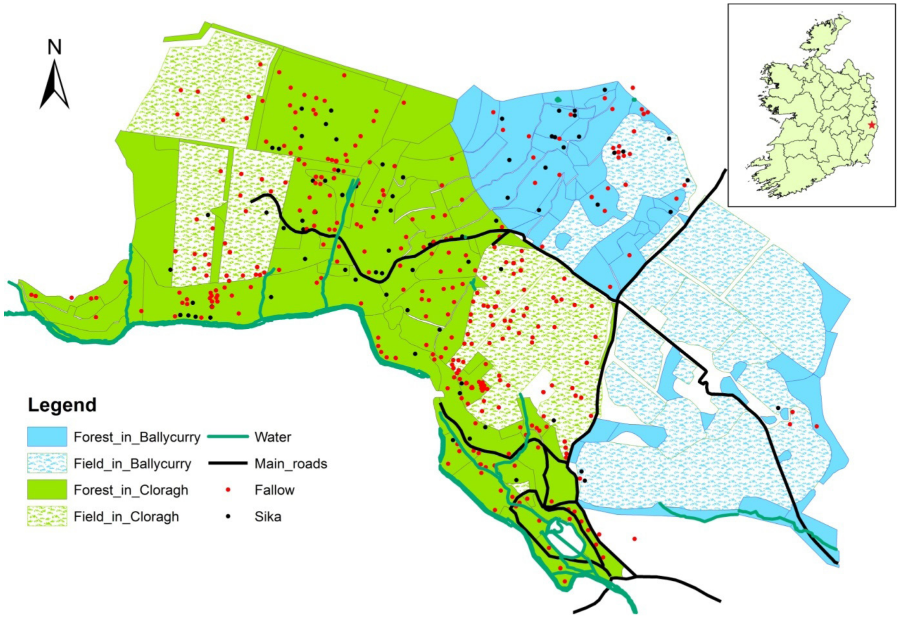


Figure 1: *Map of the study area in County Wicklow, Ireland, including the location of each culling event. The map in the upper right corner shows the location of the study area in Ireland.*

Table 2: *Deer habitat suitability of different forest types with age classes (adapted from Barrett et al. 2005).*

Age range	Broadleaf				Conifer			
	Neutral	**Cover**	**Forage**	**Both**	**Neutral**	**Cover**	**Forage**	**Both**
0-5			+				+	
6-10			+			+		
11-30				+		+		
31-40				+	+			
41-45	+					+		
46-70	+							+
71-100				+				+
100-200				+				+

Results

From 2000 to 2012, 102 sika deer and 420 fallow deer were harvested. The harvests occurred mainly in the period from mid November to late February, and fewer were shot during the calving season (Table 3). No clear trends were found in harvest number proportions for male and female deer over the annual seasons. The numbers of harvest occurrences in different land-use types (forest stands by forest type and 5-year age classes, and agricultural fields), over the 12 years, were compared for both deer species (Figure 2).

It was noted that fallow deer culling was concentrated in fields, stands aged 36-40 (82% CHF and 18% MHF) and 1-5 years (93% CHF and 7% MHF), and the culling of sika deer mainly occurred in forest stands over 40 years of age (68% CHF and 32% BHF).

Distribution patterns

After geo-coding all harvest locations, the distribution patterns were explored via nearest neighbour analysis. The null hypothesis for the t-test was that there were no differences in the distributions of harvest locations for both sika and fallow deer and of the generated random points. The comparison of the random points with harvest locations for sika and fallow deer seperately, indicated that there was less than 5% chance that the distribution of harvest locations for both species were the results of random chance.

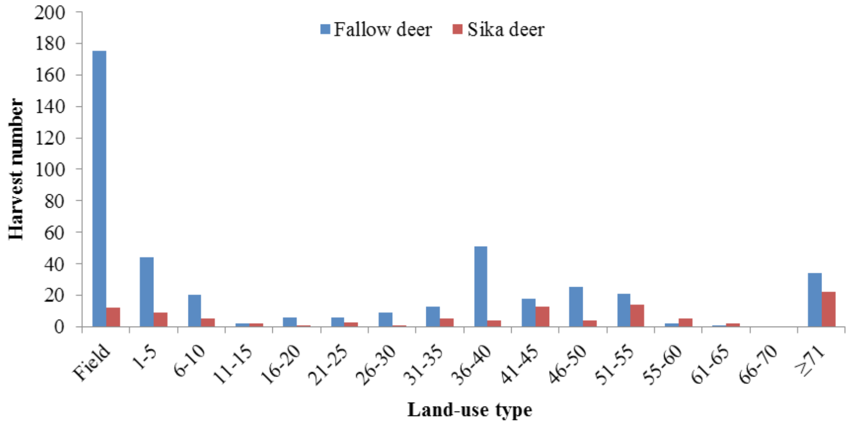


Figure 2: *Total deer harvest numbers for each species in different land-use types (field and forest age classes), for the period 2000 to 2012.*

Table 3: *Total hunting numbers, by age classification and sex (M = male; F = female), in each annual season, for both deer species.*

	Breeding season						Calving season						Remaining season					
Age	**Calf**		**Yearling**		**Mature**		**Calf**		**Yearling**		**Mature**		**Calf**		**Yearling**		**Mature**	
Sex	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**	**M**	**F**
Fallow	21	20	50	13	33	30	2	4	3	5	3	10	62	34	48	26	21	93
Sika	7	2	13	2	25	6	0	0	0	1	0	0	6	7	7	6	7	25

The t-test (t (9) = 52.744, $p < 0.05$) revealed a significant difference between the mean Z-Score of 10 sets of the random points and the Z-Score of the 420 harvest locations for fallow deer (M = 0.90, s = 1.05). Similarly, a significant difference (t (9) = 12.139, $p < 0.05$) was found between the mean Z-Score of 10 sets of the random points and the Z-Score of the 102 harvest locations for sika deer (M = 0.64, s = 1.65).

In the same way, in terms of the comparison of the mean ratios of Observed Mean Distance/Expected Mean Distance for random points and harvest locations, significant differences were found between the ratios for fallow deer (t (9) = 52.745, $p < 0.05$) and for 10 sets of 420 random points (M = 1.02, s = 0.03), and between the ratios for sika deer (t (9) = 12.129, $p < 0.05$) and for 10 sets of 102 random points (M = 1.03, s = 0.85).

Based on the results of the four sets of t-tests, the harvest locations for both sika and fallow deer were found to be non-randomly distributed. The distribution patterns were further examined using the kernel density analysis. A minimum kernel value of 1,000 culls per hectare (based on the total culls per grid cell divided by the grid cell area) was set as the cut-off value for hotspots. Several hotspot-areas can be observed in the output (Figure 3); seven hotspots (deep blue and purple) for fallow deer harvest locations and one hotspot for sika deer harvest location were found, with one hotspot-area shared by both species (i.e. the area in a 142-year-old oak forest at the south-western end of Cloragh Estate). In the seven fallow deer hotspots, three were in agricultural fields (one was at the upper north corner of Ballycurry Estate, another one was in Cloragh Estate close to borders with Ballycurry Estate and the third one was at the south-western corner of the pasture in the south-eastern part of Cloragh Estate), and two were in forest stands adjoined to fields (one a 142-year-old oak forest and the other was an 11-year-old Sitka spruce *(Picea sitchensis* (Bong.) Carr.) forest). The remaining two (within 13-year-old and 8-year-old Douglas fir (*Pseudotsuga menziesii* (Mirbel) Franco) forest) were located far removed from agricultural fields.

Forest-field boundaries and harvest locations

The Near Tool in ArcGIS facilitated the measurement of the distance from each harvest location to the nearest edge between forest stands and agricultural fields (Table 4). A set of random points (with the same number as fallow deer harvests) was created for comparison and the distances from these points to the nearest edge were also calculated. For both species, most culling events occurred within 150 m of the edges between forest stands and agricultural fields. For fallow deer, 252 were shot in forest stands, among which 144 (57%) were shot within 150 m of the edges with agricultural fields. An approximately exponential relationship was observed when fallow numbers culled in the forest were regressed against the distance from the edge of an agricultural field (Figure 4a). A logarithmic relationship best explained the trend in the numbers of fallow deer shot in agricultural fields with distance to a forest edge (Figure 4b). Comparing

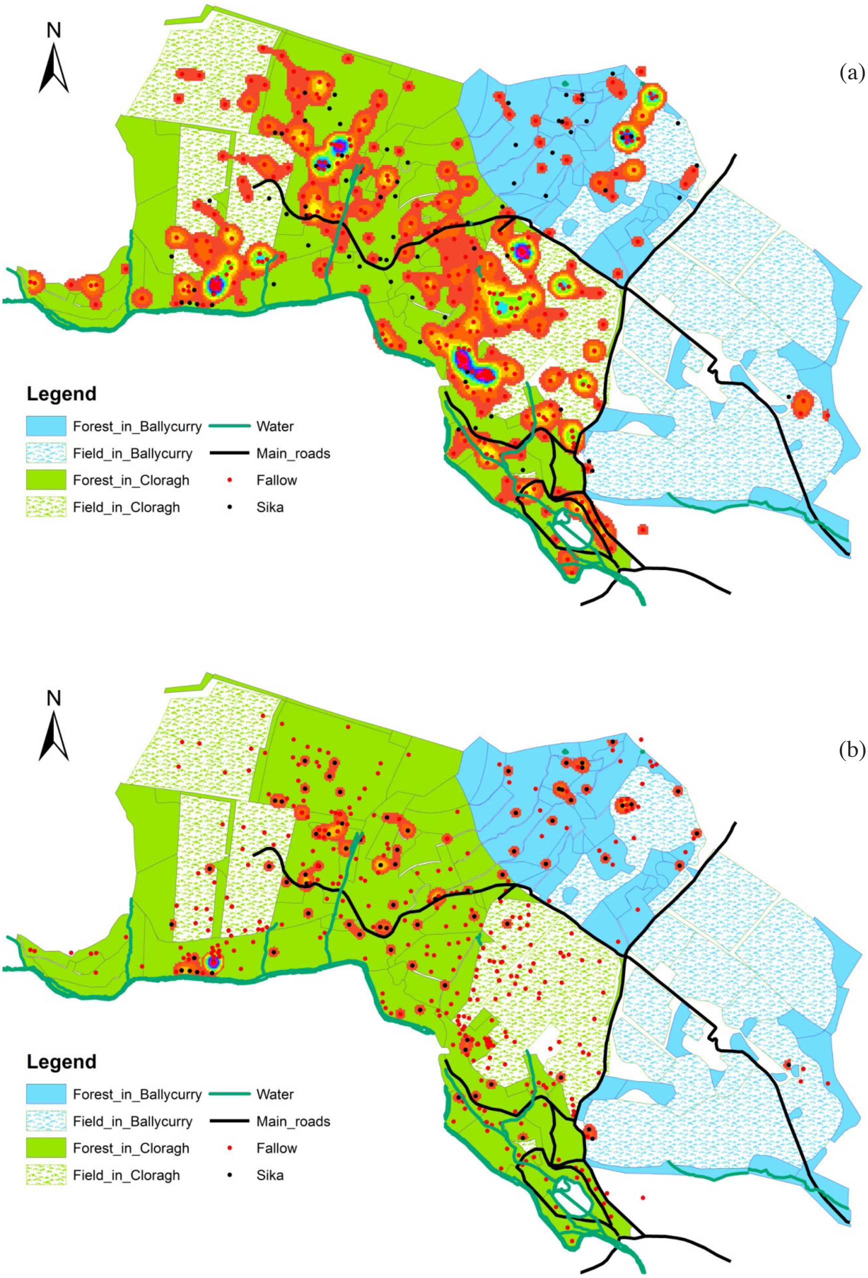


Figure 3: *Kernel density analysis for fallow deer (a) and sika deer (b) for the period 2000 to 2012*.

Table 4: *Deer numbers for both species culled in each land-use type, in comparison with random points, by distance classes to the nearest edges of forest stands and agricultural fields.*

Deer species and location	Distance classes (m)													
	0 to 50	50 to 100	100 to 150	150 to 200	200 to 250	250 to 300	300 to 350	350 to 400	400 to 450	450 to 500	500 to 550	550 to 600	600 to 650	650 to 700
Fallow forest	62	48	34	27	22	14	11	16	9	4	1	1	2	1
Fallow field	74	44	25	15	8	2	0	0	0	0	0	0	0	0
Sika forest	10	5	26	9	14	6	2	3	8	5	2	0	0	0
Sika field	6	5	1	0	0	0	0	0	0	0	0	0	0	0
Random forest	65	47	27	15	21	16	14	11	7	13	9	4	6	2
Random field	101	69	48	25	12	6	4	0	0	0	0	0	0	0

the patterns of fallow deer harvests and random points in forest stands and agricultural fields separately, half of the random points that fell in forest stands were within 150 m of the edges, and 87% of the random points in field areas were within 150 m of the edges, indicating that the patterns of fallow deer culling followed the same trend as the random points. Fallow deer were therefore randomly distributed when considering the distances from culling points to forest-field boundaries.

The situation for sika deer was very different and no obvious distribution patterns could be found for those culled in both forest stands and agricultural lands (Figure 4c). Only 12 sika deer were shot in agricultural fields, and all were shot within 150 m to a forest edge.

Effects of surrounding habitat

By applying multi-ring buffer analysis, the influences of the habitat at the harvest location and in the surrounding area were determined and the effect of scale was examined. First, an analysis was done of culling locations of both species against four land-use type categories defined by cover and forage suitability. The proportions of each habitat category were relatively constant with increasing circular width for fallow deer, but a clear trend was found for sika deer, where habitat that provided both forage and cover was much more prevalent in the circular buffer than in the study area, especially for small buffer widths. For fallow deer, there was a constant weak preference for forage habitat, independent of buffer width, compared to the proportion present in the study area (Figure 5).

A detailed analysis of the areas of each specific land-use type also was carried out. The highest proportion of harvest locations for fallow deer occurred in agricultural fields (0 label in Figure 6), while for sika deer the greatest proportion occurred in mature forest stands, over 70-years old in the 50 m buffer zones (95% BHF, 4.4% CHF and 0.6% MHF), with a significant proportion also in agricultural fields. Very

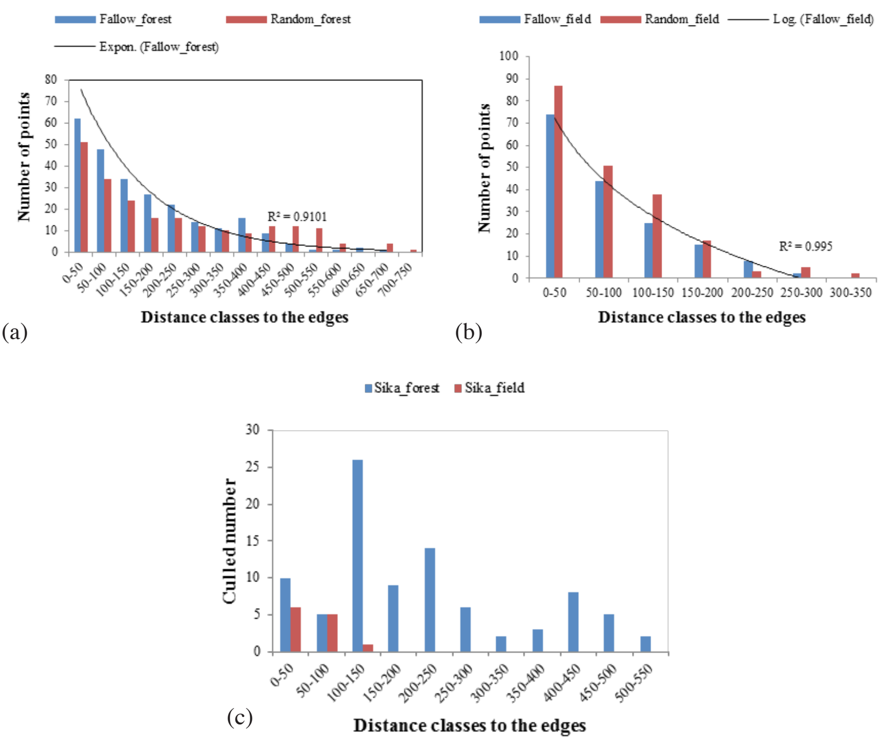


Figure 4: *a) fallow numbers culled and random points in forest stands, by distance classes (in m) to the nearest edge of an agricultural field; b) fallow numbers culled and random points in agricultural fields, by distance classes (in m) to the nearest edge of a forest stand; c) sika numbers culled in forest stands and agricultural fields, by distance classes (in m) to the nearest edge between forest stands and agricultural fields.*

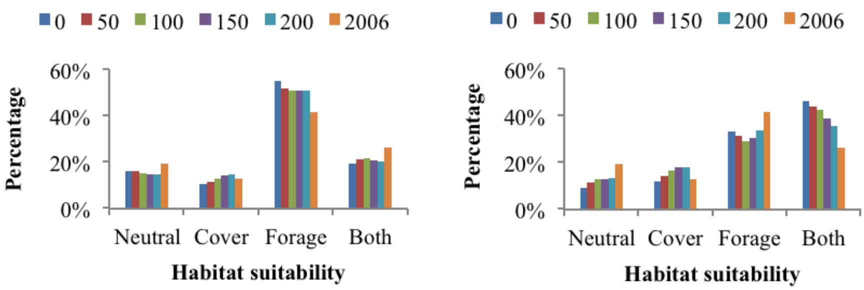


Figure 5: *Proportions of culling locations (0), circular buffers (50, 100, 150 and 200 m) and the study area (2006) categorised by forage and cover suitability, for fallow deer (left) and sika deer (right).*

few deer, either fallow or sika, were shot in or near forest stands aged 11 to 30 years; taking the circular buffer zone of 200 m around the culling venues as an example, these forest stands occupied only 8.2% of the area for fallow deer and 9.2% for sika deer, and for both species these stands were of the CHF type.

Compared with the habitat characteristics of the whole study area in 2006, the values for four land use and forest types were under-represented in the harvest location data for fallow deer, based on a 200 m buffer (Figure 6): forests aged 6 to 10 years (0.5% BHF, 97% CHF and 2.5% MHF), forests aged 31 to 35 years (98% CHF and 2% MHF), forests aged 46 to 50 years (3% BHF, 86% CHF and 11% MHF) and forests aged over 71 years (90% BHF, 8% CHF and 2% MHF). It is interesting to note that in fields and in forests aged 1 to 5 years (97% CHF and 3% MHF), the proportions of harvest locations were over-represented.

Different patterns were found for sika deer than for the other species, with the proportions for the following four land-use types under-represented in the harvest location data, based on a 200 m buffer (Figure 7): agricultural fields, forest aged 6 to 10 years (100% CHF), forest aged 36 to 40 years (96% CHF and 4% MHF), and forest aged 46 to 50 years (90% CHF and 10% MHF). For most of the remaining land-use categories the proportions for each harvest location were over-represented compared with those for the entire study area.

The most obvious difference between sika and fallow deer occurred in the proportion of culls in fields compared to the proportion of the estate in fields, with the proportion for fallow deer higher (Figure 6) and the proportion for sika much lower (Figure 7) than the proportion of fields for the study area.

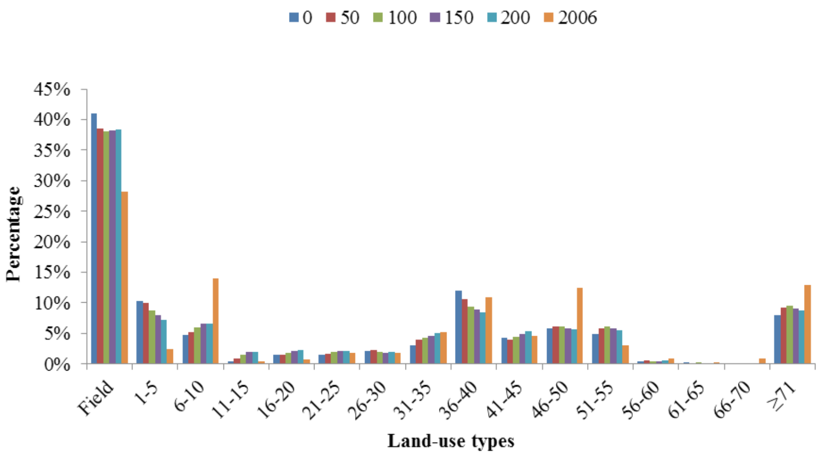


Figure 6: *Proportion of different land-use types (field and forest age classes) for the study area (2006) and in circular buffers (of 0, 50, 100, 150 and 200 m radius) surrounding harvest locations of fallow deer.*

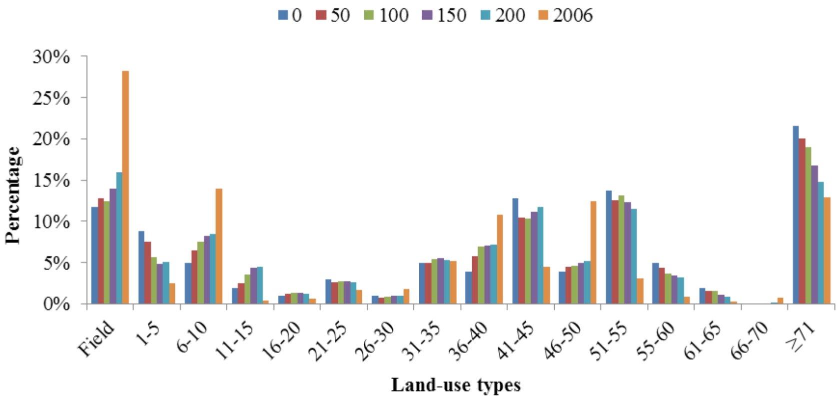


Figure 7: *Proportion of different land-use types (field and forest age classes) for the study area (2006) and in circular buffers (of 0, 50, 100, 150 and 200 m radius) surrounding harvest locations of sika deer.*

Hunting effort and public disturbance

By adding the time used for each cull for each deer species in the same hunting season, the seasonal hunting effort was calculated (Table 5). Since the data lacked hunting times for many culling events, only 188 fallow deer and 46 sika deer were included in this analysis. Although a significant difference in terms of culling numbers existed, the average hunting effort times for both species were similar (3.43 and 3.47 hours for fallow and sika, respectively).

The public disturbance study focused on the main roads in the study area; a multi-ring buffer was created around the main roads and then the culling locations were analysed against each buffer (Table 6). Culling locations for both fallow and sika deer generally followed the pattern of random points, except those for sika more than 150 m from the main roads.

Discussion

The data used in this study do not automatically reflect the distribution of both deer species over the study area, as an important factor that determines the locations of the culling events is the hunter's behaviour and his choice of hunting locations. Detailed discussions with the hunter revealed that he selected hunting locations arbitrarily, covering the whole study area. Of the seven hotspots for fallow and the one for sika deer, the hunter has identified all of these as locations he visited more frequently, at intervals, because deer were present in large numbers, either resting in or moving through these areas. He felt that the increasing sika deer population had originated from plantations to the north of Ballycurry and Cloragh estates and had settled in inaccessible areas of lodgepole pine (*Pinus contorta* Douglas). The fact that most of

Table 5: *Hunting effort (hours per deer) by hunting season and species, for the period 2000 to 2012.*

		Hunting season											
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Hunting time (hr)	Fallow	19.50	62.25	75.75	84.50	59.25	64.95	59.35	79.30	56.65	58.50	7.00	25.50
	Sika	0.00	2.00	17.50	10.00	3.25	3.00	12.50	26.25	16.50	48.00	7.00	19.50
Hunting number	Fallow	6.00	19.00	21.00	21.00	16.00	18.00	17.00	23.00	16.00	20.00	2.00	9.00
	Sika	0.00	1.00	5.00	2.00	1.00	1.00	3.00	7.00	6.00	12.00	2.00	6.00
Effort (hrs per deer)	Fallow	3.25	3.28	3.61	4.02	3.70	3.61	3.49	3.45	3.54	2.93	3.50	2.83
	Sika	0.00	2.00	3.50	5.00	3.25	3.00	4.17	3.75	2.75	4.00	3.50	3.25

Table 6: *Deer numbers and proportions culled for both fallow and sika deer, within distance classes to main roads, in comparison with those for random points (represents fallow and sika deer separately).*

Species	Distance to main roads									
	50 m		**100 m**		**150 m**		**200 m**		**>200 m**	
	Number	***Proportion (%)***	**Number**	***Proportion (%)***	**Number**	***Proportion (%)***	**Number**	***Proportion (%)***	**Number**	***Proportion (%)***
Fallow	62	*14.76*	38	*9.05*	48	*11.43*	32	*7.62*	240	*57.14*
Random (fallow)	67	*12.84*	59	*11.30*	60	*11.49*	40	*7.66*	296	*56.70*
Sika	14	*13.73*	10	*9.80*	10	*9.80*	4	*3.92*	64	*62.75*
Random (sika)	13	*12.75*	11	*10.78*	13	*12.75*	8	*7.84*	57	*55.88*

the harvest locations were within 150 m from field-forest boundaries was, according to the hunter, based on the high incidence of deer activity in these areas, and not on the hunter's behaviour. Based on this analysis of the hunter's behaviour, the culling location data can be considered, to a very large extent, to reflect the habitat preferences of the deer species, so the focus of this discussion reflects this conclusion.

Three groups of random points were applied as control groups for three different analyses in this study. The results for these three analyses to determine if the distributions of fallow and sika deer were random provided contradictory information. The reference objects differed between the three approaches, which may explain this result. The results for the nearest-neighbour analysis showed that the culling locations of both fallow and sika deer were not randomly distributed, which was then cross-verified using kernel density analysis, resulting in the identification of the hotspots. The distance to the nearest boundary between forests and agricultural fields and the distance to the main roads were the reference objects used in the other two analysis methods. These two analyses indicated that the distributions for both species were random relative to the distances to nearest edges and main roads. Fallow deer followed the general rule: the greater the distance from the nearest edges between fields and forests, the smaller the population there (Borkowski and Pudelko 2007). For sika deer the result was quite different, indicating that sika deer were more forest-based and stayed away from the edges, as the highest cull numbers were recorded for the 100-150 m distance class in the forest. This result concurs with those obtained by Takatsuki (1989), who found that the number of faecal pellets deposited by sika deer, representing the population abundance, was mainly concentrated in the forest and in the "adjacent zone" (up to 150 m out from the forest) and decreased suddenly more than 150 m from forest. The pattern of sika culled in fields in this study (all the sika deer were culled in or within 150 m from the forest) also agreed with the findings by Mysterud and Østbye (1999) that deer, especially smaller species, often used the 200 m zone closest to the forest edge for feeding. Similarly, in the analysis of distance to the main roads, the relatively high proportion of sika in the areas further than 200 m from the main roads, compared with the random points, indicated that sika deer were more sensitive to the public disturbance than fallow deer and tended to avoid the area near the main roads (<200 m).

The clustered areas (hotspots) for fallow deer were mostly distributed along the boundaries of forest stands and agricultural fields, or in fields near to forest stands. The two exceptions (hotspots within 13-year-old and 8-year-old Douglas fir stands) were far removed from the boundaries, but they both neighboured a Douglas fir stand established in 1955, which was regarded as providing both forage and cover habitat by the habitat-suitability-model. Therefore, both shelter and forage resources were provided in the fallow deer hotspots or their adjoining areas. Mysterud and Østbye

(1999) summarised that ungulates often experience a trade-off between food and cover, and use edges more often than interior areas.

In this study, fallow deer were found in agricultural fields or in forests with easy access to grassland. This finding is consistent with part of the conclusions by Borkowski and Pudelko (2007) that the most often used habitats were thickets (13-35 year-old forest stands) and meadows. They also concluded that mature forests (>50 years) and young plantations (1-5 years) were least used, but, in contrast, our study found that forests aged 1-5 years and over 50 years attracted large numbers of deer. This contrary finding may be the result of differences in the landscape structures between the two studies, and may also be caused by the favourable understorey conditions in stands in these age classes in our study, in contrast to the relatively poor understorey conditions in these types of stands in their research. In the same way, Mertzanidou and Legakis (2004) utilized point sampling technique to correlate deer presence with habitat types in the southern part of Rhodes Island, and concluded that the main habitat type occuring in the fallow deer range is the forestland (48.99%), which is in line with our results.

Sika deer were generally dispersed over the study area, and only one hotspot was found. The hotspot area was an old oak forest aged 142 years, which was classified as providing both forage and cover habitat. Overall, it is clear that sika deer were more forest-based compared with fallow deer. Uzal et al. (2013) indicated that safe access to pastures was the key criterion in the habitat selection and distribution of sika deer. This agrees with our finding that sika deer were frequently found 100-250 m from the nearest field boundary.

The habitat suitability analysis further demonstrated that sika deer considered cover as a key habitat factor to their distribution, while fallow deer seemed to regard forage conditions more important. The width of the buffer zones had little effect on the outcome of the habitat analysis for fallow deer, but for sika there were clear trends. With an increase of the buffer width, the proportion of habitats providing both cover and forage in the buffer zones went down, while those offering only cover went up, reflecting the role of cover in the habitat selection of sika deer. The analysis of the buffers around the harvest locations also identified a preference of both deer species for habitat that contained both fields and forests; however, fallow deer clearly showed more preference for agricultural fields than did sika. In addition, forest stands aged between 1 and 10 years (95% CHF and 5% MHF for fallow deer, and 100% CHF for sika deer), and especially those between 1 and 5 years (93% CHF and 7% MHF for fallow deer, and 100% CHF for sika deer), attracted relatively high numbers of deer, reflecting the opportunities for both cover and forage that these young stands provide, with large amounts of ground vegetation covering the space between the planted trees, especially in coniferous plantations. Although though a certain amount of browsing damage to these young trees has been found throughout the study area, this has not been excessive, and no need for fencing of conifer reforestation areas has been identified. It is assumed that easy access to agricultural fields throughout the study area reduced the browsing pressure on the young trees. In other areas in Wicklow, where forests cover is very high, serious damage to young conifer plantations has been observed.

Sika deer numbers in this study were relatively low across the whole period. Therefore, conclusions drawn about habitat selection by this species in the study need to be validated based on additional data over more hunting seasons.

At the final stages of the study, feedback from the hunter was obtained and he made available the harvest results for hunting season 13 and part of 14 (from 1st September 2013 to 17th January 2014). It should be noted that new hunting strategies and personnel had been introduced in season 13, with a greater focus on the culling of sika deer. In season 13, 113 deer (60 fallow and 53 sika) were shot, and in the first part of season 14, 56 deer were shot (26 fallow and 30 sika). In total, 67 out of 86 fallow deer and 24 out of 83 sika deer were shot in field areas. This re-enforces the findings that sika deer are more forest based compared with fallow deer, but also illustrates the fact that large deer populations are still present on the estates, even after the removal of considerable numbers during the 12 seasons investigated in this study. The influx of deer from neighbouring areas will make the further reduction of deer numbers on the estates a difficult and continuous process that would greatly benefit from a deer management strategy on a regional or national level.

Results of this study may have implications for the management of forests that contain large deer populations. In particular, this study shows the importance of cover for sika deer and forage for fallow deer and the preference of both species for edge and mixed habitat, containing both forests and fields. Both species also showed preference for forest aged 1-10 years (mainly coniferous plantations), and continued monitoring is needed to ensure no excess damage is done, by either species, to the young trees in these stands. However, the extent to which the criteria identified in this study as important determinants of habitat selection by sika and fallow deer can be extrapolated to other landscapes of similar scale, or even to regional scales, requires similar studies over a wider geographical range.

In conclusion, this study has identified different patterns of spatial distribution for both fallow and sika deer in the study area. These results appeared to be driven by the distribution of forage and cover resources and by the potential risks associated with using the open agricultural grasslands and with public disturbance, which is caused by the main roads in the study area. They revealed different considerations for habitat selections by the two deer species, and the modification of landscape features (e.g. further afforestation of traditionally agricultural landscapes, changes in availability of cover or/and forage resources through forest management, and increased public disturbance) may lead to changes in deer population distributions. This information is therefore of value when designing integrated deer-management strategies for these two species, which clearly must be species and site specific.

Acknowledgment

We sincerely thank Arie van der Wel (Senior) for the use of his deer harvest records in this study, and also for answering any questions we had about them. We also appreciate Paddy Purser's input in terms of GIS data of the estates. We thank the owners of Ballycurry and Cloragh estates, Charles, Kathryn and Lucy Tottenham, for giving us access to their estates.

References

Apollonio, M., Festa-Bianchet, M., Mari, F., Mattioli, S. and Sarno, B., 1992. To lek or not to lek: mating strategies of male fallow deer. *Behavioral Ecology* 3: 25-31.

Apollonio, M., Focardi, S., Toso, S. and Nacci, L. 1998. Habitat selection and group formation pattern of fallow deer *Dama dama* in a submediterranean environment. *Ecography* 21: 225-234.

Baiwy, E., Schockert, V. and Branquart, E. 2013. Risk analysis of the sika deer, *Cervus nippon*, Risk analysis report of non-native organisms in Belgium. Available at http://share.bebif.be/data/ias/Risk%20analyses/Cervus%20nippon3.pdf [Retrieved April 2014].

Barančeková, M., Krojerová-Prokešová, J., Voloshina, I. V., Myslenkov, A. I., Kawata, Y., Oshida, T., Lamka J. and Koubek, P. 2012. The origin and genetic variability of the Czech sika deer population. *Ecological research* 27: 991-1003.

Barrett, F., Nieuwenhuis, M. and Somers, M. 2005. PractiSFM – multi-purpose inventory and decision support for sustainable forest management. In proceedings of *Conference on Forest R&D Ireland 2004 – Underpinning Industry Development*. Tullamore, Ireland (September 20 – 21, 2004). Pp 73 – 76.

Bishop, M.A. 2010. Nearest neighbor analysis of mega-barchanoid dunes, Ar Rub'al Khali, sand sea: The application of geographical indices to the understanding of dune field self-organization, maturity and environmental change. *Geomorphology* 120: 186-194.

Borkowski, J. and Pudelko, M. 2007. Forest habitat use and home-range size in radio-collared fallow deer. *Annales Zoologici Fennici* 44: 107-114.

Botkin, D.B., Janak, J.F., and Wallis, J.R. 1972. Some ecological consequences of a computer model of forest growth. *The Journal of Ecology* 60: 849-872.

Caldwell, J.F., Chapman, D.I. and Chapman, N.G. 1983. Observations on the autumn and winter diet of fallow deer *(Dama dama)*. *Journal of Zoology* 201: 559-63.

Carden, R.F., Carlin, C.M., Marnell, F., Mcelholm, D., Hetherington, J. and Gammell, M.P. 2011. Distribution and range expansion of deer in Ireland. *Mammal Review* 41: 313-325.

Chapman, N.G. and Chapman, D.I. 1980. The distribution of fallow deer: a worldwide review. *Mammal Review* 10: 61-138.

Ciuti, S., Bongi, P., Vassale, S. and Apollonio, M. 2006. Influence of fawning on the spatial behaviour and habitat selection of female fallow deer (*Dama dama*) during late pregnancy and early lactation. *Journal of Zoology* 268: 97-107.

Côté, S.D., Rooney, T.P., Tremblay, J.P., Dussault, C. and Waller, D.M. 2004. Ecological impacts of deer overabundance. *Annual Review of Ecology, Evolution and Systematics* 35: 113-147.

Davini, S., Ciuti, S., Luccarini, S. and Apollonio, M., 2004. Home range patterns of male fallow deer *Dama dama* in a sub-Mediterranean habitat. *Acta Theriologica* 49: 393-404.

Genovesi, P. and Putman, R. 2006. *Cervus nippon*. Available at http://www.europe-aliens.org/pdf/Cervus_nippon.pdf [Retrieved April 2014].

Gonser, R.A., Jensen, R.R., and Wolf, S.E. 2009. The spatial ecology of deer–vehicle collisions. *Applied Geography* 29: 527-532.

Inter-agency Deer Policy Group. 2011. Draft Public Consultation Document. Available at http://www.agriculture.gov.ie/media/migration/forestry/forestservicegeneralinformation/DeerManagementPolicyVisionSeptember2011.pdf [Retrieved November 2013].

Kulikowski, L. and Bejleri, I. 2006. Building a regional traffic crash data system – bridging the gaps. In Proceedings of the 26th Annual ESRI International User Conference, San Diego, California, USA. Available at http://proceedings.esri.com/library/userconf/proc06/papers/papers/pap_1730.pdf [Retrieved November 2013].

Maeji, I., Yokoyama, S. and Shibata, E.I. 1999. Population density and range use of sika deer, *Cervus nippon*, on Mt. Ohdaigahara, central Japan. *Journal of Forest Research* 4: 235-239.

McCormick, F. 1999. Early evidence for wild animals in Ireland. In Benecke, N. (Ed) *The Holocene History of the European Vertebrate Fauna: Modern Aspects of Research*, pp. 355–371. Verlag Marie Leidorf GmbH, Rahden, Germany. Available at http://www.alexandriaarchive.org/bonecommons/archive/files/early-evidence-for-wild-animals-in-ireland_bdbfcbbf4a.pdf [Retrieved December 2013].

McCoy, J. and Johnston K. 2001. Using ArcGIS Spatial Analyst. *Environmental Systems Research Institute,* Inc., Redlands, California, USA.

McElligott A.G., Mattiangeli V., Mattiello S., Verga M., Reynolds C.A. and Hayden T.J. 1998. Fighting tactics of fallow bucks (*Dama dama*, Cervidae): reducing the risks of serious conflict. *Ethology* 104: 789–803.

McElligott, A.G., Gammell, M.P., Harty, H.C., Paini, D.R., Murphy, D.T., Walsh, J.T. and Hayden, T.J. 2001. Sexual size dimorphism in fallow deer (*Dama dama*): do larger, heavier males gain greater mating success? *Behavioral Ecology and Sociobiology* 49: 266-272.

Mertzanidou, D. and Legakis, A. 2004. Fallow deer distribution and habitat in the Mediterranean landscape of Rhodes island as determined by a track survey: preliminary data. In Arianoutsou and Papanastasis (Editors), *10th MEDECOS Conference,* Rhodes, Greece. Available at http://users.uoa.gr/~alegakis/index_el_files/PDFfiles/MertzanidouMedecos.pdf [Retrieved April 2014].

Mysterud, A. and Østbye, E. 1999. Cover as a habitat element for temperate ungulates: effects on habitat selection and demography. *Wildlife Society Bulletin* 27: 385-394.

Nakaya, T. and Yano, K. 2010. Visualising crime clusters in a space-time cube: an exploratory data-analysis approach using space-time kernel density estimation and scan statistics. *Transactions in GIS* 14: 223-239.

Nieuwenhuis, M. 2010. Terminology of forest management. *Terms and definitions in English (equivalent terms in French, German, Hungarian, Italian, Portuguese, Romanian, Spanish and Japanese)*. IUFRO World Series Vol. 9-en. 2nd (revised) Edition. IUFRO, Vienna, Austria.

Nugent, G. 1990. Forage availability and the diet of fallow deer (*Dama dama*) in the Blue Mountains, Otago. *New Zealand Journal of Ecology* 13: 83-95.

Powerscourt, V. 1884. On the acclimatization of the Japanese deer at Powerscourt. *Proceedings of the Zoological Society of London* 52: 207–209.

Purser, P., Wilson, F. and Carden, R. 2010. *Deer and forestry in Ireland: A review of current status and management requirements*. Commissioned report prepared for the Woodlands of Ireland (Coillearnacha Dúchasacha) Steering Committee, Dublin, Ireland.

Ross, Z., English, P.B., Scalf, R., Gunier, R., Smorodinsky, S., Wall, S. and Jerrett, M. 2005. Nitrogen dioxide prediction in Southern California using land use regression modelling: potential for environmental health analyses. *Journal of Exposure Science and Environmental Epidemiology* 16: 106-114.

San José, C. and Braza, F. 1992. Antipredator aspects of fallow deer behaviour during calving season at Doñana National Park (Spain). *Ethology Ecology and Evolution* 4: 139–149.

Scott, D. and Tout, C.A. 1989. Nearest neighbour analysis of random distributions on a sphere. *Monthly Notices of the Royal Astronomical Society* 241: 109-117.

Swanson G.M. and Putman R. 2009. Sika deer in the British Isles. In: McCullough D.R., Takatsuki S., and Kaji K. (eds) *Sika Deer: Biology and Management of Native and Introduced Populations,* pp. 595–614. Springer, Tokyo, Japan.

Takatsuki, S. 1989. Edge effects created by clear-cutting on habitat use by sika deer on Mt. Goyo, northern Honshu, Japan. *Ecological Research* 4: 287-295.

Uzal, A., Walls, S., Stillman, R.A. and Diaz, A. 2013. Sika deer distribution and habitat selection: the influence of the availability and distribution of food, cover, and threats. *European Journal of Wildlife Research* 59: 563-572.

Whitehead, G.K. 1950. The deer parks of Ireland, 1949. In: *Deer and their Management in the Deer parks of Great Britain and Ireland*. pp 341-341. Country Life Ltd, London.

Yokoyama, M., Kaji, K. and Suzuki, M. 2000. Food habits of sika deer and nutritional value of sika deer diets in eastern Hokkaido, Japan. *Ecological Research* 15: 345-355.

Effect of forest litter depth on seed germination efficacy of *Rhododendron ponticum*

Edward Daly[a*], Nick McCarthy[a], John O'Halloran[b], Sandra Irwin[b] and Milo Ó Rathaille[b]

Abstract
In Ireland one of the most serious invasive alien species which poses threats to local biodiversity is *Rhododendron ponticum* L. Once established on a susceptible site, *R. ponticum* can kill other plant species in the ground vegetation layer and prevent the regeneration of trees and shrubs, thereby also indirectly affecting the local fauna. Forest floor litter negatively impacts on the germination success of many plant species, and both the amount and distribution of forest litter can influence the establishment of invasive alien species. Many land management practices, particularly in forestry, disturb ground cover leading to soil exposure, which may increase the risk of *R. ponticum* invasion. In this study, the effect of forest floor litter on the germination of *R. ponticum* seeds in five different litter types was assessed. The treatments included bare soil; 1 cm, 3 cm and 5 cm depths of broadleaved litter; and 2 cm conifer litter depth. The results showed a clear relationship between litter type and seed germination success with seeds having poorer success rates in deeper forest litter. This study demonstrated that even small decreases in forest litter depth, sufficient to expose bare soil, facilitates *R. ponticum* seedling establishment. These findings will inform guidelines and standard operating procedures for future forest management plans, particularly in areas that are sensitive to *R. ponticum* invasion.

Keywords: *Invasive species control, invasion dynamics, ground disturbance, woodland management*.

Introduction
Rhododendron ponticum L. is native to an area south of the Black Sea (Caucasus, northern Turkey and the southeast corner of Bulgaria). The now naturalised *R. ponticum* was first introduced into Britain in 1763 from southwest Spain (Coats 1963) and was largely used as an ornamental garden plant. Subsequent introductions to these islands have not been well documented and are believed to have originated from the Black Sea area (Cross 1975, Stace 1991). Its suitability as game cover resulted in the species being introduced into many woodland habitats and it has since become an established invasive species throughout Ireland and Britain (Cross 1981, Gritten 1995, Dehnen-Schmutz et al. 2004).

R. ponticum is an extremely successful invasive species in Ireland (Maguire et al. 2008). It has become established in several Annex 1 habitats as listed under the

[a]Waterford Institute of Technology, Cork Road, Waterford City.
[b]School of Biological, Earth and Environmental Sciences, University College Cork.
[*]Corresponding author: edaly@wit.ie

EU Habitats Directive[1], including old oak woodland with *Ilex* and *Blechnum*, which is classified as WN1[2] by The Heritage Council (Fossitt 2000). *R. ponticum* now represents one of the greatest conservation problems in relation to the protection of oak woodlands in Ireland (Kelly 2007). It poses a serious threat to the biodiversity of native flora and fauna as it has important competitive advantages over native understory species (Cross 1975, Dehnen-Schmutz and Williamson 2006, Parrott 2013).

Many morphological and ecological characteristics convey an advantage on *R. ponticum* compared with many native species in Ireland, thus allowing it to outcompete native species on many sites in Ireland. Its rapid growth rates and seedling recruitment, compared with competing native species, are a particular advantage for *R. ponticum* (Erfmeier and Bruelheide 2004). The dark undergrowth and toxic leaf litter of *R. ponticum* combine to produce a sterile ground layer which prevents natural regeneration (Edwards 2006) and has negative impacts on the biodiversity potential of the site (Cross 1975). The reduction in native flora species has a knock-on effect on the abundance of native species that rely on native plants for resources such as food and shelter (Cross 1975).

Forest cover in Ireland currently is 10.5%, well below the EU average of 30% (Forest Service 2013). Afforestation in Ireland got underway at the beginning of the 20th century and remained low in Ireland until the end of 1980s when an improved grant system was introduced. The new system focused on encouraging private land owners to invest in forestry with financial incentives to facilitate biodiversity conservation in plantation forests. Plantation forests in Ireland are required to set aside at least 15% of their land cover for biodiversity enhancement, which essentially means that these designated areas must remain fallow. Should *R. ponticum* establish itself in these areas, as well as significantly reducing the biodiversity viability of the immediate area, the potential success of regenerative schemes like the Native Woodland Scheme is threatened. Under the Native Woodland Scheme forest owners are supported, through the awarding of grants, to plant and maintain stands of native Irish trees, predominately oak (*Quercus* spp.) but also ash *(Fraxinus excelsior* L.*)*, Scots pine *(Pinus sylvestris* L.*)*, holly *(Ilex aquifolium* L.*)* and others. However, the acidic soils favoured by these species are ideal for *R. ponticum*. A study conducted by Harris (2011) into the invasion potential of the species in different habitats found that the highest invasion speeds were in evergreen habitats and the highest invasion densities were found in

[1] The Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora, more often known as the Habitats Directive, is a European Union directive adopted on 21st May in 1992 in response to the Berne Convention. It is one of the EU's two directives referring to wildlife and nature conservation, the other being the Birds Directive. The aim of the directive is to protect some 220 habitats and approximately 1,000 species which are listed in the directive's Annexes. Annex 1 refers to habitats.

[2] WN1 is the classification for Oak-birch-holly semi-natural woodland.

open habitats; however, deciduous habitats displayed "intermediate invasion potential that is most vulnerable to relatively rapid and dense invasion". Should it establish itself as an understory in these stands, it invariably prevents the natural regeneration of native trees and suppresses ground flora.

A study conducted by Baker (1974) identified the attributes of an "ideal weed", which included fast vegetative growth to reach flowering stage, production of large quantities of seed, vegetative propagation and non-specialized pollination systems and germination requirements. While these characteristics describe the ecophysiology of *R. ponticum*, they are not the only reasons for its successful establishment in Ireland. In its native habitat (Iberia, Bulgaria), *R. ponticum* occurs in small relict populations and is not considered invasive (Mejías et al. 2002). In Turkey and Georgia it is an integral part of the forest flora and its abundance is limited by drought and by vigorous competition. Where a forested area is clear-felled *R. ponticum* spread becomes aggressive, quickly colonizing the disturbed site, in a similar manner as occurs in Ireland.

The continued requirement for *R. ponticum* control in Ireland's native woodlands means that the demand for *R. ponticum* control remains an important management consideration. Despite the clear need for effective *R. ponticum* control strategies, no definitive intervention has been established to date and there is a lack of clear scientific evidence for some commonly implemented management and control strategies (Tyler et al. 2006).

Once they reach maturity, *R. ponticum* plants produce large numbers of small wind-dispersed seeds (Cronk and Fuller 2001). The seeds are non-dormant and germinate quickly after dispersal (following five or six days in favourable conditions). Most dispersed seeds travel 10 m or less, particularly in open habitat, but providing wind speed is sufficient the seeds have the potential to travel 100 m or more (Stephenson et al. 2007). *R. ponticum* seed production has been facilitated in Ireland by native generalist pollinators, mainly bumblebees (*Bombus* spp.) (Stout 2007).

An *R. ponticum* inflorescence can typically produce up to 5,000 seeds and on average a 12-year-old tree can produce up to 1 million seeds per annum. The capsules dehisce during the winter months and early spring, dispensing seeds roughly 0.4-1.0 mm in length and weighing 0.063 mg (Cross 1975, Mejías et al. 2002). The seeds are similar in weight to those of other ericaceous plants and are regarded as some of the smallest seeds in the plant kingdom (Salisbury 1942). They need light to germinate, but low intensities will suffice (Mejías et al. 2002, Erfmeier and Bruelheide 2010). The viability of seeds kept in the dark declines steadily with time and after 160 days no germination occurs (Cross 1981).

Forest litter can affect *R. ponticum*'s establishment by influencing the microclimate (Fowler 1988), nutrient cycling (Proctor et al. 1983), allelopathic interactions (Rai and Tripathi 1984), or via the physical barrier created by the leaves themselves

(Sydes and Grime 1981). Forest litter generally has a negative effect on germination success (Xiong and Nilsson 1999). It can also have varying effects on relative species abundance within a community (Carson and Peterson 1990). There are many reasons for this, including the altering of moisture, light and temperature regimes for competing neighbouring seeds. Litter depth affects germination and subsequent seedling establishment in species that produce small seeds (Xiong and Nilsson 1999). Seeds produced by large-seeded species tend to produce more robust seedlings and are generally less affected by the presence of forest litter (Molofsky and Augspurger 1992, Myster 1994).

Germination of *R. ponticum* seeds can be successful on many different types of substrate and low light levels are the most common limiting factor (Cross 1981, Mejías et al. 2002). In woodlands, disturbance of the ground cover caused by forest management practices, animal grazing or fallen trees, creates gaps in the canopy allowing sufficient light (for germination) to reach the forest floor. As the amount and distribution of forest litter can influence the establishment of *R. ponticum* (Stephenson et al. 2006), the management of forest litter may offer an opportunity to reduce the risk of *R. ponticum* invasion. This scenario is more applicable in susceptible sites such as forests with an existing *R. ponticum* infestation or plantation forests with mature *R. ponticum* plants on neighbouring land.

The aim of this study was to investigate the effect of litter depth on the germination success of *R. ponticum* seeds using seeds collected from plants in an Irish plantation forest. In this study, the germination of *R. ponticum* on forest litter of three different depths and one conifer litter treatment was compared with the germination of *R. ponticum* seeds on bare soil.

Materials and methods

Seed collection and preparation

R. ponticum seeds were collected from two plants located on the edge of a stand of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) in Deerpark, Lismore, Co. Waterford. The stand was planted in 1985 and, as *R. ponticum* in this area is invasive, the plants were no more than 26 years old. One of the shrubs was 2.5 m in height with a crown circumference of 13.4 m and the other was 2.0 m in height and 9.5 m in circumference.

Twenty racemes were collected from each *R. ponticum* plant on January 15th 2012. On average each raceme held 15 seed pods. The following day each seed pod (still attached to its stalk) was separated from its raceme and placed in paper bags. A total of 286 seed pods were harvested from one plant and 306 from the other. The paper bags were stored in a ventilated room under ambient conditions (20 ± 2 °C) for two weeks after harvesting. The seeds used in this study were all from one plant, with the seed from the other one being retained as a backup. Each bag was shaken lightly prior to the removal of the pods to encourage the release of seeds from pods that had naturally opened. The pods were then removed leaving the seeds at the bottom of the paper bag. The seeds were then assigned to 15 batches with each batch containing 1,050 seeds.

Seed viability test

To assess the quality of each batch of seeds, and to ensure that there was no difference in viability between batches, a germination test was carried out in the laboratory. The viability of the seeds was tested using 50 seeds randomly selected from each batch which were sown on filter paper in separate 12 cm Petri dishes and soaked with 8 ml of distilled water (saturation point). The seeds were allowed to germinate in a propagator (Biogreen™ heated propagator) that was kept at a constant 20 °C with a 16-h light cycle (approximate light intensity was 202 μmol s^{-1} m^{-2}). The position of each Petri dish was assigned randomly in the propagator then swapped every three days to mitigate any effect of position on the outcome of the germination test. Distilled water was added as required to ensure that moisture was not a limiting factor in germination success. The number of successfully germinated seeds was monitored for up to eight weeks following sowing.

Germination experiment

The main experiment to test the germination of *R. ponticum* seeds on five different depths of forest litter was carried out in a climate controlled grow-house set at 20 °C ± 4 °C with 16 hours of light per day (approximate light intensity of natural light was 360 μmol s^{-1} m^{-2}). To enhance natural light, high pressure sodium lights were employed when natural light fell below 216 μmol s^{-1} m^{-2}, thus ensuring the minimum illumination value over the experiment was 180 μmol s^{-1} m^{-2} and the maximum value was 240 μmol s^{-1} m^{-2}. Fifteen (5 treatments × 3 replications) 65 L trays (0.45 m^2 base area), with holes drilled in the base to allow for drainage, were used in this experiment. Each tray held 8 cm depth of milled sphagnum peat substrate. Soil pH level was measured in each tray prior to sowing of seeds and ranged between 4.5 and 5.1. Each tray was divided in six equal sub-plots to facilitate the sowing of seeds and subsequent counting of any successfully germinated seeds. Tap water was supplied through the station's irrigation system once daily to ensure that the soil was kept moist throughout the test period.

Five different litter treatments were used in this experiment as described in Table 1. The broadleaf forest litter consisted of a mixture of litter from four common tree species: beech (*Fagus sylvatica* L.), oak (*Quercus* spp.), ash and holly. These were chosen to represent the range of leaf litter most commonly found in Irish broadleaved forests. The conifer needles were obtained from a stand of Sitka spruce. The forest litter was collected two weeks prior to the beginning of the experiment and allowed to dry in a storage area held at 20 °C.

To standardise the amount of litter used across each replicate for each treatment the

Table 1: *Details of the five litter treatments.*

Treatment	Litter type	Litter depth (cm)	Litter mass (g m^{-2})	Exposed soil (%)
1	Bare soil	0	0	100
2	1 cm Broadleaf	1	150	35
3	3 cm Broadleaf	3	210	12
4	5 cm Broadleaf	5	415	0
5	2 cm Conifer	2	398	0

required litter mass per unit area was calculated. The weighed litter was then spread evenly over the tray prior to broadcasting of *R. ponticum* seeds. The litter was spread evenly across the trays to mimic the natural state of forest litter wherein the lower the amount of litter found on the forest floor the higher the area of exposed soil present, so the amount of exposed soil was proportional to the amount of litter used. Different depths of conifer needles were not considered, mainly because this type of litter forms a uniform carpet on the forest floor preventing direct access of the seed's radicle to the soil. Each batch of 1,000 seeds was divided into six equal parts (by weight), which were spread evenly over one of the sub-plots on the garden trays. The position of each tray on the bench was randomised each week. The number of seeds that had germinated in each tray was recorded weekly until germination ceased in all trays at 16 weeks after sowing.

Data analysis

Germination success was calculated as the number of germinated seedlings expressed as a percentage of the total number of seeds sown. As the data from the germination results were non-parametric (and not normally distributed), a Kruskal-Wallis test was used to test for differences among the treatments. Pair-wise comparisons were made between individual treatments using Tukey's wholly significant tests. Weekly germination rates for each treatment were also recorded. Daily rates were then calculated (number of seeds germinated during one week divided by seven days). All results are presented as means and standard errors and data analysis was conducted using Minitab, version 16.

Results

Seed viability test

The mean germination success was 82% ± 0.4% after four weeks for all 15 batches of seeds. The batch with the lowest number of germinated seeds produced 76% germinants while the batch with the highest number of seeds resulted in 90% germinants. The standard errors for the 15 batches overlapped, indicating that batch effects were not significant. No further germination occurred after four weeks.

Germination experiment

The results of the Kuskal-Wallis test showed that treatment effects were significant ($H = 13.5$, $df = 4$, $P < 0.01$). Pair-wise comparisons between the treatments showed that bare soil and the 1 cm broadleaf treatment resulted in higher germination rates, significantly different from the remaining treatments and from each other (all $P < 0.05$) (Table 2). The 2 cm conifer treatment also resulted in a higher germination rate of *R. ponticum* seeds than the 5 cm broadleaf treatment ($P < 0.05$). The remaining comparisons indicated that the 3 cm broadleaf treatment was equally good at suppressing the germination of *R. ponticum* seeds as both the 2 cm conifer and 5 cm broadleaf treatments ($P > 0.05$).

Over half of *R. ponticum* seeds germinated successfully on bare soil (55 ± 2.0%) and seed germination ceased at week eight (Figure 1). The majority of these seeds germinated during weeks four to six (75% ± 0.3%). Seed germination success on 1 cm of broadleaf litter was 21% ± 1.5%. The highest germination occurred during week five (10 ± 1.8 seeds per day). No further germination occurred after week nine.

The germination success rate of *R. ponticum* seeds on 3 cm of broadleaf litter was 2% ± 0.2%. On the trays with 5 cm broadleaf litter fewer than 1% ± 0.1% of seeds germinated successfully. Only 7% ± 0.4% of the seeds broadcast on conifer litter germinated.

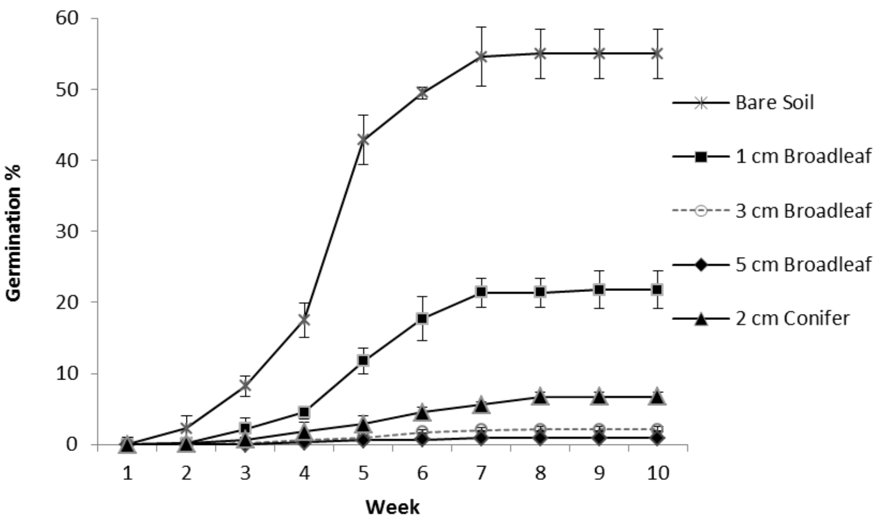


Figure 1: *Mean (± S.E.) cumulative germination rate (percentage of successfully germinated seeds) of R. ponticum seeds in different forest litter treatments over 10 weeks.*

Table 2: *Pair-wise comparisons of the litter treatments (n = 15).*

Comparison	P-value	Comparison	P-value
Bare vs. 1 cm	0.03	1 cm vs. 5 cm	0.02
Bare vs. 3 cm	0.02	1 cm vs. Conifer	0.03
Bare vs. 5 cm	0.01	3 cm vs. 5 cm	0.12
Bare vs. Conifer	0.02	3 cm vs. Conifer	0.06
1 cm vs. 3 cm	0.03	5 cm vs. Conifer	0.02

Discussion

Germination success in the greenhouse was highest on bare soil and lowest on the deepest (5 cm) broadleaf litter indicating that litter depth influences germination. Germination declined as the litter depth increased. While there was an obvious difference between bare soil and the median depth of litter tested (3 cm), there was no significant difference in the germination success between the two deeper litter depths (3 cm and 5 cm). The addition of a litter layer as a measure to control invasive species has not been used widely, perhaps because it can also hinder the establishment of desired species (Sydes and Grime 1981) or provide protection for seeds from predators (Cintra 1997). The manipulation of forest litter depth is not currently part of best practice for *R. ponticum* control in Ireland (Barron 2008, Higgins 2008, Maguire et al. 2008). However, the physiological characteristics of *R. ponticum* seeds (rapid germination and lack of dormancy) makes this species an ideal candidate for a novel control programme involving the modification of forest litter depth (Stephenson et al. 2006). For example, on a clearfell site sensitive to *R. ponticum* invasion, instead of using brash to build windrows, the excess timber could be mulched and used as a litter layer to prevent *R. ponticum* seed germination. However, it should be noted that mulch may display different morphological properties than that of leaf litter, such as a greater ability to retain moisture; more prone to moss growth etc, so it would be prudent to examine *R. ponticum* seed success on mulch in greater detail before recommending this approach as a control measure.

The germination response differed between the litter treatments, with the deeper litter layers perhaps preventing sufficient light reaching seeds that were in contact with soil. However, other seeds may have lacked sufficient vigour to allow the radicle elongate to make contact with the soil surface (Harper et al. 1970). On conifer needle beds in this study just 7% of the seeds germinated and it is likely that none of the resulting seedlings could establish or develop further. The emerging seedling radicles probably degenerated because they could not establish contact with the soil surface. In the case of species that produce small seeds the ability of the seed to germinate is not the only factor in its success in producing a healthy plant (Xiong and Nilsson 1999). A study to determine the maximum length that the radicle of *R. ponticum* seeds achieves before energy reserves become depleted and degeneration commences would be useful.

As *R. ponticum* seeds require adequate access to bare soil, or soils covered in bryophyte carpets (Cross 1981), land disturbance plays a significant factor in the spread and recruitment of this invasive species. The results of this study demonstrate that a reduction in forest litter depth, sufficient to expose bare soil, facilitates *R. ponticum* seedling establishment. Conversely the delicate ephemeral nature of *R. ponticum* seeds means that an increase in forest litter may prevent seed germination. *R. ponticum* seeds are small and delicate, they are non-dormant, germinate quickly and need light to do so (Cross 1981). Once *R. ponticum* seeds have become fully imbibed, seed germination must commence soon afterwards otherwise the seeds will degenerate. For example Mejias (2002) shallowly buried packets of 20 seeds for nine months, but once recovered, none of the seeds germinated on filter paper. Cross (1975) observed that no fully imbibed seeds germinated in the light following storage for 161 days in the dark. Erfmeire and Bruelheide (2005) compared the germination of Irish-sourced seeds against native Spanish and Georgian seeds and found that, while there was no difference in optimum germination temperature or maximum germination rate, the seeds sourced in Ireland germinated more rapidly in response to treatment. These studies reported similar rates of germination as observed in the current study. No seeds germinated after more than eight weeks, suggesting that *R. ponticum* seeds do not retain viability for much longer than this under the conditions evaluated in this study.

Differences in physical properties of litter are likely to result in different light, temperature and moisture conditions for seeds found on a forest floor (Facelli and Pickett 1991). It was beyond the scope of this study to examine the potential effects of light, temperature conditions and moisture availability on the germination of *R. ponticum* seeds. Previous studies have demonstrated the proportional relationship between different litter depths and germination success in small-seeded species (Molofsky and Augspurger 1992, Myster and Pickett 1993, Xiong and Nilsson 1999). In nearly all cases, the greater the depth of the forest litter the less favourable the conditions are for seed germination. The conifer-needle treatment (2 cm layer) had a greater mass than that of the 3 cm broadleaf treatment and resulted in no exposed soil. The conifer needle treatment had a higher germination success rate than that of the 3 cm broadleaf treatment, although bare soil was not exposed. This highlights how a change in litter type can change the dynamics of the litter depth/germination success relationship. It is, however, unlikely that these germinants would establish successfully if the radicle is unable to make contact with the soil surface. It would be useful to examine different depths of conifer needles to simulate the edge of the forest effect where needle depth would be shallower and *R. ponticum* would be more likely to establish.

Using models to estimate colonising potential of an invasive species is an established tool used by ecologists (Bezrukova et al. 2012). According to Stephenson (2006) (and later demonstrated by Harris (2011)) there is substantial potential for the development of spatial population models to predict the colonisation of *R. ponticum* in sensitive habitats. Although many habitat requirements of *R. ponticum* have been described in qualitative terms, quantitative information is important in designing a predictive model in ecology (Guisan and Zimmermann 2000). Quantitative data, such as the data described in this paper, can be integrated into a spatial population model which in turn can aid land managers in designing optimum control strategies against the spread of *R. ponticum*.

Conclusions and recommendations

Despite a good understanding of the nature of the threat posed by invasive species few eradication programs have been a complete success. If the infestation is identified early and all individuals are removed before they have a chance to seed, then eradication can be successful (Mack and Lonsdale 2002). If the infestation is allowed time to establish, then complete eradication is almost impossible. The only available course of action is then containment. Both actions require significant expenditure, the heavier the infestation the greater amount of resources needed to combat it. Many alien species do not have a detrimental effect on native ecosystems, as only a small fraction of them become insidious (Mooney and Cleland 2001). An understanding of why a particular species, compared with another, becomes successful in establishing itself in an unfamiliar habitat is important if an effective control programme is to be developed. As mentioned above, litter depth is not commonly used as a control method for invasive species and forest litter depth is not currently considered as part of a targeted control program for *R. ponticum* in Ireland. However, the physiological characteristics of *R. ponticum* seeds make the species an ideal candidate for a novel control programme involving forest litter depth.

The establishment of *R. ponticum* in an area is often very difficult to reverse. Established colonies of *R. ponticum* will persist indefinitely spreading to their ecological limit, particularly in sensitive ecosystems. Therefore the choice for the landowner is a pre-emptive one; prevention rather than cure. Better awareness and legislation coupled with defined identification and prevention tools will help to prevent new invasions. As *R. ponticum* seeds need adequate access to bare soil (or soils covered in bryophyte carpets) (Cross 1981), land disturbance plays a significant factor in the spread and recruitment of this invasive species. This experiment demonstrates that a small decrease in forest litter depth, enough to expose bare soil will facilitate seedling establishment. Conversely a small increase in forest litter can prevent significant germination. The results of this study should be incorporated into guidelines and standard operating procedures for future forest management plans, particularly in areas which are sensitive to *R. ponticum* invasion.

Acknowledgements
This project was funded by the Dept. of Agriculture, Food and the Marine under the National Development Plan 2007 – 2013.

References

Baker, H.G. 1974. The evolution of weeds. *Annual Review of Ecology, Evolution and Systematics* 5: 1-24.

Barron, C. 2008. The control of rhododendron in native woodlands. *Native Woodland Scheme Information Note #3*. Available at http://www.woodlandsofireland.com/sites/default/files/Rhodo.pdf [Accessed October 2014].

Bezrukova, M., Shanin, V., Khoraskina, Y. and Mikhailov, A. 2012. DLES framework for spatially-explicit simulation modelling. *International Environmental Modelling and Software Society (iEMSs) 2012 International Congress on Environmental Modelling and Software Managing Resources of a Limited Planet*. Germany.

Carson, W.P. and Peterson, C.J. 1990. The role of litter in an old-field community: impact of litter quantity in different seasons on plant species richness and abundance. *Oecologia* 85: 8-13.

Cintra, R. 1997. Leaf litter effects on seed and seed predation of the palm *Astrocaryum murumuru* and the legume tree *Dipteryx micrantha* in Amazonian forest. *Journal of Tropical Ecology* 13: 709 25.

Coats, A.M. 1963. *Garden Shrubs and Their Histories*, Vista Books, London.

Cronk, Q.C.B. and Fuller, J.L. 2001. *Plant Invaders: the Threat to Natural Ecosystems,* London, Earthscan Publications.

Cross, J. 1975. *Rhododendron ponticum* L. *The Journal of Ecology* 63: 345-364.

Cross, J. 1981. The establishment of *Rhododendron ponticum* in the Killarney Oak Woods. *The Journal of Ecology* 69: 807-824.

Dehnen-Schmutz, K., Perrings, C. and Williamson, M. 2004. Controlling *Rhododendron ponticum* in the British Isles: an economic analysis. *Journal of Environmental Management* 70: 323-332.

Dehnen-Schmutz, K. and Williamson, M. 2006. *Rhododendron ponticum* in Britain and Ireland: social, economic and ecological factors in its successful invasion. *Environment and History* 12: 325-350.

Edwards, C. 2006. Managing and controlling invasive rhododendron. *Forestry Commission Practice Guide*. Forestry Commission. Edinburgh.

Erfmeier, A. and Bruelheide, H. 2004. Comparison of native and invasive *Rhododendron ponticum* populations: growth, reproduction and morphology under field conditions. *Flora – Morphology, Distribution, Functional Ecology of Plants* 199: 120-133.

Erfmeier, A. and Bruelheide, H. 2005. Invasive and native *Rhododendron ponticum* populations: is there evidence for genotypic differences in germination and growth? *Ecography* 28: 417-428.

Erfmeier, A. and Bruelheide, H. 2010. Invasibility or invasiveness? Effects of habitat, genotype, and their interaction on invasive *Rhododendron ponticum* populations. *Biological Invasions* 12: 657-676.

Facelli, J.M. and Pickett, S.T.A. 1991. Plant litter: its effects on plant community structure. *Botanical Review* 45: 15-19.

Forest Service 2013. *The Second National Forest Inventory, Republic of Ireland: Main Findings*. Forest Service, Department of Agriculture, Food and the Marine, Johnstown Castle, pp 54.

Fossitt, J.A. 2000. *A Guide to Habitats in Ireland*. The Heritage Council.

Fowler, N.L. 1988. What is a safe site? Neighbor, litter, germination date, and patch effects. *Ecology* 69: 947-961.

Gritten, R.H. 1995. *Rhododendron ponticum* and some other invasive plants in the Snowdonia national park. In *Plant Invasions: General Aspects and Special Problems*. Eds. Pysek, R., Prach, K., Rejmanek, M., Wade, M., SPB Academic Publishing, Amsterdam, pp 213-19.

Guisan, A. and Zimmermann, N.E. 2000. Predictive habitat distribution models in ecology. *Ecological Modelling* 135: 147-186.

Harper, J.L., Lovell, P.H. and Moore, K.G. 1970. The shapes and sizes of seeds. *Annual Review of Ecology and Systematics* 1: 327-356.

Harris, C., Stanford, H.L., Edwards, C., Travis, J. and Park, K. 2011. Integrating demographic data and a mechanistic dispersal model to predict invasion spread of *Rhododendron ponticum* in different habitats. *Ecological Informatics* 6: 187-195.

Higgins, G.T. 2008. *Rhododendron ponticum*: a guide to management on nature conservation sites. *Irish Wildlife Manuals* 33.

Kelly, D.L. 2007. Woodland on the western fringe: Irish oak wood diversity and the challenges of conservation. *Botanical Journal of Scotland* 57: 21-40.

Mack, R.N. and Lonsdale, W.M. 2002. Eradicating invasive plants: hard-won lessons for islands. In *Turning the Tide: the Eradication of Invasive Species*. Eds. Veitch, D. and M. Clout, M., Invasive Species Specialty Group of the World Conservation Union (IUCN), Auckland, New Zealand, pp 164-172.

Maguire, C.M., Kelly, J. and Cosgrove, P.J. 2008. Best Practice Management Guidelines Rhododendron (*Rhododendron ponticum)* and cherry laural (*Prunus laurocerasus)*. Prepared for NIEA and NPWS as part of Invasive Species Ireland.

Mejías, J.A., Arroyo, J. and Ojeda, F. 2002. Reproductive ecology of *Rhododendron ponticum* (Ericaceae) in relict Mediterranean populations. *Botanical Journal of the Linnean Society* 140: 297–311.

Molofsky, J. and Augspurger, C.K. 1992. The effect of leaf litter on early seedling establishment in a tropical forest. *Ecology* 73: 68-77.

Mooney, H.A. and Cleland, E.E. 2001. The evolutionary impact of invasive species. *Proceedings of the National Academy of Sciences of the United States of America* 98: 5446-5451.

Myster, R.W. 1994. Contrasting litter effects on old field tree germination and emergence. *Vegetation* 114: 169-74.

Myster, R.W. and Pickett, S.T.A. 1993. Effects of litter, distance, density and vegetation patch type on postdispersal tree seed predation in old fields. *Oikos* 66: 381-388.

Parrott, J. and Mackenzie, N. 2013. *A Critical Review of Work undertaken to Control Invasive Rhododendron in Scotland*. A report commissioned by Forestry Commission Scotland and Scottish Natural Heritage. Coille Alba.

Proctor, J., Anderson, J.M., Fogden, S.C.L. and Vallack, H.W. 1983. Ecological studies in four contrasting lowland rain forests in Gunung Mulu National Park, Sarawak: II. Litterfall, litter standing crop and preliminary observations on herbivory. *Journal of Ecology* 71: 261-283.

Rai, J.P.N. and Tripathi, R.S. 1984. Allelopathic effects of *Eupatorium riparium* on population regulation of two species of Galinsoga and soil microbes. *Plant and Soil* 80: 105-117.

Salisbury, E.J. 1942. *The Reproductive Capacity of Plants*., G. Bell and Sons, London.

Stace, C.A. 1991. *New Flora of the British Isles*, Cambridge University Press, Cambridge.

Stephenson, C., Mackenzie, M., Edwards, C. and Travis, J. 2006. Modelling establishment probabilities of an exotic plant, *Rhododendron ponticum*, invading a heterogeneous, woodland landscape using logistic regression with spatial autocorrelation. *Ecological Modelling* 193: 747-758.

Stephenson, C.M., Kohn, D.D., Park, K.J., Atkinson, R., Edwards, C. and Travis, J.M. 2007. Testing mechanistic models of seed dispersal for the invasive *Rhododendron ponticum* (L.). *Perspectives in Plant Ecology, Evolution and Systematics* 9: 15-28.

Stout, J.C. 2007. Reproductive biology of the invasive exotic shrub, *Rhododendron ponticum* L. (Ericaceae). *Botanical Journal of the Linnean Society* 155: 373-381.

Sydes, C. and Grime, J.P. 1981. Effects of tree leaf litter on herbaceous vegetation in deciduous woodland. II. An experimental investigation. *Journal of Ecology* 69: 249-262.

Tyler, C., Pullin, A. and Stewart, G. 2006. Effectiveness of management interventions to control invasion by *Rhododendron ponticum*. *Environmental Management* 37: 513-522.

Xiong, S. and Nilsson, C. 1999. The effects of plant litter on vegetation: a meta-analysis. *Journal of Ecology* 87: 984-994.

Participation in a wood-fuel quality assurance scheme in Ireland

Nicholas Mockler[a, b*] and Tom Kent[b]

Abstract
Wood for energy is a growing market in Ireland. However, there is some concern about the quality of the available wood-fuel. Good quality wood-fuel is essential to ensure the sustainability of a supplier's enterprise; otherwise consumer confidence may be eroded. Third-party certification schemes can contribute to distinguishing higher quality wood-fuels from lower quality equivalents available on the market. To date however, there have been no studies that have investigated barriers to the uptake of certification schemes. The objectives of this study were to investigate factors that may affect operational efficiency for the production of quality firewood and woodchip and to identify potential barriers to the uptake of energy-product certification schemes. To this end, data were gathered from questionnaire surveys of firewood and woodchip suppliers, including those with and without third-party certification to investigate aspects of their general business environment and quality management systems. The results indicated that all suppliers had adopted quality management systems in response to customer requirements. Barriers to uptake into the certification schemes were found to be attitudinal. This was based on non-certified suppliers' general perceptions that the Wood Fuel Quality Assurance certification scheme offered no incentives that would be considered sufficiently advantageous to their business to warrant such investment.

Keywords: *Wood, energy, quality, firewood, woodchip*.

Introduction
Wood fuel quality is determined by combustion efficiency in the production of usable energy. Consistent production of quality wood-fuel can only be assured through the implementation of a quality management system. Quality management consists of a plan for quality control at critical control points in the wood-fuel production process. The adoption of a quality management system is an essential criterion for a wood-fuel supplier to qualify for quality assurance certification (Langheinrich and Kaltschmitt 2006). Certification schemes provide assurance to end users that they are purchasing wood-fuel to their required specifications. It also establishes trust between suppliers and end users, instils consumer confidence and facilitates efficient business management.

Guidance for quality management systems has been developed through European Solid Biofuel (CEN) standards (Alakangas et al. 2006). The full suite of standards has been adopted in Ireland, coinciding with their intermittent publishing between the

[a] Revesby Estate Office, Revesby, Lincolnshire, United Kingdom, PE22 7NB.
[b] Waterford Institute of Technology, Cork Road, Waterford.
[*] Corresponding author: n.mockler@hotmail.com

years 2009 and 2012. The standards provide descriptions of a number of parameters for different fuel types and quality categories. Suitable methods for measurement of the parameters and how test procedures may be used to monitor fuel quality during the production process are also described. The development of quality standards facilitated the certification of wood-fuel through the Wood Fuel Quality Assurance (WFQA) scheme, an industry-led initiative administered by the Irish Bioenergy Association (IRBEA). The WFQA scheme operates under the National Working Agreement 2009, coordinated by the National Standards Authority of Ireland (NSAI). The relevant documents outline the administrative and operational measures required for suppliers to receive WFQA certification (NSAI 2010).

Since its inception in 2010, 14 suppliers have been WFQA certified (Gavigan 2014), which is about 25% of all suppliers who appear in various official directories (Teagasc 2011, IRBEA 2012, Sustainable Energy Authority of Ireland (SEAI) 2013). In reality, this proportion may be lower as there may be suppliers who do not appear in the directories listed. Against this background, the trend in uptake suggests that there may be: 1) a lack of awareness of the WFQA scheme; 2) operational barriers to the implementation of a quality management system to satisfy the requirements of the WFQA scheme; 3) attitudinal barriers based on perceptions of the WFQA scheme and 4) suppliers who are not producing commercial quantities of wood-fuel to justify participation in the WFQA scheme and official wood-fuel supplier directories. To date, there have been no studies that have attempted to investigate factors that may influence uptake of the WFQA scheme.

The goal of this study was to investigate factors that may affect operational efficiency for the production of quality wood-fuel and to identify potential barriers to participation in the uptake of the WFQA scheme. This was achieved through gathering indirect evidence from questionnaire surveys of firewood and woodchip suppliers, including those with and without WFQA in an attempt to gain a better understanding of the business environment in which they work and the quality of the management systems the suppliers have put in place.

Questionnaire structure and sampling strategy

Separate structured questionnaires were developed for firewood and woodchip suppliers. The questionnaires were based on a theoretical framework of quality management performance measures for suppliers proposed by Langheinrich and Kaltschmitt (2006) and a framework for the management of operational critical control points (e.g. seasoning and chipper blade sharpening) compiled by Loibneggar (2011). The areas covered in the questionnaires included: 1) source of raw material and the payment method; 2) quality management systems concerning operational critical control points in the production process, including seasoning and storage of raw material, monitoring fuel properties in-house and machinery maintenance; 3) the information provided when selling the end product and 4) supplier's own perceptions of the WFQA scheme.

The survey of 21 suppliers (Figure 1, Table 1), with the aim of achieving a spread around Ireland, was carried out between August and December 2013. Nineteen suppliers were interviewed in person and two interviews conducted by phone. All firewood and woodchip suppliers who had WFQA certification during the last quarter of 2013 were surveyed. The remaining 10 non-certified suppliers were sourced from personal communications with members of IRBEA (Gavigan and Tottenham 2013) and from a number of wood-fuel supplier directories (Teagasc 2011, IrBEA 2012, SEAI 2013).

Results

Source of raw material

Combining data from all the firewood suppliers surveyed, the total annual intake of

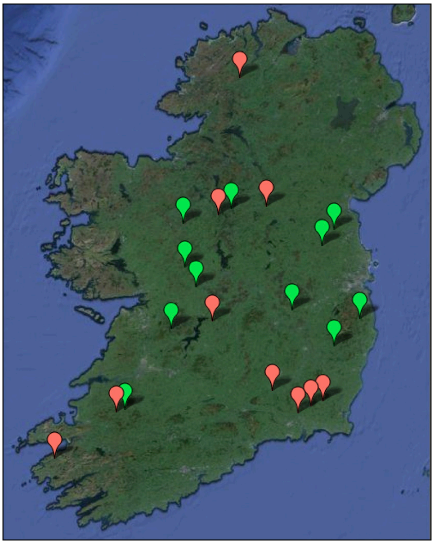


Figure 1: *Location of suppliers surveyed in 2013. Green markers indicate the location of suppliers with WFQA and red markers show those that had no certification.*

Table 1: *Suppliers surveyed by product type and certification status in 2013.*

Certification Status	Firewood	Woodchip	Firewood and Woodchip	Total
WFQA	7	3	1	11
Non-certified	2	6	2	10
Total	9	9	3	21

raw material bought was 18,426 t, whereas the total annual amount of raw material from woodchip suppliers was 54,200 t. The median annual intake of raw material for firewood suppliers was 800 t yr^{-1} and ranged from 24–4,000 t yr^{-1}. The median annual intake for woodchip suppliers was 3,250 t and ranged from 500–15,000 t yr^{-1}. For all suppliers, the predominant source of raw material for processing was roundwood. In addition to roundwood, one woodchip supplier also harvested whole trees and another woodchip supplier also used sawmill residues. Table 2 lists the timber species recorded across all suppliers.

Twelve suppliers sourced their raw material from the private sector only; of which two also sourced material from their own plantations. The remaining nine suppliers sourced their raw material from both the private sector and Coillte.

Twelve suppliers replied that they had had difficulty sourcing sufficient quantities of raw material. Among the difficulties identified were: 1) competition for raw material with sawmills and harvesting contractors; 2) lack of information about tenders for roundwood sales; 3) difficulties in sourcing hardwood species; 4) restrictions in cash flow for making purchases and 5) access difficulties into private plantations during winter. Where suppliers had no issues sourcing raw material, the reasons included: 1) good market information from contacts in the harvesting and haulage business and 2) possession of raw material purchase contracts with private forestry companies and Coillte. The majority of raw material purchased from the private sector was bought on a weight basis, whereas all purchases from Coillte were on a volume basis.

Delivery and sales methods

Five suppliers delivered nationwide, two province-wide and one supplied on a county-wide basis. For the remaining 13 suppliers, the median delivery distance was 40 km and ranged from 30 to 81 km. All suppliers charged extra for delivering over long distances.

Table 2: *Species recorded in suppliers' yards.*

Species[a]	No. of suppliers
Sitka spruce (*Picea sitchensis* (Bong.) Carr.)	14
Broadleaf species only including oak (*Quercus* spp.), ash (*Fraxinus excelsior* L.), birch (*Betula* spp.), alder (*Alnus glutinosa* (L.) Gaertn.), beech (*Fagus sylvatica* L.) and sycamore (*Acer pseudoplatanus* L.)	1
Sitka spruce and broadleaf species mixes similar to the above but also including poplar (*Populus* spp.) and maple (*Acer platanoides* L.)	2
Sitka spruce and ash	2
Sitka spruce and beech	1
Sitka spruce, Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) and larch (*Larix* spp.)	1

[a] Suppliers stated that Sitka spruce was the predominant species where mixtures were recorded.

Nineteen suppliers had no formal contracts with customers as to the quantity of fuel required or frequency of deliveries. For firewood suppliers, market demand was strongest during autumn and winter. For woodchip suppliers, those who had no formal contracts made deliveries upon demand and/or when they anticipated a customer's supply was low. In all cases, woodchip suppliers had a regular customer base. Tables 3 and 4 describe the predominant sales methods for firewood and woodchip respectively.

Quality Management systems for the control of operational critical control points

Moisture content dictated the critical control points of the fuel production process for all suppliers. All suppliers bought their raw material freshly felled. However, four suppliers stated that they occasionally purchased seasoned material. Nineteen suppliers air dried their raw material, while two firewood suppliers kiln-dried their raw material. Of the 19 suppliers who relied on natural drying, two firewood suppliers first processed roundwood into firewood without seasoning and then contained the firewood in netting packages to facilitate drying and subsequent sales. The remaining 17 suppliers allowed roundwood to dry for a period before processing into firewood or woodchip. Across all suppliers, the median period for seasoning raw material was

Table 3: *The main sales methods for firewood (including the three suppliers who were producing both products identified in the survey in 2013).*

Sales method	No. of suppliers
Bulk bags of 0.7–1.4 (m^3), loosely packed[a]	4
Wrapped bales (0.9–1.7 (m^3) capacity)	3
Net bags (45 × 65 cm dimension)	2
Customer's trailer (m^3), loosely packed[b]	1
Bulk bags or customer's trailer (m^3), loosely packed	1
Predetermined measurement of a front loader bucket (m^3), loosely packed[c]	1

[a] Meaning firewood that has not been stacked neatly (Kofman 2006a).
[b] From predetermined measurements of a customer's trailer.
[c] The supplier uses a bucket of known volume to fill customer's trailers.

Table 4: *The main sales methods for woodchip (including the three suppliers who were producing both products identified in the survey in 2013).*

Sales method	No. of suppliers
Delivered load weight and estimated moisture content	4
Delivered load weight and estimated moisture content, or by heat output[a]	6
Volume basis including moisture content[b]	1
By the delivered energy content[c]	1

[a] Suppliers are paid by the kilowatt hour (kWh) output of deliveries.
[b] From a trailer of a predetermined volume.
[c] Calculated using the load weight, estimated moisture content and a reference net calorific value.

eight months and ranged from 3 to 14 months. However, inter-annual variation was significant within this range, as seasoning conditions vary from year to year and also according to the time of year the raw material was harvested. On this basis, all suppliers adjusted their seasoning periods until the target moisture content was reached before processing. This involved partitioning roundwood stacks based on the time of year the raw material was delivered. All 21 suppliers stacked roundwood off the ground, perpendicularly aligned on top of support logs. This was to prevent incombustible contaminants, such as soil and stones, from adhering to the fuel product. In addition, once material was processed into firewood or woodchip, all suppliers kept material under cover in well-ventilated areas where further seasoning took place.

In-house testing of fuel properties is obligatory to acquire and maintain WFQA certification (NSAI 2010). Twenty of the suppliers had in-house testing methods in place for moisture content determination; one firewood supplier did not formally test for moisture content, but allowed material to season and relied on experience to determine when the fuel was fit for sale. Table 5 shows the different methods used to measure moisture content.

Ten of the firewood suppliers monitored moisture content during the processing of roundwood into firewood, during packing and before sales. One firewood supplier measured moisture content after kiln drying. Ten of the 12 woodchip suppliers sampled moisture content before each delivery, one supplier sampled one-in-six deliveries and another supplier sampled a fortnight after chipping.

Other critical control points

In addition to moisture content, firewood quality also depends on diameter and length, the piece must be of suitable dimensions to fit into the majority of stoves and fireplaces. Eleven firewood suppliers mechanically processed roundwood to an automatic pre-set maximum firewood length; the remaining supplier used a chainsaw and a rough size guide.

In addition to moisture content the size distribution of particles is an important quality parameter for woodchip, as too many fine particles can increase fly ash and the development of clinkers within the boiler, while overlong particles can jam or cause

Table 5: *Methods used to determine product moisture content from the survey in 2013.*

Method	No. of suppliers
Destructive testing with a domestic oven at ~105°C	6
Non-destructive – resistance-based moisture meter probes	6
Non-destructive – capacitance-based moisture meters	3
Destructive and non-destructive procedures[a]	5

[a] In this instance all suppliers used domestic ovens and resistance probes.

blockages in feeding mechanisms. Woodchip moisture content and particle size are normative properties, which must be specified (formerly EN: 14961–4 2010; as of May 2014 ISO: 17225–4 2014).

Nine of the woodchip suppliers owned and operated drum chippers. The remaining three suppliers outsourced chipping to a contractor who operated a drum chipper. All suppliers who owned and operated their own chippers had screens installed to produce material that met the target dimensions. In addition, they were aware of the adverse effects of blade wear on chip quality and as a consequence regularly maintained the chipper blades. The decision to sharpen and/or change blades relied on visual inspections of the woodchip produced. Suppliers' maintenance periods for blades varied from daily to weekly.

Transparency when selling the end product and perceptions of quality assurance

Fifteen of the suppliers confirmed that their customers specified the product requirements. Firewood suppliers reported four cases wherein customers inquired about moisture content and the length of firewood, whereas three suppliers received queries from customers regarding the supply of suitable length material for use in gasification stoves. For eight woodchip suppliers, moisture content and particle size were the properties specified by customers. Twenty of the suppliers provided information to the end user, bar one firewood supplier who did not measure moisture content.

For firewood suppliers, the minimum information given was moisture content, piece length and volume for payment purposes. For woodchip suppliers, the minimum information given was load weight and moisture content on delivery. One woodchip supplier sold on a volume basis only and moisture content on delivery.

Suppliers were also asked about their own target specifications for the most critical quality parameters for firewood (moisture content and length) and woodchip (moisture content and particle size). The target parameters stated by suppliers were equated to ISO biofuel specifications (Tables 6 and 7). The purpose of the specifications was to guide in the development of market rules and reduce ambiguity between supplier and end user (Alakangas et al. 2006). In addition, these specifications can also act as guidelines for suppliers working towards the production of a uniform product. In turn, this can lead to greater business efficiency and reduces the cost of production.

Perceptions of WFQA

Questions on the willingness to join the WFQA scheme were posed to non-certified suppliers. Four suppliers were preparing to make an application in the near future. The remaining six suppliers were enthusiastic about the scheme, but had reservations about joining. Among the reasons cited were: 1) the application process was onerous and entailed much paperwork; 2) the scale of production was too small to justify paying the

Table 6: *Target ISO fuel specifications of the nine firewood (F) suppliers who were certified (C) and not certified (NC), including the three suppliers who produced firewood in addition to woodchip (F+W) from the survey in 2013.*

Supplier	Moisture content (M, %)	Length (L, cm)	End-user category
F+W-1-NC	M25 ≤ 25	L20 ≤ 20 and L25 ≤ 25	Domestic
F+W-2-C	M30 ≤ 30	L20 ≤ 20	Domestic
F-1-NC	M20 ≤ 20	L25 ≤ 25	Domestic
F-2-C	M25 ≤ 25	L20 ≤ 20	Domestic
F+W-3-C	M25 ≤ 25	L20-[a]	Domestic
F-3-C	M30 ≤ 30	L20-	Domestic
F-4-C	M25 ≤ 25	L20-	Domestic
F-5-C	M20 ≤ 20	L20 ≤ 20 and L40 ≤ 40[b]	Domestic and institutional[c]
F-6-C	M20 ≤ 20	L25 ≤ 25 and L40 ≤ 40	Domestic and institutional
F-7-C	M20 ≤ 20	L25 ≤ 25	Domestic
F-8-NC[d]	N/A	N/A	Domestic
F-9-C	M25 ≤ 25	L20 ≤ 20	Domestic

[a] Assigned when the target length was below 20 cm.
[b] 40 cm-lengths are used in gasification stoves.
[c] Referred to domestic-scale appliances that were used in institutions such as hotels or nursing homes.
[d] Did not measure length or moisture content.

Table 7: *Target ISO fuel specifications of the nine woodchip (W) suppliers, including the three F+W suppliers from the survey in 2013.*

Supplier	Moisture content (M%)	Particle size[a] (mm)	End-user category[b]
W-1-C	M30 ≤ 30	P31–P45	Commercial and industrial
W-2-NC	M20 ≤ 20-M30 ≤ 30	P31–P45	Commercial and industrial
F+W-1-NC	M25 ≤ 25 and M50 ≤ M50	P31–P45	Commercial and industrial
W-3-NC	M20 ≤ 20	P45	Commercial and industrial
F+W-2-NC	M30 ≤ 30	P16	Domestic and commercial
F+W-3-C	M25 ≤ 25	P16 and P45	All scales
W-4-C	M15 ≤ 15-M35 ≤ 35	P45	Commercial and industrial
W-5-NC	M30 ≤ 30	P31	Commercial
W-6-NC	M30 ≤ 30-M50 ≤ M50	P63	Industrial
W-7-NC	M35 ≤ 35	P45	Commercial and industrial
W-8-C	M30 ≤ 30 and M45 ≤ 45	P31 and P45	Commercial and industrial
W-9-NC	M35 ≤ 35	P45	Commercial and industrial

[a] The nominal chip size, meaning that 60% of all particles (P) fall within the size category assigned from test results.
[b] The chip size required increases with the boiler size.

annual fee for scheme membership; 3) the supplier possessed a dedicated customer-base within a local area and had no intention to expand business and 4) two suppliers felt that they were already producing a quality product as a result of past errors and feedback.

In addition, all non-certified woodchip suppliers indicated that there was no price premium for certified end-products that might help to offset the expense of WFQA certification. The WFQA scheme was perceived only as a promotional label, illustrating that suppliers were compliant with quality wood-fuel regulations.

The same questions were posed to certified suppliers on their perceptions of the WFQA, in addition to what possible measures could be taken to entice more suppliers into the scheme. All certified suppliers were satisfied with the scheme as it ensured full transparency between the supplier and end user. The perception among approved suppliers was that the scheme was effective for those who supply fuel nationwide and may not be justified for small scale suppliers. Other suggested measures included that WFQA certification be a requirement in situations where formal supply contracts were agreed with end users.

Discussion

The small sample size of this study and its inevitable confinement to suppliers who were already aware of the need to produce quality wood-fuels and possess quality management systems, means that results should be treated with some caution. Furthermore, suppliers are just part of market supply chains. Wood fuel quality management should also be of interest to end users, who if informed about wood-fuel quality, may be more likely to make better use of this alternative and sustainable source of energy. A previous survey (Kissane 2013) reported on issues with woodchip installations in Ireland. These issues included poor design planning of installations for woodchip delivery and ash removal, as well as a lack of after-sales service from boiler installers. SEAI approved wood-fuel stove and boiler suppliers/installers could be targeted for education and training, to address issues with planning the layout of woodchip delivery and storage facilities. Such an initiative may also appeal to end users in creating awareness towards their responsibility to store wood-fuel in a manner that maintains its quality.

Aside from suppliers and end users, there are numerous agents involved in the wood-fuel supply chain. As a result, contentious issues may arise from a lack of understanding in the interpretation of the responsibilities each of these agents has to ensure operational efficiency is maximised. Structured questionnaire surveys across all agents of the wood-fuel supply chain with the aim of gaining a better understanding of the wood-fuel market in Ireland could be conducted. Such a measure could help to inform policy makers and industry stakeholders on the efficacy of policy instruments and incentives that have been introduced to stimulate market growth in the wood energy sector and to help devise solutions to issues that may be having a detrimental effect on market growth. The agents that should be targeted include: 1) the general public; 2) raw material suppliers who sell their products for wood-fuel; 3) wood-fuel suppliers, including those who produce other products on the market in addition to firewood and woodchip (e.g. wood briquettes and wood pellets); 4) boiler installers/fitters and 5) end users. These questionnaire surveys could form the basis of a multi-institutional research collaboration combining the knowledge and expertise of partners who have oversight on designing questionnaires, coupled with oversight into the five categories identified.

Operational barriers

The majority of fuel stock identified in this study was Sitka spruce (*Picea sitchensis* (Bong.) Carr.) roundwood which had been purchased on a fresh weight basis. However, Sitka spruce in its fresh state is not suitable for domestic and commercial appliances. Sitka spruce from fresh stem sections in Ireland can have a moisture content of 61% (Mockler 2013), rendering this within the M55+ category (ISO 17225–1 2014). The M55+ category has limited application for industrial end users and is not suitable for extended periods of storage.

The quality management systems for firewood and woodchip production were largely dependent on reducing moisture content. Therefore, payments for roundwood aimed at wood energy markets should be based on a standardised system that assesses moisture content. Purchasing roundwood on the basis of weight and/or volume has advantages and disadvantages for wood-fuel suppliers. Roundwood purchased on a weight basis is inexpensive and requires little professional input (Purser 2000). However, though roundwood with a high moisture content may be heavier, its energy yield will be lower. Including moisture content information would ensure roundwood was traded on a fairer basis. The moisture content of timber could be determined on delivery, with the price being paid on the basis of dry tonnes (FOROPA 2013). The methods described for measuring moisture content by FOROPA are similar to the oven-dry bark-free method described by Purser (2000). The methods described by Purser were presented as a standard procedure to determine the dry tonnages of roundwood for Irish conditions. There were no perceived operational barriers to ensuring wood-fuel could be produced to a consistent dimension. Firewood suppliers, with one exception, all employed firewood processing machinery with adjustable cutting facilities. All woodchip suppliers employed chipping machinery with screens designed to maintain a specified particle size.

Certification schemes

The WFQA scheme should offer incentives for certified suppliers to make it a more effective instrument for distinguishing quality wood-fuels from lower quality equivalents available on the market. In turn, this could also encourage new applicants, as the WFQA scheme was perceived by non-certified suppliers to offer no incentives despite their efforts to produce quality wood-fuels; this has clearly discouraged further applications. A similar sentiment towards the uptake of certification schemes was found in a UK-wide questionnaire survey of firewood suppliers conducted by Kinash et al. (2013). However, the main reservation about how certification schemes were perceived by suppliers was reported to be due to a lack of knowledge of end users about quality parameters and their effect on combustion efficiency. As a result, it was perceived by suppliers that prices in general were driven down by poor quality (i.e. high-moisture content) firewood being sold on the market. In addition, some suppliers who were selling seasoned firewood found difficulties in charging a premium for their product, presumably for the same reasons relating to end user knowledge.

Increasing the impact of the WFQA scheme could first be achieved by confining market access, where end users are convinced to seek certified fuel only; this can only be effective if there is an increase in the uptake into the WFQA scheme. A potential cost-benefit analysis as part of an industry-led initiative to establish baseline prices for certified firewood and woodchip products may also contribute to increasing uptake of the WFQA scheme. However, given the heterogeneous nature of wood-fuels, a market price for certified wood-fuel products would be compromised by: 1) different wood-fuel products; 2) varying fuel specifications and requirements between and within different products depending on end user demands; 3) the methods used to sell products (e.g. volume, weight and energy content); 4) the associated business costs for individual suppliers to produce a quality wood-fuel; 5) varying transportation distances for delivering the end product and 6) an end user's willingness to pay a premium.

Conclusion

The data collected in this study indicated that all suppliers were aware of the importance of wood-fuel quality and had adopted quality management systems in response to customer requirements. Engaging in wood-fuel quality management was not viewed by suppliers as a barrier to operational efficiency. Barriers to increased uptake into the WFQA scheme were found to be attitudinal. This was based on non-certified suppliers' perceptions that WFQA certification offered no incentives that would be considered sufficiently advantageous to their business to warrant such investment.

An industry-led cost-benefit analysis with a view to creating price premiums for certified products could help to convince suppliers to join the scheme. However, product type, the associated business costs incurred in producing a quality wood-fuel product and the end user's willingness to pay a premium for a quality product were the key issues influencing the lack of participation in the scheme.

Acknowledgements

Funding for this work was provided by the Department of Agriculture, Food and the Marine, under the COFORD research programme Forest Energy 2010–2014, supported under the National Development Plan 2007–2013.

References

Alakangas, E., Valtanen, J. and Levlin, J.E. 2006. CEN technical specifications for solid biofuels – fuel specification and classes. *Biomass and Bioenergy* 30: 908–914.

CEN. 2010. EN 14961–1: 2010. Solid biofuels – Fuel specifications and classes. Part 1: General requirements. *National Standards Authority of Ireland*, Dublin.

CEN. 2010. EN 14961–4: 2010. Solid biofuels – fuel specifications and classes. Part 4: Wood chips for non-industrial use. *National Standards Authority of Ireland*, Dublin.

CEN. 2010. EN 14961–5: 2010. Solid biofuels – fuel specifications and classes. Part 5: Firewood for non-industrial use. *National Standards Authority of Ireland*, Dublin.

FOROPA. 2013. *Round Wood Takeover by Weight and Moisture Content at Biomass Trade Centre Leoben*. FOROPA, Austria.

Gavigan, N. 2014. Wood fuel quality assurance scheme. *Forestry and Wood Update Newsletter, Volume 14, No. 1*. COFORD, Dublin.

IrBEA (Irish Bioenergy Association). 2012. Catalogue of Irish wood-fuel companies 2012. *Irish Bioenergy Association, Clonmel*.

ISO. 2014. ISO 17225–1: 2014. Solid biofuels – Fuel specifications and classes. Part 1: General requirements. *National Standards Authority of Ireland*, Dublin.

ISO. 2014. ISO 17225–4: 2014. Solid biofuels – fuel specifications and classes. Part 4: Graded woodchip. *National Standards Authority of Ireland*, Dublin.

ISO. 2014. ISO 17225–5: 2014. Solid biofuels – fuel specifications and classes. Part 5: Graded firewood. *National Standards Authority of Ireland*, Dublin.

Kinash, D., Walmsley, J. and Hemery, G. 2013. The British domestic firewood supply chain. *Quarterly Journal of Forestry* 107 (4): 303–308.

Kissane, A. 2013. *An Investigation into the Usefulness of Home Testing of Woodchip for Suppliers and Customers*. Irish Bioenergy Association, Clonmel.

Kofman, P. 2006a. *Firewood. COFORD Connects Harvesting and Transportation Note No. 5*. COFORD, Dublin.

Kofman, P. 2006b. *Quality woodchip fuel. COFORD Connects Harvesting and Transportation Note No. 6*. COFORD, Dublin.

Kofman, P. 2007. *Ordering and receiving woodchip fuel. COFORD Connects Processing/Products Note No. 8*. COFORD, Dublin.

Kofman, P. 2014. International wood-fuel standards – Ireland's involvement. *Forestry and Wood Update Newsletter, Volume 14, No. 1*. COFORD, Dublin.

Langheinrich, C. and Kaltschmitt, M. 2006. Implementation and application of quality assurance systems. *Biomass and Bioenergy* 30: 915–922.

Loibneggar, T. 2011. *Roadmap for Implementing Standards*. Intelligent Energy Europe, Austria.

Mockler, N. 2013. *Physical Characterisation and Quantification of Total Above Ground Biomass Derived from First Thinnings for Wood Fuel Consumption in Ireland*. Unpublished MSc. thesis. Waterford Institute of Technology, Waterford.

National Standards Authority of Ireland (NSAI). 2010. *Wood Fuel Quality Assurance – Guidelines for Implementation*. NSAI, Dublin.

Purser, P. 2000. *Timber Measurement Manual. Standard Procedures for the Measurement of Round Timber for Sales Purposes in Ireland*. COFORD, Dublin.

Sustainable Energy Authority of Ireland (SEAI). 2013. *SEAI List of Known Wood Fuel Suppliers*. SEAI, Dublin.

Teagasc. 2011. *Wood Chipping Contractors. Suppliers of Woodchip for Outwintering Pads (OWP)*. Teagasc Forestry, Athenry.

Residue bundling – a case study in Ireland

Enda Coates[a*], Tom Kent[a], Billy Horgan[a]
and Nicholas Mockler[a]

Abstract
Bundling residues from clearfell sites for use as a fuel is widely practiced internationally and more recently in Ireland. However, there is little information as to which bundling approach is most appropriate under Irish conditions. To this end, a clearfelling operation that included residue harvesting was evaluated in a 45-year-old stand of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) in mixture with 5% grand fir (*Abies grandis* (Douglas ex D. Don) Lindl.). The objectives of the study were to determine if arranging the brash for bundling during timber harvesting would impact on the supply chain costs, quantity and quality of the fuel. This included operations of a cut to length harvester, a forwarder, a residue bundling machine, a forwarder extracting residue bundles, and a shredder processing bundles into hogfuel. The fuel quantity mobilised was estimated, and the fuel quality was assessed. Three treatments (which were not replicated) were applied. Roundwood harvesting and extraction cost to the roadside ranged between treatments from €6.58 to €7.66 per m^3. In total, 589 bundles were produced, costing €4.80 to €6.43 per bundle between treatments (including forwarding). Shredding bundles into hogfuel cost €2.31 per bundle. The biomass removed ranged between 17.0 odt ha^{-1} and 28.7 odt ha^{-1}. It was found that residues were most available for harvest and with highest energy content, when not used as a brash mat prior to bundling, and conversely were least available, with lowest energy content, when used as a brash mat and driven over.

Keywords: *Logging residues, residue bundling, wood fuel quality, roundwood harvesting, machine productivity.*

Introduction
During cut to length harvesting, tree stems are usually delimbed and cross-cut into specified assortment dimensions. The branches and un-merchantable stem (top portion e.g. < 7 cm diameter over bark, defective stem sections, breakage, undersized trees, and any logs missed by the forwarder) are left behind. This material is termed as logging residues (Hakkila 1989). Machines have been developed to gather these residues off the forest floor, and compact them into cylindrical bales to make the process of forwarding, stacking, road haulage and storing more cost effective. These machines, called residue bundlers, are relatively new. They were developed commercially in Sweden in the late 1990s. The bales they produce are referred to as residue bundles, brash bales, or compact residue logs (CRL) (Spinelli and Magagnotti 2009). Two companies, Wood Pac and Fibrepac, began developing residue bundlers

[a] Waterford Institute of Technology, Cork Road, Waterford.
*Corresponding author: ecoates@wit.ie

around the same time, and both were still testing their prototypes as recently as 1998 (Andersson and Nordén). At this time, residue bundling was still considered as only a concept. By 2000 the method had been adopted, and both companies had started to export machines outside of Sweden. In 2002, Timberjack bought the product patents from Fibrepac, and shortly afterwards the Wood Pac patents were bought by Valmet (Karha and Vartiamaki 2006).

Currently, residue bundling systems are widespread in the Nordic countries. For example, residues were recovered on 41% of the clearfell area in Sweden in 2011 (79,097 ha of a total clearfell area of 192,000 ha) representing 1.9 TWh of energy (National Board of Forestry 2011). A prototype residue bundler was constructed in the mid 1990's in Ireland but was not commercialised (Hoyne and Thomas 2001). A European-wide review of residue harvesting in 2006 reported that no logging residues were being harvested in Ireland (Kuiper and Oldenburger 2006). Recently, a study of a residue bundling supply chain in Northern Ireland found that the system was a viable source of wood fuel, with a relatively low production cost (Forbes et al. 2014).

The potential volume of residues on a site depends on tree species, age, silvicultural treatment over the rotation, and the assortment specifications to be cut from the main stem during timber harvesting (Hakkila 1989). In particular, the specifications and demand for small-diameter logs that constitute the upper-most portion of the stem will have a large impact on the amount of material available for energy. Tree size is also an important factor that determines the volume of residues available. Although larger trees have more total biomass, the proportion of residual biomass to merchantable stem biomass changes with tree height (Levy et al. 2004). Therefore, it may be difficult to predict the residual biomass available on any site, and the amount of residue available may vary greatly between sites. In a recent study, an indicative figure of 25 oven dry tonnes (odt) per hectare were baled on six clearfellerd Sitka spruce (*Picea sitchensis* (Bong.) Carr.) sites in Ireland (Coates and Kent 2013). Bales were produced on an average of 58% of the clearfelled area, so the biomass removed was 42 odt ha^{-1} for the net area where bales were produced. Van den Broek et al. (2001) recognised that harvesting residues could constitute a substantial biomass resource in Ireland, estimating that residues from clearfell and thinning operations might provide an energy potential of 3.4 PJ (Lower Heating Value). This was based on 30% residue biomass per roundwood harvest for clearfells, 60% for thinning, 50% of the sites being suitable for residue harvesting, and 70% of the residues being recoverable on any site. However, these predictions may have been over estimated as residue harvesting is restricted mainly to clearfelled forest sites (Hakkila 1989). Phillips (2011) recently identified that 1,453,000 m^3 of forest biomass may be available in Ireland for the bioenergy market by 2020, but this supply falls short of demand, which is projected to reach 3,084,000 m^3 (CRDG 2011). However, Phillips' forecasts did not include logging residues. Phillips accounted for tree stem tops but not logging residues, so this resource could be used to partially fill the gap between supply and demand.

In terms of the supply chain productivity, a bundler can operate after standard harvesting and extraction of the roundwood products without any prior planning. However, bundler productivity and the quality of the fuel can be improved considerably if best practices are followed at the bundling and harvesting stage, which result in a reduction of soil contamination and drier logging residues (Vonk and Theunissen 2007).

The study was a collaboration between Waterford Institute of Technology (WIT) and Coillte, the Irish State forestry company. A previous trial conducted by Coillte and WIT satisfied the stakeholders that a residue bundling supply chain was technically and economically feasible in Ireland (Coates and Kent 2013). However, fuel contamination with soil and stones was identified as a barrier to using residues for energy, so the trial described in this paper was established. The objectives of the study were to determine if arranging the brash for bundling during timber harvesting would impact on the supply chain costs, quantity and quality of the fuel.

Materials and methods

The trial made use of a 45-year-old stand of Sitka spruce mixed with 5% grand fir (*Abies grandis* (Douglas ex D. Don) Lindl.) on a free-draining, mineral soil, with a 7 to 15° slope, located near Inistioge, Co. Kilkenny (52°28'10" N, 7°4'23" W; 230 m asl). The stand was divided into three treatment plots. The treatments used were as follows:

Figure 1: *Residue bundler working on the study site in Co. Kilkenny.*

- **Treatment A:** ***All Residues Driven upon (ARD)***. Logging residues were used as a brash mat for all timber harvester and forwarder machine passes (see Figure 2);
- **Treatment B:** ***Driving on Residues Reduced (DRR)*****.** Logging residues were used as a brash mat, but the forwarder only travelled on alternative extraction racks, the harvester travelled on all extraction racks (see Figure 3);
- **Treatment C:** ***No Residues Driven on (NRD)***. No residues were used as a brash mat; instead they were piled to the side of the racks (see Figure 4).

An inventory was carried out on each plot prior to harvesting operations. A portable GPS was used to estimate the treatment areas, and the stand descriptions were estimated from four 400 m^2 subplots per treatment area. The total site area was 3.7 ha, the average stocking was 623 trees ha^{-1}, the mean top height was 26 m, the quadratic mean DBH was 24 cm, the mean tree volume was 0.52 m^3, and the stand volume was 325 m^3 ha^{-1}. The treatment plots had the following characteristics: treatment ARD: 0.91 ha, 619 trees ha^{-1}, 0.58 m^3 $tree^{-1}$, treatment DRR: 1.58 ha, 569 trees ha^{-1}, 0.53 m^3 $tree^{-1}$, treatment NRD: 1.21 ha, 681 trees ha^{-1}, 0.45 m^3 $tree^{-1}$. The treatment plots were not identical in size, mainly due to practical constraints (e.g. shape of site).

Figure 2: *All Residues Driven upon (Treatment A). Logging residues were used as a brash mat for all timber harvester and forwarder machine passes.*

Figure 3: *Driving on Residues Reduced (Treatment B). Logging residues were used as a brash mat, but the forwarder only travelled on alternative extraction racks; the harvester travelled on all extraction racks.*

Figure 4: *No Residues Driven on. Residues were not used as a brash mat, instead were piled to the side of the racks.*

Harvesting was carried out in March 2011 with a Ponsse Beaver harvester. The roundwood products were brought to the roadside with a Timberjack 810D forwarder. The brash was left in situ on the ground for seven months (March – November 2011), and then a John Deere residue bundler fitted to a John Deere 1490 base machine bundled the residues on each of the plots. The bundles were forwarded to the roadside with a John Deere 1110 forwarder, and transported to Medite (Europe) Ltd., a medium density fibreboard MDF producer in Clonmel, Co. Tipperary using self-loading timber haulage trucks. At Medite a Jenz AZ 660 shredder fed by an agricultural tractor, fitted with a grapple bucket, shredded the bundles into hogfuel, which was then used as fuel in the boiler for the MDF production process. During the operations, a work study of the machines took place using Husky data loggers running the SIWORKS 3 software program (Kofman 1995). Mean roundwood assortment volumes were estimated from sample log measurements of mid-diameter and length, and calculated using Huber's formula, and used to quantify harvester and forwarder output, as per Spinelli et al. (2002). The residue bundler, bundle forwarding and shredder output was quantified as the number of bundles produced / forwarded / shredded per hour. The number of bundles and weight of bundles transported to Medite were also recorded over a weighbridge. Operation costs per production unit were calculated from the time and production studies and machine costs for the machines. The machine costs were estimated using the method of Miyata et al. (1980) and the COST model developed by COST Action FP0902 (Ackerman et al. 2014). Miyata's method has been used in many productivity studies (LeDoux and Huyler 2001, Behjou et al. 2009), and very recently by Magagnotti and Spinelli (2011). The COST model has been developed as a harmonisation of the procedures for forest engineering and economic machine cost analysis. The estimated machine costs are detailed in Table 1. The results are expressed per scheduled machine hour (SMH) and productive machine hour (PMH). The following values were used in the machine cost calculations: Salvage value was set at 13% for all machines. An interest rate of 10% was used. Insurance cost was calculated as 3% of the average annual investment. Machine engine power was sourced from manufacturer's specifications. A fuel cost of €0.88 l^{-1} was used for all machines. Fuel consumption was calculated as a function of engine size and engine loading, whereby a 25% engine load was used for all machines, except the shredder which was set at 50%. Lubrication cost was calculated as 15% of the fuel costs. The following consumables were included: brash bundler sawbar, chains and baling twine; harvester: saw bar and chains; shredder knives and hammers. The number of work days per year was assumed to be 250, with 1 ten-hour shift per day. Operator costs included benefits and operator insurance. An overhead cost of 5% was applied and a normal operating profit of 5% was used. Sources for the inputs are detailed in the footnotes of the Table 1.

The moisture content of the brash was determined at the time of timber harvesting, and again at the time of bundling. At the time of timber harvesting, one full forwarder load of brash was extracted from each treatment area. Each forwarder load was obtained by placing one grab of brash into the forwarder at 15 random intervals over the treatment area. The brash was unloaded at roadside into three separate piles. For each of these piles, the brash was progressively chipped using a TP200 disk chipper mounted on a double-axle trailer into 10 separate piles. Five samples of approximately 1 kg-size were taken from each of these piles to estimate moisture content. Moisture content was determined

Table 1: *Machine costs, based on productive machine hours (PMH) and scheduled machine hours (SMH), calculated for the harvesting, bundling, and shredding operations.*

Machine	**Brash bundler**	**Forwarder 1110E**	**Harvester**	**Forwarder 810E**	**Shredder**	**Loader**
Fixed costs						
Purchase price (€)	425,000 [a]	265,000 [a]	332,000 [b]	200,000	330,000 [c]	72,000 [d]
Salvage value (€)	55,250	34,450	43,160	26,000	42,900	9,360
Economic life (PMH)	18,000 [e]	18,000 [e]	18,000 [e]	18,000 [e]	7,000 [f]	18,000 [e]
Annual depreciation [g] (€)	36,153	22,543	27,681	17,013	72,185	6,125
Insurance cost [g] (€)	7,746	4,830	6,061	3,645	6,676	1,312
Machine power (kW)	134	135	129	95	375	74
Utilisation (%)	65	65	65	65	75	65
Total fixed costs (€ h^{-1})	**41.11**	**25.21**	**31.24**	**20.08**	**56.57**	**6.96**
Variable costs						
Fuel use [h] (L h^{-1}_{PMH})	10.40	10.40	10.00	7.40	58.13	5.80
Fuel cost (€ h^{-1})	9.13	9.18	8.80	6.48	51.15	5.07
Maintenance & repair [i] (%)	100	80	100	80	100	80
No. additional track sets	1	2	1	2	-	-
Cost per track set [f] (€)	5,500	5,500	5,500	5,500	-	-
Track set lifespan [f] (h^{-1}_{PMH})	18,000	6,000	18,000	6,000	-	-
Consumables (€ h^{-1}_{PMH})	21.00 [a]	-	1.30 [J]	-	24.06 [c]	-
Total variable costs (€ h^{-1})	**55.41**	**23.94**	**31.03**	**21.28**	**131.03**	**8.78**
Operator costs (€ h^{-1}_{PMH})	23.82	23.82	22.43	23.82	20.64	-
Total costs (€) per:						
PMH	**131.42**	**79.20**	**92.02**	**70.60**	**228.50**	**17.35**
SMH	**85.42**	**51.48**	**63.49**	**45.89**	**171.38**	**11.23**

Sources:
[a] O' Dwyer, W. O'Dwyer Timber Contractors Ltd, personal communication, February 19th 2014;
[b] Väätäinen et al. 2006;
[c] Colman, R. CTO Environmental Solutions Ltd, personal communication, February 18th 2014;
[d] Egan, D. Finning (UK & Ireland) Ltd, personal communication, January 28th 2014;
[e] Spinelli 2011;
[f] Horgan, J. Horgan Brothers Timber Extraction Ltd, personal communication, January 29th 2014;
[g] Miyata 1980;
[h] Ackerman 2014;
[i] Calculated as a percentage of the machine replacement value, after Ackerman 2014;
[J] Kärhä 2004.

using the oven-dry method at 105°C. These samples were then homogenised and reduced for determination of calorific value and content of ash, carbon, hydrogen, nitrogen, chlorine and sulphur. Calorific value was determined using a Parr 6300 oxygen bomb calorimeter under constant volume according to EN 14918: 2010. Ash content was determined using a muffle furnace according to EN 14775: 2010. Carbon, hydrogen, and nitrogen were determined using an elemental analyser according to EN 15104: 2010, and sulphur and chlorine using titration according to EN 15289: 2010.

At the time of bundling (seven months later), 20 bundles per treatment area were sampled for moisture content. The bundles were dissected with a chainsaw and three subsamples (approx. 1 kg each) per bundle were taken to determine the values for moisture content and the other parameters, following the same method as previously described.

Results

Cut-to-length roundwood harvesting

The time study results and productivity calculations for operating the harvester in the three treatment areas are detailed in Table 2. The time taken to process trees was examined across the three treatments; 192 trees in ARD, 457 in DRR and 235 in NRD. The harvester productivity was identical for treatments ARD and NRD, processing 41 trees per productive machine hour (hr^{-1}_{PMH}) but was faster under treatment DRR with 46 trees h^{-1}_{PMH}. Volume harvested per scheduled machine hour (hr^{-1}_{SMH}) was estimated as 14.2 m^3 h^{-1}_{SMH} under treatment NRD, 15 m^3 h^{-1}_{SMH} under treatment DRR and 15.8 m^3 h^{-1}_{SMH} under treatment ARD. Applying a machine cost of €63.49 h^{-1}_{SMH}, the harvester cost ranged from €4.02 per m^3 for ARD, €4.23 per m^3 for DRR and €4.47 per m^3 for NRD.

Roundwood forwarding

The time study results and productivity calculations for the forwarder operations on the three treatment areas can also be viewed in Table 2. The number of loads extracted per productive machine hour varied between treatments. An average of 3.1 loads h^{-1}_{PMH} were extracted from treatment ARD, whereas only 2.2 loads h^{-1}_{PMH} were extracted from DRR. The mean volume per load differed between treatments, with the average load volume of 7.7 m^3 under treatment ARD, and 10.3 m^3 under treatment NRD. Thus, even though extraction per load was faster under treatment ARD, a greater volume was carried per load under treatment NRD, resulting in similar hourly extraction costs of 17.9 m^3 h^{-1}_{SMH} and 19.3 m^3 h^{-1}_{SMH} respectively. Production was lower under treatment DRR, with 1.7 loads h^{-1}_{SMH} extracted and an average load volume of 8.1 m^3 resulting in 13.4 m^3 h^{-1}_{SMH} extracted. Using a machine cost of €45.89 h^{-1}_{SMH}, the timber forwarding costs under treatments ARD and NRD were €2.56 m^{-3} and €2.38 m^{-3}, respectively, whereas under treatment DRR, the forwarding costs were higher at €3.42 m^{-3}.

Residue bundling

A total of 589 bundles were produced during the study. Mean bundle dimensions were 0.65 m diameter and 2.45 m length. Table 2 also displays the productivity and cost of the bundler and forwarding operations under the three different conditions. The residue bundler produced 18 bundles h^{-1}_{SMH} under treatment ARD, 16 bundles h^{-1}_{SMH} for DRR and 22 bundles h^{-1}_{SMH} for NRD. The unit bundling cost was €4.75 under treatment ARD, €5.34 for DRR and lowest at €3.88 under NRD treatment conditions.

Bundle forwarding and road transportation

The forwarder extracted 43 bundles h^{-1}_{SMH} in treatment NRD, 47 bundles h^{-1}_{SMH} in treatment DRR and 56 bundles h^{-1}_{SMH} in NRD. Bundle forwarding cost was highest for treatment ARD at €1.20 per bundle, while the lowest at €0.92 per bundle was calculated for treatment NRD. In total, 560 bundles, amounting to 160.4 t were transported in seven self-loading rigid and trailer timber trucks into Medite, which equated to an average of 80 bundles per truck. There was some loss of bundles from the supply chain. A total of 22 bundles were not forwarded from treatment DRR, as some were deemed inaccessible by the forwarder operator due to slope and several were used under the forwarder to aid traction. Seven bundles from treatment NRD were left at the forest roadside and were not transported to the end-user.

Bundle shredding

The time study results of the residue bundle shredding are also detailed in Table 2. The mean number of bundles processed per scheduled machine hour was 79 bundles, with an estimated cost of €2.31 per bundle (using an estimated cost per scheduled machine hour of €182.61 for the shredder and a loader to feed the shredder).

Fuel quality

At the time of harvesting, treatment mean moisture content values differed by less than 2% (Table 3). The moisture content of the loose residues increased from 44% to 61% under treatment ARD, from 42% to 52% for DRR and from 42% to 46% for NRD. Ash content, expressed on a dry weight basis, increased in treatments ARD and NRD between harvesting and bundling (Table 6). Gross and net calorific values, expressed as the energy content on a dry-weight basis (GCV_{db} and NCV_{db}, respectively), remained relatively unchanged between harvesting and bundling, meaning that the energy potential due to the chemical composition did not change. Net calorific value, at the time of delivery, (NCV_{ar}) which is the term used to describe the energy content available accounting for the moisture content, reduced in all treatments between harvesting and bundling, as the moisture content increased in all treatments. The loss of useful energy content was greatest from the ARD treatment and least from NRD.

Table 2: *Productivity and cost results covering machine operations for harvesting and bundling across the three different treatments.*

	ARD treatment	DRR treatment	NRD treatment
Roundwood harvesting			
Total no. of trees	192	457	235
Harvesting rate (trees $h^{-1}{}_{SMH}$)	28	32	28
Harvesting cost (€ m^{-3})	4.02	4.23	4.47
Roundwood forwarding			
Total no. of loads	16	31	26
Average extraction distance (m)	127	166	152
Volume extracted (m^3 $h^{-1}{}_{SMH}$)	17.9	13.4	19.3
Extraction (€ m^{-3})	2.56	3.42	2.38
Roadside roundwood cost (€ m^{-3})	6.58	7.66	6.85
Residue bundling			
Total no. of bundles	74	270	230
Bundles ($h^{-1}{}_{SMH}$)	18	16	22
Cost per bundle (€)	4.75	5.34	3.88
Bundle forwarding			
Total no. of loads	6	7	10
Mean extraction distance (m)	193	197	138
Bundles ($h^{-1}{}_{SMH}$)	43	47	56
Forwarding cost per bundle (€)	1.20	1.10	0.92
Cost per bundle at roadside (€)	5.94	6.43	4.80
Bundle shredding			
Bundles ($h^{-1}{}_{SMH}$)	79	79	79
Shredding cost per bundle[a] (€)	2.31	2.31	2.31

[a] Shredding cost was an average for all treatments, n = 78 bundles.

The industry reference for woodfuels across Europe, the EN standards document EN ISO 17225-1: 2014, Solid biofuels – Fuel specifications and classes – Part 1: General requirements, published by the NSAI (2014), gives typical values for coniferous wood, sourced throughout Europe, including virgin harvesting residues. These values are displayed in the final column of Table 3 for comparison. The energy content delivered was highest under treatment NRD, which was estimated as 501 GJ ha^{-1} (Table 4). The lowest energy content was observed under treatment ARD, which was estimated at 240 GJ ha^{-1}.

Table 3: *Quality parameters of the residues were tested at time of harvesting and at time of bundling (seven months later). Mean values are presented with a standard deviation from the mean in brackets. Parameters were calculated on a dry-weight basis (db) where indicated. Typical values presented are taken from EN 14961-1: 2010, Solid biofuels – Fuel specifications and classes – Part 1: General requirements (NSAI 2014) and describe what can generally be expected of conifer logging residues in Europe.*

Treatment operation	ARD Harvest	ARD Bundling	DRR Harvest	DRR Bundling	NRD Harvest	NRD Bundling	Typical values
MC (%)	44.0 (3.7)	60.7 (8.2)	42.0 (2.3)	51.7 (10.1)	42.3 (4.9)	45.8 (9.1)	<10->55
% ash (db)	3.7 (2.0)	6.5 (2.6)	3.2 (1.3)	3.2 (0.5)	2.9 (1.8)	5.8 (2.7)	<1-10
% C (db)	52.7	50.4	52.3	51.1	53.6	50.7	48-52
% H (db)	5.14	4.74	5.31	4.65	4.98	4.81	5.7-6.2
% N (db)	0.98	0.86	0.58	0.47	1.02	0.64	0.3-0.8
% S (db)	<0.1	0.0	<0.1	<0.1	0.0	<0.1	0.02-0.06
% Cl (db)	0.03	0.02	0.03	0.01	0.04	0.01	<0.01-0.04
GCV_{db} (MJ kg^{-1})	21.0 (0.2)	20.1 (0.1)	20.8 (0.2)	20.8 (0.2)	20.8 (0.3)	20.8 (0.7)	19.5-21.5
NCV_{db} (MJ kg^{-1})[a]	19.8	19.0	19.6	19.7	19.7	19.8	18.5-20.5
NCV_{ar} (MJ kg^{-1})[a]	10.0	6.0	10.4	8.4	10.3	9.6	-

[a] *NCV_{db} and NCV_{ar} are calculated according to EN 14918. An oxygen value of 40% db for logging residues was used for the calculations, as per ISO 17225-1. NCV_{ar} used the MC% observed in the field to estimate the net energy value at field MC%.*

Table 4: *Energy content per hectare from residue bundles as delivered by the fuel from across the three treatments.*

	ARD treatment total	ARD treatment ha^{-1}	DRR treatment total	DRR treatment ha^{-1}	NRD treatment total	NRD treatment ha^{-1}
No. bundles	108	119	207	131	245	202
Delivered weight (t)	36.4	40.0	60.7	38.4	63.2	52.2
Dry matter weight (odt)	15.5	17.0	30.5	19.3	34.8	28.7
Delivered energy (GJ)	218	240	502	318	606	501
Energy per bundle (MWh)	**0.56**		**0.67**		**0.69**	

Discussion

The treatments represented scenarios with different levels of preparation for bundling. Brash that was driven over, particularly with multiple passes by the forwarder, may become contaminated with soil and stones that can cause wear and damage to the bundler and chipper/shredder. The driven-on brash may also become compacted and sodden if allowed to stand in water, perhaps delaying needle shedding. Soil and stone contamination of delivered fuel will increase the ash content of the fuel, reducing energy output and increasing ash disposal and boiler maintenance costs. The higher moisture content of the wood from the ARD treatment (60.7%), than in DRR (51.7%) and NRD (45.8%) treatments, suggests that the preparation of the brash facilitated drying of the bundles to a lower moisture content. This was most likely due to less brash being compacted in treatment DRR, and in treatment NRD being loosely piled to facilitate drying. It must be also noted that even though the moisture content may rise during the seasoning period, seasoning is still necessary, as green needles should be allowed to desiccate and fall off as they are not appropriate boiler fuel.

As expected, ash content after roundwood harvesting was highest from treatment ARD due to soil and stone contamination in residues. Values were lowest in treatment NRD, where residues were not driven on. Ash content increased after bundling, suggesting that soil contamination occurred during bundling as a result of the gathering of loose residues in the grapple.

The results of this study suggest that fuel characteristics of Irish logging residues are comparable to the European normal standard for conifer logging residues. The ash values observed in the study ranged from 3.2% to 6.5%, which is higher than the normative values of 1 to 4%. Hydrogen values were slightly lower than the normative of 5.7 to 6.2% at both harvesting and bundling. All the sulphur values were low, so much so that there was difficulty in detecting them, consequently a result of <0.1 is presented for values in this study. Chlorine content is an important component of woodfuel to evaluate, as high chlorine content corrodes boilers during combustion at temperatures above 480 °C (Alakangas 2005). The normative figures for chlorine in Europe are given as between <0.01 to 0.04%, corresponding to values tested here. In Finland, the energy content of a residue bundle is approximately 1 MWh (Laitila 2005). In this study it was found that the energy content per bundle was in the region of 0.6 – 0.7 MWh. In Finland, bundles are produced to a length of 3 m, whereas in this study the bundles were made to approximately 2.5 m in length, in order to maintain the structural integrity of the bundles (longer bundles fell apart). The reason the 3 m-length bundles are practical in Finland may be related to a larger top diameter specification for pulp logs (8 cm), which allows longer lengths of roundwood to be included in the bundles providing greater stiffness and rigidity.

The forwarder cost under treatment DRR was high due to the reduction in space for stacking the logs along the extraction racks. In this treatment, the logs were stacked only on alternate extraction racks, so less space was available for machine movement. This caused the assortments to be stacked less precisely, so the forwarder had to spend more time sorting logs while loading.

Unfortunately, because of budget and logistic limitations, the trial could not be replicated on more sites. For this reason, site interaction effects could not be controlled, which meant an in-depth statistical analysis could not be carried out. Nevertheless, the results of the inventory carried out prior to treatment indicated that tree volume and other tree characteristics differed little between plots, suggesting that within site variation was unlikely to have confounded the results. The plots were located adjacent to one another so that the plot characteristics were as similar as possible. There are also other considerations to residue harvesting which were outside the scope of the trial, such as impacts on soil structure due to the non-use of a brash mat under treatment NRD, as well as the potential nutrient loss resulting from the removal of the brash. The UK forest standards (UKFS) (Forestry Commission 2011) recommend that the harvesting of forest residues should be avoided on soils that are at risk of increased soil and water acidification. The UKFS also identifies that the removal of brash could potentially contribute to a reduction of the net fertility of a site, especially on sites with naturally low fertility and with shallow soils subject to high rainfall. The UKFS recommend that a risk assessment prior to residue harvesting on a site is needed to insure that long-term fertility is not compromised. For these reasons, residue harvesting will not be suitable at all forest sites. The impacts of residue harvesting and the criteria for site selection will be topics for future research.

Conclusions

Preparation of brash where suitable, by minimising its use as a brash mat, significantly improved the quality of the bundles. The quality parameters of the fuel all fell within the European normative figures. Seventeen odt ha^{-1} were recovered from the treatment with no brash preparation. Over 60% more, 28 odt ha^{-1}, was recovered from the treatment where all brash had been piled to one side, and no machines had driven on the brash. The brash that was not driven over also had a lower moisture content which resulted in a higher energy content: 9.59 MJ kg^{-1} in comparison to 5.99 MJ kg^{-1} for the brash recovered without any preparation. This resulted in a delivered energy content of 501 GJ ha^{-1} where all the brash had been prepared, compared to 240 GJ ha^{-1} in the treatment without any preparation. The cost of roundwood production (at forest roadside) varied between treatments, from €6.58 m^{-3} to €7.66 m^{-3}. The main cause of higher roundwood harvesting costs in treatments where the residues were partially driven over was the additional time the forwarder spent loading. The bundler productivity was higher (34 bundles $h^{-1}{}_{SMH}$) on the treatment where all the brash had been prepared, where as a result the cost of production was lower. The cost of bundling and bundle forwarding was €4.80 per bundle under this treatment, compared to €5.94 where no preparation was involved.

Acknowledgements

This work was carried out as part of the Forest Energy 2010 – 2014 Research Programme and was funded by the Department of Agriculture, Food and Fisheries Competitive Forest Research and Development Programme, supported under the

National Development Plan 2007-2013. The work was carried out in collaboration with Coillte and Medite.

References

Ackerman, P., Belbo, H., Eliasson, L., De Jong, A., Lazdins, A. and Lyons, J. 2014. The COST model for calculation of forest operations costs. *International Journal of Forest Engineering* 25: 75-81.

Alakangas, E. 2005. *Properties of Wood Fuels Used in Finland-Biosouth Project*. VTT Processes, Technical Research Centre of Finland. Jyvaskyla. pp 58.

Asikainen, A. 2001. Design of supply chains for forest fuels. *Supply Chain Management for Paper and Timber Industry*. pp 90-179.

Andersson, G. and Nordén, B. 1998. Composite residue logs: a new concept in bioenergy fuel. *Skogsforsk News*.

Behjou, F.K., Majnounian, B., Dvorak, J., Namiranian, M., Saeed, A. and Feghhi, J. 2009. Productivity and cost of manual felling with a chainsaw in Caspian forests. *Journal of Forest Science* 55: 96-100.

Brinker, R.W., Miller, D., Stokes, B.J. and Lanford, B.J. 2002. *Machine Rates for Selected Forest Harvesting Machines*. Circular-Alabama Agricultural Experiment Station (USA).

Coates, E. and Kent, T. 2013. Biomass estimates for mobilising wood for energy using compact residue logs on harvested conifer plantations in Ireland. *Proceedings of BIOENERGY 2013 – A Boost for Entire Industry*. Jyvaskyla, Finland.

CRDG: Coford Roundwood Demand Group (2011) *All Ireland Roundwood Demand Forecast 2011-2020,* Dublin, Ireland, COFORD.

Forbes, E.G.A., Easson, D.L., Fairgrieve, M., Wilson, B.P. and Love, R.J. 2014. Brash bale production on a clear-felled farm forest and comminution of bales to a biomass energy fuel. *Biomass and Bioenergy* 64: 124-132.

Forestry Comission 2011. *UK Forestry Standard Guidelines*. Forestry Commission, Edinburgh.

Hakkila, P. 1989. *Utilization of Residual Forest Biomass*. 1st Ed. Springer Verlag, Helsinki, Finland.

Hoyne, S. and Thomas, A. 2001. *Forest residues: Harvesting, Storage and Fuel Value*. COFORD, Dublin, Ireland.

Johansson, J., Liss, J.E., Gullberg, T. and Bjorheden, R. 2006. Transport and handling of forest energy bundles – advantages and problems. *Biomass and Bioenergy* 30: 334-341.

Kärhä, K., Rönkkö, E. and Gums, S.I. 2004. Productivity and cutting costs of thinning harvesters. *International Journal of Forest Engineering* 15: 43-56.

Kofman, P. 1995. *Siwork 3: User Guide*. Danish Forest and Landscape Research Institute, Vejle, Denmark.

Laitila, J. Cost structure of supply chains in Finland. *Northern Woodheat Symposium 2005*. June 5th – 9th, Joensuu, Finland.

Ledoux, C. and Huyler, N.K. 2001. Comparison of two cut-to-length harvesting systems operating in eastern hardwoods. *International Journal of Forest Engineering* 12: 53-59.

Lehtikangas, P. and Jirjis, R. 1997. Storage of logging residues in bales. *Proceedings of the International Conference Biomass for Energy and Industry*. Wurzburg, June 1997. pp 1013–5.

Levy, P.E., Hale, S.E. and Nicoll, B.C. 2004 Biomass expansion factors and root: shoot ratios for coniferous tree species in Great Britain. *Forestry* 77: 421-430.

Liska, S., Klvac, R. and Skoupy, A. 2011. Evaluation of John Deere 1490D operation phase in typical conditions of the Czech Republic. *Journal of Forest Science* 57: 394-400.

Magagnotti, N. and Spinelli, R. 2011. Integrating Animal and Mechanical Operations in Protected Areas. *Croatian Journal of Forest Engineering* 32: 489-499.

Miyata, E. 1980. *Determining Fixed and Operating Costs of Logging Equipment*. North Central Forest Experiment Station, Forest Service, US Dept. of Agriculture.

Murphy, G. 2009. *Irish Logging Productivity and Costing Model*. (Version 1.10) [Computer software].

National Board of Forestry. 2008. *Statistical Yearbook of Forestry 2008*. Jönköping, Sweden.

NSAI. 2014. *EN ISO 17225-1: 2014, Solid biofuels – Fuel specifications and classes – Part 1: General requirements*.

Phillips, H. 2011. *All Ireland Roundwood Production Forecast 2011-2028*. COFORD, Department of Agriculture Fisheries and Food, *Dublin*.

Rummer, B., Len, D. and O'Brien, O. 2004. *New Technology for Residue Removal*. Forest operations research unit, Auburn, Alabama.

Spinelli, R., Owende, P.M. and Ward, S.M. 2002. Productivity and cost of CTL harvesting of *Eucalyptus globulus* stands using excavator-based harvesters. *Forest Products Journal* 52: 67-77.

Spinelli, R. 2011. *Supply of Wood Biomass for Energy Purpose: Global Trends and Perspectives*. Italy.

Spinelli, R. and Magagnotti, N. 2009. Logging residue bundling at the roadside in mountain operations. *Scandinavian Journal of Forest Research* 24: 173-181.

Spinelli, R., Magagnotti, N. and Picchi, G. 2011 Annual use, economic life and residual value of cut-to-length harvesting machines. *Journal of Forest Economics* 17: 378-387.

Spinelli, R., Magagnotti, N. and Picchi, G. 2012. A supply chain evaluation of slash bundling under conditions of mountain forestry. *Biomass and Bioenergy* 36: 339-345.

Steele, P., Mitchell, B., Cooper, J. and Arora, S. 2008. Bundled slash: a potential new biomass source for fuels and chemicals. *Applied Biochemistry and Biotechnology* 148: 1-13.

Väätäinen, K., Liiri, H. and Röser, D. 2006. Cost-competitiveness of harwarders in CTL-logging conditions in Finland — a discrete-event simulation study at the contractor level. In *Precision Forestry in Plantations, Semi-natural and Natural Forests*. Eds. Ackerman, P., Längin, D. and Antonides, M., Proceedings of the International Precision Forestry Symposium, Stellenbosch University, Stellenbosch, South Africa. pp 451–463.

Van den Broek, R.,Teeuwisse, S., Healion, K., Kent, T., Wijk, A van., Faaij, A. and Turkenburg, W. 2001. Potentials for electricity production from wood in Ireland. *Energy* 26: 991-1013.

Vonk, M. and Theunissen, M. 2007. *Harvest of logging residues in the Dutch forest and landscape*. Biomassa-upstream stuurgroep. Wageningen Netherlands.

The role of subsidy payments in the uptake of forestry by the typical cattle farmer in Ireland from 1984 to 2012

Mary Ryan[a*], Michele McCormack[a], Cathal O'Donoghue[a] and Vincent Upton[a]

Abstract
Since the 1980's, forestry has been growing as a land use in Ireland due largely to financial incentives offered to farmers to convert land from agriculture to forestry. Cattle farmers are the group that may financially benefit most from planting and have been found to be more interested in establishing forests. This makes cattle systems the most relevant alternative land use to compare with forestry. Previous examinations of afforestation trends have recognised the importance of competing subsidies on understanding the relatively low uptake of forestry supports but no detailed examination of this issue has been undertaken to date. The primary goal of this study was to review, quantify and compare annual cattle and forestry subsidies for a typical farm over the period 1984 to 2012. Eligibility and payment changes were examined for both forestry and agricultural subsidies over this period and form the basis of a subsidy model. The relative effect of forestry and agricultural subsidies on income is modelled for a "typical" farm using a hypothetical model, which facilitates direct comparison on an area basis. The results show that the loss of agricultural supports could have been substantial for a typical cattle farm for most of the period examined. This novel finding may assist in understanding afforestation rates to date.

Keywords: *Farmer afforestation, cattle subsidies, direct payments.*

Introduction

While the first afforestation incentives were introduced by the Irish government in 1922 it was not until the 1980's that there was an appreciable increase in planting on private land. Prior to this, landowners were unfamiliar with forestry and deterrents included "the competition for the scarce land resource, small farm size and the uncertainty around the long-term nature of forestry" (Gillmor 1992). However from the 1980's onwards, developments in national and EU forest policies incentivised farmer planting, leading to an increase from 100,774 ha in 1981 to 360,834 ha of privately owned forests by 2012 (Forest Service 2013). Over this period, the afforestation programme in Ireland changed from being almost exclusively carried out by professional foresters in the State sector on public land to being carried out by new types of forest owners. Initially planting on private land was undertaken largely by forest contracting companies and investment institutions however farm afforestation grew quickly and the majority of private planting is now undertaken by farmers (Forest Service 2013). Figure 1

[a] Rural Economy and Development Programme, Teagasc, Athenry, Co. Galway.
[*] Corresponding author: mary.ryan@teagasc.ie

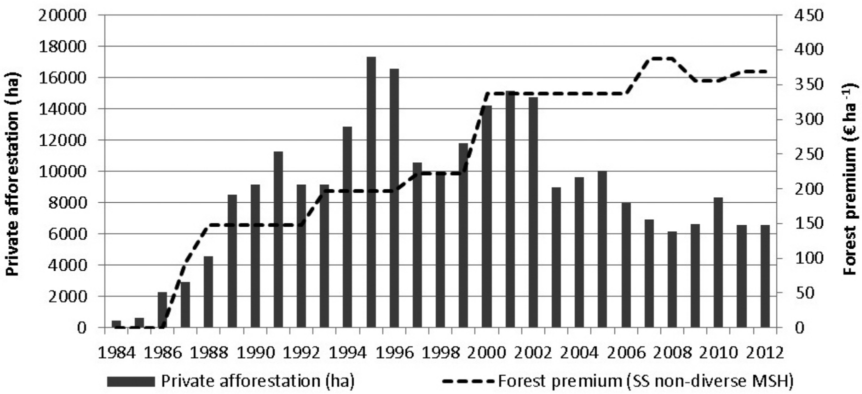


Figure 1: *Annual private afforestation (ha) and forest premium payments (€ ha^{-1}) for Sitka spruce non-diverse conifer plantations from 1984 to 2012. Source: Forest Service (2013).*

shows the slow rate of growth in annual private afforestation in the 1980's with an almost exponential growth in the early 1990's, before slowing down again from 2000 onwards. The recent decline has generated much interest as it occurred against the back-drop of a series of increases in forestry subsidies[1]. This seemingly contradictory trend has prompted a number of Irish studies that have examined the factors that led to the decline in annual private afforestation.

Previous studies

The attitudes and behaviours of landowners in relation to forestry are analysed in surveys conducted by Kelleher (1986) and Ní Dhubháin and Gardiner (1994), finding that the vast majority of farmers would only consider planting land that is "good for nothing else". Frawley (1998) reasons that, although farmers have economic goals when considering forestry, strong beliefs about the appropriate use of farmland can act as a barrier to afforestation. A recent study by Duesberg et al. (2013) suggests that this is still the case: while farmers in the study would plant marginal land, they would be opposed to planting "good" land that could be used for food production.

From an economic perspective, McKillop and Kula (1988) and McCarthy et al. (2003) found that the profitability of agriculture and forestry were significant factors in determining afforestation rates. In an analysis of farm forestry versus other farm enterprises, Behan (2002) finds that the uptake of afforestation lagged behind what would be expected on the basis of the relative economic returns between agriculture and forestry, but noted that "the long term and irreversible nature of the afforestation decision make it difficult to compare forestry returns with annual agricultural returns". To compare like-with-like, Breen et al. (2010) included agricultural income foregone

[1] Establishment grant and annual premium payments.

as an opportunity cost for each year of the forestry rotation in modelling forestry returns and showed that forestry was most financially attractive on cattle farms. This concurs with Teagasc National Farm Survey (NFS[2]) survey data which showed that of the farmers who intended to plant, almost 50% were livestock farmers (cattle rearing and cattle other systems) on relatively large farms (Ryan et al. 2008). Upton et al. (2013) also examined the net returns to forestry taking account of the opportunity cost of lost agricultural market margin across different soil types over the period 1995-2009. Again cattle enterprises were found to benefit most financially from converting to forestry and forestry also appeared to have become more competitive over time. However, the authors noted that due to data limitations the loss of all available agricultural subsidies was not included in their calculations.

Although standard economic measures examine profitability over a full rotation, the role of subsidies has been recognised as central to understanding afforestation rates. While reporting on a drop in annual planting in 1992, duQuesne Ltd. (1993) concluded that the gains from increased forestry subsidies were eroded by the availability of animal subsidies, which encouraged farmers to increase their stock numbers. Collier et al. (2002) found that the majority of farmers retained their land in agriculture to avail of agricultural subsidies, particularly since the reform of the Common Agricultural Policy (CAP) in 1992. McCarthy et al. (2003) reported that the rate of afforestation was sensitive to both forestry and agricultural subsidies, particularly to the Rural Environment Protection Scheme (REPS), which was introduced in 1994. The duQuesne (1993) report also noted that the value of the final timber crop was not often taken into account in the afforestation decision-making process and that "changes (or even anticipated changes) in subsidies have an immediate and demonstrable effect on the uptake of the forestry support measures". It is evident from NFS annual reports that the reliance of farmers on agricultural subsidies has increased significantly since the early 1990's particularly in the cattle rearing (suckler cow) system where subsidies can comprise a larger proportion of farm income than that achieved from the marketplace (Connolly et al. 2009). These studies point to the fact that short-term subsidy payments are very important to farmers and may be a greater influencing factor in the afforestation decision than the longer-term market returns. Despite their importance, a detailed modelling of the loss of agricultural subsidies once land is afforested has not been previously undertaken. This may be due to the significant complexity of agricultural subsidy payments.

This paper describes a longitudinal comparison of forestry and cattle subsidies over the period 1984 to 2012. The first section describes the development of forestry and agricultural policies with particular emphasis on annual payments and eligibility in the pre and post CAP reform periods. The development of a subsidies model, which

[2] Appendix 1 contains a list of the abbreviations used in this paper.

accounts for the requirements and restrictions of subsidy payments, is then outlined. Employing this model, annual forestry and cattle subsidies are calculated and compared utilising a hypothetical "typical" farm framework, which allows for the isolation of the cattle and forestry subsidies available to a cattle farmer in each year of the period. The results are discussed in relation to afforestation targets and evolving forestry policy.

Forestry and agricultural policies and subsidies: pre CAP reform

The purpose of this section is to describe the changing policy context in relation to both forestry and agriculture over time, with particular reference to eligibility restrictions for cattle subsidies in relation to animal stocking rates and Less Favoured Areas (LFA), which are the parameters most likely to have an impact on the relativity of forestry and agricultural payments. A summary of forestry (conifer and broadleaf) and cattle payments is presented in Table 1.

Less Favoured Area (Disadvantaged Area) payments for agricultural land

The origin of Ireland's current agriculture schemes and payments dates back to accession to the EEC in 1973. The Less Favoured Areas payment was introduced in 1975 in the form of headage payments (payments per head of livestock). This was the first direct payment scheme, the main objective being farm income support in "disadvantaged" or "handicapped" areas to halt the depopulation of rural areas. These LFAs were classified as More Severely Handicapped (MSH), Less Severely Handicapped (LSH) or Mountain Grazing. When first introduced in 1975, 58% of agricultural land was classified as LFA. Subsequent revisions increased the area designated as MSH and LSH to 75%, leaving just 25% of farmland in the non-LFA category (DAFM 2013). Payments were allocated on the basis of the number of eligible livestock units (LU) in the herd with the highest payments available in MSH areas.

Western Package Scheme for Forestry

The 10-year Programme for Western Development was introduced in April 1981 with the aim of promoting forestry in the 12 western counties. The programme which became known as the "Western Package" was later made available to land-owners in LFA's in all counties. A grant of up to £800 ha^{-1} (€3,033 in 2013 Euro value)[3] was available to cover 85% of establishment costs for farmers and 70% for non-farmers. This led to a new phenomenon in Irish afforestation. Co-operatives, pension funds and private investors who were not deterred by the up-front cost, began to buy and afforest land in areas where agricultural productivity was marginal but forest productivity was high. In the first six years of the Western Package scheme, almost 6,500 ha were grant-aided in western counties (Forest Service 2013). Concurrent with the Western

[3] For ease of comparison across time, forestry and agricultural subsidy values are also presented in brackets in 2013 Euro equivalents using the Consumer Price Index (CPI).

Table 1: *Summary of historic conifer (Sitka spruce) and broadleaf (ash) forest premium payments alongside agricultural payments and subsidies*[a].

Year	Forestry		Agriculture	
	Scheme	**Forest premium (farmer)**	**Scheme**	**Subsidy payments**
1931	State scheme, all eligible			
1975			Disadvantaged Area Payments	Headage (payment per head of cattle)
1981	Western Package Grant Farmers: 85% Others: 70%		More Severely Handicapped (MSH) area payments:	8 or less cattle: £32 per head (€121) 9-30 cattle: £28 per head (€106)
1987	Farm Forestry Scheme-max £24,000 per farm	Forestry headage: £74 ha^{-1} (€177) 15 yrs		Max headage payments (livestock + forestry): £3,762 yr^{-1}
1989	OPF/Forest Premium scheme Max: £6,000	£116 ha^{-1} (€261) Conifer (Con) (15 yrs) Broadleaf (20 yrs)		Off-farm income threshold for forestry and agricultural subsidies: £11,000 yr^{-1}
1992	Revised scheme	As above + £50 ha^{-1} (€102) – part-time		Off-farm income threshold increased to £13,900 yr^{-1}
1993	Afforestation Grant & Premium Scheme Grant: 100% Premium: 20 yrs	Con non-diverse (MSH)[b]: £155 ha^{-1} (€313) 75-100% ash (non-LFA)[c]: £300 ha^{-1} (€606)	CAP Reform Suckler cow : Beef 10 month: Beef 22 month: Extensification: Slaughter premium:	 £79 per head (€159) £53 per head (€107) £53 per head (€107) £26 per head (€53) £53 per steer (€107)
1994			Rural Environment Protection Scheme (REPS)	1-20 ha: £120 ha^{-1} (€236)

1998	Revised CAP scheme 13.5% increase	Con n/d (MSH): £175 ha^{-1} (€318) Ash (100%) (non-LFA): £315 ha^{-1} (€572)		
2000	Rural Development Programme, no LFA supplement	Con n/d: €336 (€450) ha^{-1} Ash: €442 (€592) ha^{-1}		
2001			Disadvantaged Area Scheme (DAS)	Area based compensatory allowances
2005			Single Farm Payment	Average of payments for 2000/2001/2002
2007	FEPS (if in REPS) 15% premium increase	€150 - €200 ha^{-1} (€155 - €206) for 5 yrs Con n/d: €387 ha^{-1} (€399) Ash: €508 ha^{-1} (€523)		
2008			Suckler Cow Welfare (SCW)	€80 (€79) per cow
2009	8% reduction	Con n/d: €356 ha^{-1} (€370) Ash: €467 ha^{-1} (€486)	REPS 4	1-20 ha: €234 (€243) ha^{-1}
2011	New planting only	Con n/d: €369 ha^{-1} (€376) Ash: €481 ha^{-1} (€491)		

[a] Amounts in brackets represent 2013 Euro values relevant to the year in question (converted using the consumer price index).
[b] Premium payment for new planting comprised of "non-diverse" (n/d) conifer (con) (i.e. Sitka spruce) in MSH areas.
[c] Premium payment for new planting comprised of minimum 75% ash in non-LFAs.

Package scheme, a State scheme initiated in 1931 continued to be available to farmers and non-farmers. However, the lower grants led to little uptake of this scheme, which was followed by the part EU-funded Farm Forestry Scheme in 1987, under which planting grants were increased.

Forestry Headage

A promotional campaign was launched in 1985 to increase awareness of forestry, which was followed by the introduction of the Farm Compensatory Allowances (headage) Scheme in 1987, which allowed farmers and farmer Co-ops in receipt of livestock headage payments in Less Favoured Areas to claim a forestry headage payment of £74.13 (€177) ha^{-1} for 15 years after planting. This partially addressed the loss of agricultural income for the initial period of forest development and made forestry more attractive, however forestry headage was conditional on a reduction in stock numbers and this may have acted as a disincentive for intensive farmers.

Operational Programme for Forestry

In 1988, Power et al. reported that family farm income was less than £5,000 on two-thirds of farms reflecting government concerns around the preservation of the family farm (Government of Ireland 1991). With this in mind, the Operational Programme for Forestry (OPF) launched in 1989 under the National Development Plan, continued to favour planting by farmers who could claim 85% of costs, (non-farmers could claim 70%), but the up-front cost may still have been a disincentive. The OPF further incentivised farmer afforestation by introducing a Forest Premium Scheme to compensate farmers for loss of agricultural income with annual payments ranging from £50 (€102) ha^{-1} for conifers up to £116 (€261) ha^{-1} for broadleaves (although the first premium was not paid until the first anniversary of planting). This scheme included a stipulation that off-farm income could not exceed £11,000 per annum, precluding households from availing of premiums if the spouse's income was above this threshold. Nevertheless, a major shift in planting from the public to the private sector occurred in response to the introduction of this scheme. By 1989, the level of private planting exceeded State planting for the first time (Forest Service 2013).

Revised Scheme

In advance of the 1992 CAP reforms, speculation that payments would be increased and eligibility relaxed led to a decline in the number of grant applications. Under a revised scheme announced in 1992, grant payments were increased and the off-farm income limit was increased to £13,900. For the first time, part-time farmers or farmers with off-farm income (above the threshold) could avail of a forestry premium, albeit at a lower rate.

The reform of the Common Agricultural Policy

In the previous decade, agriculture had undergone major change but the reform of the CAP promised even more change for Irish farmers and speculation continued concerning the impacts of CAP reform on the afforestation programme. Under the MacSharry Reform of the CAP, which was agreed in May 1992, prices and market supports for beef were significantly reduced. However increased direct payments were made available to beef farmers on the basis of stocking rate reductions. Farmers in LFA's could avail of these new payments while also continuing to avail of the LFA payments. Extensification payments were available to farmers with a livestock density below 1.4 LU[4] ha^{-1}. In 1993, O'Connor and Kearney estimated that 71% of the grassland area of the state was stocked at less than the threshold stocking rate of 1.4 LU ha^{-1}. This meant that many farmers had the option to increase stocking to 1.4 LU ha^{-1} to maximise their payments rather than afforest surplus areas.

Review of the uptake of afforestation

In advance of the implementation of the new afforestation scheme under the MacSharry CAP reforms, the Forest Service commissioned an evaluation of the forestry measures in Ireland in effecting change in land-use from agriculture to forestry between 1981 and the end of 1992. The evaluation reported the "almost exponential increase" of a net extra 90,000 ha of agricultural land (predominantly cattle and sheep grazing) that had been afforested (duQuesne Ltd. 1993). However, the report concluded that the positive impact of the forestry measures was being eroded by the availability of CAP and related support measures for conventional agricultural enterprises, particularly headage payments. The duQuesne report includes a recommendation that the premium payment should be increased considerably to make it competitive with agricultural payments. While the afforestation rate had increased year-on-year, the total area of 33,500 ha planted under the OPF had fallen well short of the target of 77,500 ha (Government of Ireland 1991), although the 1920's government target of one million acres (404,686 ha) of forest cover was finally reached in 1993.

Forestry and agricultural policies and subsidies: post-CAP reform

In May 1994, the Afforestation Grant Scheme and Forest Premium Scheme were introduced under Council Regulation 2080/92, but eligibility for payment under this scheme was back-dated to include new forests planted from 1993 onwards. Both grant and premium payments were significantly increased and for the first time, this scheme provided a grant to cover 100% of the forest establishment costs (within limits). Differential forest premium payments were introduced for LFA designations, i.e. higher forest premium payments were available for planting more productive land in

[4] Eligible LUs: Adult bovines over two years (except dairy cows) represent 1.0 LU; dairy cows, 0.8 LU; other bovines 6-24 months, 0.6 LU.

non-LFA areas (£220 (€444) ha^{-1}) for non-diverse conifers, while the lowest payments were available on less productive MSH areas (£155 (€313) ha^{-1}). Eligibility criteria for farmers availing of these higher premium payments also became more restrictive. However the premium increases, the 20-year payment time-frame, the tax-free status of the payments and the lack of up-front cost to the farmer, all contributed to a dramatic increase in annual private afforestation, which peaked at 17,343 ha in 1995.

Rural Environmental Protection Scheme (REPS)

On the agricultural front, REPS was launched in 1994. The scheme provided supplementary income for farmers for a period of five years in return for undertaking environmental measures. The REPS scheme was of huge importance to rural Ireland and peaked with over 60,000 farmer participants, with average annual payments of approximately €5,000 (DAFM 2014a). However, it was not possible to avail of REPS and forestry payments on the same land and this acted as a disincentive to afforestation for many farmers (McCarthy et al. 2003). Similarly, participation in the Early Retirement Scheme (ERS) precluded farmers from availing of afforestation premiums as retired farmers were no longer allowed to undertake farming activity and were thus not eligible for the farmer rate of premium for new planting.

National Forestry Forum

In 1996, a forum of forestry stakeholders was convened to make recommendations to Government on the future direction for the sector. The report of the forum identified the forest premium payment as the most significant factor affecting the rate of farm afforestation, with the caveat that the uptake is “dependent on the agricultural subsidies and market prices available to farmers” (National Farm Forestry Forum 1996). The forum also recommended the development of a strategy for the sector, which would take on board the increase in afforestation by farmers.

A Strategic Plan for Forestry

This led to the publication of “Growing for the Future” (DAFF 1996), a Government strategy for the development of the forestry sector in Ireland. The afforestation strategy set a target to increase forest cover from 6% to 17% of the land area by 2030 in order to reach a scale of timber production large enough to support the growing timber-processing sector. The strategy aimed to increase afforestation to 25,000 ha per annum until 2000 and 20,000 ha per annum from 2001 to 2030. At the time, these ambitious targets did not seem implausible as annual private afforestation had reached a peak of 17,343 ha in 1995 and only dropped marginally in 1996. However, annual private afforestation had dropped to just over 10,000 ha by 1997.

To encourage additional afforestation, a 13.5% increase across all categories of forestry subsidies was announced in late 1997. The farmer rate of premium then ranged from £175 (€318) ha^{-1} for non-diverse conifers in MSH areas to £340 (€617) ha^{-1} for broadleaf forests in non-LFA's. For the first time, the issue of the small scale of farm forests was addressed by applying supplementary payments on forests over 6 and 12 ha respectively.

From October 1998 onwards, the premium was paid in the year of planting and in the spring of each year thereafter. This was a positive development, as previously, farmers didn't receive the first premium payment on planted land until the end of the first year. The next change in forestry payments was introduced for the 2000 planting season with grant rates increasing to a single rate of premium regardless of LFA category. The largest increases were applied to MSH land, which increased by £90 (€163) ha^{-1} whereas non-LFA payments increased by £15 (€27) ha^{-1}. Additionally, all land afforested since January 1993 was eligible for the new increased rates of payment. Annual private afforestation increased to 15,147 ha in 2002 before dropping back to 8,969 ha by 2003.

Decoupled payments

In a further reform of CAP, LFA payments were decoupled from production in 2001, and were replaced by a flat rate per hectare, known as area-based compensatory allowances. The distinction between MSH and LSH was continued and the highest Disadvantaged Area Scheme (DAS) payment was available in MSH areas. The Single Farm Payment (SFP) was introduced in 2005 to further decouple agricultural payments from production and was based on the average historic livestock payments and the average land area farmed in the years 2000, 2001 and 2002. Eligibility for payment is contingent on maintaining the land in "good agricultural and environmental condition" but does not require the farmer to continue to carry livestock. The average SFP for cattle farmers since 2005 was approximately €315 ha^{-1} (DAFM 2014a). While the SFP was not payable on afforested land, it was possible to plant up to 50% of the farm holding and "consolidate" the Single Payment onto the remaining land without losing SFP but the land base eligible for future agricultural payments was reduced by the afforested area. In 2008, a regulation change obviated the need for consolidation as afforested land became eligible for payment. Thus from 2009 onwards, farmers already in receipt of SFP could continue to claim payment on afforested land without reducing the SFP eligible area. It was expected that this would lead to a considerable increase in farm afforestation, but this was not the case. Anecdotally, the fear of losing future SFP has been a factor in the reluctance of farmers to permanently commit land to forestry due to fears that a reduction in agricultural area could endanger future area based payments.

The Suckler Cow Welfare (SCW) payment introduced in 2008 was a coupled payment paid on a per head basis. The scheme lasted until 2012 but payments were halved due to the large numbers of farmers wishing to join the scheme. The range of cattle subsidies over the period led to a large increase in suckler cow numbers of 162% to approximately 1.12 million cows between 1987 and 1998. The number of cows varied slightly in the interim but remained largely unchanged at 1.13 million cows in 2012 (McCormack and O'Donoghue 2014).

Decrease in forest premium

The upward trend in forestry subsidies continued through 2005 when forestry grant rates were increased with larger proportional increases for broadleaf categories. In 2007, grants were increased marginally and an increase of 15% was applied to forest premium payments. In an attempt to combat the competition between REPS and afforestation, the Forest Environment Protection Scheme (FEPS) was introduced in 2007, which allowed farmers currently participating in REPS to avail of annual payments (in addition to the forest premium) to establish more environmentally focused forests. However, since the closure of the REPS 4 scheme in July 2009, farmers are no longer eligible to apply for FEPS.

Reduction in forest premium

Due to budgetary constraints, forestry subsidies were reduced by 8% across all premium payment categories in 2009, raising concerns about the long-term security of what had been thought of as "guaranteed" payments. This was expected to lead to an immediate drop in the afforestation level however, afforestation increased in 2010 by almost 700 ha. This may be accounted for by the fact that 2009 was one of the worst farming years on record (Connolly et al. 2010) as average Family Farm Income declined by 30% in 2009, on top of a 13.7% decline in 2008 income figures. However, there was a rise in farm incomes in 2010 and again in 2011, when farm incomes reached the second highest level since 2005. These high farm incomes are likely to have had an adverse impact on afforestation as despite an increase in payments for afforestation from 2011 onwards, planting levels fell to just over 6,500 ha in 2011 and 2012 (Forest Service 2013).

Revised targets

In recognition of the falling afforestation rate, the target was reduced to 14,700 ha yr^{-1} in 2011 (DPER 2011). However, in 2014, a review of Ireland's forest policy set new targets of 10,000 ha yr^{-1} to 2015 and 15,000 ha yr^{-1} to 2046 (DAFM 2014b). Over the period of this study, there were many policy changes in both forestry and agriculture, which may have resulted in both incentives and disincentives for farmers to consider forestry. The summary of payments presented in Table 1 illustrates some of the complexity in terms of the relative eligibility and payment criteria.

Methodology

Farm forestry and cattle enterprises are difficult to compare as afforestation grants and premiums are paid on a per hectare basis, whereas many of the payments to cattle farmers are allocated on the basis of cattle numbers and stocking density. This section describes the methodology used to disentangle the complexity of forestry and cattle subsidies available to farmers over the study period in order to analyse the relativity of cattle and forestry subsidies on an area basis. The analysis utilised was based on the "Typical Farm" methodology developed as part of The International Farm Comparison Network (IFCN). The IFCN typical farm model is a unique methodology that is used to compare farms in a single year across a range of countries, which provides a realistic database of different farm types in several different regions (Deblitz 2005). A hypothetical cattle farm is generated to be representative of Irish cattle farms in terms of size, livestock systems, labour organisation and production technology used. Typically, the IFCN methodology compares farms in a given year across a range of countries, however this analysis uses a time series of data on agricultural and forestry subsidies within a single country across a range of years. Models based on hypothetical data offer useful insights, despite their simplicity. The purpose of the IFCN is to facilitate the identification of the impact of changes in a single component of farm income by removing the diversity of other farm characteristics. Thus, the relativity of the subsidies that prevailed in each of the years can be compared on a per hectare basis and reasons advanced to explain how this may have affected the afforestation decision.

Structure of the Typical Farm Model

The literature on the changes in agricultural and forestry subsidies in the preceding section forms the basis of a model in which each agricultural and forestry subsidy is defined by the parameters for eligibility for agricultural and forestry schemes. The Teagasc (Agriculture and Food Development Authority) Typical Farm Model (TTFM) is constructed using actual NFS data from 1995, from which a stylised farm scenario is developed. The TTFM characterises a typical farm for the main agricultural systems (dairy, cattle, sheep and tillage) and for three classes of economic performance (top, middle, bottom) based on gross margin[5] per hectare. As cattle farmers are the most likely to consider afforestation (Ryan et al. 2008, Breen et al. 2010), this analysis is based on a typical middle performing, cattle rearing system where calves are reared and fattened until they are ready for slaughter. This hypothetical farm has 34 ha of land with suckler cows, 10-month and 22-month steers, heifers and a bull. The parameters used to generate annual subsidies per hectare are stocking rate and land

[5] Gross margin (GM) is defined as gross outputs minus direct costs, such as fertilisers and feed stuffs, and is a common measure of the profitability of agricultural enterprises.

area. The relevant livestock payments that applied in each year were calculated for each LFA designation. They were also calculated for a low (0.7 LU ha^{-1}) stocking rate; a medium (1.39 LU ha^{-1}) stocking rate which maximises headage payments up to the extensification threshold of 1.4 LU ha^{-1}; and a high (1.75 LU ha^{-1}) stocking rate at which farmers have higher headage payments but are not eligible for extensification payments. The subsidies modelled include livestock headage payments, Less Favoured Area payments, extensification payments, Rural Environment Protection Scheme, Single Farm Payment and Suckler Cow Welfare payments. The payments for REPS and SFP were calculated from 1994 and 2005 onwards respectively on an area basis. In this way, the impact of different stocking rates and LFA designations on the level of subsidies per hectare received on a typical farm can be evaluated.

For the purpose of illustrating the relativity of cattle and forestry payments, we focus on the forestry headage and premium payments for the widely planted conifer "non-diverse" (n/d) and "diverse 20%" Sitka spruce (*Picea sitchensis* (Bong.) Carr.) categories on enclosed land. The "ash (*Fraxinus excelsior* L.) 40-100% and 75-100%" broadleaf categories were selected as the most widely planted broadleaf species over the period[6]. For simplicity this analysis is conducted on a per hectare basis, therefore the forestry subsidy figures for one hectare are used.

Results

The influence of (a) LFA designation and (b) stocking density on cattle payments was examined. It is evident that over the time period evaluated, the largest payment increases corresponded with the CAP reforms in 1992 and 2000. The SFP scheme was based on the average livestock headage and area-based payments made to farmers in 2000, 2001 and 2002 (which were lower than 2003 and 2004), resulting in a decrease in cattle payments in 2005. However, subsidy payments on the typical farm increased in 2008 with the introduction of the Suckler Cow Welfare Scheme.

The impact of LFA designation on cattle subsidies, keeping the stocking rate constant at 1.39 LU ha^{-1} is shown in Figure 2. The payments available to farmers in non-LFA areas were lower than in LFA's although there is very little difference between the payments available to farmers in MSH and LSH areas. As 75% of land in Ireland is designated as LFA (MSH and LSH), the relevant payments in MSH areas only were evaluated, thus simplifying the comparison of cattle with forestry payments.

Payments for low, medium and high stocking rates on the typical farm were examined keeping LFA designation constant at MSH (Figure 3). A large differential between payments for the low stocking rate (0.7 LU ha^{-1}) and the medium to high

[6] Ash is no longer planted due to the incidence of ash dieback disease (*Chalara fraxinea*). In recent years, broadleaf afforestation has accounted for approximately 30% of annual afforestation (Forest Service 2013).

stocking rates (1.39 and 1.75 ha^{-1}) emerged. The payments for the lower stocking rate are considerably lower than the medium and high stocking rates across the period. Above a stocking rate of 1.4 LU ha^{-1} payments no longer include extensification and increasing cattle numbers above this stocking rate provided only marginal subsidy gains. The average stocking rate on cattle farms between 1993 and 2012 was 1.06 LU ha^{-1} (NFS various years). Therefore, only the 0.7 and 1.39 LU ha^{-1} stocking rates were compared in this study.

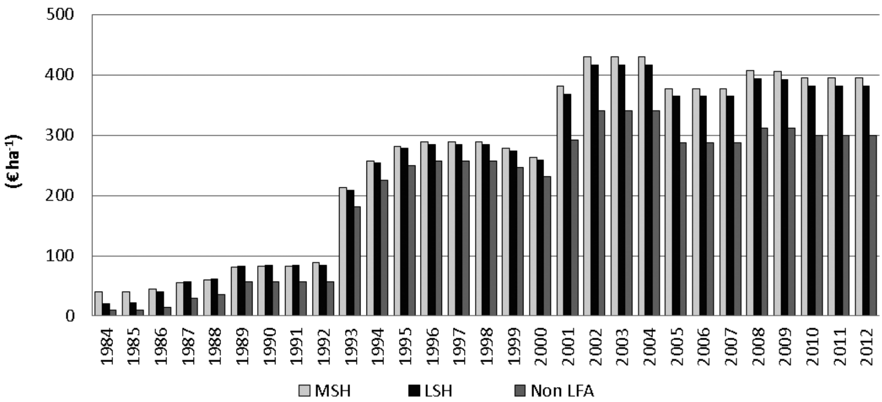


Figure 2: *Subsidies available (€ ha^{-1}) to suckler cattle farms at medium stocking density in MSH, LSH and non-LFAs from 1984 to 2012. (Based on TTFM outputs.)*

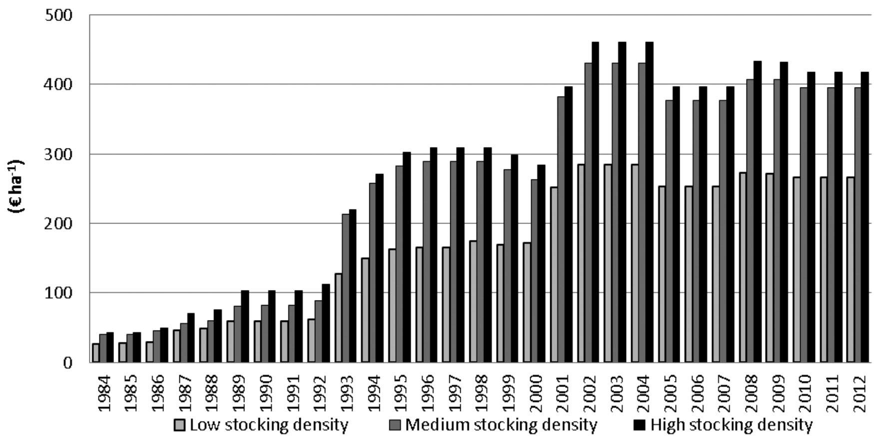


Figure 3: *Subsidy payments (€ ha^{-1}) available to suckler cattle farms at low, medium and high stocking densities in MSH areas from 1984 to 2012. (Based on TTFM outputs.)*

Cattle payments for the low and medium stocking rates (0.7 and 1.39 LU ha^{-1}) were compared against the payment for a crop of pure Sitka spruce non-diverse (Figure 4). It is only in the initial Western Package and OPF schemes that forestry premium payments were higher than cattle subsidies, regardless of stocking rate or LFA designation. From the 1993 MacSharry CAP reform onwards, cattle subsidies were higher than conifer (Sitka spruce) premiums for medium-stocked farms. Only the lower-stocked extensive suckler farms could have increased their subsidy payments by planting trees on their land.

The influence of participation in REPS was also examined. The addition of REPS payments to the cattle subsidies was examined for both the low and medium stocking rates in MSH areas (Figure 5). These are compared with the higher conifer payments available for a Sitka spruce crop, which included 20% of another species (Sitka spruce 20% diverse) and broadleaf (ash) premium payments. It is evident that the inclusion of REPS payments from 1994 onwards pushed the cattle payments up to the level of the higher conifer (Sitka spruce 20% diverse) payments, except for a short period in 2000 when LFA payments were decoupled from production. From 2002 onwards, cattle subsidies for REPS farms were higher than the conifer payments, particularly for the more intensive medium stocked farms. The payments for ash were higher than the low stocking rate cattle payments in the earlier years but are comparable in later years. From 2002 onwards, the cattle payments for medium stocked REPS farms were significantly higher than either the conifer or broadleaf payments. The relative payments for cattle and forestry in LSH and non-LFA's (not shown here), also displayed similar trends but at slightly lower payment rates.

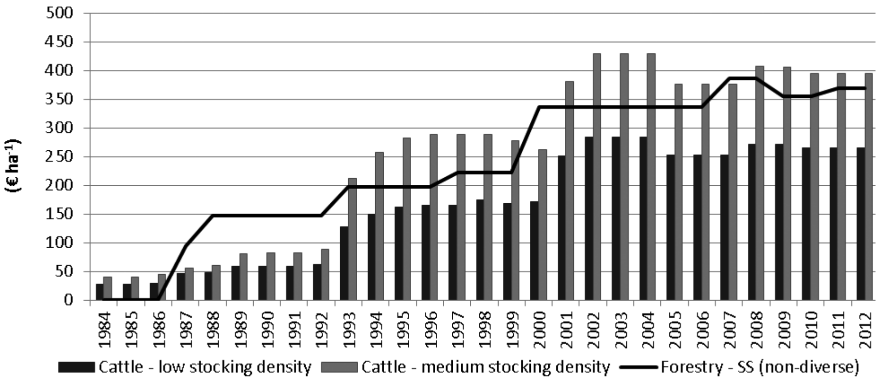


Figure 4: *Payments available in MSH areas from 1984 to 2012 (€ ha^{-1}) for suckler cattle farms at low and medium stocking densities and for Sitka spruce non-diverse conifer afforestation. (Based on TTFM output.)*

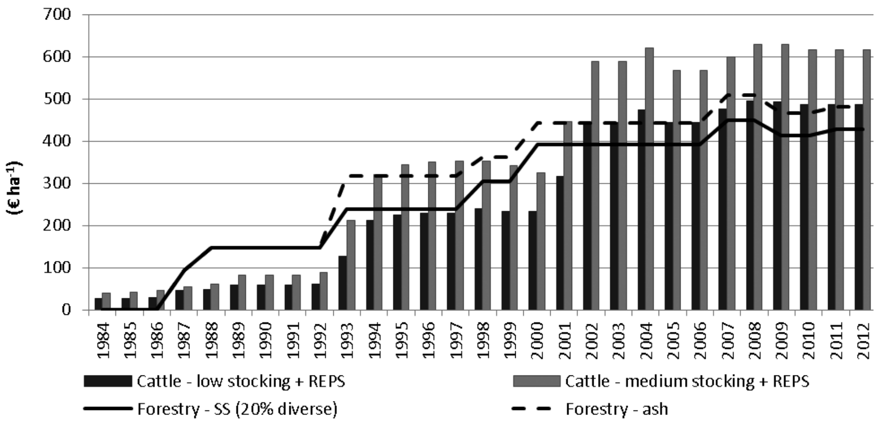


Figure 5: *Payments available in MSH areas from 1984 to 2012 (€ ha^{-1}) for suckler cattle farms participating in REPS schemes at low and medium stocking densities and for Sitka spruce non-diverse conifer and broadleaf (ash) afforestation. (Based on TTFM output.)*

In summary, the main results were:

- While several increases were applied to the level of forest premium payments, these tended to coincide with increases in agricultural payments which dampened their net effect;
- For most of the period in question, cattle subsidies exceeded conifer payments in MSH and LSH areas at medium to high stocking rates;
- The more intensive farms stocked at medium- and high-stocking densities had higher payments than extensive farms;
- The tiered forestry subsidies in LFA's kept the forestry subsidies above the cattle subsidies between 1994 and 1999, but were reduced to a flat rate in 2000;
- While forestry subsidies were higher than agricultural subsidies from 1987 to 1993, the available grants only covered 85% of the establishment costs;
- For cattle farms participating in REPS, cattle subsidies were higher than forestry subsidies for medium stocked farms in MSH and LSH areas, which represent 75% of total agricultural area.

Discussion

It is evident that for much of the period reviewed, cattle subsidies were higher than forestry subsidies, particularly in MSH areas and for more intensive farms. This finding is consistent with a recent analysis of the characteristics of NFS farms with and without forestry, which concludes that farms with higher stocking densities are less likely to consider converting land to forestry (Howley et al. 2012). In essence, the opportunity cost of undertaking forestry is higher for intensive farms than for less intensive farms, in terms of the income foregone from agricultural subsidies.

However, farming at high stocking densities requires "good" land which is unlikely to be considered for forestry. Less intensive farms are more likely to have been in receipt of REPS payments (DAFM 2014a), which would have added to their opportunity cost. Other studies have also found that agricultural subsidies play an important part in the afforestation decision Barrett and Trace 1999, (Collier et al. 2002, McCarthy et al. 2003). This is echoed by O'Connor and Kearney (1993), who concluded that "other things being equal, the expected returns from forestry must show a premium over the returns from land before landholders will seriously consider the forestry option".

Financial analyses of planting conducted in Ireland to date have indicated that forestry outperforms cattle and sheep systems over the period of one rotation (Breen et al. 2010, Upton et al. 2013). However these studies focused on the market component of income and did not include detailed analysis of the relevant subsidies. The analysis in this study focused only on the forestry and cattle subsidies available to a cattle farmer in each year of the examined period and did not take into account the market income from cattle or timber sales or the income tax exemption for forestry premium payments. This analysis shows that the combination of cattle subsidies, LFA payments and agri-environment payments (REPS), exceeded the forestry payments available to many cattle farmers over the period. REPS schemes have been recognised as a significant competitor with afforestation schemes (McCarthy et al. 2003). REPS is now closed however, and 20,000 farmers are currently availing of Agri-Environment Options Schemes (AEOS) at an average payment of €3,200 per applicant (DAFM 2014a). From late 2014 onwards, farmers will have the opportunity to enter the new Green Low carbon Agri-environment Scheme (GLAS) under which the payment will be €5,000 per applicant for a maximum of 50,000 applicants (DAFM 2014a).

It is well recognised that financial analysis alone may not explain planting patterns. This study did not take into account the fact that the permanency of the afforestation decision is a barrier to many farmers (McDonagh et al. 2010). The expectation of future (direct) payments has been recognised as affecting land use decisions as farmers position themselves to ensure they are able to avail of future payments (Coble et al. 2008, O Donoghue and Whitaker 2010). This flexibility is not available to farmers who afforest land. This is again evident in a behavioural model of the characteristics of NFS farms with and without forests between 1984 and 2012 (Ryan et al. 2014). The model results showed that the preference of these farmers for agriculture or forestry is heavily influenced by the perceived fall in wealth due to the decline in self-reported land value as a result of the inflexibility of forestry as a land use.

Duesberg et al. (2013) concluded that the reason why forestry is not an option for some farmers is that "it simply isn't farming". This desire to continue farming is not a uniquely Irish phenomenon. Gorton et al. (2008) examined farmer attitudes in

EU countries and concluded that even post-decoupling of payments from production, farmers retain their productivist objectives and prefer to utilise their land by farming it.

Conclusions

A detailed examination of the cattle and forestry subsidies available to farmers who may have considered forestry over the time period has not previously been undertaken in the Irish literature. Previous studies (duQuesne 1993, Collier et al. 2002, McCarthy et al. 2003) explicitly comment on the sensitivity of farmers to the level of agricultural and forestry subsidies. The results of this analysis highlight the potentially significant opportunity cost of the agricultural subsidies lost by cattle farmers converting to forestry. Stocking density, LFA status and participation in REPS all contribute to the magnitude of the loss of these cattle subsidies. In general over the entire period, the subsidies available to farmers considering afforestation have been less attractive financially than for remaining in cattle farming, in particular for intensive farms with higher animal stocking rates and for more extensive farms participating in REPS. While there was a significant increase in forestry subsidies up to 2009, when these are examined in conjunction with concurrent increases in cattle payments, the increases in forestry subsidies in general did not exceed those available for cattle farming.

Overall, it is evident that the increases in forestry payments only served to maintain the relativity with cattle payments rather than providing forestry with a financial advantage over cattle farming during that period. The slower than expected uptake of afforestation in Ireland may not be surprising in this context.

References

Barrett, A. and Trace, F. 1999. The impact of agricultural and forestry subsidies on land prices and land uses in Ireland. *Policy Research Series, 35*. The Economic and Social Research Institute, Dublin.

Behan, J. 2002. Returns from farm forestry vs. other farm enterprises. Paper presented at the *IFA Farm Forestry Conference*, 8th November 2002, Limerick, Ireland.

Breen, J., Clancy, D., Ryan, M. and Wallace, M. 2010. Irish land use change and the decision to afforest: an economic analysis. *Irish Forestry* 67: 6-20.

Coble, K.H., Miller, J.C. and Hudson, M.D. 2008. Decoupled farm payments and expectations for base updating. *Review of Agricultural Economics* 30(1): 27–42.

Collier, P., Dorgan, J. and Bell, P. 2002. *Factors Influencing Farmer Participation in Forestry*, COFORD. Dublin.

Connolly, L., Kinsella, A., Quinlan, J. and Moran, B. 2009. *National Farm Survey 2008*, Teagasc. Oak Park.

Connolly, L., Quinlan, J., Moran, B. and Kinsella, A. 2010. *National Farm Survey 2009*, Teagasc. Oak Park.

DAFF. 1996. *Growing for the Future. A Strategic Plan for the Development of the Forestry Sector in Ireland*. Department of Agriculture, Food and Fisheries, Dublin.

DAFM. 2013.Available from http://www.agriculture.gov.ie/farmerschemespayments/singlepayment schemedisadvantagedareasschemebeefdataprogrammebdp/categoriesofdisadvantagedareas [Accessed June 2014].

DAFM. 2014a. *Agri-Environment Schemes – RDP 2014-2020*. Presentation by Liam Fahy, senior inspector Department of Agriculture Food and the Marine. March 2014.

DAFM. 2014b. *Forests, Products and People. Ireland's Forest Policy – a Renewed Vision*. Department of Agriculture Food and the Marine. Dublin.

Deblitz, C. 2005. *The International Farm Comparison Network* (IFCN): bridging the gap between farmers, science and policy. Federal Agricultural Research Centre (FAL). Available at http://www.macaulay.ac.uk/elpen/work2/cdsab [Accessed August 2014].

DPER. 2011. *Programme for Government*. Available from http://www.per.gov.ie/wp-content/uploads/ProgrammeforGovernmentFinal.pdf [Accessed February 2014]. Department of Public Expenditure and Reform. Dublin.

Duesberg, S., O'Connor, D. and Ní Dhubháin, Á. 2013. To plant or not to plant—Irish farmers' goals and values with regard to afforestation. *Land Use Policy* 32: 155–164.

duQuesne Ltd. 1993. *EC Funds and Irish Forestry*. Thematic evaluation of EC co-financed forestry measures in Ireland. duQuesne Ltd. Economic and Environmental Consultants. Dublin.

Forest Service, 2013. *Annual Statistics*. Department of Agriculture, Food and the Marine. Dublin.

Frawley, J.P. 1998. Farmers' attitudes towards forestry as a farm enterprise in Ireland. In *Forestry in the Context of Rural Development*, Ed. Wiersum, F.K., Proceedings of the Final Scientific COST Action E3, Villa Real, Portugal.

Gillmor, D.A. 1992. The upsurge in private afforestation in the Republic of Ireland. *Irish Geography* 25: 89-97.

Gorton, M., Douarin, E., Davidova, S. and Latruffe, L. 2008. Attitudes to agricultural policy and farming futures in the context of the 2003 CAP reform: A comparison of farmers in selected established and new Member States. *Journal of Rural Studies* 24: 322-336.

Government of Ireland 1991. *Forestry Operational Programme 1989-1993*. Government of Ireland, Dublin.

Howley, P., Hynes, S. and O'Donoghue, C. 2012. Explaining the non-economic behaviour of farm foresters: The effect of productivist and lifestyle motivations. *Rural Economy and Development Programme Working Paper Series* 12-WP-RE-03, Teagasc.

Kelleher, C. 1986. Forestry for farmers. In *The Changing CAP and its Implications*. An Foras Taluntais, Dublin. pp 188-213.

McCarthy, S., Matthews, A. and Riordan, B. 2003. Economic determinants of private afforestation in the Republic of Ireland. *Land Use Policy* 20: 51-59.

McCormack, M. and O'Donoghue, C. 2014. Policy incentives as behavioural drivers of beef enterprises in Ireland: Where are the kinks? Paper presented at *European Association of Agricultural Economists*. Ljubljana, Slovenia. 25-28th August 2014.

McDonagh, J., Farrell, M., Mahon, M. and Ryan, M. 2010. Missed opportunity or cautionary steps? Farmers, forestry and rural development in Ireland. *European Countryside* 4: 236-251.

McKillop, D. and Kula, E. 1988. A planting function for private afforestation in N. Ireland. *Journal of Agricultural Economics* 39: 133-141.

National Farm Forestry Forum. 1996. *Report of the National Farm Forestry Forum*. Department of Agriculture, Food and Forestry, Dublin.

Ní Dhubháin, Á. and Gardiner, J. 1994. Farmers' attitudes to forestry. *Irish Forestry* 51: 19-26.

O'Connor, R. and Kearney, B. 1993. Economic issues in Irish forestry. *Journal of the Statistical and Social Inquiry Society of Ireland* XXVI Part V: 179-209.

O Donoghue, E.J. and Whitaker, J.B. 2010. Do direct payments distort producers' decisions? An examination of the farm security and rural investment act of 2002. *Applied Economic Perspectives and Policy* 32(1): 170–193.

Power, R., Connolly, L. and Roche, M. 1988. *National Farm Survey 1987*. Teagasc, Dublin.

Ryan, M., Kinsella, A. and Cushion, M. 2008. An assessment of farmer intentions to plant a forest. *Agricultural Research Forum 2008*. Teagasc.

Ryan, M., O'Donoghue, C. and Upton, V. 2014. Land use change from agriculture to forestry: a structural model of the income and leisure choices of farmers. Paper presented at *European Association of Agricultural Economists*. Ljubljana, Slovenia. 25-28th August 2014.

Teagasc. 1984 to 2008. *Management Data for Farm Planning*. Teagasc, Dublin.

Upton, V., Ryan, M., Farrelly, N. and O'Donoghue, C. 2013. The potential economic returns of converting agricultural land to forestry: an analysis of system and soil effects from 1995 to 2009. *Irish Forestry* 70: 61-74.

Appendix 1

Table 2: *List of abbreviations used throughout the text.*

Abbreviation	Explanation
AEOS	Agri-Environment Options Scheme
CAP	Common Agricultural Policy
Con	Conifer
CPI	Consumer Price Index
DAS	Disadvantaged Area Scheme
ERS	Early Retirement from farming Scheme
FEPS	Forest Environment Protection Scheme
GLAS	Green Low-Carbon Agri-Environment Scheme
IFCN	International Farm Comparison Network
LFA	Less Favoured Areas (includes MSH and LSH)
LSH	Less Severely Handicapped area
LU	Livestock units (see footnote 3)
MSH	More Severely Handicapped area
N/d	Non-diverse conifer planting category (e.g. Sitka spruce)
NFS	National Farm Survey
OPF	Operational Programme for Forestry
REPS	Rural Environment Protection Scheme (REPS1-4)
SFP	Single Farm Payment
SCW	Suckler Cow Welfare Scheme
SS	Sitka spruce
TTFM	Teagasc Typical Farm Model

Cost-benefit analysis of tree improvement in Ireland

Conor O'Reilly[a*], Henry Phillips[b] and David Thompson[c]

Abstract
The use of genetically improved trees usually results in better returns due to one or more of the following responses: higher growth rates, better timber quality and higher rates of carbon sequestration. Tree improvement is expensive, so it is important that available scarce resources are spent wisely. To this end, cost-benefit analysis (CBA), using the net present value approach, was used in this study to assess tree improvement investment possibilities for a large number of species of potential interest to Irish forestry, assuming that a 15% gain could be achieved and the costs of improvement were similar for all species. The CBA results showed that the conifer species with the greatest potential were (in order): (1) Sitka spruce and Douglas fir; (2) hybrid larch and Norway spruce; (3) Scots pine; and (4) lodgepole pine. The ranking for the broadleaved species were: (1) Eucalyptus; (2) ash; (3) red oak and sycamore. When issues such as availability of material from other programmes abroad, biological constraints (e.g. disease vulnerability, breeding and propagation problems), and the potential usage of species in a planting programme are also considered, the establishment of new breeding programmes are difficult to justify for most species, with the exception of Sitka spruce. The best approach for most species is to establish seed stands or seed orchards (with untested, or if available, tested material) to provide material for planting, but for some species it may also be possible to secure material from improvement programmes abroad.

Keywords: *Net present value, tested nursery material, breeding programme.*

Introduction
The reproductive material (seed, planting stock, etc.) used in afforestation and reforestation in Ireland must come from approved sources. The current regulations on the use of reproductive material, such as the EU Directive on Marketing of Forest Reproductive Material (FRM), provides for the identification of seed, with traceability from collection to production. Although these measures help safeguard the genetic quality of the material used, there is no requirement that only improved material should be planted, so there is a tendency to use the cheapest (often lowest quality) material that is permissible.

The EU FRM classifies reproductive material as (i) Source Identified, (ii) Selected, (iii) Qualified and (iv) Tested. The Source Identified category only confirms that the material has been collected from stands within a single seed zone (provenance). The Selected category refers to material from stands that appear superior (phenotypically).

[a] UCD Forestry, UCD School of Agriculture and Food Science, University College Dublin, Belfield, Dublin 4.
[b] Rathonoragh, Sligo, Co. Sligo.
[c] Coillte Teoranta, Tree Improvement Programme, Technical Services, Kilmacurra Park, Kilbride, Co. Wicklow.
[*] Corresponding author: Conor.oreilly@ucd.ie

The Qualified category refers to material derived from seed orchards that have been established with phenotypically superior individuals. The amount of improvement that both the Selected and Qualified categories deliver is unknown because phenotypic superiority can be due to either environmental or genetic factors. For example, work in Scotland with Scots pine[1] showed that seed from a seed orchard containing phenotypically selected material (which would be considered as Qualified under the FRM Directive) provided a 2% increase in harvestable volume compared to seed from seed stands (Source Identified) (Gill 1983). However, if the parent trees in the seed orchard had been tested and only the genetically superior individuals had been retained in the orchard, a 10% increase in harvestable volume could be expected. Genetic improvement can only be guaranteed through the use of Tested material, which involves implementing a breeding programme, which is expensive.

Forest trees generally have a high degree of intraspecific variation for commercially important traits, but the amount of genetic control is low in some species, making improvement costly and inefficient. Furthermore, it is more difficult to justify an improvement programme for a species that has a long rotation because the payback is delayed (thus incurring higher costs). The first step in a tree improvement programme is to determine the best provenance, a step that has been completed for most tree species in Ireland (but climate change concerns may bring this into question for some species). Provenance selection may be the final step in the improvement process for some species, mainly because further returns on any investment are likely to be low (or even negative). In other species however, it may be economically worthwhile to select phenotypically superior plus trees and use them to establish seed stands or seed production areas. It may be difficult to justify going to the next step, which involves the evaluation (i.e. progeny testing) of these plus trees to determine their genetic worth. While a breeding programme may be difficult to justify for many species, the establishment of untested seed orchards may deliver sufficient gains, assuming that heritability is high enough to support the investment.

The use of genetically improved planting stock results in permanent changes in the growth and/or quality of trees. Improved trees are also likely to sequester carbon more quickly than unimproved material because they grow faster. Tree improvement efforts in Ireland have been underway since about the 1950s, with most of the early work focussing on provenance testing of conifers (Fennessy et al. 2012). Improvement work in later years was devoted to Sitka spruce, such that a relatively advanced programme is now in place for this species (Thompson 2013). There is a more limited improvement programme for other conifers, such as lodgepole pine and Scots pine. Much of the broadleaved tree improvement efforts commenced about 20-30 years ago. Coillte (the state-owned forestry company in Ireland) selected phenotypically

[1] See Table 1 for the botanical names of all species.

superior ash, oak, sycamore and cherry trees, which were established in gene banks and in an untested seed orchard near Ballyhea, Co. Cork (Fennessy et al. 2012). Teagasc (Agriculture and Food Development Authority in Ireland) commenced a birch improvement programme, establishing two seed orchards with phenotypically selected, untested material (O'Connor 2007). Teagasc have also established an untested alder seed orchard (O'Connor 2011).

Investment in tree improvement has resulted in increased forest productivity in Ireland (Fennessy et al. 2012, Thompson 2013). For example, improved Sitka spruce will on average result in at least one yield class (YC) improvement over unimproved Washington material in Ireland, equating with a 2010 value of €987 ha^{-1} (Phillips and Thompson 2010). However, rotation length has a large impact on the net present cost[2] of improvement, so the returns from improvement efforts are lower for some species, especially broadleaves. In addition, some species have complex inheritance patterns, making improvement strategies difficult to apply. Genetic gain estimates have not been calculated for most tree species in Ireland, but the results for Sitka spruce were similar to those achieved in the UK (a 15% increase in height growth, a 7% improvement in stem form and no significant loss in wood density). The expected gains for other species are likely to mirror those estimated elsewhere for the same species (but most often for a different provenance).

Background and objectives

With the exception of Sitka spruce (Pfeifer 1988, Phillips and Thompson 2010), no cost-benefit analysis (CBA) has been carried out on tree improvement programmes in Ireland. The decision as to whether or not improvement effort can be justified will depend far more on factors such as the inherent productivity of species, the likely availability of suitable sites for planting and rotation length, than on the costs of tree improvement.

All CBA methods have advantages and disadvantages, but the most widely used method is the net present value (NPV) approach (Anonymous 2011). The CBA approach used in this study focussed primarily in assessing the potential for improving a wide range of species of interest to Irish forestry. The NPV is the sum of discounted revenues minus discounted costs. The NPV method was used as it allows the ranking of project outcomes. In addition, the probable future use of the species was considered in the light of various issues, including the potential suitability (e.g. likely soil types), the inherent productivity of the species, estimated impact on the area planted for reforestation and afforestation and the inherent productivity of the species. It was assumed that a 15% gain in productivity could be achieved through tree improvement. The costs of improvement in this study were considered the same for

[2] See next section for explanation.

all species and were based on Coillte's information on file for Sitka spruce. The CBA was used to rank species, after which the optimal tree improvement strategy for those that ranked highest was considered, taking into consideration practical constraints and other issues (e.g. availability of improved material from programmes abroad, ease of breeding, disease issues, ease of propagation, disease threats etc.).

Materials and methods

NPV in CBA of forest genetics can be summarised using the following formula (Ahtikoski 2000):

$$NPV = \sum_{t_1}^{T_1} B_t^{diff} + \left(\mathrm{D}_p\right)^t - \left[\sum_{t_2}^{T_2} C_t^{es} + (D_P)^t + \sum_{t_3}^{T_3} C_t^{diff} + (D_P)^t\right] \quad (1)$$

Where B^{diff} = Differential benefits i.e. increase in growth rate, volume outturn or timber quality; C^{es} = Cost of establishing the tree breeding programme, seed orchards etc.; Differential cost of improved material, i.e. annual management and administration was calculated as: $D_P = (1 + \frac{p}{100})^{-1}$ i.e. a discount factor with percentage rate p.

In the proposed framework, a time horizon of one rotation was assumed. The length of the rotation varied with species.

Costs

The additional costs arising out of the new research needed to deliver the predicted 15% gain and the subsequent management and administration costs were included. Based on the estimated costs of the improved Sitka spruce Washington provenance developed by Coillte and its predecessor the Forest and Wildlife Service, over the last 35 years, the investment cost of a tree improvement programme per species was €2.5 million over a 15-20 year period. The costs of grant aid for planting, road construction and other forestry support schemes were assumed to be the same whether improved or unimproved planting material was used. Similarly, the costs to the forest owners of maintenance, insurance, on-going management, a proportion of roading costs and reforestation following clearfell were not considered as these are incurred irrespective of whether improved or unimproved material is used.

Benefits

The categories of benefits considered were timber (including thinnings) and carbon sequestration. Other benefits (e.g. biodiversity, landscape enhancement) were excluded because of the paucity of data for all species. The impact on water quality was considered neutral on the basis that future planting complies with environmental guidelines and forestry measures under the Water Framework Directive.

The increase in timber volume yield arising from the use of the improved planting stock was the main benefit considered. A default increase of 15% was used, based on an average YC for each species. Estimates of volume increase were based on Forestry Commission yield models (Edwards and Christie 1981) rather than the Irish GrowFor dynamic models, mainly because GrowFor can only be applied to relatively few species and initial stand data input parameters are required (McCullagh et al. 2013). The additional carbon sequestered in the main stem was estimated from the volume increase data (Hawkins et al. 2012).

In calculating the impact on volume production, an average rotation length and YC was allocated to each species. Yield class, a measure of forest productivity, is the timber volume (m^3 ha^{-1} yr^{-1}) that the forest crop will produce on average over the rotation. The thinning and clearfell volumes over the assumed rotation were then discounted (5%) to present values and multiplied by 0.15 to provide the additional discounted volume (DV) attributable to the improved planting material. Forestry Commission yield tables were used to estimate volumes and where an appropriate model was not available, the most suitable substitute was used, in line with the routine protocol adopted in the private sector roundwood forecast (Phillips et al. 2009). The discounted volume multiplied by the average price for the particular species provided an estimate of the increase in NPV per hectare. The main difficulty in carrying out this task was the scarcity of reliable price information on conifer species, other than spruce, and the absence of any dependable information for broadleaved species. To overcome this, the average price for standing conifer sales by Coillte over the past 10 years was used as a baseline. For broadleaves there was little reliable information, so an estimate was made based on a combination of UK prices (Pryor and Jackson 2001) and anecdotal information on prices achieved in Ireland. Species that provide a wide range of timber and timber products, and those species with higher value timber products, had their timber price increased relative to the baseline in the absence of species-specific information. Likewise species with limited timber end uses and lower value timber products had their timber price reduced relative to the baseline.

Analysis process

A six-step process was followed in this analysis, as described below.

1. The species eligibility for planting was determined, based on the current list of approved species for grant aid under the current afforestation schemes as issued by the Forest Service. Species were categorised as: (a) approved (grant aided), (b) delisted (no longer supported; e.g. Japanese larch and ash), (c) tolerated (cannot be planted in pure blocks; e.g. birch), and (d) unapproved. A total of 47 species were considered.

2. The potential for using eligible species in reforestation and afforestation was estimated. The potential for species use in reforestation was estimated through

a combination of (a) range of soil types suited to the species, (b) existing planted area based on the National Forest Inventory (NFI) (Anonymous 2007) and (c) percentage area of suitable soil types in the forest estate. The range of suitable soil types was taken from Horgan et al. (2004). There was some subjectivity involved in this approach.

3. The potential to increase roundwood volume was assessed and was based on a combination of (a) the estimated impact on the area planted for reforestation and afforestation and (b) the inherent productivity of the species.

4. The increase in timber value from improved material was calculated. The potential increase in value was expressed in terms of NPV (€ ha^{-1}), assuming an average 15% increase in volume production.

5. Carbon sequestration was the only non-timber benefit included. A long-term price of €22 t^{-1} CO_2 was used in the sensitivity analysis (Phillips 2006).

6. The analysis to this point (steps 1 to 5) revealed that a number of species showed potential for improvement. Only those top-ranking species were considered further in this step. The other issues considered included the availability of material from other programmes abroad, biological constraints such as disease vulnerability, breeding and propagation issues.

Results

Suitability for planting, potential impact on roundwood production and timber value

Some species (e.g. Sitka spruce, Norway spruce, lodgepole pine) had a high potential for planting on many sites, others had more limited potential (e.g. Corsican pine, Monterey pine, *Eucalyptus nitens*, and rowan), while other species had little potential (e.g. hornbeam, lime, Macedonian pine) (Table 1).

Sitka spruce, Norway spruce, lodgepole pine, sycamore and oak were found to have the greatest potential to contribute to future roundwood volumes (Table 2). Other minor species, such as southern beech, hornbeam, lime and poplar, were considered unlikely to make a significant impact on future overall woodflows, given the low rates of planting.

The estimated net gain in NPV per hectare varied considerably for each species (Table 2). Sitka spruce (€629), Douglas fir (€615), western hemlock (€554), western red cedar (€516), hybrid larch (€504) and Norway spruce (€500) provided the highest returns. There was a longer list of species that provided more intermediate returns, which included ash (€429), the two lodgepole pine subspecies (ca. €350), sycamore (€341) and the three oak species (ca. €300). Many species yielded returns below €250, which included common alder (€214) and birch (€138). Because of the paucity of data, it was not possible to calculate reliable estimates for several species.

Proposed tree improvement approaches

The CBA (previous section) showed that some species provided similar returns (e.g. Sitka spruce and Douglas fir), in which case they were given equal ranking in the next CBA step.

The conifer species with greatest potential were:

(1) Sitka spruce and Douglas fir;

(2) hybrid larch and Norway spruce;

(3) Scots pine; and

(4) lodgepole pine.

The broadleaved species were ranked as follows:

(5) eucalyptus;

(6) ash;

(7) red oak and sycamore.

Beech and birch did not rank highly, but may have potential for improvement.

The current status of the tree improvement programme for the species that ranked highest is shown in Table 3. Currently Sitka spruce, Scots pine and lodgepole pine are the only species for which tested material is available. However, the amount of improved seed available is limited, especially for lodgepole pine. In most other cases no improvement has been carried out (e.g. Douglas fir), or plus tree selection is already underway. Progeny testing is underway for ash and Scots pine, but no tested material is available.

The recommended improvement approach for the ranked species is shown in Table 4. Tested material, that may be suitable for use in Ireland, may also be available in the market outside Ireland, so this option is suggested for Douglas fir and red oak. Sitka spruce is the only species that clearly warrants investment in a breeding programme. Norway spruce also showed potential for improvement. However, all current planting stock of Norway spruce is derived from seed collected from a single seed orchard in Denmark, which may provide improvement, but there is no information to confirm this.

The seed orchard option assumes that selection and testing must be done first, with exception of lodgepole pine where selection and testing has been completed (Table 4). In sycamore, selections have been made, but testing has not been initiated. The most promising broadleaved species for improvement are relatively minor components of the current national planting programme, so improvement options are limited, and ash has been delisted due to the dieback disease *(Chalara fraxinea)*.

Table 1: *Eligible species and potential of their use in afforestation / reforestation in Ireland (Horgan et al. 2004).*

Species		FS[a]	Area[b]	Soil type[c] A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Alder, common	*Alnus glutinosa* (L.) Gaertn.	A	11.50																	
grey	*Alnus incana* (L.) Moench	N	n/a																	
Italian	*Alnus cordata* Desf.	N	n/a																	
Ash, common	*Fraxinus excelsior* L.	D	19.16																	
Beech, European	*Fagus sylvatica* L.	A	8.71																	
southern	*Nothofagus procera* (Poepp. & Endl.) Oerst.	A	0.14																	
Birch, downey	*Betula pubescens* Ehrh.	T	15.49																	
silver	*Betula pendula* Roth	T	14.20																	
Cherry, wild	*Prunus avium* L.	A	0.24																	
Chestnut, Spanish	*Castanea sativa* Mill.	A	0.20																	
Eucalyptus, nitens	*Eucalyptus nitens* (De & Ma) Ma	N	-																	
Hornbeam, common	*Carpinus betula* L.	N	0.50																	
Lime, common	*Tilia x europaea* L.	A	0.23																	
Maple, Norway	*Acer platanoides* L.	A	0.16																	
Oak, pedunculate	*Quercus robur* L.	A	7.34																	
red	*Quercus rubra* L.	T	-																	
sessile	*Quercus petraea* (Matt.) Leibl.	A	7.30																	
Poplar, black	*Populus nigra* L.	N	0.35																	
white	*Populus alba* L.	N	0.01																	
Rowan	*Sorbus aucuparia* L.	T	4.80																	
Sycamore	*Acer pseudoplatanus* L.	A	8.06																	
Willow, goat	*Salix caprea* L.	N	14.26																	
other	*Salix* spp.	N	17.96																	
Cypress, Lawson	*Chamaecyparis lawsoniana* (Murr.) Parlatore	A	0.41	x																
Leyland	*xCupressocyparis leylandii* (Jacks. & Dallim.)	A	-																	
Monterey	*Hesperocyparis macrocarpa* (Hartw.) Bartel	A	-																	
Douglas-fir	*Pseudotsuga menziesii* (Mirb.) Franco	A	10.20																	
Fir, grand	*Abies grandis* Lindl.	A	0.54	x																

noble	*Abies procera* Rehd.	A	2.60																	
silver	*Abies alba* Mill.	N	0.27																	
Hemlock, western	*Tsuga heterophylla* (Raf.) Sarg.	N	0.54																	
Larch, European	*Larix decidua* Mill.	A	0.53	x																
hybrid	*Larix x eurolepsis* Henry	A	n/a	x																
Japanese	*Larix kaempferi* (Lamb.) Carr.	A	21.51	x																
Pine, Austrian	*Pinus nigra* Arnold ssp. *nigra*	D	0.26	x	x															
Corsican	*Pinus nigra* ssp. *maritima* (Ait.) Melville	A	-	x	x		x													
lodgepole N.C.	*Pinus contorta* Dougl. ssp. *contorta*	A	12.69																	
lodgepole S.C.	*Pinus contorta* Dougl. ssp. *latifolia* Wats.	A	46.41																	
Macedonian	*Pinus peuce* Griseb.	A	n/a	x	x	x	x	x					x	x		x				
Monterey	*Pinus radiata* D. Don	N	0.23																	
Scots	*Pinus sylevestris* L.	A	7.34	x																
Redwood, coastal	*Sequoia sempervirens* (D. Don) End.	A	0.03	x																
Spruce, Norway	*Picea abies* (L.) Karst.	A	25.96																	
Serbian	*Picea omorika* (Pancic) Purkyne	A	-																	
Sitka	*Picea sitchensis* (Bong.) Carr.	A	327.83																	
Thuja, western red cedar	*Thuja plicata* D. Don	A	0.03																	
Yew, Irish	*Taxus baccata* L.	N	0.04																	
	Total Forest area		625.75																	
	% Forest area			2	13	1	3	4	3	1	3	2	12	9	3	11	20	1	11	1

The colours indicate the range in potential productivity: excellent (dark green), very good (light green), good (yellow), poor (dark orange) and very poor (red).

[a] Approved by Forest Service: A, approved; N, not approved; T, tolerated; and D, delisted. Species predisposed to coarse growth, poor form, instability or butt rot by the excessively favourable growing conditions and /or high pH provided under on particular soil types are indicated (x).

[b] Area under forest cover.

[c] Soil types listed are as follows: A. Alkaline brown earths and free draining, deep grey brown podzolics. B. Acid brown earth and brown podzolics. C. Rendzinas/ shallow brown earths/ shallow grey brown podzolics. D. Podsols/ peaty podsols ± weakly developed iron pan. E. Indurated iron pan podsol (organic layer or furze present). F. Indurated iron pan podsol (scrawed with heather). G. Peaty podsolized gleys (fertility class C) – organic layer present. H. Peaty podsolized gleys (fertility class C) – scrawed. I. Lithosols. J. Gleys/ peaty gleys (mottled profile) and grey-brown podsolics (fertility class A or B). K. Gleys/ peaty gleys (blue/ grey or yellow profile) (fertility class B). Gleys/ peaty gleys (fertility class C). M. Flushed and/or reclaimed blanket peat. N. Unflushed blanket peats and intact raised bogs. O. Cutaway blanket bogs (milled peat). P. Cutaway raised bogs (milled peat) post 1980 and fen peats. Q. Cutaway raised bogs (hand or machine sod) pre 1980.

Table 2: *Potential impact of species on predicted future roundwood volumes and estimated increase in timber value (€ ha⁻¹) from tree improvement.*

Species		Reforestation potential	Afforestation potential	YC range (m^3 ha^{-1} yr^{-1})	Mean YC (m^3 ha^{-1} yr^{-1})	Mean rotation (yrs)	Discounted vol. (m^3)	Price relativity	Average price (€)	NPV benefit (€ ha^{-1})	AE benefit (€ ha^{-1} yr^{-1})
Alder	common			4-10	8	45	9.7	0.60	22	214.45	12
	grey			4-10	8	45	9.7		NA	NA	NA
	Italian			4-10	8	45	9.7		NA	NA	NA
Ash	common	D	D	4-12	8	45	9.7	1.20	44	428.90	24
Beech	European			4-10	6	90	2.9	1.00	37	105.45	5
	southern			10-18	14	49	18.2		NA	NA	NA
Birch	downey		T	4-10	6	55	6.2	0.60	22	138.31	7
	silver		T	4-10	6	55	6.2	0.60	22	138.31	7
Cherry	wild			6-12	8	55	9.2		NA	NA	NA
Chestnut	Spanish			4-12	8	60	5.9		NA	NA	NA
Eucalyptus	nitens			20-36	26	15	27.7		NA	NA	NA
Hornbeam	common			4-10	6	90	2.9	0.90	33	94.91	5
Lime	common			4-10	6	90	2.9	0.90	33	94.91	5
Maple	Norway			4-10	6	55	6.2	0.90	33	207.46	11
Oak	pedunculate			4-10	6	85	4.1	1.20	44	183.37	9
	red		T	4-14	8	75	5.6	0.90	33	186.15	10
	sessile			4-10	6	85	4.1	1.20	44	183.37	9
Poplar	black			4-12	8	40	9.7	0.75	28	270.01	16
	white			4-10	8	40	9.7	0.75	28	269.73	16
Rowan			T	4-8	6	55	6.2		NA	NA	NA
Sycamore				4-12	8	55	9.2	1.00	37	340.77	18
Willow	goat			4-8	6	40	6.7	0.60	22	148.30	9
	other			4-12	6	40	6.7	0.60	22	148.30	9
Cypress	western red cedar			8-22	16	55	13.8	1.10	37	515.75	28
	Lawson			8-20	16	55	13.8		NA	NA	NA
	Leyland			8-22	16	55	13.8		NA	NA	NA
	Monterey			6-18	14	55	11.3		NA	NA	NA
Douglas fir				8-26	16	50	16.4	1.10	37	614.86	34
Fir	grand			8-32	18	45	17.8	0.60	20	363.73	20
	noble			8-24	16	50	13.6	0.70	24	322.73	18
	silver			8-24	16	50	13.6	0.70	24	322.73	18
Hemlock	western			8-24	18	45	18.1	0.90	31	554.17	31
Larch	European			4-12	8	45	8.3	1.00	34	280.50	16
	hybrid			6-20	12	40	15.6	0.95	32	503.88	29
	Japanese	D	D	6-14	10	45	12.1	0.85	29	349.69	20
Pine	Austrian			6-14	10	55	8.2		NA	NA	NA
	Corsican			6-20	12	55	10.9		NA	NA	NA
	lodgepole NC			6-16	12	45	12.1	0.84	29	344.72	19
	lodgepole SC			6-20	14	45	15.1	0.70	24	358.43	20
	Macedonian			4-12					NA	NA	NA
	Monterey			4-20	16	40	17.2		NA	NA	NA
	Scots			6-16	10	55	7.9	1.05	36	282.39	15
Redwood	coast			6-18	12	60	9.8		NA	NA	NA
Spruce	Norway			8-24	16	50	14.0	1.05	36	499.80	27
	Serbian			6-14					NA	NA	NA
	Sitka			8-34	18	40	18.5	1.00	34	629.00	37
Yew	Irish			4-6					NA	NA	NA

See Table 1 for explanation of colour codes regarding volume potential of reforestation and afforestation and discounted volume. The base timber prices assumed were €34 m^{-3} (conifers) and €37 m^{-3} (broadleaves). The estimated values indicated are: <€150 (dark pink), €150-249 (light pink), €250-374 (dark blue), €375-499 (blue) and ≥ €500 (light blue); Price relativity is the timber price (ratio) relative to the baseline (see Materials and Methods). AE is the NPV expressed as its annual equivalent. Blank boxes indicate data were unavailable.

Table 3: *Current improvement status of the species that ranked highest in the cost-benefit analysis*.

Species	Provenance testing	Plus tree selection	Progeny testing	Improved (tested) material available	Mass propagation (untested clones)	Mass propagation (tested clones)
Conifers						
SS	Completed	Completed	Completed	Yes	In use	Underway
DF	Completed	No	No	No	No	No
HL	Underway	No	No	No	No	No
NS	Complete	No	No	No	No	No
SP	Limited	Incomplete	Underway	Yes	No	No
LP	Completed	Completed	Completed	No	No	No
Broadleaves						
EU	No	No	No	No	No	No
AS	Underway	Limited	Initiated	No	No	No
RO	No	No	No	No	No	No
SY	No	Limited	No	No	No	No
BE	Underway	No	No	No	No	No
BI	Limited	Complete	Underway	No	No	No

Tree species abbreviations: SS, Sitka spruce; DF, Douglas fir; HL, hybrid larch; NS, Norway spruce; SP, Scots pine; LP, lodgepole pine; EU, *Eucalyptus*; AS, ash; RO, red oak; SY, sycamore; BE, beech and BI, birch.

Table 4: *Improvement option(s), relative costs of achieving gains, recommended approach, further work and recommendation for breeding programme.*

Species	Improvement option(s)	Predicted availability of improved material	Comments and recommended approach	Need for breeding programme
Conifers				
SS	Seed orchards and mass propagation of best tested genotypes	Available	Develop on-going programme. Low cost relative to returns.	Yes
DF	Seed orchards	30-35 years	Use improved material available elsewhere.	No
HL	Seed orchards	17-22 years	Exploit existing EU programmes and develop to suit Irish needs.	No
NS	Seed stands Seed orchards	20-25 years	Improved material available elsewhere.	No
SP	Seed stand Seed orchards	Available	Copious seed producer. Seed orchards provide good return. Need to replace ageing seed orchards with new material.	No
LP	Seed orchards	3-5 years	Copious seed producer. Seed orchards provide good return. More seed orchards of improved material need to be established.	No
Broadleaves				
EU	Species and provenance selection	N/A	Test species and provenances (if available).	No
AS	Seed stands Seed orchards	22-33 years	Difficult to justify improvement, especially due to disease issue.	No
RO	Seed stands Seed orchards	25-40 years	Difficult to justify improvement programme.	No
SY	Seed stands Seed orchards	22-28 years	Seed orchard option can be justified.	No
BE	Seed stands Seed orchards	30-43 years	Improvement programme difficult to justify.	No
BI	Seed stands Seed orchards.	Available	Copious seed producer so seed orchards should provide good return.	Yes, if improvements are verified and worthwhile

Tree species abbreviations: SS, Sitka spruce; DF, Douglas fir; HL, hybrid larch; NS, Norway spruce; SP, Scots pine; LP, lodgepole pine; EU, Eucalyptus; AS, ash; RO, red oak; SY, sycamore; BE, beech and BI, birch.

Discussion

The CBA approach used in this study assumed that a 15% gain could be achieved in one generation of improvement, whereas in reality it will be more difficult to achieve this in some species than in others, which might be reflected in higher costs per unit gain. Nevertheless, the costs of tree improvement tended to be influenced more by seed yield and rotation length than other factors (South 1991). Since many species form a minor component of forestry in Ireland, it is difficult to justify a tree improvement programme for these species beyond the EU FRM Qualified (untested seed orchards) category.

Conifers

The results of this study showed that excellent returns are likely to accrue from improvement efforts in Sitka spruce, in agreement with previous CBA findings (Phillips and Thompson 2010). If a total of €3,307,099 (€2.5 million, including interest) was invested in Sitka spruce research over a 15 year period, then a €629 ha^{-1} increase in NPV can be expected (Table 2). This would generate a potential annual benefit of €1.9 million, assuming an annual planting programme of 3,000 ha yr^{-1}. A minimum of 1,157 ha must be planted each year over five years to cover the cost of the investment. An annual planting level of 1,455 ha is needed to justify a similar investment for Norway spruce, based upon the cost assumptions and the AE returns estimated in this study (Table 2).

Sitka spruce performs exceptionally well on a wide range of sites in Ireland (Farrelly et al. 2011), so it is an ideal species for improvement. These results are also not surprising given that the Forestry Commission in Britain have also reported gains in Sitka spruce of more than 20% for some traits (Lee 2004). The current Sitka spruce programme in Ireland is relatively advanced in comparison with all other species. In addition to the establishment of conventional seed orchards, which will take about 10 years to produce seed, other options are being developed. Seed derived from specific crosses known to produce well above-average progeny are "multiplied" using vegetative propagation, thus allowing greater than average gains to be achieved (Thompson 2013). Nevertheless, further efforts are needed to advance the Sitka spruce improvement programme. Methods for early selection, approaches to screen families and individual trees for tolerance to stress and new ways to increase vegetative propagation yields are required. Bioassays to screen for tolerance and resistance to stress, pests and diseases are also needed.

Douglas fir produces high value wood and tree improvement efforts have delivered good returns at a modest cost and improved stock is widely used in the Pacific Northwest (Howe et al. 2006) and elsewhere. The species grows well on relatively sheltered sites with free-draining soil, but is prone to deer damage (Horgan et al. 2004). Therefore, it may be difficult to justify a tree improvement programme in Ireland, given the low availability of suitable planting sites. It may be preferable to source improved seeds for planting in Ireland from the Pacific Northwest or the UK.

The CBA results also showed that hybrid larch has potential to deliver improvement. The best approach to achieve improvements in a hybrid species may be quite different from the approach used to achieve improvement within a species. Most untested hybrid larch seed orchards yield gains of only about 5% (Lee 2004). Furthermore, seed orchards flower erratically with only about 20% of hybrid seed resulting. Results from trials of hybrid larch in Europe have shown that material from a Dutch programme performed best across a wide range of sites across Europe. This suggests that a common European hybrid larch breeding programme may be the optimal approach. However, the planting of hybrid larch needs to be considered in light of the current problems with *Phytopthora ramorum* that has affected Japanese larch; hybrid larch may succumb to this disease in the future.

Norway spruce is a relatively adaptable species, doing well on moderately fertile, moist mineral soils and the more fertile, shallow peats (Horgan et al. 2004). In particular, Norway spruce is often planted on sites that are considered unsuitable for Sitka spruce, especially where the risk of frost damage may be a factor. Heritability for many traits is high (Steffenremab et al. 2009). Trials to test this material have been established, but are still too young to provide conclusive results. Therefore, it is difficult to justify improvement work on this species until further information is available.

Because lodgepole pine is the only species suitable for planting on relatively low quality, wet sites in Ireland (Horgan et al. 2004), the demand for lodgepole pine stock is likely to continue. The high heritability for most economically important traits, the strong juvenile-mature genetic correlations, early sexual maturity, and ability to produce seed regularly, make this an ideal species for improvement (Xie and Ying 1996). To meet the demand for seed in Ireland, further seed orchards of the original Irish selections of south coastal material, as well as of an inter-provenance hybrid material, need to be established and managed, but it may be difficult to justify investment in a breeding programme given the limited potential for planting and the relatively low AE returns (Table 2).

Scots pine showed some potential for improvement also, but its low usage in Irish forestry makes it even less attractive than lodgepole pine as a potential species for improvement. Furthermore, the species is sometimes used in mixtures with oak and other broadleaves (Horgan et al. 2004), but the economics of using improved stock for use in mixtures may be difficult to justify. Material from Scottish clones has been propagated to establish two new seed orchards in recent years, which may provide sufficient material for future use.

Broadleaves

Broadleaf species planting accounts for about 35% of the current national afforestation programme (Anonymous 2013), so they are likely to form an increasingly important element in the national forest estate. There has been considerable debate about broadleaved tree improvement in Ireland and Britain (Savill et al. 2005). The long rotation (not true for all species), high establishment costs, low productivity, breeding and propagation difficulties and the low levels of genetic gain that are likely to accrue in many cases, make improvement work challenging. Although Palmer et al. (1998) showed that broadleaf improvement in Britain was resulting in significant gains, it was concluded that only simple mass selection and simple recurrent selection methods could be justified economically. Simple mass selection yielded the highest net returns. In particular, it may be difficult to justify the use of advanced methods for most broadleaved species, such as clonal propagation. It has been argued that the appropriate silvicultural practices may provide a greater improvement in a shorter period of time than classical breeding techniques in broadleaved species (Hubert and Lee 2005). Stem quality is far more important than yield for most broadleaved tree species, a trait that is very heavily influenced by the environment. It is highly unlikely that any improvements in tree form will be realised if broadleaves are planted on unsuitable sites and are not managed to a high standard. The best option may be to secure a supply of good quality seed, perhaps by establishing seed orchards with phenotypically selected, but untested (tested should of course be used if available) material (i.e. Qualified under EU FRM classification).

Several broadleaved species also ranked well in the CBA results, with *Eucalyptus* and ash providing the best returns. An annual planting programme of 1,696 ha would be needed to realise the returns from investing in a breeding programme in ash. In light of the uncertainty of the potential effect of the dieback disease on ash however, it is difficult to justify an improvement programme. It has been suggested that a programme to breed resistance to the disease should be initiated, but without a better understanding of the disease, this effort may be premature. Furthermore, breeding for resistance to the dieback disease may be difficult and expensive. In one study carried out in Denmark for example, only a small fraction of the ash trees were found to possess resistance, so it may not be possible to exploit this resistance without the risk of other adverse consequences (McKinney et al. 2011). Investing in a disease resistance breeding programme at national level is difficult to justify, but collaborating with other European countries on breeding efforts may be a more realistic approach.

While *Eucalyptus* showed good potential, this species forms only a minor part of the planting programme, predominantly for biomass production (Neilan and Thompson 2008). The main species of interest to Ireland have been identified by Neilan and Thompson (2008). While there may be considerable variation among provenances within species in *Eucalyptus* (King and Wilcox 1988), a limited number of provenances are likely to be suitable for Irish conditions. However, it is difficult to justify an improvement programme given the limited use of *Eucalyptus* species in Ireland. In addition, some improved seed is already available in the market for some species (e.g. *E. nitens*). It is likely that this improved material would be suitable for use in Ireland, but there is no scientific evidence to confirm this.

Although not native, sycamore has been naturalised in Ireland for several hundred years. No provenance testing has been undertaken to date with the species. Like ash, about 100 plus trees have been selected and used to establish one small seed orchard, but none of this material has been tested. More plus trees would have to be selected (500 to 1,000) and tested to provide enough material for an improvement programme, but the establishment of a breeding programme cannot be justified.

Beech and birch were deemed to have some potential for improvement. Results from Sweden for *Betula pendula* Roth have shown that significant improvement in yield can be achieved through breeding and selections can be made at an early age (Koski and Rousi 2005). The species also flowers regularly and profusely at an early age, making it an attractive species for improvement. There has already been substantial investment in birch improvement in Ireland. If improvements of 15% are achievable in birch, then it would require an annual planting level of 2,199 ha over the next 15 years to justify the estimated investment cost of €3,307,099. It is unlikely that birch planting levels will reach levels that are high enough to sustain the investment. Since a considerable amount of money has already been invested in this programme, it should be continued if significant improvement can be verified. Similar to many other species however, the most suitable improvement option might be to establish seed orchards with selected (untested and tested, as available) material.

Beech improvement efforts should focus initially on selecting appropriate provenances for use in Ireland. Information from provenance trials established in the 1990s should provide this information (Fennessy et al. 2012), but further work is difficult to justify given the low demand for planting stock. It is also difficult to justify improvement work in red oak for similar reasons. There are no other known breeding programmes that might provide suitable sources of improved material.

Conclusions and recommendations

After taking into consideration other issues (disease and other constraints, availability of improved material from other programmes abroad, etc.) in addition to the CBA data, it was difficult to justify a breeding programme for all species except Sitka spruce. Sitka spruce provides an excellent return on most site types in Ireland, but further investment in the programme is needed so that the species full potential can be realised. Since Douglas fir is a minor species, it may be preferable to source improved seeds from other countries. Improvement work beyond the establishment of seed orchards (i.e. Qualified category) is difficult to justify for all other conifer and all broadleaved species.

Acknowledgements
This research was undertaken as part of the Forest Genetics Resources Research Programme (ForGen), which was funded by the Department of Agriculture, Food and the Marine under the programme of Competitive Forestry Research for Development (COFORD).

References

Ahtikoski, A. 2000. *The profitability of Scots pine* (Pinus sylvestris) *and Silver Birch* (Betula pendula) *Next-Generation Seed Orchards*. Helsingin Yliopisto, Metsaekonomian Laitos, Julkaisuja 7. PhD Thesis, University of Helsinki, Helsinki, Finland.

Anonymous 2007. *National Forest Inventory Republic of Ireland Results*. Forest Service, Department of Agriculture, Fisheries and Food, Johnstown Castle Estate, Co. Wexford, p. 252.

Anonymous 2011. *The Public Spending Code: D. Standard Analytical Procedures Overview of Appraisal Methods and Techniques*. Central Expenditure Evaluation Unit. Department of Public Expenditure and Reform, Government of Ireland, Dublin.

Anonymous 2013. *Forestry and Timber Yearbook 2014*. Irish Timbers Growers Association, Dublin, Ireland.

Edwards, P.N. and Christie, J.M. 1981. Yield models for forest management. *Forestry Commission Booklet*. No 48. London.

Farrelly, N., Ní Dhubháin, Á. and Nieuwenhuis, M. 2011. Productivity models for Sitka spruce based on available GIS data and readily available accessible site quality factors. *Irish Forestry* 68: 23-40.

Fennessy, J., Doody, P. and Thompson, D. 2012. A review of tree improvement programmes in Ireland – historical developments, current situation and future perspective. *Irish Forestry* 69: 184-203.

Gill, J.G.S. 1983. Genetic improvement in some forestry practices – with special reference to natural regeneration. *Scottish Forestry* 37: 250-258.

Hawkins, M.K., Black, K. and Connolly, J. 2012. Validating generalised diameter-height models for several species and heterogenous crop structures. *Irish Forestry* 69: 58-72.

Horgan, T., Keane, M., McCarthy, R., Lally, M. and Thompson, D. 2004. *A Guide to Forest Tree Species Selection and Silviculture in Ireland*. COFORD, Dublin.

Howe, G.T., Jayawickrama, K.J., Cherry, M.L., Johnson, G.R. and Wheeler, N.C. 2006. Breeding Douglas-fir. In *Plant Breeding Reviews*. Ed. J. Janick. John Wiley & Sons, New York, pp. 245-353.

Hubert, J. and Lee, S.J. 2005. A review of the relative roles of silviculture and tree breeding in tree improvement: the example of Sitka spruce in Britain and possible lessons for hardwood breeding. *Forestry* 78: 109-120.

King, J.N. and Wilcox, M.D. 1988. Family tests as a basis for the genetic improvement of *Eucalyptus nitens* in New Zealand. *New Zealand Journal of Forest Science* 18: 253-266.

Koski, V. and Rousi, M. 2005. A review of the promises and constraints of breeding silver birch (*Betula pendula* Roth) in Finland. *Forestry* 78: 187-198.

Lee, S.J. 2004. The products of conifer tree breeding in Britain. In *Information Note June 2004*. Forestry Commission, Edinburgh.

McCullagh, A., Hawkins, M., Broad, L. and Nieuwenhuis, M. 2013. A comparison of two yield forecasting methods used in Ireland. *Irish Forestry* 70: 7-17.

McKinney, L.V., Nielsen, L.R., Hansen, J.K. and Kjær, E.D. 2011. Presence of natural genetic resistance in *Fraxinus excelsior* (Oleraceae) to *Chalara fraxinea* (Ascomycota): an emerging infectious disease. *Heredity* 106: 788–797.

Neilan, J. and Thompson, D. 2008. Eucalyptus as a potential biomass species for Ireland. In *COFORD Connects Reproductive Material*. COFORD, Dublin.

O'Connor, E. 2007. Progress in the selection and improvement of Irish birch. In *COFORD Connects Reproductive Material*. Dublin.

O'Connor, E. 2011. Birch and alder – the development of a tree breeding programme and a seed supply for Irish forestry. In *Technology Updates*. Teagasc, Dublin.

Palmer, E., Newton, A., Doyle, C.J., Thomson, S. and Stewart, L.E.D. 1998. An economic evaluation of alternative genetic improvement strategies for farm woodland trees. *Forestry* 71: 333-347.

Pfeifer, A.R. 1988. Clonal forestry – a view to the future. *Irish Forestry* 45: 101-111.

Phillips, H. and Thompson, D. 2010. Economic benefits and guidelines for planting improved Washington Sitka spruce. In *COFORD Connects Reproductive Material*. Department of Agriculture and Marine, Dublin.

Phillips, H. 2006. *Commodifying Carbon and other Forest Values to Support Afforestation*. Unpublished report prepared for COFORD.

Phillips, H., Redmond, J., Mac Siurtain, M. and Nemesova, A. 2009. *Roundwood Production from Private Sector Forests 2009-2028*. COFORD, Department of Agriculture, Fisheries and Food, Dublin.

Pryor, S.N. and Jackson, T.J.F. 2001. *The Cost of Restoring Plantations on Ancient Woodland Sites. An Analysis of the Economics of Future Management Options for Plantations on Ancient Woodland Sites*. Woodland Trust, UK and Oxford Institute.

Savill, P.S., Fennessy, J. and Samuel, C.J.A. 2005. Approaches in Great Britain and Ireland to the genetic improvement of broadleaved trees. *Forestry* 78: 163-173.

South, D.B. 1991. Nursery seed efficiency can affect gains from tree improvement. In *Proceedings, Southern Forest Nursery Association*. *Southern Forest Nursery Association,* Biloxi, Mississippi, pp. 46-53.

Steffenremab, A., Kvaalena, H. and Hibb, O.A. 2009. Genetic variation of wood quality traits and relationships with growth in *Picea abies*. *Scandinavian Journal of Forest Research* 24: 15-27.

Thompson, D. 2013. Development of improved Sitka spruce for Ireland. *Irish Forestry* 70: 104-118.

Xie, C.Y. and Ying, C.C. 1996. Heritabilities, age-age correlations and early selection in lodgepole pine *(Pinus contorta* spp. *latifolia)*. *Silvae Genetica* 45: 101-107.

The Forests of Atlantic Europe

This is the third in a series of articles on forestry in Atlantic Europe. While production is the primary management objective throughout the region, forests are used for a variety of purposes. This article deals with the distribution and uses of Spanish chestnut (*Castanea sativa* Mill.) in southwest France and in Asturias and Galicia, in northern Spain.

An example of multiple grafting of a chestnut. A Fonsegrada, Lugo Province, Galicia.

Spanish chestnut in southwestern France and northern Spain

Edward P. Farrell[a]*

Abstract
Spanish or sweet chestnut (*Castanea sativa* Mill.) is a truly multifunctional tree, highly valued for both its fruit and its timber. In Europe, it is found mainly in a small number of countries with a long tradition of chestnut cultivation. It is particularly important in southwest France and northern Spain. It has been cultivated since Roman times and now occurs as high forest, as coppice and in orchards.

Chestnut was historically a valued tree across the whole spectrum of society. Large plantations were established for coppice to provide poles for vineyards, and orchards supplied high-quality fruit for the rich. Peasant communities cultivated the tree for the dual purposes of wood and fruit production. The fruit provided an essential component of their diet through the winter months. The cultivation of chestnut is now declining. However, government-supported schemes are helping to improve neglected coppice and to restore old orchards and establish new ones.

Keywords: *Sweet chestnut, marron, coppice, multifunctional stands.*

Background

Spanish or sweet chestnut (*Castanea sativa* Mill.) is generally considered to be native to southern Europe, having reached there from its post-glacial refugia in Eastern Turkey (Villani et al. 1991, cited by Pereira-Lorenzo and Ramos-Cabrer 2004). It has long been recognised as a particularly useful species. In consequence of this, there has been, for over 3,000 years, a strong human influence in its movement and its introduction to many countries, in temperate regions. It was apparently introduced into Britain by the Romans and reached Ireland sometime before the 17th century (Nelson and Walsh 1993).

The species has a variety of common names in English. In addition to Spanish and sweet chestnut, it is also known as European chestnut, Portuguese chestnut and "marron". Sweet and Spanish are the adjectives best known for the species in Britain and Ireland, but their origins are not entirely clear. It seems that the reason for any prefix is to distinguish the tree from horse chestnut (*Aesculus hippocastanum* Linnaeus). The importance of the species in the Iberian Peninsula is reflected in the word "Spanish" used to describe it, although it could be argued that "French" would be a more appropriate descriptor. This author was unable to find documented explanation as to why "sweet" is used to describe the species. Most likely, it was

[a] Sequoia, Mart Lane, Foxrock, Dublin 18.
*Corresponding author: epfarrell@gmail.com

applied originally to the less abundant, but economically more important trees bearing the sweet, high-quality fruit, known as "marron" (more about this below).

While chestnut occurs from southern Europe to Britain and Ireland, chestnut forests and orchards are concentrated in a small number of countries with a long tradition of chestnut cultivation: France, Italy, Spain, Portugal and Switzerland. By one estimate, France accounts for over 45% of the total area of chestnut in Europe (Conedera et al. 2004). In keeping with the theme of this series of articles, the focus here is on southwest Europe.

Ecology

According to Afif-Khouri et al. (2011), chestnut in Asturias, in northern Spain, performs best under conditions of high rainfall, with a frost-free period of at least three to four months on soils with a relatively high base status. The high base status might appear to contradict both the perceived wisdom that chestnut "prefers" acid soils and the experience in the Dordogne, in southwest France, where chestnut is confined to acid soils rather than the predominant limestone soils of the region. Afif-Khouri et al. (2011) explain this apparent discrepancy through their finding that on the one hand, while chestnut will tolerate acid conditions, such conditions are not optimum for the species and on the other, that the crucial element contributing to the high base status in their study was magnesium, rather than calcium which will generally dominate on calcareous soils. Thus, Pereira-Lorenzo and Ramos Cabrer (2004) recommend the application of a magnesium fertiliser on soils with a pH greater than 6.

Chestnut is particularly intolerant of waterlogged soil, which leads to a higher incidence of ink disease (*Phyhophthora cambivora* (Petri) Buisman and *P. cinnamomi* Rands). Ink disease is easily recognised by a blue-black stain around damaged roots, producing root and collar rot. Interspecific hybrids from *C. sativa* (Miller) with *C. crenata* (Siebold and Zuccarini) (Japanese chestnut, the most important Asiatic species) or *C. mollissima* (Blume), another Asiatic species, have greater resistance to ink disease. Chestnut breeding in Europe began with the production of hybrids resistant to ink disease in the first half of the 20th century (Pereira-Lorenzo and Ramos Cabrer 2004).

Another pathogen of chestnut, chestnut blight (*Cryphonectria parasitica (*Murrill) Barr) destroys the bark and cambium and is usually fatal. *C. sativa* may be less susceptible to chestnut blight than American chestnut, *C. dendata* (Marshall, Borkhausen).

Bees and nectar-loving insects are attracted to the heavily scented flowers of chestnut. Squirrels will eat the nuts. Young and newly-cut coppice is attractive to scrub and ground-nesting birds.

Distribution

Conedera et al. (2004) produced the first comprehensive account of the distribution of chestnut in Europe. This was a complex task due to the versatility of the species and the different management systems under which it is cultivated. Chestnut trees occur as both the dominant and minor species in forest stands, with or without a defined productive purpose (timber or fruit), as dual-purpose trees, as high forest or coppice. Stands designated for fruit production may be orchards or high forest. Chestnut orchards are a traditional form of agroforestry, combining fruit production with intercropping with cereals, hay or pasture.

Due to its suitability for both wood and fruit production, chestnut has a history of cultivation in Europe going back to Roman times. In the Middle Ages, large coppice plantations were established by the great monasteries and also in the wine producing regions, as the coppice provided abundant stakes needed to support the vines.

The area of chestnut in southwest Europe is small compared to species of pine or eucalypt, but it has long been a species valued for its fruit and the versatility of its timber. Estimates of the total area of the species in France vary from 732,000 ha, according to the French forest inventory (Anon. undated) to in excess of 1 M ha, 6.7% of the total forest area (Condera et al. 2004); Condera's figure comprises high forest, coppice, coppice with standards and orchards; the last-mentioned is usually not from forest statistics.

In France, chestnut was first planted extensively in the Middle Ages. In the southwest, the largest area of the species is in the Dordogne. The Dordogne has the fifth largest forest area of all the French departments. It is one of five departments in the Aquitaine region. Almost all the forests of the Dordogne are broadleaved, some mixed with maritime pine (*Pinus pinaster* Ait.). It is interesting to note that in a region dominated by the vast maritime pine forests of the Landes, according to CRPF (Le Centre Régional de la Propriété Forestière d'Aquitaine), the standing volume of chestnut in Aquitaine is about 16 M m^3. Much of the surface geology of the Dordogne is limestone. However, the chestnut grows on acid outwash sands which occur on the hills, overlying the limestone.

In Spain, chestnut is grown at relatively high elevations (400 to 1,000 m), compared to southern France. Estimates of the area of chestnut in pure and mixed stands vary considerably from 138,000 (Condera et al. 2004) to in excess of 272,000 ha (Afif-Khouri et al. 2011, Menéndez-Miguélez et al. 2013). Most chestnut stands in Spain are situated in the northwest, in Asturias. Chestnut is the most abundant forest tree species in the province, covering almost 120,000 ha (Jose Alberto Oliveira Prendes, University of Oviedo, unpublished). Chestnut also occurs further west, in Galicia, mainly in the mountainous, eastern part of the province and in the adjoining western region of Castile-Leon. In Galicia, the emphasis is on chestnut orchards, for fruit production, located mainly in the southern province of Orense. Efforts are being made to develop this industry (Jacobo Aboal, Xunta de Galicia, pers. comm.). Grazing is traditionally practised in orchards in Galicia (Eloy Villada, Xunta de Galicia, pers. comm.). Chestnut for timber production is not developed to its full potential in Galicia, but is much better developed in Asturias (Victor M. Garcia, Xunta de Galicia, pers. comm.).

Information from Portugal is limited, but the area of chestnut has been reported as 40,579 ha. Seabra et al. (2001) report a figure of 19,881 ha in fruit production. Both orchards and chestnut forest are located, in the main in north-central Portugal.

Chestnut in the Dordogne

Coppice management in the Dordogne is well organised with an active furniture and joinery industry. Much of the coppice originated as orchards, specially planted for that purpose. Many of these were abandoned in the 19th century. In recent times, fruit producers in the Dordogne and Aveyron, in the Midi-Pyrénées region, have tended to establish new orchards, whereas in southeastern France, growers have generally regenerated old orchards. These old orchards tend to produce smaller nuts because of the lack of pruning.

Almost all the forests of the Dordogne are privately owned. There are 100,000 owners in the in the Dordogne, 10,000 of whom own more than 10 ha. Forest work in the region was always secondary to farming. In the past, stand quality declined with the use of coppice for fuel, as quality was not an important issue. Wood was used for fencing, fuel and as a support for agriculture. Chestnut wood is very good for fuel. Traditionally, it was used, as coppice, for charcoal for iron smelting or directly for steel manufacture; this declined in the 19th century.

The mission of CRPF is to direct the management of private forests in France and to provide training and information services to forest owners. It actively supports chestnut growers in the Dordogne, encouraging good silviculture, accrediting management plans and assisting in obtaining PEFC certification. Thinning is now seen as a priority, with thinning to waste encouraged where appropriate. There is concern about the sustainability of the resource, its uneven age-structure, lack of maintenance and wood quality. There is also concern about the impact of climate change on wood quality due to the sensitivity of chestnut to spring and summer drought and to late spring frost.

Coppice (Figure 1) is harvested at 35-40 years, stems ~20 cm diameter, cut in 2 m lengths. On average, about 10% of the total produce goes for furniture or joinery; in the best stands, about 50% of the total is used for these purposes. Flooring is cut to 1-2 m lengths from stems 12 cm in diameter. The residue is used for pulp or fencing. However, chestnut is not favoured for pulp as, because of its high tannin content, it must be bleached. Dead stems are used for fuel.

Figure 1: *Managed coppice, Villefranche-du-Périgord, the Dordogne.*

Forest policy aims to improve the quality of the coppice and to develop even-aged stands. For about one third of the chestnut forests in the Dordogne, those on the best soils, in the south of the department, it is possible to grow saw-timber for flooring and barrels (Figure 2). Where the existing coppice is poor, the aim is to replace it with maritime pine / chestnut mixtures. Pine is planted in rows 15 m apart with chestnut coppice in between; this is not ideal, but is the best that can be achieved. Cost is the first concern, but owners are concerned about changes to the traditional landscape. They want to return to conditions that are good for mushrooms and for hunting; cèpes (*Boletus edulis* Bulliard) mushrooms do best in mixed forest. Hunting is also improved because there is better cover and food for game and pine provides good lines of sight.

Chestnut is also an important species in Poitou-Charentes, immediately northwest of the Dordogne. There chestnut is utilised differently from the Dordogne; the industrial sector is poorly developed; consequently, much of the wood goes for pulp with a small amount of joinery.

A multifunctional tree for rich and poor

Chestnut was, historically, a valued tree across the whole spectrum of society. Chestnut is a truly multifunctional tree, providing wood for construction, roofing, furniture, baskets, tools and poles for supporting vines, as well its use for firewood

Figure 2: *Chestnut for joinery, Villefranche-du-Périgord, the Dordogne*.

and for tanning. In addition, it provided an essential component of the diet of rural communities and for the rich, higher quality varieties of the fruit were used to produce an expensive delicacy, “marrons glacés”.

Historically, chestnut was grown by peasant farmers to produce both fruit and timber (Figure 3). It was referred to as “pain de pauvre”, the bread of the poor, or “l’arbre à pain”, the “bread tree” (Bourgeois 1992). It was the staple diet of rural populations, assuring their survival in times of shortage. This was particularly true of isolated communities in the mountains of Galicia, in northwest Spain, in Trás-os-Montes and in Portugal. For centuries before the arrival of the potato, populations in chestnut regions depended on the fruit, as virtually their only food, through the winter months.

Grafting was practised to improve fruit production and quality. The trees were topped above the grafting point, 2 m above ground, producing multiple shoots, suitable for pole production. Dual purpose trees are still favoured in Galicia today (Pereira-Lorenzo and Ramos Cabrer, 2004).

In the mountains of Galicia, holdings were traditionally very small. Sometimes an owner had just one tree for nut production. It is said that a family, their pig and perhaps a cow, could survive through the winter on the fruit of a single tree. This was undoubtedly a monotonous diet (it also gave rise to flatulence), but chestnuts can be eaten raw, boiled, baked or roasted and can be incorporated into a variety of recipes. Daily consumption of chestnuts in these communities was 1- 2 kg per day (Kipple and Kriemhild 2000). They were generally eaten fresh until January. Later in the winter, dried chestnuts were used. Peeling by hand was a very tedious operation taking as much as three hours per day for a family of five (Kipple and Kriemhild 2000). Then early in the morning the newly peeled chestnuts were boiled. Drying the chestnuts, often in purpose-built smoking sheds, greatly reduced the labour involved in peeling.

Chestnut is an excellent food source. Dried chestnuts provide 371 calories per 100 g. Potatoes, by comparison provide 86 and wholegrain wheat bread 240 calories per 100 g. In addition, chestnuts are a significant source of trace minerals and are also the only nut to contain a significant amount of vitamin C (Randoin et al. 1976, cited by Kipple and Kriemhild 2000).

In France, there are two words for chestnut, “châtaigne” and “marron”. Châtaigne was the chestnut of the peasant, the basis of his diet for much of the year. Marron was the product of a lower-yielding, higher quality variety of chestnut, such as marigoule, the fruit of a hybrid of *Castanea sativa* and *C. crenata* (Siebold and Zucc.). A marron-type cultivar is characterised by the low percentage of poly-embryonic nuts (Pereira-Lorenzo

Figure 3: *Dual-purpose trees. A Fonsegrada, Lugo Province, Galicia.*

and Ramos Cabrer 2004). The marron is large, globular and broader than long, and usually occurs as a single embryo. They were grown commercially, mainly in Italy and in a few areas in France, to sell to the rich (Kipple and Kriemhild 2000). These high-quality nuts have been used since the late 17th century in the production of the French and Italian delicacy, "marrons glacés", chestnuts candied in sugar syrup and glazed.

The Future

Chestnut production, for both timber and fruit, is declining throughout Europe, although efforts are being made to stem this decline. Nut production in France has gone from 500,000 t yr^{-1} in the late 19th century to less than 10,000 t today. In southwest France, production is about 3,500 t, most of it in the Dordogne (Hennion 2010). In the mid-nineteenth century, there were 80,000 ha in chestnut orchards in France; now there are about 5,000 ha. Many factors have contributed to the decline. It may have started with the spread of ink disease and the introduction of an alternative staple food, the potato. Chestnut use has also been replaced by cereals. Both chestnut orchards (harvesting is still carried out by hand in most orchards) and coppice management are labour intensive and many coppices have been abandoned or their rotation length markedly increased. These factors and the depletion of the rural population have contributed to the decline. Other factors include the widespread felling of chestnut stands for tannin production.

Figure 4: *Bole burned to prevent ink disease. A Fonsegrada, Lugo Province, Galicia.*

Against this trend, new orchards are being established. New orchards are best established on slopes to afford good drainage (Pereira-Lorenzo and Ramos Cabrer 2004). However plantations on steep slopes can only be used for timber production, as they do not easily allow mechanisation. Cutini (2001) explored new management options for chestnut in Italy. The increasing demand for high quality wood cannot be met through traditional short-rotation coppice. He concluded that highly productive stands could be managed sustainably for sawlog production through relatively heavy thinning and longer rotations than are currently used. Stands for timber production should be located in areas of relatively high rainfall (over 1,000 mm per annum in Spain), so as not to limit growth (Pereira-Lorenzo and Ramos Cabrer 2004). The aim in timber production is to produce a branch-free trunk of up to 7 m in length (Pereira-Lorenzo and Ramos Cabrer 2004). *C. sativa* is best for timber production, being the most vigorous. It also produces the largest nuts, but not the best flavoured (Pereira-Lorenzo and Ramos Cabrer 2004).

In southern Galicia, south-facing slopes are favoured for vineyards, north-facing for chestnut orchards (Pereira-Lorenzo and Ramos Cabrer 2004). Currently old orchards are being coppiced to transform them into timber stands. Government support and advice is available for this work.

Afterword

Spanish chestnut is a special tree. It is an integral component of the landscape over much of southwest Europe. It is a tree with a long history, endowed with many traditions. Over the centuries, it made an important contribution to the survival of rural communities. But while it provided both "the bread" and the wood of the poor, it was also a tree of the rich, a valuable source of wood for monasteries and large vineyards and for a delicacy manufactured from its fruit.

In the region, it has been in decline for more than a century. The flight from the countryside, increasing affluence, the high cost of labour, alternative food sources, have all contributed to the decline. Despite this, the future for the species is relatively bright. There is no doubt that chestnut remains a highly valued tree. For many, mushroom production is the main benefit provided by Spanish chestnut stands. For others, chestnut coppice is favoured for hunting. Governments throughout the region promote its retention, whether through the improvement of coppice, for the production of sawlogs, or the development of orchards. Spanish chestnut will remain a special tree for a long time to come.

Acknowledgements

I am heavily indebted for the assistance given me by Sébastian Drouineau, CRPF, Bordeaux and to Roque Rodríguez, University of Santiago de Compestela, Lugo. They in their respective areas, the Dordogne and Galicia, gave a great deal of help and information on the history and current status of the chestnut industry. Much of the unattributed information in this article is derived from discussions with them and with Joël Lefievre, CRPF, Lambras, le départment de la Dordogne.Thanks also to Jacobo Aboal, Eloy Villada and Victor M. Garcia, Xunta de Galicia, Santiago de Compestela and Lugo.

My thanks are due also to Jean-Michel Carnus, INRA, Pierroton, Aquitaine and Agustín Merino, University of Santiago de Compestela, Lugo, who facilitated my stays in Aquitaine and Lugo, respectively and both of whom generously assisted me during my visits there.

References

Afif-Khouri, E., Álvarez- Álvarez, P., Fernández-López, M.J., Oliveira-Prendes, J.A. and Cámara-Obregón, A. 2011. Influence of climate, edaphic factors and tree nutrition on site-index of chestnut coppice stands in north-west Spain. *Forestry* 84(4): 385-396.

Anon. Undated. *Résultats d'Inventaire Forestier. Résultats Standards. La France Administrative. Les Résultats des Campagnes d'Inventaire 2008-2012*. IGN, pp 179.

Bourgeois, C. 1992. *Le Châtaignier, un Arbre, un Bois*. Institut pour le développement forestier, Paris, pp 352.

Condera, M., Manetti, M.C., Giudici, F. and Amorini, E. 2004. Distribution and economic potential of the sweet chestnut (*Castanea sativa* Mill.) in Europe. *Ecologia Mediterranea* 30(2): 179-193.

Cutini, A. 2001. New management options in chestnut coppices; an evaluation on ecological bases. *Forest Ecology and Management* 141: 165-174.

Hennion, B. 2010. Chestnut production in France: Review, Perspectives. *Acta Horticulturae* (ISHS) 866: 493-497.

Kipple, K.F. and Kriemhild, C.O. (Eds). 2000. *The Cambridge World History of Food*. Cambridge University Press, pp 1958. Available at http://www.cambridge.org/us/books/kiple/chestnuts.htm [Retrieved September 2014].

Menéndez-Miguélez, M., Canga, E., Barrio-Anta, M. and Majada, J. 2013. A three level system for estimating the biomass of *Castanea sativa* Mill. coppice stands in north-west Spain. *Forest Ecology and Management* 29: 417-426.

Nelson, E.C. and Walsh, W.F. 1993. *Trees of Ireland, Native and Naturalised*. Lilliput Press, Dublin, pp 247.

Pereira-Lornezo, S. and Ramos-Cabrer, A.M. 2004. Chestnut an ancient crop with future. In *Production Practices and Quality Assessment of Food Crops*, Volume 1 *Preharvest Practices*. Eds Dris, R. and Jain, S.M., pp 105-161.

Randoin, L. and Le Gallic, P., Depuis, Y., Bernardin, A., Duchene, G. and Brun, P. 1976. *Tables de Composition de Aliments*. Institut d'Hygiène Alimentaire, Paris, pp 116.

Seabra, R.C., Simões, A.M, Baeta, J. and Pais, M.S. 2001. Evaluation of Portuguese chestnut stands by RAPDS. *Forest Snow Landscape Research* 76: 435-438.

Villani, F., Pigliucci, M., Benedettelli S. and Cherubini, M. 1991. Genetic differentiation among Turkish chestnut (*Castanea sativa* Mill.) populations. *Heredity* 66: 131-136.

Forest Perspectives

Celebrating 100 years of Forestry education in UCD

John J. Gardiner and Maarten Nieuwenhuis

This paper is a revised version of the Sean Mac Bride lecture given by Prof. (Emeritus) John J. Gardiner on 26th November, 2013 at University College, Dublin.

Figure 1: *Pictured at the event were (right to left, front row) Prof. Gardiner, Mr Pacelli Breathnach (president of the Society), Dr Hugh Brady (President of UCD), Prof. Nieuwenhuis; (back row) Mr John Mc Loughlin, Dr Áine Ní Dhubháin, Mr Kevin Hutchinson, Ms Marie Doyle and Dr Brian Tobin (Photograph: Catherine Hutchinson).*

Introduction

In the beginning there was Trinity College. Founded in 1593 by Queen Elizabeth I; in the words of one of its distinguished alumni "…. Founded by Protestants, for Protestants and in the Protestant Interest .…". It was to remain exclusively Protestant for 200 years. University statutes made it (1) obligatory for all students to attend services, and (2) religious tests and anti-papal oaths were imposed on provost, fellows, scholars and all who wished to obtain a degree. Trinity was an exclusively Protestant university. The Catholic Relief Act of 1793 enabled Catholics to enter Trinity and obtain a degree but they could not hold administrative office or become fellows or scholars.

Then in 1845, Sir Robert Peel established Queens Colleges at Belfast, Galway and Cork. These were to be un-denominational with religious teaching and catechetical instruction prohibited. The setting up of these colleges was a political ploy designed to break the link between home-rule politics and the people, and between the church and people. According to Archbishop McHale, Catholics aspiring to a third-level education had a choice of entering a Protestant university or a Godless university. Thus, a National Synod of Bishops held in Thurles in 1850, decided to establish a Catholic University and in 1851, they invited John Henry Newman, the most famous Catholic scholar in England, to become its first Rector. A total of £30,000 was available, raised through church collections, and a property at 86 St. Stephen's Green was purchased at a cost of £3,500.

Newman's idea was that the students should live in self-supporting halls or colleges, and so the University Committee bought 6 and 16 Harcourt Street. Newman himself lived and was Dean or House Master at 6 Harcourt Street. Newman appointed Catholics of eminence, whose names were well-known, as professors; e.g.

- Eugene O Casey — Professor of Archaeology and Irish History
- Aubrey de Vere — Professor of Political and Social Science
- Denis Florence McCarthy — Professor of Poetry and Literature

The Catholic University of Ireland opened on 5th November 1854, offering courses in Logic, English Literature, Italian, Spanish, French, Mathematics, Physics, History, Geography and Chemistry. There was a total of 17 students. The Medical School was the only section of the University that could be said to be a success. The remainder suffered from lack of students and resources and its degrees were not recognised.

University College (University College, Dublin)

Then in 1880, Disraeli introduced the University Education (Ireland) Bill, leading to the establishment of the Royal College of Ireland. This was a non-teaching, degree awarding institution – the forerunner of the National University of Ireland.

The Catholic University was renamed University College, later University College, Dublin. At this time (1880), the Catholic University was a failure – basic problems: little money, few students and its degrees were not recognised. After Disraeli's Act, two things happened: 1) University College degrees were recognised by the Royal University, and 2) the Jesuits took over the management of University College. With Jesuit help and encouragement, constituent colleges at Kilkenny, Clonliffe, Blackrock, Carlow, Terenure, etc. set up university departments. These would: 1) prepare students for matriculation, and 2) permit students to take the University courses in their home school or college and undertake Royal University Examinations – with the exception of final year courses, which they were required to attend in Dublin. The University began to prosper and the number of students increased. From 1895 to 1909, University College greatly outstripped the provincial Colleges in the number of students and in the quality of its degrees.

The Royal College of Science (RCSI)

The Royal College of Science was established in 1867 to provide advanced education in branches of science connected with industry, and particularly engineering, chemistry and agriculture. It never attracted large numbers of students. With the formation of the Department of Agriculture and Technical Instruction (DATI) in 1900, the College, its staff and the Albert Agricultural College (Figures 2 and 3), came under its control. From1840-1926, it (with the Albert College) was the premier establishment in Ireland in the provision of higher education in Agriculture, Horticulture and Forestry. It offered a three-year course, which was adjusted to four years when the new building (at Merrion Street) opened in 1911. With the passing of the University Education (Agriculture and Dairy Science) Act in 1926, the Royal College of Science and the Albert College, Glasnevin, were transferred to UCD. They housed the Faculty of Science and the Faculty of General Agriculture, respectively, until these were accommodated at Belfield.

The Recess Committee

At the suggestion of Horace Plunkett, a committee was formed in 1895, representing virtually all of the factions in Irish society (political and religious). Representation was invited from any group wishing to participate on a thirty-two county basis. In essence, anyone who wanted to contribute to the working of the committee was welcome. It was called the Recess Committee because it could only meet when parliament was in recess. The purpose of the committee was to consider: 1) the setting up of a Board of Agriculture for Ireland, and 2) technical and practical education. The Chairman was Horace Plunkett who was an agnostic and a Unionist. The Secretary was T.P. Gill, who was a Catholic Nationalist. One would have imagined that such a committee could not agree on anything. However, in 1896 the committee issued a unanimous

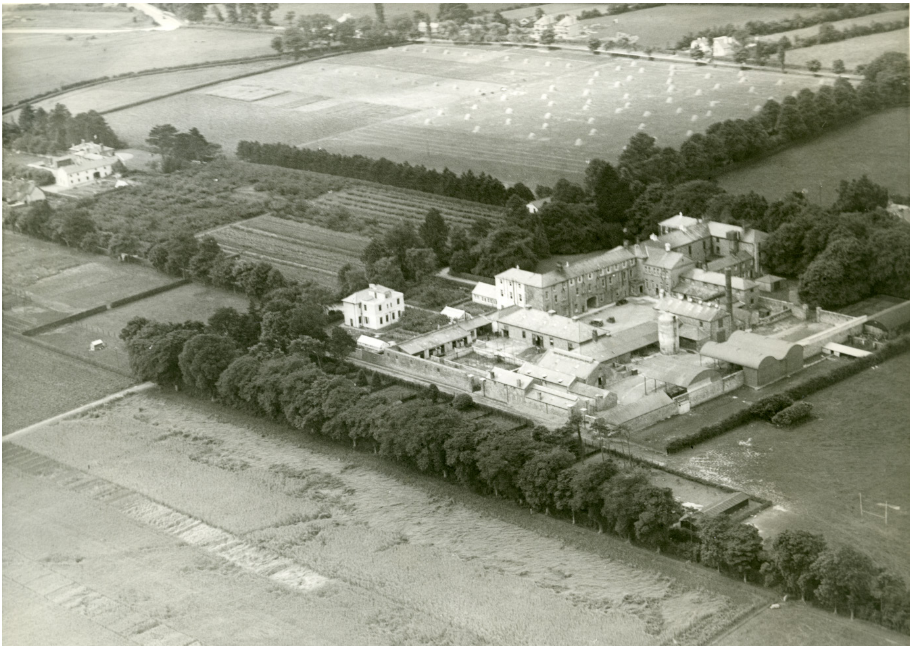


Figure 2: *Aerial view from the south-east of the Albert Agricultural College in Glasnevin. Part of the Stormanstown estate is visible on the left. Stormanstown was demolished in 1979 to make way for a community housing scheme in Ballymun. Image courtesy of UCD Archives.*

Figure 3: *Main teaching buildings at the Albert College from the south-west (left), the east wing is behind the trees and the lecture theatres are to the right. View from west through the arch from the sundial path into the yard (right). Photographs taken in the period 1927-38. Many of the buildings at Glasnevin date from the middle of the 19th century. Following UCD's departure to Belfield, the site forms part of Dublin City University. Image courtesy of UCD Archives.*

report, recommending that the Government should provide the necessary financial and administrative support for agricultural development. Such was the political clout and drive of the Chairman and Secretary, that in 1900 the Department of Agriculture and Technical Instruction (DATI) was established. It was given widespread and sweeping powers, including control of the Royal College of Science and the Albert Agricultural College. From 1898, students could theoretically take a three-year course in Forestry at the Royal College of Science. However, the volume of relevant subject matter in the course may have been quite limited. The appropriate calendar gives the syllabus as " ...... the cultivation of trees in nursery, plantation and woods .....". On reflection, I suppose this gave plenty of scope for the inclusion and teaching of technical subjects. After 1905, the Department was offering generous scholarships to suitably qualified students to undertake three-year courses in Agriculture, Horticulture and Forestry. There appear to have been no "takers" for the Forestry course until 1910 when those courses were expanded to four years. This may have been due to the difficult matriculation and practical experience requirements.

In 1905, Arthur C. Forbes was appointed "Forestry-Expert" at the DATI. He had been Forester-in-Charge at the Longleat Estate in Wiltshire and Lecturer in Forestry at the College of Science, Newcastle-upon-Tyne. He directed the development of Avondale and presumably the establishment of the teaching programme. In addition, he was involved in setting-up a Forestry Committee within the Department and in organising an advisory service, in forestry, to landowners. He was a prolific author and many of his articles were published in the Journal of the Department. They were on topics of a somewhat mundane nature, such as Forest Protection and aspects of the production and use of Irish timber. He travelled widely and wrote accounts of the organisation of forestry activities in Demark, Sweden and Germany. In 1904, he delivered a series of public lectures at the Royal College. Registration for these lectures cost 10/- (roughly equivalent to €0.63). After the Treaty of 1922 he was styled, Director of Forestry. Later in his career, he was involved with John Crozier, his assistant in the DATI from 1910 to 1933, in visiting sites and making recommendations in relation to site preparation, species selection and planting. He was one of the first foresters to be made an Honorary Member of the Society of Irish Foresters. He retired from the Department in 1931.

Earlsfort Terrace (1912-1924)

The building of University College at Earlsfort Terrace rings so many bells in today's terms that I felt I just had to say a few words about it. Essentially, the story was of an inadequate site and budget for what the University wanted to build. UCD wanted university buildings that could accommodate 2,000 students. The neighbouring landlords – Hely-Hutchinson on the Hatch Street end and Lord Iveagh on the St Stephen's Green end – were not too willing to help rectify the site difficulties. The former was of no help, and while the latter was willing to help (he was Chancellor of Trinity at that time), he was anxious that his gardens, tennis courts and stables should not be overlooked. Hence, he imposed restrictions upon the height of buildings on his sides and on the positioning of windows. With the advent of the war, the cost of labour and materials soared. Cramptons' (the builders) workers went on strike and the whole project quickly ran over budget. UCD was not able to source any additional funding. There was much recrimination as builders and contractors were unpaid. The entire project ran years behind schedule. The original design was for a set of buildings in quadrangular design, with a library and *Aula Maxima* in the centre. The building of the University was never completed.

The Degree Programme (B.Agr.Sc. in Forestry)

Since the appointment of Augustine Henry in 1913, the number of academic staff associated with the Forestry programme has slowly increased (Table 1). In this section, we focus on some of the earlier appointees.

Augustine Henry

Augustine Henry joined the staff of the DATI in 1913 as Professor of Forestry (Figure 4). However, while Forbes's duties were manifold, Henry seems to have confined himself to teaching, research and publication duties at the Royal College of Science. There is no evidence that he became in any way involved in Avondale, in advisory activities or in State afforestation affairs. After he took up office, the Forestry curriculum began to evolve and by 1921/22, it had assumed the "shape" which we know today (by year of study): science, science, practical, professional, professional. In addition, the gradual transfer of the teaching programme to the Faculty of Science in UCD began. Initially, this took the form of course work at the Royal College of Science and accreditation at NUI (UCD). The culmination of this gradual change was the transfer of the Royal College of Science and The Albert College to UCD in 1926. The Faculty of Agriculture and the Faculty of Science both had a centre of operations.

Henry had very few students, but he was responsible for lectures to Agriculture and Horticulture students, who were required to take his courses. These third-year and fourth-year courses were extensive in scope and depth. The appropriate calendar indicates that they were supplemented by excursions and practical work. At the Royal College, Henry continued the research on hybridisation, which he had begun at Kew. His publications in the period 1915 to 1925 very much reflect his interests, e.g.

- "A New Hybrid Poplar", 1914.
- "American Sycamores are Possibly Hybrids", 1917.
- "The History of the Dunkeld Hybrid Larch", 1919.
- "The Douglas Firs", 1920.
- "The Swamp Cypresses, Glyptostrobus of China and Taxodium of America", 1926.

Figure 4: *Professors and heads of Forestry at UCD, past and present. Top to bottom and left to right: Prof. Augustine Henry (watercolour by Anna O'Leary, courtesy of the National Botanic Gardens, Glasnevin), H.M. FitzPatrick (Ann Luke collection), A.C. Forbes (Coillte), Prof. Tom Clear (UCD School of Agriculture and Food Science), Prof. Padraic Joyce, Prof. John J. Gardiner (UCD School of Agriculture and Food Science) and Prof. Maarten Nieuwenhuis.*

They appear, however, to have been mostly of a review nature and do not suggest a concentrated or focused research programme. With the passing of the University Education (Agriculture and Diary Science) Act in 1926, Henry transferred to UCD. The Statute appointing him was most unusual in that he was made Professor for life, but without pension rights. I am guessing that these unusual conditions were imposed because of his age; he was sixty-nine at the time. In 1926, his salary was fixed at £600 yr^{-1} (€762) with a potential bonus of £226.14 yr^{-1} (€287). Only four students studied for the Associateship / Degree in Forestry during the eighteen years in which he was Professor of Forestry. In the period 1913 to 1926, there were two forestry experts in the DATI; remember that the Royal College was under the control of the DATI, so Henry and Forbes worked for the same department. Yet there is no evidence of any interaction whatsoever between the two men. Socially they must also have moved in different circles. Pim (1984) has written about Henry dining at the Vice-Regal Lodge and mingling with the artistic and medical "sets" (Æ, Eoin McNeill, Padraic Colum, Lady Gregory). Forbes is never mentioned in these circles.

Table 1: Academic staff over the period 1913 - 2013.

Timeline	Staff
1910[a]	
	A. Henry, Professor of Forestry
1930	H.M. FitzPatrick A.C. Forbes
	T. Clear
1950	
	T. Clear, Professor of Forestry
	L.U. Gallagher
	P.M. Joyce
1970	J.J. Gardiner
	P.M. Joyce, Professor of Forestry
	J.J. Gardiner, M. Mac Siúrtáin, M. Nieuwenhuis
1990	
	J.J. Gardiner, Professor of Forestry
	M. Mac Siúrtáin, M. Nieuwenhuis, Á. Ní Dhubháin, C. O'Reilly
2010	Current staff: M. Nieuwenhuis, Professor of Forestry M. Mac Siúrtáin, Á. Ní Dhubháin, C. O'Reilly, M. Doyle B. Tobin, C. Harper, O. Grant, A. McCullagh

[a] Indicative dates only.

Hugh M. FitzPatrick

Hugh M. FitzPatrick graduated in UCD with a primary degree specialising in Forestry in 1927 and a Master's degree (M.Agr.Sc.) in 1928. His mentor was Professor Henry. His task as a postgraduate student was to compile a series of descriptions of the conifers, based on the morphology of the twigs and foliage and to arrange them in an artificial key. This key was published by the Royal Dublin Society in 1929 and is one which I found most useful for instruction in Dendrology. He was Acting Lecturer in Forestry in 1937/38.

A.C. Forbes

Arthur C. Forbes retired from the DATI in 1930. From 1931 to 1935, he was solely responsible for the delivery of the Forestry Degree Programme at UCD. This was the period following the death of Henry and before the appointment of Tom Clear.

Tom Clear

Tom Clear was a very experienced silviculturalist and forester. As a final year student, he and his classmates had studied in Sweden for four months under the direction of A.C. Forbes. As a result, he was au fait with modern methods of site classification and inventory. In his postgraduate work, he travelled extensively in Germany and acquired an in-depth knowledge of European forestry systems and species. Because of his contacts with the likes of Lord Meath, Thomas Pakenham and the Tottenhams, he appreciated how European tree species performed in Ireland on ecologically suitable sites. Like Henry before him, he favoured the use of North Western American tree species on the sites which were available for afforestation in Ireland, but he feared ".... that a growing flood of blanket bogs drains the hopes that State afforestation will ever be anything more than a relief scheme ....". In general terms, Tom Clear was much more at ease in the forest than in the classroom. The fact that he had access to such an enormous range of forest sites (public and private), and could use them for student exercises, greatly enhanced his course in Silviculture. He was a big advocate of student fieldwork, the practical year and the final year tour. He believed that silviculture, in particular, should have a substantial field element. Despite being something of a reluctant lecturer, he was a talented raconteur. This facility, combined with his wide local knowledge of Irish forestry, often made his lectures in Forest Policy quite entertaining.

The Society of Irish Foresters must be very aware that Tom gave very generously of his time and expertise to the causes that he avowed. The same is true relative to UCD. He served two terms as Dean of this Faculty, at a time when the Faculty feared for its well-being. Despite this involvement in College administration, he was quite indifferent to Faculty and College politics; it appeared as if he just could not be bothered. As a result, he was easily duped by the machinations of more aggressive colleagues. A simple anecdote may serve to illustrate this point. Tom Clear was keen to have a small nursery attached to the Department. At Stormanstown House, Ballymun, he had access to a suitable site but he lacked technical assistance. Requests to the Faculty for such help fell on deaf ears, until, lo and behold, one day a fellow professor approached to inform him that he had in his department the ideal man, whom he would let him have on a permanent basis. No doubt, Tom was overcome with this outburst of collegiality, particularly as the technician in question turned out to be suitable and reliable. I do not know if Tom ever appreciated that his benefactor had been trying to get rid of this man for some time because he was the local union organiser. Such was the manner in which a gem of a gentleman called Louis O'Reilly came to join the Forestry Department in UCD in the late 1950s.

I want to mention specifically the year 1963; not simply because it was the mid-point of the centenary, but for three other, related reasons:

1. The list of graduates for that year is as follows: M. Bulfin, M. Cassidy, J. Treacy and J.J. Gardiner.

2. Also in 1963, Len Gallagher returned to UCD from study leave at the University of Washington, Seattle.

3. In the autumn of that year, the first Science and Technology show was mounted at the RDS, with the science departments of the Universities putting on exhibits.

Tom Clear induced me (a few £s changed hands) to assist Len to prepare an exhibit which would show the work of the Department. The actual exhibit was a mock-up of a hydroponics-based experiment to show the impact of low oxygen levels in the soil upon tree growth. It consisted of trees growing in glass tubes with oxygen from cylinders bubbling through the nutrient solution. It attracted much favourable attention and I just wanted to mention it as Len Gallagher was a staff member in the Department of Forestry, Stormanstown House, at the time.

Pádraig Joyce

In reviewing 100 years of Forestry education at UCD, I consider that the recruitment of P.M. Joyce to the staff in the 1960s had a transformational impact upon the entire degree programme. To this time, the emphasis had been upon silviculture and silviculturally related subjects. Pádraig introduced computer applications and a hard numeracy to the teaching of subjects such as Forest inventory and Management. His input in statistics, experimental design and data analysis stiffened and added impetus to the teaching and research of the Department. From the late 1960s onwards, the Forestry Degree programme presented the concept of a scientifically-based and commercially viable land-use enterprise. You might consider that in this way, the degree course anticipated the formation and development of Coillte Teo. At this point, I must remind you that the innovative techniques introduced by Pádraig were accomplished at a time when the only computer system available was the old Fortran-based one. With this, users had to write their own programs, punch and arrange their own decks of cards and bring them to a dedicated building for processing. Introducing computer applications into a degree curriculum was not a task for intellectual wimps. P. M. Joyce is Emeritus Professor of Forestry, UCD.

It is appropriate here that I should mention that for much of the time during which Tom Clear, Pádraig Joyce and I were employed at UCD, the Department of Forestry was fortunate to have the services of an exceptionally talented and dedicated administrator, Ms. Valerie Guilfoyle.

The Curriculum

In its core philosophy, the curriculum for education in Forestry is older than the degree programme itself. The acquisition of the farm at Glasnevin in 1838, gave a clear signal that the Board of Education, of the time, appreciated the benefit of experience and demonstration in the education of instructors in Agriculture. In addition, it has been acknowledged from this time that graduates in Agricultural Science, Horticulture and Forestry should have a first class exposure to basic science as well as professional matter.

The first Professor of Forestry discovered these elements of the curriculum at Nancy where the year's lectures were followed by end-of-year excursions to the forests of the Jura, Pyrenees and Landes regions. He introduced similar elements into the curriculum at the Royal College and so we read of FitzPatrick undertaking practical work at Gort Forest and preparing a working plan for the hardwood forest of Tronçais. Forbes also maintained a strong element of fieldwork in the curriculum, preferable in a European context. Hence, the sojourn of Clear et al. in Sweden during their final year of studies. Clear, in turn, appears to have striven to maintain the fieldwork element, even under the most difficult wartime conditions. Dermot Mangan (1988) has referred to a student tour, by bicycle, in 1941, in the Gort area. So the forestry curriculum in UCD, as indeed in most other Forestry Schools in Europe has, for many decades, opened with a strong element of basic science, followed by extensive exposure to applied science subjects and professional work experience. This foundation was capped with a full complement of professional subjects. This core curriculum has remained unchanged over the past 100 years.

The emphasis upon fieldwork is still in position but the detail has been significantly upgraded and modernised. In the Forest Management Plan module, each student must undertake a case study of an actual forest area (Ballycurry and Cloragh Estates) and, in compliance with given economic, social and environmental objectives, produce a management plan based on sustainable forest management (SFM) principles. This plan must incorporate a description of the site, including both timber and non-timber details, based on the results of the GIS and Forest Inventory and SFM Assessment modules. Using SFM criteria and multi-criteria decision-support software, each student is required to analyse the inventory data and produce detailed prescriptions for yield regulation, harvest scheduling, silvicultural practices, forest protection and environmental, cultural and social indicators. A financial analysis must also be included.

Staff and students have always appreciated the beneficial effects of exposure to the forestry culture and environment of another country. Hence, the fourth year tour remains. Traditionally, this tour attempted to visit a different country each year. However, for the past 15 years or so, the tour has been hosted by Professor Jürgen Huss of the Albert Ludwigs University in Freiburg and includes students from the University of Aberdeen. Many aspects of forestry in Germany and the Black Forest, including silviculture, management, harvesting and utilisation, and farm forestry are explored. A trip to the coppice with standards forests, across the border in France, is also included. The learning experience is enhanced by Professor Huss's knowledge of Irish forestry. This tour has been generously sponsored by Coillte, COFORD, and recently also by Green Belt and Forest Enterprises Limited.

However, to say that the core of the curriculum has not changed is not to suggest no change. Indeed, there have been major changes over the past 100 years and the actual syllabus is in a constant state of evolution. A major change introduced in the mid-nineties was to reduce the duration of the programme from 5 to 4 years. This was a Faculty decision and was to apply to the nine degree options in the Faculty. In the era of competition for students and resources, a five-year degree programme (no matter how good) could not compare with a three-year Bachelor of Arts (for example). The only way to accommodate such a major change in the curriculum was to abbreviate the duration of the professional work experience component to six months. This may not have been a bad thing, in itself, since feedback from students had indicated that the value of the practical year was a "mixed bag". Some students considered it the most valuable and informative year in the curriculum; others considered that they had learned nothing and that it was a waste of time. Another important change that was introduced was to make the final year almost entirely composed of project work (*sans* lectures). The aim was to shift the entire focus from passive teaching to active learning and skills acquisition; from the lecturers to the students. One of these final year projects would be an elective research one. This would give students a choice of subject area and would bring them into contact with research problems: problem identification and formulation; method(s) of study, design and analysis, scientific reporting and meeting deadlines.

I could go on all night about other changes that have been introduced, notably in the areas of inventory, management planning and forecasting. However, there just is not sufficient time, so I will confine my remarks to just two: around 1990, a new subject, "Introduction to Forestry" (later renamed "Trees and Forests of Ireland"), was included at first year level and was opened to all comers – simply to permit students to find out a little bit about forestry. Now 60 to 80 students – most of them non-forestry – take this course each year, on an elective basis. In addition, the School's second year course in Statistics is now delivered by a Forestry staff member and is taken by approximately 300 students each year. The curriculum for the primary degree in Forestry has indeed changed significantly over the past 100 years, but in such a way as to maintain, in its entirety, the integrity of the B.Agr.Sc. in Forestry.

From time to time, other innovative developments have been introduced. The Higher Diploma / Taught Masters in Forestry was launched in 1996. The course was unique in the Faculty in that students registered initially for a Higher Diploma (1 year); these students, reaching a set standard in the Higher Diploma examinations, could opt to change their registration to a Taught Masters programme. To facilitate those with full-time jobs, lectures were delivered on alternate weekends with students required to undertake a considerable amount of reading in between. Originally, the course was open to those with a previous forestry qualification but in 2000, it was opened to those with a prior science qualification. In 2001, a transfer programme was introduced to facilitate forestry graduates from Waterford Institute of Technology and the Galway-Mayo Institute of Technology to get access to the Honours Degree Programme in Forestry in UCD.

The most recent curriculum development is the introduction of a 2+2 undergraduate programme in Forestry with the South China Agricultural University (SCAU). Chinese students will take the first two years of study at the SCAU and for their remaining two years will transfer to the Forestry Degree Programme of UCD.

Students and Graduates

The number of students studying for the B.Agr.Sc. in Forestry has never been big. During the entire period of Henry's tenure as Professor (1913-1930) there were just four; D. McCaw or M'Caw qualified in 1913 and M. O'Beirne in 1914 (Table 2). Both were subsequently founder members of the Society of Irish Foresters. To my knowledge, Michael O'Beirne was the only forestry student to be awarded a scholarship to study forestry by the Department of Agriculture and Technical Instruction. These were valuable scholarships since not only did they give free instruction but also free board and residence at the Albert Agricultural College. In addition, there were generous allowances for travel and course materials. Arthur C. Forbes graduated, as an Associate of the Royal College, in Forestry in 1923. He was the only son of Arthur C. Forbes, forestry expert at the DATI. Afterwards, he had a distinguished career in New Zealand forestry. H. M. FitzPatrick, after graduation in 1927, lectured in Forestry for one year. He went on to complete an M.Agr.Sc. under the direction of Professor Henry.

The total number of graduates in the period 1913-2013 is 483, including 425 men and 58 women (Table 3). However, in some years there were no students and in at least six years there was just one. The first woman to study for a degree in Forestry was Philomena Tuite in 1981 and then in 1982 there were two others: Helen Maher and Melissa Newman. A bit like 46A buses, I suppose; you wait 70 years for the first to come along and then three come together. The maximum number of students taking Forestry in any one year was 28 in 1996. The relatively big number of Forestry graduates taking higher degrees is worthy of note (Table 3). I just want to mention one. The first forestry graduate to gain a M.Agr.Sc. and a PhD in Forestry was Denis Quirke who graduated with a primary degree in 1942 and with a PhD in 1949. The research for his two postgraduate degrees involved "A Survey of Insect Pests of Irish Woodlands". The entire survey was carried out by bicycle. It was funded by the Forestry Division of the Department of Lands and supervised by Professor John Carroll, Professor of Agricultural Zoology, UCD. It still remains one of the most complex and detailed PhD studies that I have seen and I believe that no comparable study of insect pests has been undertaken in Irish forests since that time.

I should also mention here two other groups of students who studied Forestry at UCD. For many years, it was possible for undergraduates from other Colleges of the National University to take the first two years of study at their "home" colleges and then to transfer to UCD to undertake the professional subjects of the degree programme. There were many such transfer students from University Colleges, Cork and Galway, but no record of the exact number or of student names is now available. From 1906, a Diploma course in Agriculture was available at Trinity College. When this was combined with an abbreviated B.A. course, a degree, Bachelor in Agriculture, could be conferred. This course disappeared about 1912 and shortly

Table 2: *Early Forestry graduates.*

Year	Graduates
1913	D. McCaw or M'Caw
1914	M. O'Beirne
1923	A.C. Forbes
1927	H.M. FitzPatrick
1935	T. Clear
	M. Feehan
	O.V. Mooney
	S. O'Sullivan
	D.M. Walsh

Table 3: *Number of graduates for the period 1913-2013.*

Undergraduate students			Graduate students			
Male	**Female**	**Total**	**M.Agr.Sc.**	**M.Sc.Agr.**	**Ph.D.**	**Total**
425	58	483	64	33	35	132
Number of students in final year in 1996						
18	10	28				

afterwards Bachelor degrees in Agriculture, Horticulture and Forestry were instituted. The extent of the technical (professional) components in the Diploma course had been very meagre and hence, for the purpose of these degrees, students attended courses at the Royal College of Science (University College Dublin from 1926). This appears to have been facilitated by an informal agreement between the universities. These degree programmes offered at Trinity College generally attracted few students and available records indicate that no student from Trinity attended lectures in the Forestry courses at UCD prior to 1945. From 1946-1973, 19 students (all male) took the 3rd and 4th year courses in Forestry at UCD to fulfil the requirements for the Trinity College degree, Agr. (Forest.) B. (*Baccalaurei in Agri Forestarii Cultura*). From the mid-1970s onwards, these kinds of arrangements with other Colleges and Universities became more difficult due to curriculum changes introduced by the Faculty of Agriculture, UCD. In any case, there was little demand and these arrangements just fizzled out.

Throughout all of its existence, UCD and the Forestry Department have been fortunate in the academic quality and discipline of the students. To this day, the security force and arrangements at Belfield are skeletal. So one of the very few, semi-organised, mass student protests, which came to be known as the "Gentle Revolution", is worthy of brief comment. In the autumn of 1968, university campuses all over the world, but notably those in the USA (Columbia, UC Berkeley) and Europe (The Sorbonne) exploded in a tsunami of student protest. It was the era of protest – civil rights protests in the US and Northern Ireland; protests against Viet Nam, nuclear armament etc. It threw up student cult figures and images: "Danny the Red" (Paris), Rudi Dutschke (Berlin) and Tariq Ali (London); it was the era of dropouts, hippies and angry young men. At this time, a whole series of minor stresses were experienced in Dublin universities, including:

- talks of a merger between UCD and Trinity;
- massive and chronic overcrowding at UCD;
- very poor library and recreation facilities at Earlsfort Terrace; and
- demands for participation by students in university government.

These circumstances led to a ripple of this tsunami reaching Dublin. It took the form of protest marches and "sit-ins". Thousands of students took part in the marches and hundreds in the sit-ins. The whole thing was encouraged, and to some extent directed, by Junior Staff who had their own grievances. It culminated in the disruption and blockade of an Academic Council meeting in Earlsfort Terrace. Professors attending this meeting included Tom Clear who was eventually rescued by a porter via a window. The idea of a quite portly, non-athletic, Tom escaping via a window was amusing to us at the time and Tom, who could make any story sound exciting made this affair sound like Armageddon. The actual sit-in in Earlsfort Terrace which caused the abandonment of the Academic Council meeting involved about 300 students – but it is agreed that there were only about 9-12 hard-core romantic activists (extremists, if you must). Furthermore, it is agreed that one of the leaders of this dozen, if not the leader, was a then Architecture student and leader of the UCD Student Branch of the Labour Party – Ruairi Quinn – the current Minister for Education.

Concluding Remarks

For most of the century under review, higher education in Forestry was conducted in accommodation and at locations peripheral to the University, such as The Royal College of Science, 51 St. Stephen's Green East; Royal College of Science, Merrion Street; Albert College, Glasnevin; Stormanstown House, Ballymun; Roebuck Grove, Belfield; and Builders Prefabs, Belfield (Table 4). For many years, it was never quite an integral part of the Faculty, the University or the wider academic community. This acted to the detriment of the development of staff, students and forestry education. It is only in relatively recent decades that Forestry as a scientific/commercial activity has begun to be recognised as a subject worthy of serious research and study. Many of us would claim some small recognition for this transition. However, much credit is due to the present staff who have accelerated the advancement of the study of Forestry towards a central position within the academic milieu. The impact upon future graduates and the profession of Forestry will be positive.

Table 4: *A chronology of Higher Education in Forestry at UCD, 1900-2013.*

1900	Department of Agriculture and Technical Instruction established
1908	Foundation of the National University of Ireland
1908/09	Scholarship(s) at Royal College of Science to Forestry student(s) for the first time
1911	Four-year Associateship / Degree Programme in Forestry introduced
1912	Augustine Henry appointed Professor of Forestry
1913	First Associate (Graduate) in Forestry conferred
1926	University Education (Agriculture and Dairy Science) Act, 1926, passed. Forestry Degree Programme transferred to UCD
1933	First land-purchase by UCD at Belfield
1959	Forestry Department relocated to Stormanstown House, Ballymun
1912-1969	Higher education in Forestry successively located at St. Stephen's Green; Merrion Street; Albert Agricultural College, Glasnevin; Stormanstown House, Ballymun; Roebuck Grove, Belfield
1969-2013	Forestry Department and Degree Programme located in the Agricultural Building, Belfield (Figure 5)

Figure 5: *UCD Forestry is currently located in the Agriculture and Food Science Centre in Belfield.*

Sources

The following papers, journals, reports and other unpublished sources were used in the preparation of this talk.

Anon. 1938. *Albert Agricultural College* (Centenary Souvenir 1838-1938), Unpublished.

Anon. 1962. *Vocational Guide to the Agricultural Science Profession*. Agricultural Graduates and Associates, R. C. Sci. Agricultural Record 18.

Anon. 2000. Department of Agriculture; *A Century of Service*. A supplement issued with the *Farmer's Journal*, December. 2000.

Carroll, J. 1983. *Most of the Century; An Autobiography*. Privately published.

Curran, P.L. (Ed.) 1992. *Towards a History of Agricultural Science in Ireland*. The Agricultural Science Association, Dublin.

Curran, P.L. 1964. *The Profession of Agricultural Science*. Agricultural Record 22.

Daly, M. 2002. *The First Department. A History of the Department of Agriculture*. Institute of Public Administration, Dublin.

FitzPatrick, H.M. (Ed.) 1965. *The Forests of Ireland*. Society of Irish Foresters. Bray, Co. Wicklow.

FitzPatrick, H.M. no date. *Conifers; Keys to the Genera and Species, with Economic Notes*. The Scientific Proceedings of the Royal Dublin Society, Series A, Vol. 2, No. 4.

Henry, A. 1914. A new hybrid poplar. *Gardeners' Chronicle*, Series III 56: 257-258.

Henry, A. 1917. American sycamores are probably hybrids. *Heredity* 8(12): 553.

Henry, A. 1919. The history of the Dunkeld Hybrid Larch (in collaboration with Miss M.G. Flood). *Proceedings of the Royal Irish Academy* (Abstract in *Nature*, July 1919).

Henry, A. 1920. The Douglas Firs (in collaboration with Miss M.G. Flood). *Proceedings of the Royal Irish Academy* (Abstract in *Nature,* February, 1920).

Henry, A. 1926. The Swamp Cypresses, Glyptostrobus of China and Taxodium of America (in collaboration with Mrs. M. Mclntyre). *Proceedings of the Royal Irish Academy* (Abstract in *Nature*, July, 1926).

Hoctor, D. 1971. *The Department's Story. A History of the Department of Agriculture*, Institute of Public Administration, Dublin.

Larkin, M. (Ed.) 2000. *A Social History of Forestry in Ireland*. Crainn Publications, Kilkenny.

Mangan, D. 1988. Letter to the Editor. *Irish Forestry* 45(1): 78.

Mc Cartney, D. 1999. *U.C.D. A National Idea. The History of University College Dublin*. Gill and MacMillan, 1999.

O Brien, S. 2011. *In the Footsteps of Augustine Henry and his China Plant Collectors*. Garden Art Press, Suffolk.

Pim, S. 1984. *The Wood and the Trees: Augustine Henry, a Biography* (2nd Edition). Boethius Press, Kilkenny.

Quirke, D. 1949. *Insect Pests of Irish Woodlands*. Unpublished PhD Thesis 3700B, UCD.

Report [Minutes of evidence, appendices and index] *of the Departmental Committee on Irish Forestry*: Presented to Parliament by command of His Majesty, 1908. Main Author: Ireland Department of Agriculture and Technical Instruction.

Irish Forestry. Various issues from 1943 to 1985. Published by the Society of Irish Foresters.

U.C.D. Calendars. Various volumes from 1926 to 2000. Calendars are published annually by the Governing Body of UCD.

U.C.D. Acts, Charter and Statutes of UCD. Published by the Governing Body, UCD. Statute XXIII gave effect to the University Education (Agriculture and Dairy Science) Act, 1926.

Journal of Department of Agriculture and Technical Instruction: Annual issues 1901 to 1923.

Trees, Woods and Literature – 38

The Forest

Among the primary rocks
where the bird spirits
crack the granite seeds
and the tree statues
with their black arms
threaten the clouds,

suddenly
there comes a rumble,
as if history
were being uprooted,

the grass bristles
boulders tremble,
the earth's surface cracks

and there grows
a mushroom,

immense as life itself,
filled with billions of cells
immense as life itself,
eternal, watery,

appearing in this world for the first
and last time.

This poem appears in *Selected Poems* by Miroslav Holub[1] (1923-98). Born in Pilsen, Western Bohemia in former Czechoslovakia (now Czech Republic), Holub had a remarkable career as a poet, essayist and scientist.

He studied medicine at Charles University, Prague after World War II. Initially, Holub worked in a psychiatric ward in Prague and began his clinical research when he turned 30, about the time he began writing poetry. In 1990 he was appointed Head of Immunology in Prague Institute for Clinical and Experimental Medicine.

"While the combination of poetry and science is not unprecedented" observed

[1] Excerpt reproduced with permission from Penguin Books Ltd, London.

Alfred Alvarez (Holub 1967) "what makes Holub so unusual is his distinction in both fields". When asked how he managed to reconcile these two callings, Holub, while acknowledging the "uneasy relationship" between science and poetry said: "I have a single goal but two ways to reach it…I apply them both in turn. Poetry and science form the basis of my experience" (Ibid.).

It is impossible to discuss Holub's poetry without reference to the political climate under which he lived in Russian-controlled post-World War II Czechoslovakia. He worked, seemingly unfettered, as an immunologist for much of this period and has been criticised for not speaking out against communism. Andrew Motion (2004) regarded this criticism as unfair. "After the Warsaw Pact invasion of 1968, he was sacked from his job in the Microbiological Institute, and his books were banned," Motion maintained.

However, Motion admits that Holub came under pressure from the regime and did eventually relent which "caused dismay among former colleagues, who felt that he had betrayed his liberal beliefs". Sarah Boxer (1998) understood his plight and struggle;

> Shortly after the Prague Spring of 1968, Mr. Holub became a "nonperson" in Czechoslovakia. Any mention of his work was forbidden. And none of his poetry was published there between 1970 and 1980. During that period, Mr. Holub continued to work as an immunologist in Prague, but he also wrote poetry 'to the table,' a Russian phrase meaning for an underground audience.

Alvarez (1967) acknowledged that his poems were "sharply against the establishment" but in truth, Holub found his own voice – and his own way – of dealing with the "the big traumas of his time" as Motion (2004) observed: "…rather than approaching these things head-on, he broadened their significance by subtleties – by wry humour, by stoicism, and by moving very rapidly from the actual to the symbolic."

Seamus Heaney (1988), who was an admirer of Holub, touched on this aspect of his work in a paper that revolved around *Sagittal Section: Poems New and Selected* (1980), Holub's first book published in the United States. "It has in it all the worn-down truth-to-life of the disillusioned man, but it also has a contrary and heartening vision of a possible good based upon stoicism about decencies and impulses in the usual life. It is at once down to earth and wide open".

Although nature and landscape frequently appear in his poems, Holub eschewed romanticism and sentimentality as he demonstrates in *The End of the World* (1990):

> The bird had come to the very end of its song
> and the tree was dissolving under its claws.
>
> And in the sky the clouds were twisting
> and darkness flowed through all the cracks
> into the sinking vessel of the landscape.

In *The Forest* he probes the undergrowth to create a great nature poem. He even creates a sound to describe an event that is silent in essence but needing resonance – “a rumble” – to remind us of what we take for granted. The scientist and poet in him fuse to describe this moment of startling beauty as the mushroom emerges (“immense as life itself / filled with billions of cells”).

He captures a moment of creation but as in many of his poems, his ending – “for the first and last time” – catches the reader off guard. It is abrupt and unnerving, but as Heaney (1988) observed [he] “finds an image of his truth-telling responsibilities as scientist and artist”.

On another level it may be a reference to the “embattled Communist Party vision of the world reduced to microscopic dimensions” (Holub 1967), which coloured poems such as *Pathology* and *In the Microscope*. From whatever level the reader approaches *The Forest,* it is “poetry in which intelligence and irony make their presence felt without displacing delight and the less acerbic wisdoms” (Heaney 1988). In *The Forest* – as in so many of his poems – “science and poetry become two ways of looking at the same reality, differing only in technique” (Holub 1967).

Heaney (1988) described Holub as a poet “in pursuit of the ‘fully exposed poem’” and he shares Alvarez’s view that his poems are always inventive, experimental and “eager to tell truths about the nature of reality”;

> They brim with inventiveness and are driven by a logic generated out of the friction between two contradictory, equally commanding truths: annihilation is certain and therefore all human endeavour is futile – annihilation is certain and therefore all human endeavour is victorious.

Donal Magner
Wicklow
2014

References

Boxer, S. 1998. Miroslav Holub is dead at 74; Czech poet and immunologist (Obituary). *New York Times,* 22nd July 1998.

Heaney, S. 1988. *The Government of the Tongue: The 1986 T.S. Eliot Memorial Lectures and Other Critical Writings*. Faber and Faber Limited, London.

Holub, M. 1967. *Selected Poems*. (Translated by Ian Milner and George Theiner, with an introduction by Alfred Alfred Alvarez.). Penguin Books, London.

Holub, M. 1980. *Sagittal Section: Poems New and Selected*. (Translations by Stuart Friebert and Dana Hábová.) Oberlin College Press. Oberlin, Ohio.

Holub, M. 1990. *Poems Before and After: Collected English Translations*. Bloodaxe Books, Northumberland.

Motion, A. 2004. Climbing to the edge of the abyss. *The Guardian, 21st May 2004*.

Book Reviews

A list of books on trees and forestry, recently published, which may be of interest to readers is provided below. Titles marked with an asterisk are reviewed in this section.

List of publications of interest to SIF members

***An Atlas of the World's Conifers** by Aljos Farjon and Denis Filer. Published by Brill. 2014.

Ancient Trees: Portraits of Time by Beth Moon. Published by Abbeville Press. 2014

Ancient Trees: Trees That Live for a Thousand Years by Anna Lewington. Published by Batsford Ltd. 2013.

Ancient Woodland by Ian Rotherham. Published by Shire Library. 2013.

Continuous Cover Management of Woodlands: A Brief Introduction by Rodney Helliwell. Published by Author. 2013.

Forests: Reason to be Hopeful by Bill Liao. Ideos Publication Ltd. 2013.

Hemlock: A Forest Giant on the Edge by Anthony D'Amato, Benjamin Baiser, Aaron Ellison, David Orwig, Wyatt Oswald, Audrey Barker Plotkin and Jonathan Thompson. Published by Yale University Press. 2014.

***Forests, Products and People – Ireland's Forest Policy – a Renewed Vision** by the Department of Agriculture, Food and the Marine, Dublin. 2014.

***Forest Vision: Transforming the Forestry Commission** by Roderick Leslie, New Environment Books. 2014.

***Glennon Brothers: Céad Bliain ag Fás, One Hundred Years a Growing 1913-2013** by Denis Glennon. Glennon Holdings Ltd. 2014.

God's Trees: Trees, Forests and Wood in the Bible by Julian Evans. DayOne Publications. 2013.

***Heritage Trees of Ireland** by Aubrey Fennell, Carsten Krieger and Kevin Hutchinson. Published by Collins Press in Association with The Tree Council of Ireland. 2013.

Introduction to Forest Ecology and Silviculture (3rd Ed.) by Thom McEvoy. Published by Forestry Press Inc. 2014.

***Ireland's Generous Nature – the Past and Present Uses of Wild Plants in Ireland** by Peter Wyse Jackson. Missouri Botanical Garden Press. 2014.

Land Use and Land Cover Mapping in Europe: Practices and Trends by Ioannis Manakos and Matthias Braun (Eds.). Published by Springer. 2014.

Magnolias in Art and Cultivation by Barbara Oozerally and James M. Gardiner. Kew Publishing. 2014.

Multiaged Silviculture – Managing for Complex Forest Stand Structures by Kevin L. O'Hara. Published by Oxford University Press. 2014.

***Oak: Fine Timber in 100 Years** by Jean Lemaire. Translated from original French by Bede Howell. Published by Future Trees Trust. 2014.

Overleaf by Richard Ogilvy and Susan Ogilvy. Published by Kew Publishing. 2014.

***Phytophthora – A Global Perspective** by Kurt Lamour (Ed.). CABI. 2013.

Poplars and Willows: Trees for Society and the Environment by J.G. Isebrands, J. Richardson. Published by CABI. 2014.

Saving the World's Deciduous Forests: Ecological Perspectives from East Asia, North America and Europe by Robert A. Askins. Yale University Press. 2014.

The Ash Tree by Oliver Rackham. Published by Little Toller Monographs. 2014.

***The Cabi Encyclopedia of Forest Trees** by Andrew Praciak et al. (compilers). CABI Publishing. 2013.

The Herbaceous Layer in Forests of Eastern North America (2nd Ed.). Edited by Frank S. Gilliam. Oxford University Press. 2014.

***The New Sylva: A Discourse of Forest and Orchard Trees for the Twenty First Century** by Gabriel Hemery and Sarah Simblet. Published by Bloomsbury. 2014.

The Woodlands of Ireland, 700-1800 by Nigel Everett. Published by Four Courts Press. 2014.

Trees: Their Natural History (second revised edition) by Peter A. Thomas. Cambridge University Press. 2014.

Trees Up Close: The Beauty of Bark, Leaves, Flowers and Seeds by Nancy Ross Hugo and Robert Llewellyn. Published by Timber Press. 2014.

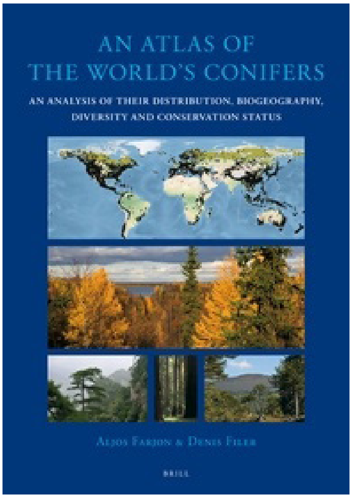
Willow by Alison Syme. Published by Reaktion Books. 2014.

Woodland Gleanings: Being an Account of British Forest-Trees by Charles Tilt. Published by CreateSpace Independent Publishing Platform. 2014.

Woodland Management: A Practical Guide (2nd Ed.) by Chris Starr. Published by Crowood Press. 2013.

An Atlas of the World's Conifers

Aljos Farjon and Dennis Filer.
Koninklijke Brill NV, Leiden, the Netherlands. 2014.
512 pages. Hardbound. ISBN 9789004211803
€145



The subtitle of this book states that the objective is to provide for conifers "an analysis of their distribution, biogeography, diversity and conservation status" and the book does fulfil this objective. It is not and it does not try to be the typical "coffee table" book full of photographs of individual conifer species and their habitats, however, such a book would complement this volume.

An Atlas of the World's Conifers provides detailed information on the distribution of genera and their species across the world. It starts with a discussion of the global and trans-continental distribution of coniferous genera to show how genera have spread across the earth, mainly as a result of continental drift. It then discusses the distribution of genera and species across eight major regions of the world (North, Central and South America, Europe and the Mediterranean, mainland Asia and Japan, Malesia, Australasia, and Africa). Discussions on individual species provide geographic details of where the species are found including site requirements and associated species. Computer generated maps of species distribution based on verified herbarium specimens are provided for each species.

There are many interesting facts provided between the covers of this book. For example, the second largest of the coniferous genera (after pines) are the Podocarps which consists of 175 species mainly located in the southern hemisphere. Although when we think often of only one member of this family, *Araucaria* (the monkey puzzle), there are in fact 36 other genera in the family. While some genera such as the Podocarps and Araucarias are found only in the southern hemisphere, the entire 24 members of the yew (*Taxus*) family all originate from the northern hemisphere. This book explains why. California is home to 52 different species of conifers, but there are many other such conifer "hotspots" discussed here. If you find these facts interesting you will find more in this book.

Of particular interest are conifers from Malesia, which includes the countries of Brunei, East Timor, Indonesia, Malaysia, Papua New Guinea, the Philippines and Singapore, as well as Australasian species, which includes the countries of Australia, New Zealand and the neighbouring Pacific Ocean islands. Here many exotic and very different genera can be found, some of which at first do not seem at all like conifers.

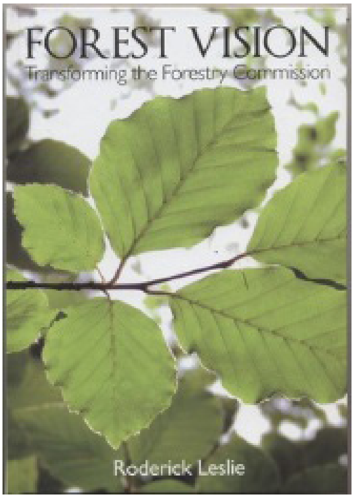
This is a book for real "dyed-in-the-wool" conifer enthusiasts. It is not the type of book that readers will pick up and read from cover to cover, but rather to select specific genera or species to explore. There are species here that most of us have never seen, but will discover in this book. Readers may be disappointed with the lack of species photographs, but there are other books available that can complement this volume. My only criticism of the book is that the herbarium-based maps do not always show the complete natural distribution of the species.

If you think Sitka spruce, lodgepole pine and the other conifers we see so frequently every day are "boring", then I would suggest you take a look at the range of species discussed in this book. Conifers will no longer be "boring".

David Thompson
Hollybrook
Ashtown Lane
Wicklow Town
Co. Wicklow

Forest Vision: Transforming the Forestry Commission

Roderick Leslie.
New Environment Books. 2014.
218 pages. Hardback. ISBN 978-9928789-0-0.
£12.99.



The book contains a personal, almost autobiographical account of Roderick Leslie's career, between joining in 1976 and his retirement 30 years later, in the part of the British Forestry Commission called Forest Enterprise. It does not deal with the Forestry Authority which administers grants. He started just as the Forestry Commission was ending the huge planting programmes of the first 50 years of its existence, to managing the forests it had created: a period of major changes which have also been paralleled in Ireland.

Roderick Leslie joined the Commission after graduating from Oxford University. In the subsequent 30 years, he worked in a very wide variety of posts and ended up as Head of Policy for England. He was at the centre of some violent verbal conflicts that eventually stopped new conifer planting in the uplands; he lived through the near fatal unpopularity of the Forestry Commission in 1988 after the "Flow Country" episode[1], to the trusted organisation that it is now, with overwhelming public support. This public support halted the Government's plans to sell all the Forestry Commission's forests first when John Major was Prime Minister in 1993-94 and then again in 2010-

[1] The Flow Country is a large expanse of peatland and wetland area of Caithness and Sutherland in Scotland. It amounts to one of the largest expanses of blanket bog in Europe, and covers about 4,000 km^2. The wetland was severely damaged by extensive drainage and afforestation between 1979 and 1987. Controversy over the management of this area was largely accepted as being responsible for the removal of forestry tax reliefs in the UK.

11 under David Cameron. How this was achieved is what the book is really about. It is an account of splendid leadership during a period of great difficulties.

Mr Leslie describes how the requirement arose for timber production to be balanced with care for the environment, wildlife, landscape, heritage, local employment and recreation. He explains how he recognised that where the population was largely urban, rural areas would lose out. Urban people see the countryside as a place for entertainment and leisure and do not recognise the wider social and economic diversity present in it. In the New Forest, for example, the priorities for management are, in the order stated below:

- Conservation of the natural and cultural heritage;
- Public enjoyment;
- Rural development (including timber production).

The author also points out that the importance of carbon sequestration is largely ignored although it was rated above both timber and biodiversity in a study by the Economics for the Environment Consultancy. A theme throughout the book is how much politicians and career Civil Servants (or "quangocrats") appear to dislike what the Forestry Commission stands for and have frequently attempted to emasculate it. Early attempts to do this were efforts to extinguish common rights in the New Forest. The current view is usually either that you are commercial or you are for wildlife, or for people, but never all three combined. The problem with the Forestry Commission is that it operates both as a business and as a spending department and bureaucrats simply cannot understand this. The normal government approach revels in its ignorance as people "with wide experience" are appointed to posts requiring a foundation of relevant scientific or technical knowledge. They then try to manipulate policy but are at a complete loss when a situation fails to improve. This has applied equally to the failure of those appointed from the outside to the Forestry Commission to make it more businesslike. Forestry Commission staff are quite the opposite; they have the technical skill and are flexible, and are programmed for immediate action and fast delivery. There has been a view within Government, and especially Defra, saying "do nothing – it'll be OK, we'll get away with it". Agencies are casually re-organised in ways that look designed to deplete the national knowledge base. This lack of professional expertise has been a big factor in addressing many of the problems encountered of recent years.

On recreation, the National Household Survey revealed that after parking the car, countryside visitors want good toilets, refreshments and a chance to buy a souvenir, in that order. The serious museum-style displays of the 1970s feature around 15th in people's preferences. New chunky picnic furniture designs were introduced and standards of construction and design were vastly improved during the 1980s. The importance of catering for local visitors was recognised for the first time. Creating facilities that appeal to children was accepted in 1990 with the opening of the play trail at the Moors Valley country park in East Dorset. The author regrets that more versions of this popular place were not constructed more quickly.

The management of unusual habitats was also a major priority; heathlands have been a target for restoration as the biggest potentially open habitat in England. This is in spite of the view that it is more "natural" not to manage. Doing nothing does not lead back to the "Wildwood" which occurred before human intervention. Even the Woodland Trust and National Trust now recognise this.

The 1985 British broadleaves policy signalled an end to planting conifers in England and the beginning of a phase of restoration. The author goes into some of the many financial problems endured by the Forestry Commission. He says that every time foresters saved 10% on costs, the value of timber went down 20% until he finally realised that the Forestry Commission's financial problems were not going to be resolved by a recovery in prices. Other assets, especially income from recreation and cellphone transmission masts, had to work. English woodlands are so under-thinned and generally unmanaged, that timber production could probably double without planting a single new tree. In 1992, as part of the fallout from the Flow Country episode, the Forestry Commission was split between land management and regulatory functions; the so-called Forest Enterprise and Forestry Authority.

After a somewhat rocky start, forest certification has become entrenched as part of forestry in Britain, in fact the UK was the first country to have the whole of its publically owned forests fully FSC certified. It remains unpopular with smaller owners, being disproportionally costly for them.

In a chapter entitled "The Cutting Edge", the author explains how a new and powerful alliance between the Forestry Commission and private sector developed. Such things as concerts, mountain cycling and "Go Ape" have proved immensely popular with teenagers and young adults. The latter two also provide popular adrenalin fixes. The aftermath of the collapse of the coal industry in the 1980s signalled the start of environmental improvement of derelict land for deprived communities. Urban practitioners were of little help and, being egged on by landscape architects on percentage fees, their schemes were often hugely expensive and inappropriate. In the drive for "privatisation" it was found that medium to large companies' proposals were unimaginative, risk averse and greedy; and where local authorities were involved, the scale of enthusiasm and ambition by local people and organisations died away as local authority involvement increased. Smaller businesses have proved very different, ranging from Go Ape to cycling. Local people were also involved in imaginative planning, which resulted in a dog swimming pond being constructed at Jeskyns Wood. Roderick Leslie believes that what the Forestry Commission did in the urban fringe during the 2000s is an achievement comparable to the original drive for reforestation.

For the future the author notes that the Bishop of Liverpool's Independent Panel on forestry called for a new woodland culture to be developed. He (Mr Leslie) believes that there are two obvious, big, directions for the Forestry Commission and forestry in England: the first is around towns and cities, and the second is related to the low carbon economy and climate change. These will be the challenges for the future. Another key challenge is that, whoever owns the present Forestry Commission estate, it will be desirable to do several things simultaneously, the way the Forestry Commission does today. Roderick Leslie concludes that the forests are not safe yet!

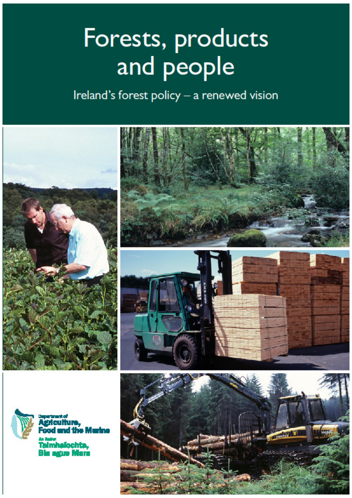
This splendidly written book will interest anyone involved professionally in forestry or who appreciates and enjoys forests, especially those who have been involved since the 1970s. It is clearly and simply written and reveals much that is completely new to lay people. I only wish it had been available for our students at Oxford before I retired.

Peter Savill

This review was originally prepared for the Woodland Heritage Journal 2015 where it will also be printed.

Forests, Products and People – Ireland's Forest Policy – A Renewed Vision

Department of Agriculture, Food and the Marine. Dublin. 2014.
75 pages. Softbound. ISBN 978-1-902696-73-7
€10



Almost 20 years have passed since the last major forest policy statement from the Government, *Growing for the Future* was published, so this document is timely, given, as it points out the total value of the sector to the economy is now ca. €2 billion with direct and indirect employment of 12,000 and an estate of over 730,000 ha. The report is the result of a process initiated in 2009 involving three groups: overall policy, forestry schemes and the future of Coillte. The policy group met on 15 occasions and accepted submissions from concerned individuals and organisations. While this publication is relatively compact, it deals with the whole range of issues likely to impact on the forestry sector into the future and as such merits a careful analysis of its content. It begins with a foreword by the Minister of State for Forestry.

The booklet is well designed and to some extent follows the format of *Growing for the Future*, outlining the current position, policy considerations and proposed actions, perhaps to allow comparison. There is an analysis of the earlier report, though perhaps an opportunity was missed here to comment on the successes and failures of that policy as a prelude to each of the revised policies and actions. Some useful background papers are also included. To get a minor caveat out of the way and knowing something about the vagaries of printing, a misprint on the front cover seems, surprisingly, to have eluded all editorial barriers and will no doubt be rectified in a later print.

As is indicated in the summary, the broad objectives of *Growing for the Future* stand, though goals have changed due to changes in the sector, especially a shortfall in planting and the many new areas of regulation. As the new strategy "to develop an internationally competitive and sustainable forest sector that provides a full range of economic, environmental and social benefits to society which accords with the Forest Europe definition of forest management" indicates, the tenor of the document reflects the positive impacts of sustainability and environmental factors on forest policy as expressed in the Oslo Decision on European Forests 2020, but tends also to lean, in parts, towards a cautionary view of forestry development.

Fourteen areas of policy are dealt with in detail. The first, and one of the key policies, is expanding the resource, as much of what is aspired to arises from the implementation of a viable afforestation programme. No one can argue with the goal of 10,000 rising to 15,000 ha of new planting per annum. However, the experience of *Growing for the Future* indicates that in reality, this will be enormously difficult to achieve and setting unrealistic targets may question their credibility. Already the impact of shortfalls on the previous goals is a much reduced timber harvest forecast and the graphs shown in Appendix 5 indicate how heavily wood production is influenced by variations in the planting programme. It is surprising, in this context, that the work of the COFORD working group established in 2012 on land availability (CCLAWG) – which is very different to *suitability* only – was not referred to. This looked in detail at the barriers to expanding the sector such as farming developments, conservation constraints and land classification and ways in which they might overcome such limitations. In this part of *Forests, Products and People* 18 actions are proposed, and while these are laudable, questions arise as to how feasible to implement they may be. For example, the desire to increase the size of afforestation projects will be countered by the impacts of planning and environmental impact assessment, and persuading other agencies to allocate their land resource to forestry can be difficult. Neither will providing sufficient and consistent funding be an easy task. On the positive side, a more flexible approach to premium differentials and the classification by yield class of lands suitable and available for forestry, presumably irrespective of enclosed/unenclosed status, is to be welcomed, as is targeting more non-farmer landowners. Incentives to increase planting native riparian woodlands and short-rotation forestry may go a modest way to achieving targets and carbon incentives may also help. Time will shortly tell if these strategic actions can be put into effect.

Policy on best forest management is less fraught with controversy. The recognition, understanding and application of sustainable forest management (SFM) principles, the establishment of a national forest inventory, one of the successes of *Growing for the Future*, a Code of Practice and the evolution of owner groups have meant that forest management can keep pace with developments. The need for an inventory unit regularly updating, with better planning and forecasting, is self-evident and not really new to Irish forestry and was one of the strengths of the Forest Service prior to the establishment of Coillte. Many of the measurement and planning tools already exist and managers are familiar with them. One area which will require attention is a coordination as to how these tools should be used, such as GROWFOR, PractiSFM or iFORIS, to allow for monitoring, management and review of private forests nationally. Action on forest road construction and access to public roads will be helpful. The continuation of long-term research as a backup to management, is essential and is dealt with further on in the document.

Forestry has become a highly regulated sector and this is quite evident in the section on the environment and public goods. The cautionary tone of much of this section could well be replaced by a more focussed recognition of the real and tangible public benefits which forests provide such as biodiversity, recreation with its attendant health benefits, rural contribution, greenhouse gas sequestration and replacing fossil fuels with renewable energy. This is especially relevant given that upward of two million ha of land are now reserved for conservation or restricted in their use for environmental reasons. Many of the recommended actions relate to implementing, refining and reporting on potential environmental constraints and even identifying areas to be taken out of forestry, though some concession is made to water values and native woodland establishment and the quantification of non-woodland benefits. It is surprising that the National Forest Standard, based on the Lisbon forest principles, has been little used as a measure of sustainable management in Irish forests. Bringing the forest inspectorate into the ecological site assessment procedure is to be welcomed. More emphasis in speeding up the resolution of outstanding issues such as that of the hen harrier would have been desirable.

The sections on the supply chain and the processing industry in the main reflect market conditions. It is somewhat disturbing that the harvesting fleet built up in the 1990s has run down to a noticeable extent and a new and positive input by the Department of Agriculture Food and the Marine (DAFM) is welcome. Support measures to help develop haulage and small-scale harvesting and residue energy initiatives are proposed and are timely. Some of the supply difficulties arise due to the scattered nature and small size of many forests. These form barriers to the development of more efficient and larger-scale forestry enterprises. Coillte, DAFM and the industry need to cooperate in this area, as will Local Authorities in the area of access to public roads. Again the proof of the pudding will be in the eating. Clarity on Coillte's future will be a key to the interim supply of timber to industry and indeed to the future of the panel industries, as also will be the continued growth of wood supplies. With the expected drop in wood supply from the 2030s on, Government will need to monitor how this scenario develops especially in the context of present sawmill overcapacity.

Obviously the support for a fragile broadleaf market will require state input. While the establishment of the Wood Marketing Federation has provided a fillip to forest products, the requirement to establish an agency similar to Bord Bia, as referred to in Section 9, seems most obvious.

Since the 1990s, threats to forests have grown significantly. The most serious of these are deer, *Phytophthora ramorum*, *Chalara fraxinea* and the invasion of *Rhododendron ponticum* and policy actions address these in the document. A national deer management unit is to be set up, which will also undertake surveys. Hopefully we will be provided with more information on this initiative in the next annual programme. Details are not given of special measures to be implemented concerning major tree infections, but perhaps DAFM already have enough supports in this respect. Outwardly there appears to have been a rather fatalistic attitude to the spread of rhododendron, a threat to both forests and conserved habitats. It would seem that we should be advanced enough with remote sensing techniques to monitor and to take specific action to check or avoid the spread or colonisation of such new areas.

It is appropriate that the next section relates to research, training and education though research, which is basic to understanding future challenges receives fairly modest attention. Research activity has reduced in recent years with the winding down of Coillte's involvement and the absorption of COFORD and its budget into DAFM. The commitment to the maintenance of current levels of funding and continued consultation with stakeholders is encouraging, but a clear policy on long-term and project-based research and how these will be structured staffed, administered and financed, would be appropriate here, accepting the fact that some progress on supporting long-term research has been made recently. Getting the industry to fund research has proved difficult in the past but it is worth trying again. Much consultation is planned but in the end this must translate into an operating structure. Funding for training has significantly reduced and the document seems to rely on the industry for more investment. Forestry operations require skill and the support of Teagasc, the HSA and the industry makes sense. Foresters should be well able to acquire environmental expertise, which is a component of SFM, and is routinely taught in 3rd level forestry courses. Model-farm forests are also a good idea. Product and process certification has become established successfully since the early 2000s and a number of bodies now undertake this work. The Code of Best Forest Practice has been instrumental in this and a revised edition is to be welcomed and will hopefully maintain its focus on sustainable forestry as an established activity. An addendum – the report might have given credit to the Society of Irish Foresters, which has helped research survive as a major publisher of peer-reviewed forest research papers in this Journal.

The remaining policies relate to implementation and review, cost appraisal, legislation, institutional arrangements and Coillte. These are clearly the concern of

Government and will direct the development of other actions into the future. They have already been the source of much discussion and debate has taken place up to Oireachtas Committee level. The recent history of response to policy reviews has not been encouraging. No follow-up to three major studies, the Timber Industry Development Group, the Bacon and Malone Reports took place. Perhaps *Forests, Products and People* may prove more effective with actions proposed for a forest council on research and development, forestry schemes and the environment, albeit with monitoring, reporting and advisory powers only. A more significant action would be the establishment of a Forestry Board as mentioned earlier, but again we are only at another task force stage. Forest Service five-year business plans would be welcome. The long awaited Forestry Act is almost on the statute books and will no doubt be subject to a final review. Many concerns at drafting and Bill stage, especially regarding conflicting elements appear to have been taken on board, but the final document will clarify this. There is now of course, as is shown in this report, an enormous amount of other primary and secondary legislation and regulation impacting on this Act and therefore, on the practice of forestry. Some gesture is made therein to recognise the sustainable nature of good forestry management enabling some flexibility for the sector within those parameters. While a less rigid approach to restocking is welcome, this reviewer believes that caution is needed to avoid deforestation on any excuse.

The heavy reliance of development of the sector on state funding which was opted for in the programme just ending is addressed in the report. The actions of looking at taxation, carbon funding, institutional investment, co-funding through the CAP rural development programme and multi-annual budgeting, while admirable, will require significant support from the Dept. of Finance which has not been very forthcoming, e.g. following the 2006 review on forestry taxation. Multi-annual funding would be particularly valuable in providing predictability to the nursery and forestry establishment sectors. Finally, it is encouraging to see that the Forest Service is aware that efficiencies must be achieved and that an Annual Report needs to be reinstated. The fragmenting of the Forest Service responsibility with regard to, for example research, to the overall DAFM research function is to be regretted. Interestingly the title Forest Service appears only four times within all the Strategic Actions.

Coillte has been subject to scrutiny over the last number of years and its final structure is still not clear. The appendix on the Coillte recommendations makes rather chilling reading. The proposal to sell off forestry assets has been abandoned but the proposed link with Bord na Mona was too recent for inclusion in this report which is confined to general observations on the need for the company to work along with the private sector, especially on roading and supply and transparent pricing. The need for recreation and biodiversity to be recognised (financially?) under a new management regime is accepted. However, the many changes that could take place will impact across the sector. This has been signposted in the many submissions already made by stakeholders, including the Society, at Oireachtas Committees and elsewhere with the view of the Society that a state forestry company, refocused on its core activities, would be best.

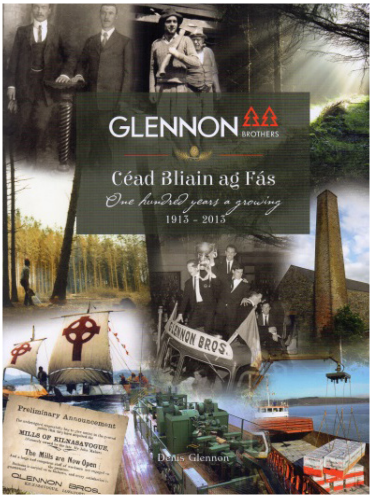
The papers in the appendices are useful, particularly those on costs/benefits and the sensitivity analysis on the impact of different planting policies. While the cost study shows that benefits outweigh costs for wood and non-wood products, the fragility of the sector to its past and predicted planting policies is demonstrated. Fluctuations in afforestation mean that there will be reductions in wood supply in mid-century, and to a serious degree if planting rates cannot be increased. This could well cause disruption and lack of confidence in the sector. The lessons of this report are that realistic achievable targets must be set, with structural reforms and regular transparent policy reviews, to allow the sector continue to grow and survive as a significant economic and environmental contributor to Irish society.

I recommend reading this report to anyone with an involvement or interest in Irish forestry for an informed view of a wide and complex area and an insight into current official thinking and intention. Events in Irish forestry are, at time of writing, moving fairly rapidly, which may bring further insights on issues such as the finally agreed forestry programme to 2020 with its accompanying Strategic Environmental Assessment (SEA) and a new relationship between Coillte and Bord na Mona, so readers should assess *Forests, Products and People* in that context.

Gerhardt Gallagher

Glennon Brothers: *Céad Bliain ag Fás*, One Hundred Years a Growing 1913-2013

Denis Glennon. Glennon Holdings Ltd. 2014.
158 pages. Hardback and paperback
Available from Glennon Brothers Timber Ltd., Longford



This book is a celebration of the family's first century in the sawmilling business. A lavish publication, it is well written and designed and is illustrated with good-quality images which evoke the essence of the early days in the business. It features reproductions of early account books, invoices and order books together with details of wage advances given to millworkers. All of these will be of immense value to historians in the future. The family must be congratulated for its significant investment in recording the evolution of the business. In doing this they create an excellent headline for other family businesses. The book was written by Denis Glennon, a teacher at St. Mel's College, Longford. Denis is a member of the extended family and, though he is not involved in the business, he displays a well-honed appreciation of his subject.

The past one hundred years witnessed many changes in the sawmilling industry in Ireland. When Glennon Brothers Timber Ltd. began in 1913 there were approximately 850 sawmills on the island of Ireland. Currently only nine large mills and a few smaller mills remain. Glennon Brothers Timber Ltd. ranks high among the largest sawmills operating in Ireland and the UK and is the oldest-surviving family-owned sawmill business in Ireland. It is now managed by the third generation of the family.

For the first eighty five years the mill operated on the original site in Longford. This was once a flax mill, which were then quite common in the northern half of the country. Since

1998 the business has grown and developed dramatically both organically and through acquisition. It now has three plants in Ireland (Fermoy, Longford and Arklow) and two in Scotland (Toon and Humbie, near Edinburgh). The modern mill was developed over the period 1980-1998. There was a huge investment in kiln drying, which helped enormously with export market penetration.

This book eloquently chronicles the hardships endured in the 1920s and 1930s; the installation of electricity and the replacement of horses with lorries in the 1940s and 1950s. The rising economic tide of the 1960s is also recorded, together with the increased use of technology. There are chapters on employee and family reminisces of events at the mill over the years. The 1970s oil crisis is well documented. It had a huge impact on the sawmilling sector as timber was hauled by lorry, usually over great distances. It cites an example of timber from Kenmare, Co. Kerry, which took eight hours to transport to the mill over roads which were, in many cases, primeval by today's standards. The energy crisis further impacted on sawing costs as the mill had been converted to electricity at this stage.

The book features a delightful chapter on Tim Severin's book *The Brendan Voyage*. Wood for this special boat was supplied by the late Paddy Glennon who took a personal, almost paternal, interest and pride in the project. Ash (*Fraxinus excelsior* L.) in 30-foot lengths was required. Paddy located a suitable 80-year-old ash tree and personally ensured that the timber for the mast was taken from the north-facing side of the tree, where he believed the wood was strongest. Typical of the man, Paddy presented the wood timber to Severin, saying "I'm repaying a debt, as my family has made a good living out of Irish-grown timber".

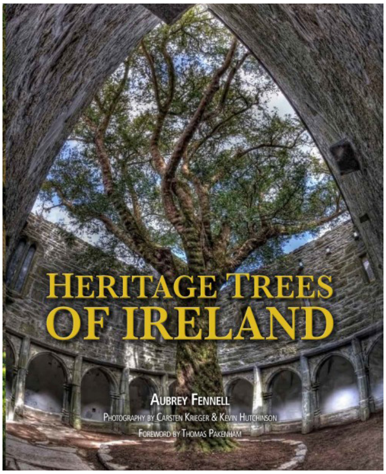
An interesting table at the end of the book catalogues the products currently produced and compares them with those produced in 1913. Back then the demand was for the following items: wheel shafts, wheel spokes, wheel stocks, felloes (for the benefit of younger readers, felloes are the parts of a wooden cart wheel directly inside the metal tyre rims which hold the spokes), egg cases, fowl-cases, doors, windows, gates, table legs, ladder poles, box barrows, fork, spade and scythe handles. The current production comprises kiln dried strength graded carcassing timber, pallet, packing case material, machined whitewoods, decking, fencing, roof trusses, timber frame houses, woodchip for MDF, bark mulch, etc. This gives us a glimpse of the versatility of Irish timber.

This is the first book published on the Irish sawmilling industry. Unfortunately a lot of lore and knowledge has already disappeared because people failed to record the stories of sawmillers, who once plied their trade in almost every part of the country. Most sawmills had their origins on the large estates, and as the estates disintegrated these sawmills disappeared, most without record. This book makes a fine beginning in recording the evolution and development of a now vibrant sawmilling sector from its humble origins.

John Mc Loughlin is Business Editor of the Society of Irish Foresters and Chairman of the Tree Register of Ireland

Heritage Trees of Ireland

Aubrey Fennell, Carsten Krieger and Kevin Hutchinson, 2013 (reprinted 2014).
Collins Press and the Tree Council of Ireland, with support of Kerry Group, Society of Irish Foresters and Irish Tree Society.
328 pages. Hardback. ISBN: 978-1-84889-159-3
€29.99



This handsome hardback publication has its genesis in the survey of heritage trees initiated in 2009, jointly funded by the Tree Council of Ireland, the Heritage Council, the Irish Tree Society and Crann. This work identified 1,200 trees of particular heritage significance, complementing the database of 11,000 (… and counting) trees already recorded by the Tree Register of Ireland, which was initiated in 2000 to record "champion trees", defined as the tallest or oldest or the more massive example of a species in a given region. The author undertook Trojan work under both projects. In *Heritage Trees of Ireland* he takes a plunge into the records and pulls out a personal selection of just over 140 trees of particular note. Each entry comprises text and photographs. Through the pen of the writer and the eye of the photographers, these elements combine to capture the beauty and character of each subject.

In many ways, the author of *Heritage Trees of Ireland* has delivered us a swashbuckling adventure through Irish history and folklore – both local and national – as viewed through the "prism" of those trees contemporary within those now historical landscapes. Trees are used to explore local manifestations of history, bringing it into sharp focus and lending it a certain human scale. For example, we have the Courtown

Holm Oak (thought to be Ireland's first of that particular species), planted around the time a particular Cromwellian solider, called Ford, stood on a local hill greedily pointing out land he wanted for himself in this part of Co. Wexford. Similarly, the Crannabachall Lookout Tree is described as an ash used to keep watch over local approaches during illegal masses at Coolaghmore, Co. Kilkenny during the Penal times. In this regard, Fintan O'Toole's *A History of Ireland in 100 Objects* springs to mind.

Of course, for a sense of deeper history, there is the yew and the section entitled "The Ancient Yews" does not disappoint. In this section these glorious trees provide us with further tantalising glimpses into earlier times. Yew is an evocative tree and it is interesting to note that this section of the book presents perhaps the greatest number of individual specimens that would be generally known outside "tree" circles – the Muckross Abbey Yew, the Florence Court Irish Yew (the "mother" of all such yews the world over) and the Crom Yews (actually two, not one). Why is it that the yew occupies such a prominent position in our collective consciousness – perhaps a shared cultural memory harking back to the status of these trees as sacred entities and as one of the "Nobles" under the Brehon Laws? The photographs included remind this reviewer of trees in the ancient Ta Prohm Temple in Cambodia – roots like frozen quicksilver. Regarding age, looks can be misleading. We have the monolithic Glencormac Yew at Kilmacanogue, long thought by many to be Ireland's oldest and largest. However, the author's gut instinct is telling him that a far more diminutive-looking specimen, the modestly named Cliff-Face Yew at Turloughmore, is in contention. This yew is located in the wildest Burren, where trees have more to worry about than putting on mere girth. Regardless of which is the senior, both trees earn their position in this book.

As is the nature of these works, *Heritage Trees of Ireland* also captures interesting juxtapositions. We read about the Brian Bórú Oak in Raheen Woods, Co. Clare, associated with the High King of Ireland who was born nearby and who went on to defeat the Dublin Norse at the Battle of Clontarf (incidentally, an event that features in one of the principal Icelandic sagas, The Saga of Burnt Njál). In the same entry, the author points out the source of our "native" sessile oak, which migrated northwards from its refuge in the Iberian Peninsula after the Great Ice retreated. This entry alone captures the constant churn of influences – both natural and historic – through which time delivers us.

There is great fun here. For example, several entries describe various trees gorging themselves on unlikely items, including a headstone (a beech at Adare, Co. Limerick), a park seat (a London plane at King's Inn, Dublin) and even a castle (or at least, part of one) (an ash at Bawnboy, Co. Cavan). There is also the Turkey-Roost Tree (a European larch) at Moone, Co. Kildare and an enigmatically entitled entry "Strange

Trees Indeed" regarding a specimen in Glengarriff, about which this reviewer won't write another word, just to stoke up the reader's curiosity! However, sombre entries cut through, such as the Hanging Oak among the parkland trees at Shane's Castle, Co. Antrim, used to dispatch highwaymen and those who failed to pay for using the nearby toll road. Often the passage of time and erosion of detail depersonalises these people and the desperate fear and resignation they must surely have felt, whether guilty or not. Judging from the picture accompanying this entry, the tree itself seems to remember them all too well, and to curse its form and the use it was put to.

Numbering more than 140, there are so many entries to savour in this book that the metaphorical box of chocolates just doesn't do it justice – here we are presented with the entire sweet shop to choose from. The variety of trees is huge, but by using broad brush categories ("The Ancient Yews", "The Europeans", "Landmark and Junction Trees", "Trees Associated with a Person", etc.), the author has done a heroic job in bringing order to merry chaos, to produce a catalogue whose readership will surely encompass many disciplines and interests, from tree people to historians to visitors to our wonderful outdoors, both domestic and from further afield. The tone of the book is warm and inviting. It reads like a conversation, with the use of the first and second person reminding this reviewer of what it is like listening to an individual whose love for a topic – be it trees, sport, music or whatever – creates an electric hum of infectious curiosity. The text is inclusive and will draw even the most lukewarm reader into a conversation with the author, with each entry revealing a wonderfully diverse conglomerate of facts, folklore and informed commentary. One unfortunate drawback with this publication is that it's unlikely to ever leave the house. This is a book you'd want on your person, best produced as you gaze upon the tree in question. If ever there was a book ripe for conversion into an "app" for a smartphone, complete with GPS functionality, contact details of landowners, and links to other relevant sources of information, then this is it. Indeed, such an app would sit very well beside a similar app for Donal Magner's *Stopping by Woods*, to give potential enthusiasts every reason for getting up and out to experience our trees and woodlands at first hand.

Another inclusive aspect of this book is the very selection of trees. It's not all about the tallest, oldest or rarest. These "A-listers" are present, of course, but so too are less obvious candidates – local landmarks, "lesser" trees, curiosities and misfits. All have great stories to tell and a reason for being here in this collection, and this will help readers to bridge the gap between trees deemed to merit inclusion in this publication, and trees within their own physical landscape, or indeed, that of their past. This will underscore for readers the value of all trees in our environment, and will, in all likelihood, yield many new candidates for future editions of the book.

Each entry is accompanied by at least one full-page photograph. These are consistently illustrative and often works-of-art in their own right. Two visual styles dominate: a factual depiction (with some slight leaf blur, to create a sense of motion); and a slightly "otherworldliness" depiction, with some post-shot image processing used to realise the photographer's vision. While Pakenham's glorious Linhof large-format camera will always be missed (although perhaps not by the poor unfortunate who has to carry it!), all of these photographs work closely alongside the text to create as much of a presence of these trees as one can achieve in any book. Many would also merit larger reproduction, perhaps as a limited edition run of fine art prints or as a public exhibition. They also create invaluable "baseline" information on the trees themselves, for any future monitoring or assessment of health. However, as a keen photographer, this reviewer would like to have read about the equipment and techniques used, perhaps also some of the stories the photographers themselves might have to tell of their own experiences approaching these trees. This would have encouraged other photographers to try their hand at capturing their own images of these specimens, or indeed, of other potential candidates for heritage tree status.

Of course, underlining this work is the need to highlight the tremendous heritage – natural, historic and cultural – that these trees represent, and also their fragility and often tenuous hold on life, and the concerted effort needed to protect and conserve them. Natural causes will of course take their toll – the 42-metre-tall grey poplar at Birr Castle Demesne is now no more, having been toppled by storms in early 2014. However, human interventions – whether deliberate or not – are likely to be the main drivers towards their demise and over this we have at least some control. Writing about the wise stewardship of our natural resources for the sake of future generations, Chief Dan George, a 20th century chief of the Tsleil-Waututh Nation in British Columbia, asks "Have I done everything I could to earn my grandchild's fondness?" These trees are sparkling jewels in our shared heritage, and in light of the wonder and delight they give us now, doing what we can to protect and conserve them will indeed gain us some much-needed favour with future generations. Multiple examples throughout the publication which document the efforts of landowners, community groups and county councils in standing guard over many of these trees, give us every reason to hope.

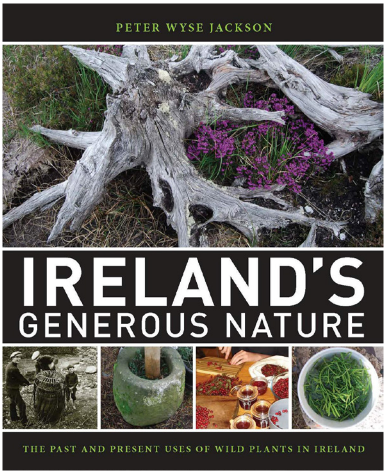
But in the meantime, we can only marvel. The section entitled "The Ancient Yews" describes the Burton Hall Yew at Ballynakilly Wood. According to the text, measuring this tree started the author off on his quest to record Ireland's champion trees. We have much to thank the Burton Hall Yew for, as the result is this remarkable collection and its unequivocal reminder of how precious – and precarious – these trees really are. As for the yew itself, this fateful meeting with the author is no doubt just one of the many tales it could tell, as it approaches its sixth century of life. We wish it many more.

Heritage Trees of Ireland is a great read, a visual treat, and a real credit to all involved.

Kevin D. Collins

Ireland's Generous Nature – the Past and Present Uses of Wild Plants in Ireland

Peter Wyse Jackson. Missouri Botanic Garden Press. 2014.
750 pages. Hardback. ISBN: 978-0-915279-78-4
€65



Ireland's Generous Nature is the first comprehensive account of the historical and present-day uses of wild plant species in Ireland. It records a wealth of traditional knowledge about Irish plant use, knowledge that has been disappearing fast. More than 1,500 wild plants are detailed in a systematic list, which gives both their Irish and English names. Many historical references from a wide range of Irish literature have been included. In this lively and scholarly book, Professor Wyse Jackson shows how plants were used in virtually every aspect of life in Ireland; food, clothes, medicine, construction, beverages, veterinary medicine, human health and beauty, and even death. The book is richly illustrated with photographs, as well as botanical paintings by the Irish artist, Lydia Shackleton (1828–1914).

The blending of scientific and historic facts with myths, superstition, folklore and personally tested recipes, produces an unrivalled account of the rich heritage of Irish plants. Needless to say, of particular interest to foresters is the information on the uses of different woods throughout the ages and such a reader will not be disappointed. There is a fascinating account of trees and timber used in construction and handicrafts together with the use of timber for musical instruments. He lists the woods used in different parts of the Irish harp. His analysis of the trees used in the tanning of leather is enthralling. He devotes a chapter to basketry, which was a very important activity in the pre plastic era. Today, most baskets are imported from south-east Asia and now most of us would struggle to make a simple item with hazel, willow or straw.

Our ancestors possessed a remarkable knowledge of the medicinal uses of plants, including trees. For example, willow was used to cure aches and pains, ash for anti-inflammatory purposes, elder and ivy for bronchitis. He also mentions oak as a cure for diarrhoea, together with cherry and juniper which alleviate flatulence! He also lists the plants that are used to treat animals. Plants including trees were used as dyes and were also used to make ropes. It is very easy to forget how dependant our ancestors were on the plants that grew in their locality. The author believes that the famine played a part in the demise of the use of local flora. In a similar way it created a stigma among the poor about collecting shell fish which in parts of the west is still called "famine food", although it has long been a highly prized delicacy in expensive restaurants. Today, there is a resurgence of interest in foraging and it is now regarded as a very fashionable pursuit.

Peter Wyse Jackson is the current President and Director of the Missouri Botanical Garden in St. Louis and the George Engelmann Professor of Botany at Washington University, St Louis. He formerly held positions as Secretary General of Botanic Gardens Conservation International, based at Kew in London. He was Director of the National Botanic Gardens in Glasnevin, before moving to his present position in 2010. He has published widely on Irish botany, botanic gardens and plant conservation.

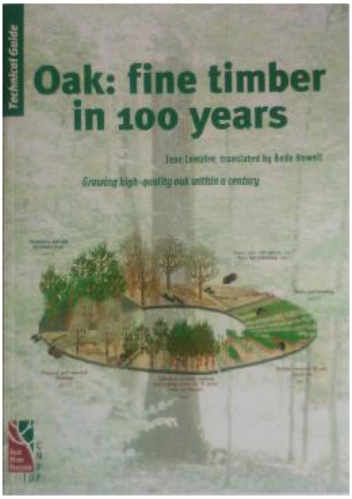
Overall, this book is a stimulating read and the author promises a second edition on this important subject that has been neglected for generations.

Watercolour of Prunus spinosa *L. (blackthorn, sloe) by Lydia Shackleton. Courtesy of the National Botanic Gardens, Glasnevin.* Ireland's Generous Nature *is published by the Missouri Botanical Gardens Press.*

John Mc Loughlin is Business Editor of the Society of Irish Foresters and Chairman of the Tree Register of Ireland.

Oak – Fine Timber in 100 Years

Jean Lemaire, translated by Bede Howell
Growing high-quality oak within a century.
Future Trees Trust. 2014.
176 pages. Paperback. ISBN 978-0-9929345-0-7
€30



Silviculture is not an exact science. There are probably as many opinions on silvicultural strategies as there are silviculturists! Yet, all silviculturists would agree on one basic tenet: it does not make economic sense to grow a low-value timber crop for 100 years; a quality product is essential. This is the core message of this translation of Jean Lemaire's insightful book. It is based on 30 years of study, by a group of foresters and landowners, of growing oak in France. The outcome of the study and of the group's deliberations is the subject of this book.

The publication follows the accepted silvicultural stages from establishment to harvest. It is presented in four parts and begins with making a distinction between sessile and pedunculate oak on the basis of their morphological characteristics. This is an essential requirement for the choice of sites suitable for each of the species. Pedunculate oak, for example, requires higher soil fertility and water availability than sessile.

The migration routes of the species, from their refugia in southern Europe, after the last ice age are shown and it is emphasised that oak species have great genetic variability. This makes it more difficult to find pure stands with the desired characteristics. Mast (seed) years are periodic and the seed (acorn) is one of the most difficult of any tree species to work with. This has implications for natural regeneration and for seed collection and storage. Heat treatment of acorns before storage is recommended to counter the risk from black rot, a common fungal rot of acorns. This is said to prolong their life for a maximum of 3 to 4 years.

The theme of Part II is how to achieve successful oak regeneration and here the book highlights the importance of planning to ensure good stocking. Regeneration can be achieved by natural means, by planting or by direct seeding. The various stages – site assessment, establishment, protection of the crop and maintenance – are described and each is colour-coded for the reader's guidance. Assessment of site potential for producing high-quality timber is emphasised and the phases to be followed are presented. The reader is reminded that it is better to spend a few hundred euros on a professional assessment than to lose millions on restocking a site which will never produce high quality timber.

Moving on to establishment, the procedure for natural regeneration of oak crops is described and the essential requirements are presented. Natural regeneration depends largely on a mast year. Even then, oak seedlings will only survive in overhead shade for the first year. Opening of the canopy is therefore essential to ensure high survival. Knowing where and when to begin cutting is important as is the intensity of opening-up. Heavy cuttings, which admit too much light, must be avoided. This will tend to swamp the regeneration area with weeds and grasses before the seedlings become established. Successful natural regeneration will of course involve respacing, as stocking density is closely associated with individual-tree diameter growth. For guidance, the results of different respacing regimes are presented. Setting out of racks at an early stage for timber extraction and later maintenance is strongly recommended. Another important consideration highlighted is the importance of protection from grazing animals and here a particular dilemma is discussed – the balance between game and sustainable forest management.

Recommendations for restocking old woodland sites and planting farmland will generate some controversy. The recommended stocking density of not more than 1,400 plants ha^{-1} for oak is a radical departure from standard practice. Traditionally, oak was planted at 6,000 to 10,000 plants ha^{-1} to ensure a quota of good quality trees for the final crop. Efforts to reduce this number in recent years have still resulted in a stocking per ha in excess of 3,000. Stocking density, however, should not be viewed in isolation. Other factors, such as soil preparation, planting method, vegetation control and particularly plant quality and provenance interact with stocking density, all of which have a bearing on the success of a plantation. In support of the 1,400 plants ha^{-1} recommendation, it is claimed that there is no effect on the branchiness of the best 400 oak ha^{-1} in plantations of between 1,400 and 3,000 ha^{-1}. On old woodland sites with regrowth, the required number lies between 800 and 1,400 ha^{-1}. These data are based on a major study of planting farmland in the Loire area of the Centre Region of France in 2008. Two-year-old (1u1) plants are recommended for both planting of farmland and replanting of old woodland. These are grown from acorns sourced from seed stands selected along strict lines for purity, quality and growth. The correct provenance and quality of plants is deemed to be of first importance and is likely to be the main reason for the recommended stocking of not more than 1,400 ha^{-1}.

Direct-seeding is treated briefly. It is particularly well adapted to planting farmland but was also used for restocking woodland on the continent during the past century. Its main disadvantage is that it requires a large supply of acorns and will, of course, necessitate respacing.

Part III deals with the growth characteristics of oaks and in particular addresses the leader (shaping) characteristics, and pruning and thinning practices. It follows that the guidelines are called Active Silviculture. This is now the conventional procedure for broadleaves. Potential crop trees ("winners") are selected at first thinning and given a crown thinning (halo thinning). Silviculturists may have different views as to when a first thinning should take place. Here it is recommended before 20 years of age (ideally nearer 15), before 12 m top height. How to select "winners" is explained: this should be done at a young age, when about 70 stems ha^{-1} are selected and high pruned (including dead branches). Of these 70 stems ha^{-1}, about 50 will form the crop at maturity.

For existing oak stands, which have not had the benefit of Active Silviculture from an early age, a roadmap for catching-up is presented. This involves more frequent thinnings. Although this exercise shortens the rotation, it will still exceed 100 years to produce logs of 60 to 70 cm diameter.

When dealing with oak one must accept epicormics. Without an understorey they are almost an inevitable occurrence and are a cause of degrade in timber. Two eminent French silviculturalists are quoted to the effect that: "For growing healthy, vigorous high quality oak in under 100 years avoid pure stands by accepting a mixture of understorey species – this is the message for every landowner or forester growing oaks". An understorey is easily obtainable in restocked old woodland but is not readily available in planted farmland. Should it be introduced at first thinning? The book makes no recommendation on this matter.

Part IV provides an insight into the quality grades of oak timber and the factors that cause degrade, such as knots, rot and spiral grain in oak. To reinforce the need for quality in the marketplace, a graph shows the mean price paid for different qualities and sizes. This is supplemented by a diagram, which illustrates the importance of quality by reference to a mature oak tree of good quality: the first 6 m length of quality A and B accounts for 35% of the tree volume but 85% of its value. It is a useful reminder of the need to grow oak of high quality.

The publication concludes with four Annexes. Readers involved in regeneration of oak will find Annex 2 of particular interest. It contains 10 silvicultural roadmaps, each showing details of the necessary operations and costs. Silvicultural roadmap 9, planting sessile oak on former farmland, may cause some surprises: for ground preparation it includes complete ploughing and sub-soiling. The latter is presumably to break up the plough pan. Some basic lessons are provided in the measurement of standing tree volume and even an illustration of how to make a homemade relascope for measuring basal area.

The book does not follow the usual textbook format. If one accepts the adage that, "a little picture is worth a thousand words", this book is a massive tome. Every page contains pictures, drawings, graphs, or decision charts to illustrate and support the text and guide the reader, making the material more readable and understandable. In keeping with this approach there are "True or False?" and "Did you know?" sections to emphasise important points.

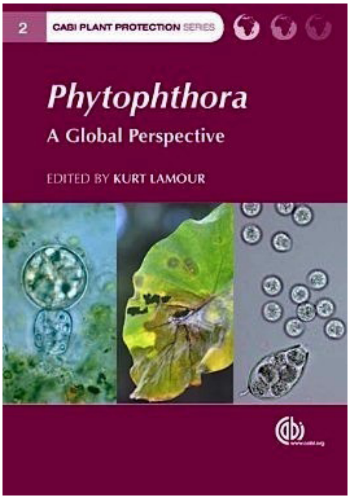
Figure 1: *Left, a mature spreading oak crown and right, the author describes how to simply measure basal area. Images courtesy of Future Trees Trust.*

This technical guide is the ideal book for the practitioner – the forester or enthusiastic landowner who wishes to learn how to grow quality oak. Studying the guidelines provided in the book and implementing them will bring reward.

P.M. Joyce

Phytophthora – a Global Perspective

Kurt Lamour (Ed.). CABI. 2013.
244 pages. Hardback. ISBN 978-1-78064-093-8
€110



Phytophthora is a genus of fungus-like organisms that contains many infamous plant pathogens such as *Phytophthora infestans* (cause of Potato blight), *P. ramorum* (cause of Sudden oak/larch death) and *P. cinnamomi* (the cause of Jarrah dieback in Australia). In recent years the number of known *Phytophthora* species has dramatically increased, from 51 in the year 2000, to 125 at present. Therefore, it is timely that the CABI publication *Phytophthora – a global perspective* has arrived to bring together 64 respected scientists to provide an overview of the antagonistic effects the genus *Phytophthora* has on plants world-wide. As with other books in the CABI series, the book is hardback and caters for the more specialised audience, a fact reflected in its rather high price (€110). The book contains 25 chapters, many of which may not be of immediate interest to Irish Forestry readers. The first five chapters deal with the basic biology of the genus *Phytophthora*, including chapters on the history (Chpt. 1), phylogeny (Chpt. 2) and mating practices (Chpt. 5) of the genus; while two chapters review the current best practice for describing *Phytophthora* species using both molecular (Chpt. 3) and traditional morphological (Chpt. 4) methods. In a fitting finale, the last chapter explores the past, present and future effect that globalisation will have on the genus *Phytophthora*. In between chapters 5 and 25, we are brought on a journey that spans all continents (except Antarctica), and includes agricultural, agroforestry, forestry and horticultural settings.

My main disappointment with this book is that it is not quite what I had expected. Upon reading of its forthcoming publication I had hoped this book would be an update on previous publications dealing with the *Phytophthora* taxonomy through the listing of species profiles. The genus *Phytophthora* is expanding so quickly that the currently available species identification texts published in 1996 and 2008 are lacking the more recently described species, such as *P. ramorum* and *P. kernoviae*, respectively. However, there are several online resources that assist in identifying *Phytophthora* species[2], so an identification guidebook to *Phytophthora* species is not all that vital. From a format point of view, I find that there is a bit of redundancy throughout the book. For example, *P. cinnamomi* is mentioned in at least six different chapters, as its effect is discussed in relation to the African, Australian, European, Mexican and North American forests as well as in European nurseries. Furthermore, the chapters differ greatly in their area of focus, some focussing on the effect a single species has on a single host plant in a "small" sized region (Chpt. 17: *P. pinifolia* on *Pinus* in Chile), some focus on a single species and all its hosts in a "medium" sized region (Chpt. 11: *P. capsici* in Eastern USA) while others detail all known species on all hosts from a "large" region (Chpt. 24: *Phytophthora* in China). In this way, the book is probably more accessible to readers not primarily interested in *Phytophthora* species, as it gives a very broad viewpoint of the problems *Phytophthora* species cause world-wide. I am aware that both of the previous faults I have identified in this book are ones probably only evident to someone involved in *Phytophthora* focussed research, those with a general interest in *Phytophthora* will be unperturbed by my critiques. As for myself, being a *Phytophthora* enthusiast, with an interest in taxonomy, I find it easiest and more concise, to review the book by highlighting three species that are especially damaging to forests. Rather than detailing each individual chapter, I feel that this method of review will help force home the immediate risks faced by world forests because of the pan-global movement of *Phytophthora* species via human enterprises – thus in a way echoing the main message in the book itself.

P. cinnamomi

P. cinnamomi is dealt with several times throughout the book. This soil-borne species has an incredibly broad host range (>3,000 species of plants; Chpt. 18), including chestnut, oak, pine, macadamia, avocado and eucalyptus to name a few. Indeed, research results have indicated that >2,500 native Australian plants are susceptible to the non-native pathogen *P. cinnamomi* (Chpt. 14). This threat and others like it have lead to a total ban on untreated soil crossing into Australia (Chpt. 25). Some might call this an over exuberant phytosanitary step, however I imagine there are few plant pathologist who would not agree with the policy. In developments a little closer to

[2] E.g. Phytophthora Database (www.phytophthoradb.org) or Forest Phytophthoras of the World (www.forestphytophthoras.org).

home, *P. cinnamomi* has been found to be one of the causal agents in ink disease of chestnut (*Castanea* spp.) in mainland Europe (Chpt. 16). This disease is wreaking havoc on chestnut forests in Western Europe. Even closer to home, the pathogen has also been found to be affecting Yew (*Taxus baccata*) in Ireland, with the botanic gardens at Kilmacurragh currently dealing with an outbreak. As with all *Phytophthora* species, eradication is extremely difficult due to the persistence of the organism (in soil and leaf litter) in the site even after host removal. Thus prevention of pathogen spread through stringent biosecurity measures is paramount.

P. ramorum

P. ramorum is currently of most worry to Ireland, Britain and the American Pacific Northwest. It forms the main species of concern in the chapters on *Phytophthora* in US forests (Chpt. 15). The impact of invasive Phytophthoras on European forests (Chpt. 16), and *Phytophthora* in woody ornamental nurseries (Chpt. 18). *P. ramorum* is non-native to Europe and North America, and was probably introduced into both regions in the late 20th century from somewhere in Eastern Asia. It then escaped into forests, and spread on susceptible hosts. In North American forests the main sporulating hosts are bay laurel (*Laurus nobilis* L.) and tanoak (*Notholithocarpus densiflorus* Manos, Cannon & S.H.Oh), while rhododendron (*Rhododendron ponticum* L.) and more recently Japanese larch (*Larix kaempferi* (Lamb.) Carr.) act as sporulating hosts in Irish and British forests. It was most likely spread to both Europe and North America via plant trade. Indeed, Chapter 18 on plant trade lists more than 17 species of *Phytophthora* that are spread within horticultural trade, but *P. ramorum* is highlighted as one of the more threatening. Trade in live plants has been identified as the most effective way to spread plant diseases world-wide. Weaknesses in the current system, which includes the use of a phytosanitary passport and border visual assessment, have been heavily criticised. Many confounding factors, such as lack of inspection staff, the use of fungicides which mask disease symptoms, and non-compliance of some states within the EU to country-wide yearly pathogen surveys[3] hinder our ability to control the spread of plant pathogens within horticultural trade networks. Within the EU there is a balance to be struck between trade and plant health, at present the balance is most certainly in favour of free trade, to the detriment of plant health. Plant trade and plant production systems are in need of more disease awareness (Chpt. 25). The tale of *P. alni* is a reminder of this.

P. alni

In a real life Frankenstein's monster tale, *P. alni* came into being when two different *Phytophthora* species, possibly *P. cambivora* and *P. fragariae*, successfully mated in

[3] Brasier, C.M. 2008. The biosecurity threat to the UK and global environment from international trade in live plants. *Plant Pathology* 57: 792-808.

a plant nursery somewhere in Europe (Chpt. 5). This brief courtship between parent species went unnoticed by both the nursery owner and the scientific community. It was not until a new species of *Phytophthora* was discovered damaging alder trees across Europe[4], that retrospective study and analysis indicated the genesis of the new species of *Phytophthora*. While neither of the parent species causes negative effects to alder, the off-spring is unexpectedly damaging to several alder species. This species is the causal agent of alder decline across Europe, and has also been found in alder forests in Alaska. *P. alni* should be taken as a warning of the unpredictable dangers that hybridization of *Phytophthora* species pose to plants. By creating the right conditions (moist, warm environment with abundant host plants) and bringing the two species together (via plant trade: Chpt. 18) mankind can claim total responsibility for the creation of the monster that is the alder Phytophthora, *P. alni*.

As this book focusses on species of *Phytophthora* that cause disease to plants, it is easy to mistakenly think that all *Phytophthora* species are bad for plant health. In fact, most forests probably have several native (including unnamed) *Phytophthora* species present, yet most of these do not cause any significant damage to tree health[5]. It is normally only invasive *Phytophthora* species that threaten plant health. A chapter I would have liked to see, but is missing from the book, is one examining the possible origins of the invasive *Phytophthora* species causing so much damage in regions where they are introduced. The same chapter could detail some of the expeditions (often to eastern Asia) undertaken to trace the native range of species such as *P. ramorum*, *P. lateralis* and *P. kernoviae*. Incidentally, *P. kernoviae* is a woody plant pathogen that is only known from Ireland, Britain and New Zealand. Up until 2007 it was thought to be present in Britain only, but retrospective DNA analysis of archive cultures and re-examination of a 37-year-old Master's thesis revealed that the previously undescribed *Phytophthora* species found in New Zealand (and present there since before 1950) was the indigenous *P. kernoviae*. A chapter dealing with the "detective work" that sometimes helps pathologists find the origin of the exotic pathogen would have been interesting.

It is difficult to put a cost on the damage done by *Phytophthora* species world-wide. Any estimate would be hampered by the lack of figures from developing countries, and by the inability to put a price on the massive negative effects on forests by the disease, either through increment loss or entire crop losses. Just one species of *Phytophthora*, *P. infestans*, cost over $8 billion to the US and European potato industries through either control efforts or in crop losses (Chpt. 1 and 7). With 72 of the 125 known *Phytophthora* species being present in forests (Chpt. 25), and many of these being pathogenic to trees, the cost of *Phytophthora* to the forestry industry

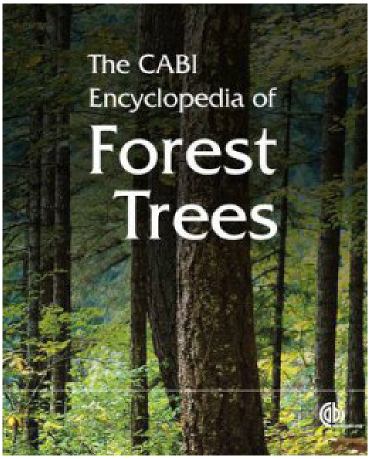
[4] Pain, S. 1999. Fiendish Fungus. *New Scientist* 2186: 7.
[5] Hansen, E.M., Reeser, P.W. and Sutton, W. 2012. Phytophthora beyond agriculture. *Annual Review of Phytopathology* 50: 359-378.

world-wide is most likely exorbitant. Indeed, the authors of chapter 15 of the book rate *Phytophthora* as one of the most significant threats to forest health world-wide. When we consider this analysis, it is important that people involved in forestry and plant health work together to future proof our forests against these threats; and getting to grips with these threats is the first step. I feel that this is where books such as *Phytophthora – a global perspective* can be particularly useful.

Richard O'Hanlon, www.rohanlon.org

The CABI Encyclopedia of Forest Trees

Andrew Praciak, Nick Pasiecznik, Douglas Sheil, Miriam van Heist, Marilke Sassen, Cristina souse Correra, Christopher Dixon, George E. Fyson, Keith Rushforth and Claire Teeling (Compilers).
CABI Publishing. 2013.
532 pages. Hardback. ISBN 978-1-78064-236-9
€195



This is a book that is long overdue and therefore must be welcomed by all involved in forestry. Books on dendrology, silviculture and monographs of different species and genera have been relatively easily accessible in the market place. This book is different. It deals with all of the above and more, as well as providing a level of information that is sufficient for both the professional forester or researcher.
Each species is discussed under the following headings:

- Importance;
- Botanical features;
- Distribution;
- Silvicultural practice;
- Diseases and pests;
- Uses.

It also suggests sources of further reading which are often very up-to-date. What is described under Silvicultural Practice is detailed and covers stages from germination and production of material, to establishment, tending, respacing and thinning requirements, to productivity rates and pruning. The section dealing with "uses" is very informative in that it not only describes the potential timber uses but also the non-timber benefits as well. Detailed information is provided on the timber properties including ranges for density at specific moisture contents of most species, as well as attributes like stiffness, shock resistance, modulus of elasticity, … etc. and even the crude protein value of some species foliage commonly used as fodder: 24% for *Robinia pseudoacia*.

This book is remarkable in that it describes 300 significant forest trees from all corners of the earth. Thus, the reader can study everything from *Picea sitchensis* (Sitka spruce) in North West America to *Eucalyptus regnens* (mountain ash) in Australia to *Swietenia macrophylla* (big leaf mahogany) in Central/South America. It is truly an encyclopaedic work.

However, as with most publications, it is not perfect and is deserving of some criticism. In attempting to choose 300 trees from the many thousands of possibilities, it is not surprising that readers will identify what might be considered omissions. These might include for example, *Eucalyptus nitens* (shining gum), *Populus tremula* X *tremuloides* (hybrid aspen), *Larix* X *marschlinsii* (hybrid larch) and others depending on your choice. A random search relating to current work of the reviewers found that *Pinus pinea* (stone pine) was only mentioned in passing in relation to another species, so omissions do not only relate to species of significance to Ireland. It is a pity that the authors do not provide a preface or some form of introduction to the work to identify the niche for which the book was intended.

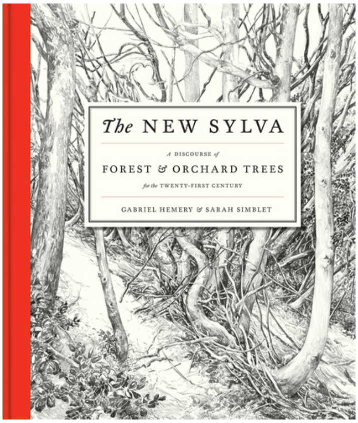
There are surprisingly few photographs, considering the potential practical use and the capabilities of modern publishing. All of the photographs are located together in an 8-page section in the middle of the book, which does not permit easy picture referencing of specific species. The image plates present an apparently random selection of species, the first 45 showing characteristic tree shapes from a distance, a further 18 showing flowers and seeds, and the final nine show tree stems and bark patterns. Disappointingly, quite apart from the lack of a theme, the images are rather poorly chosen in some cases and generally badly reproduced.

This is a big, heavy and expensive book, which would have benefitted from stronger binding in order to reduce the likelihood that the pages might part over time. However, in the overall context, these are relatively minor criticisms and this book should be on the shelf of all professional foresters with an interest in world forestry and silviculture. Once there it may well attract continued use. In fact, in a world where changing economic circumstances and altering climate are likely to affect the range of products we require from our forests, as well as the species used therein, we may well be expanding our list of potentially suitable species before long.

Kevin J. Hutchinson and Brian Tobin

The New Sylva: A Discourse of Forest and Orchard Trees for the Twenty First Century

Gabriel Hemery and Sarah Simblet. Bloomsbury. 2014.
390 pages. Hardback. ISBN 978/408835449
£50



In 1662 John Evelyn, and English writer, diarist and ambitious gardener, presented a paper to the newly formed Royal Society entitled *Sylva – A Discourse of Forest Trees, and the Propagation of Timber in his Majesty's Dominions*. Two years later it was published in book form. Several editions were published over subsequent years and the book has become probably the most famous English text on trees and forestry. Original copies are highly sought after, with first editions sometimes attracting prices of between €2,000 and €3,000.

Now, 350 years later, a new book has appeared to celebrate the legacy of Evelyn's Sylva, a legacy that is best known for encouraging tree planting to satisfy England's timber needs, particularly for shipbuilding. This new book, authored by Gabriel Hemery and illustrated by Sarah Simblet, is entitled *The New Sylva: A Discourse of Forest and Orchard Trees for the Twenty First Century*. The book starts with a profile of Evelyn and describes his life and work in the context of the era that he lived in. For everybody who has heard of John Evelyn, but didn't know much about him, this makes fascinating reading. The book deals not only with his horticultural and arboricultural exploits, but also his work as a diarist of turbulent political times.

The next chapter profiles 44 trees used in Britain. For each species we learn about its biology, distribution and habitat, its silviculture, timber and uses, pests and diseases and what the future may hold for it. This information is presented in a concise and very readable form and is suitable for the professional forester/arboriculturalist as well as the layman. The range of tree species covered gives much food for thought, particularly in times of apparently rapid climate change and attendant biological changes/threats.

There are also chapters like "Of Silviculture and Forest Produce" and "Of Future Forests".

What really makes this book very special are the absolutely wonderful drawings by Sarah Simblet (Figure 1), some showing whole trees and forests while others illustrate flowers, buds, cones etc. These illustrations are exquisite and full of gently dignified and graceful detail. It is a charming feature of the text that the up-to-date information of various species is interspersed with anecdotes from Evelyn's original text.

Figure 1: *The New Sylva by Gabriel Hemery and Sarah Simblet is published by Bloomsbury, the artwork is by Sarah Simblet and taken from The New Sylva and reproduced with kind permission. Here a couple of very mature maples are depicted. Below, a remarkable level of "real-life" detail is included, right down to the partially insect-eaten leaves so common to blackthorn.*

This is a magnificent book which will appeal not only to anybody interested in trees, but also those who appreciate beautiful books.
Highly recommended!

Kevin J. Hutchinson

Society of Irish Foresters Study Tour to Sweden

5th – 8th June 2013

The 2013 study tour visited southern Sweden, a rolling countryside of farmland and forests. The forests became more prominent in the landscape as we travelled north towards the town of Växjö, where we were based for the tour. Both our host companies, Sveaskog (South) and Södra are headquartered there, and the ElmiaWood Fair at Jönköping was an hour away by motorway.

Sweden boasts Europe's second largest forested area after Russia. Its productive forests cover 28.1 million ha or almost 67% of the country's land surface. Norway spruce (*Picea abies* (L.) Karsten) and Scots pine (*Pinus sylvestris* L.) are by far the predominant species. Together they account for 80% of the growing stock which is estimated at 2,930 million m^3. In northern Sweden pine is the most common species, whereas spruce mixed with birch (*Betula* spp.) dominates in southern Sweden. Sweden's annual harvest is approximately 74 million m^3. The forest industry employs 205,000 people and annual exports are in the order of €14.8 billion.

This study tour gave us valuable insights into many aspects of the industry in one of the giants of the forestry world. The overriding lesson we learned was that Swedish foresters keep things simple but that they do them exceedingly well. Both Sveaskog and Södra are huge commercial entities and it is refreshing to see that silviculture is fundamental to their decision making processes. We were fortunate to have been hosted by such open and confident, professional foresters. We are indebted to them for the success of this study tour.

Pat O'Sullivan, Tour Convenor

Thursday, 6th June

The warm sunshine that welcomed us on our arrival in Växjö on Wednesday evening remained with us for the following days of the study tour. Swedish flags were flying in the market square close to our hotel. Flags were also flying on many of the houses along our route as we travelled east of Växjö to the forest at Högaskog. However, the flags were not there to welcome the visitors from Ireland but to mark Sweden's national holiday; one of several days in the year when the distinctive blue and yellow flag of Sweden is unfurled from countless flagpoles throughout the country.

The visit to Högaskog was hosted by Sveaskog, Sweden's state forestry company. Our leaders were Kjell Gustavsson, Vice-President Silviculture, at Sveaskog and Stefan Bergqvist, Forestry Field Assistant, together with his dog, Lisa. Both officials welcomed us to Högaskog with refreshments in the form of strong coffee and traditional "morning" cake. Sveaskog is Sweden's largest forest owner (3.1 million ha of productive forest land). It employs 720 people and had annual sales of €755 million in 2012. Forestry is its core business; the focus is on silviculture, the sale of forest products and the development of the forest's other values. Sveaskog achieved FSC certification in the early 1990s and is currently working towards gaining PEFC certification also.

Sveaskog's South Division owns 280,000 ha or 8% of the productive forest land in southern Sweden. The main species here are Norway spruce, Scots pine and birch. 20% of the forest is designated Nature Conservation Land, which falls into three categories – Ecoparks, specific stands for conservation and small features. In Sweden the landowner owns the hunting rights. Revenue from hunting on Sveaskog's land accounts for 7% of the company's income. Moose, wild boar and roe deer are the main species. Interestingly, public access to the forest is a legal right in Sweden but members of the public are fully responsible for their own health and safety in the forest.

The process of planning for final felling was explained to the group by Stefan Bergqvist who manages approximately 20,000 ha of forest. His work is completely field based and his "office" is a specially reinforced tablet which has up-to-date maps, inventory information and archaeological/heritage layers (Figure 1). He prepares

Figure 1: *Stefan Bergqvist, Sveaskog forestry field assistant, with his office – a reinforced Armor tablet.*

the harvesting plan at a site and forwards it to Sveaskog's office and to the Forest Authority for approval. Cultural features, such as the 16th century "tar production" site we visited, are excluded from the harvest area and are delineated on the ground by "cultural stumps" which is a cordon of trees cut at 3 m above ground level to identify the site for exclusion from all future forest operations. In addition, approximately 100 "eternity trees" per ha are left standing to provide shelter for the following crop.

Scots pine is the preferred species in this drier area but it is very prone to damage by moose, whereas Norway spruce is much less attractive to them. When the regeneration reaches 0.5 m in height, the number of these so called "eternity trees" is reduced to 10 ha^{-1}. In addition, three "deadwood" trees per hectare are left to encourage wildlife. Almost all the lop and top is removed from the site to the road-side where it is chipped for use as bio-fuel. On a nearby site a six wheeled Eco Log 590D harvester was clearfelling 90-year-old Norway spruce. This Swedish manufactured harvester processes between 70,000 m^3 $annum^{-1}$ and 80,000 m^3 $annum^{-1}$. This machine's on-board computer uses the Forestry Field Assistant's harvesting plan to oversee the clearfelling operation.

Following lunch at the famous Kosta glass factory, it was back to harvesting operations in a 35-year-old stand of Scots pine which was getting its first thinning. For thinning operations, the smaller Eco Log 580D harvester was used (Figure 2). This machine had a specially adapted harvesting head which could bundle up to three

Figure 2: *The Swedish manufactured Eco Log 580D carries out a first thinning of a 35-year-old Scots pine stand.*

trees and process them simultaneously, thus greatly improving harvesting efficiency. The thinning intensity was determined by the basal area of the crop. Normally 35% of the basal area is removed at first thinning. On this site the lop and top was also being removed to the roadside for chipping. All of Sveaskog's machine operators must complete a three-year operator's training course at an approved forestry school.

In southern Sweden, first thinning is usually done when the crop reaches 35 - 40 years of age and is followed by the second thinning when the crop is 55 years of age and the crop is often clearfelled at approximately 70 years of age. The Forest Authority will not permit clearfelling until the crop is at least 65 years old. Our next stop was a typical 50-year-old pine stand. Here there was plenty of ground vegetation for moose and a number of shooting platforms to facilitate game control.

Travelling to the final stop of the day, we passed through an area which carried a fine stand of Scots pine, but the forest terrain was extremely rough due to the large number of huge boulders scattered throughout the area. Their presence impedes conventional harvesting operations and in some cases, such as here, can prevent harvesting altogether. The final stop was in a 25-year-old pine stand which had been badly damaged by moose browsing. The upper level of tolerance is 30% damage and here that limit was close to being breached. Michael O'Brien, our Chairman for the day, thanked Kjell for a very pleasant, informative day and for spending his national holiday showing us around the forest.

Overnight – Växjö *Richard Jack*

Friday, 7th June

On Friday morning, we travelled west from Växjö for about 40 minutes to a site at Toftaholm which is owned by Södra, the largest private growers' co-operative in southern Sweden. The Södra staff who hosted us for the day were Magnus Petersson, Magnus Linden and Anders Ehstrand, Södra's broadleaf specialist.

Södra is owned by its 51,000 members, who have 36,000 forest estates, representing more than half the privately-owned forest in southern Sweden. Many of these estates have more than one owner, the average age of owners is 60 years, and the average size of holding is 50 ha. The south of Sweden has the best growth rates which range from eight to ten m^3 ha^{-1} $annum^{-1}$.

Södra's main function is to secure markets for its members' forest produce and to contribute to the profitability of their forests. Members do not pay a fee, but each member invests in Södra by making capital contributions that are drawn from payments for wood deliveries. Members receive advice and training on forest management and are offered value creating forestry services ranging from planting to harvesting. The members also share in the profits of Södra's processing mills. Södra employs 3,800 staff and owns three pulp mills, 11 softwood mills and two hardwood mills. Södra is a very democratic organisation; each member has one vote irrespective of the level of capital contributed or the size of their forest estate. Members may also be elected to Södra's Board of Directors.

The 1,500 ha site we visited at Toftaholm is owned by Södra and is used as a "best practice in forest management" demonstration area. Södra also permits the University to conduct both long- and short-term research experiments here. In January 2005, a catastrophic wind storm toppled 200 ha of old Norway spruce here. During the night of 8th January 2005, almost 75 million m^3 of timber was windblown, which is equivalent to the annual harvest for the entire country. The storm came from the south-west and travelled to the east, with wind-speeds in excess of 100 km hr^{-1}. Membership of Södra significantly increased after the storm and the company bought some nurseries to ensure an adequate supply of plants for replanting of the blown areas. Approximately 90% of reforestation was done with Norway spruce, with some small experimental planting of aspen (*Populus tremula* L.) and birch, hybrid larch (*Larix X eurolepis* Henry), Sitka spruce (*Picea sitchensis* (Bong.) Carr.) and Douglas fir (*Pseudosuga menziesii* (Mirbel) Franco).

Almost 90% of all clearfell sites are scarified at an average cost of €300 ha^{-1}. The preference is for mounding as it gives much better survival rates, but mounding costs are high at about €470 ha^{-1}. Södra's foresters are actively seeking to reduce the cost of mounding. Currently, they have a derogation from the FSC for using insecticide for

Figure 3: *A wax coated seedling at Södra's reforestation site at Toftaholm*.

pine weevil control. They are experimenting with wax-coating their seedlings (four million per year) to protect them against weevil damage. Results to date are very promising but the wax coating needs to be very flexible as the seedling diameter increases significantly during the first two growing seasons.

One of the main problems encountered on reforestation sites is the amount of natural regeneration of birch, which can be in the order of 20,000 to 100,000 stems ha^{-1} (Figure 4). The preferred species on these reforestation sites is Norway spruce as its yield class is three or four times greater than that of birch. However, it is accepted that on approximately 15% of reforestation sites, particularly on wetter sites, birch will be the dominant species. In order to successfully establish the Norway spruce crop, two "pre-commercial" thinnings of the birch are generally made, the first at seven years (Figure 5) and the second at ten.

Foresters have found that when birch is cut, the subsequent re-growth of the birch shoots is much faster than birch from seed and that is why they do not want to cut it too early. These pre-commercial thinnings are normally done with a brush-cutter but a new "chain brush-cutter" which uses a chainsaw head instead of a circular saw head, is becoming more popular. The birch is cut at approx 30 cm height as this is the height roe deer prefer to graze at, and this helps to control the re-growth. We also saw other trials where the number of birch in Norway spruce plantations is reduced to 4,000 and 1,000 stems ha^{-1} respectively, and later the birch is harvested at 8 m or 9 m height as an energy crop. However, this will inevitably lead to some extraction damage to the spruce and result in harvesting tracks being left behind.

Figure 4: *Strong birch regeneration before a first pre-commercial thinning.*

Figure 5: *Norway spruce regeneration following a first pre-commercial thinning.*

Figure 6: *The new "chain brush-cutter" which uses a chainsaw head instead of a circular saw head for pre-commercial thinning operations.*

We then visited a stand of Norway spruce that had already received a first thinning. This is usually carried out about 20 years after the second pre-commercial thinning when the crop is between 12 m and 15 m in height and has a DBH of 10 cm or greater. Approximately 40% of the basal area is generally removed; 15% from the racks which are spaced 60 m apart, and 25% from between the racks. Such crops will usually be thinned once more about 15 years later when the crop is 18 m to 22 m in height. These crops will receive no further treatment until clearfell when it should have 1,000 stems ha^{-1} and an average DBH of 35 cm. Swedish forest law prohibits clearfelling before the crop is 65 years of age.

Our final stop was in an area of semi-natural forest which had been grazed until 70 years ago. It contained a lot of old birch but they believe that oak and beech will become more prominent as the crop ages. This area has had continuous tree cover throughout its history and therefore had very high levels of biodiversity. In Sweden, there are two types of nature conservation areas – "NO" where there is no management intervention and "NS" where some level of management is permitted. We saw some old oak trees, probably 200 years old, which were home to the Hermit beetle, *Osmoderma eremite*. This is a very rare European beetle that lives on decaying wood or mould in old trees and can fly a distance of only 20 m. In places where this beetle is found, there are likely to be a further 40 or 50 other "Red Data" species also present.

Overnight – Växjö *Eugene Griffin*

Saturday, 8th June

The group made the trip north to ElmiaWood, Sweden's mammoth forestry trade fair. Located east of Jönköping, the ElmiaWood fair takes place every four years in early June. Few would dispute the organisers claim to be the world's biggest international forestry trade fair; the Olympics of the global forestry and forest products industry!

Enthusiasts of forestry machinery and new products usually spend several days at the show to fully absorb its wide range of activities, machinery and products. With more than 54,000 visitors and some 500 exhibitors, ElmiaWood demands this level of attention. It takes place over four days and we visited it on the final day in glorious sunshine. Single-day visitors need to be quite selective as it's very easy to be seduced by the large harvesting companies with their spectacular exhibitions of tree felling and extraction, often accompanied by heavy metal music and theatrical fire displays (Figure 7). The leaders in this regard were Komatsu, John Deere and Ponsse.

However, there were also many harvesting units designed for small-scale forests. We tend to forget that in Sweden, and throughout much of Europe, average forest size can be small and their owners prefer machines which are adapted to

Figure 7: *Attention grabbing displays at an ElmiaWood demonstration area.*

harvest such sites. Discussing forestry issues with Södra foresters the previous day, we learned that while some forest owners leave the management of their crops to the experts, many take a hands-on approach. The huge interest shown in ElmiaWood supports the view that many Swedish forest owners are actively managing their own forests.

As there is practically no afforestation in Sweden, the emphasis is on harvesting and reforestation. Although Sweden is over five times larger than the island of Ireland, it has a population of only 10.6 million but has some 355,000 forest owners. The State owns 25% of the forest estate which is managed mainly by Sveaskog, an organisation with similarities to Coillte, while a further 25% of forests are owned by private companies. However, half the forests are in private ownership, so it's easy to see why forestry is not only a key industry but also a way of life for so many people in Sweden. This was reflected in the attendance at ElmiaWood, although it also attracts a large number of overseas visitors from around the world including Ireland.

The catastrophic windblow of January 2005 created new challenges in reforestation, mainly in private plantations in the south where much of the damage was caused and where most of the forests are privately owned, unlike in northern Sweden where forests are predominantly state owned. It was obvious from the previous two days of the study tour that the re-emergence of competing birch in reforestation sites is a major silvicultural issue. Innovative new brushcutters designed to clear birch around recently established Norway spruce exemplifies the Swedish "can do" approach to successful reforestation. These were on display and are now the main tool used during the first few years after establishment as chemical weed control is banned. Insecticides are also banned in controlling the pine weevil in reforestation sites. Environmentally friendly ways to treat seedlings to control damage by this insect pest were on display at the show. In some instances, plants were dipped in wax up to 80°C around the root collar and this was proving to be an effective control method (as was already seen at the Södra reforestation site at Toftaholm; Figure 3). Another method involved the application of water-based glue to the seedling, which is then sprayed with sand.

Having dealt with the weevil, the next problem in the reforestation site is preventing deer and moose from eating the tips of young trees. Interagro Skög AB has developed an environmentally friendly spray, Arbinol B, which it claims is a deterrent because of its bitter taste. Jokingly referred to as the "anti-Bambi method", it might have potential for use in Ireland to control deer damage.

There was a strong emphasis on technology, computerisation and innovation in forest planning, management and measurement. Likewise, environmental issues featured highly and the main forest certification companies had a strong presence there. Even the large-scale machines are adapting to environmental issues and are equipped to minimise damage to soil and flora.

ElmiaWood placed huge emphasis on renewable energy and this is now part-and-parcel of Swedish forestry from chip and pellet production to traditional log production and its associated log processors, log splitters and traditional axe users. With an annual cut of 74 million m^3 Sweden can afford to feed its sawmills, panel board and pulp mills as well as the wood energy sector. The wood energy sector is designed for local production with short haulage distances, which is more easily achievable in a country with greater than 60% forest cover.

The exhibitors made every effort to cater for both specialists and the general public alike by patiently explaining the virtues of their merchandise and services (Figure 8). Advice and technical lectures were accompanied by souvenirs, food and drinks, which ranged from coffee to birch sap.

Finally, for those who missed the 2013 ElmiaWood or for those who wish to re-visit the show, the organisers extend a *céad míle failte* or *välkommen tillbaka till ElmiaWood* on 7th -10th June, 2017!

Overnight – Växjö *Donal Magner*

Figure 8: *Yes, we did encounter moose during our visit to Sweden!*

Tour Participants (34)

Pacelli Breathnach, Richard Clear, John Connelly, Clodagh Duffy, PJ Fitzpatrick, Jerry Fleming, Tony Gallinagh, Eugene Griffin, John Guinan, George Hipwell, Richard Jack, Erick Johnson, Joyce Johnson, Kevin Kenny, Brendan Lacey, Brendan Lally, Donal Magner, Tony Mannion, Jim McHugh, Willie McKenna, Paul McMahon, Liam Murphy, Frank Nugent, Benny O'Brien, Dermot O'Brien, Michael O'Brien, Paddy O'Kelly, Tim O'Regan, Matt O'Rourke, Pat O'Sullivan, Paul Ruane, Kieran Walsh, Trevor Wilson, Cathal Woods.

Obituaries

Adrian Carroll
1983-2013

The death of Adrian Carroll on 23rd April 2013, less than two weeks before his 30th birthday, caused great shock and sadness in the forestry community. Adrian had borne his illness with remarkable fortitude during the previous twelve months.

He was born on 3rd May 1983 at Ballinaboul, Churchtown, Mallow, Co. Cork, to John Carroll and Mairéad (nee Stack). He received his early education at Churchtown National School and later progressed to The Nagle Rice Secondary School at Doneraile, Co. Cork.

From an early age, Adrian was steeped in forestry as both his father and his brother, John Jnr., were involved in the forest industry. Thus he began his forestry course at Waterford Institute of Technology already armed with a keenly developed interest in and a deep practical knowledge of forestry. He enthusiastically engaged with the academic programme, yet never lost his practical focus. His questions in class were invariably prompted by an observation he had earlier made in the forest, as he sought to reconcile forestry theory with his personal experience. On an early forest fencing field day, while his classmates came with packed raingear and lunches, Adrian arrived on site with a maul over his shoulder, all set for a day of driving posts. Adrian graduated with a BSc in Forestry in 2006. In 2007, he was awarded the Augustine Henry Medal by the Society of Irish Foresters. This medal is presented each year to the forestry students who secure the highest marks in their final examinations.

In 2010, he began working with Deel Forestry in Rathkeale, Co Limerick where he remained until the onset of his illness. Adrian was an enthusiastic forester and was keenly interested in all aspects of the subject. He was a dedicated member of the Association of Irish Forestry Consultants (AFIC).

When I first met Adrian he was working with his father and brother in their forestry business. During that initial meeting he displayed a great knowledge of forestry together with a keen eye for detail and pride in his work. When asked if he liked working in forestry his reply was “I look forward to going to work every day”. Not many people can say that!! Irish forestry needs good people like Adrian and his passing is a great loss to our profession. Outside of work, Adrian was a dedicated badminton player in his native Churchtown and also a car enthusiast. He was the administrator of Honda-Haven website.

To his parents John and Mairéad, his sisters Celina and Louise, his brother John Jnr. and his girlfriend, Laura Burns, we offer our sincere sympathy.

Go ndéanfaidh Dia trócaire air.

Kieran O'Connell

Pat Farrington
1961-2013

There was genuine shock throughout the forestry community when news circulated on Wednesday, 4th September that Pat Farrington had fallen gravely ill. This was followed by stunned sadness on Thursday, 5th September when news of his death, at the early age of fifty two years, was announced. However, through organ donation, his passing ensured that five young people's lives were enhanced; this has provided great solace to Pat's family.

Pat Farrington was born in Ballymore Eustace, Co. Kildare on 12 May 1961 to Seán and Letty (nee Dwyer). He attended Ballymore Primary School and received his secondary education at CBS, Naas. He began his forestry training at Kinnitty Castle Forestry College in 1980 and went on to complete his studies at Avondale in 1983.

Pat's early career in forestry was impeded by the absence of positions in the Forest and Wildlife Service due to a Public Service recruitment embargo which meant that only one in every three positions could be filled. Pat's determination to develop a career in forestry in Ireland was already evident at this early stage. He had secured a "Green Card" to work in the United States but declined this when offered a temporary position in nearby Blessington Forest where he worked with Forester in Charge, Jim Crowley. When Coillte was set up in January, 1989 his career took off. Initially, he worked in the Inventory Section in the Bray Region and eventually progressed to become the Regional Environmental Officer. In the meantime, he embarked on an academic career which led to a Master's degree in forestry followed by a qualification in landscape design. These qualifications facilitated his appointment as Forest Landscape Architect with the Forest Service in 2002.

In the Forest Service Pat worked on forest landscape issues, including the redesign of forest plans within sensitive landscapes, he was also the District Forestry Inspector for the Wicklow District. In this role, Pat was instrumental in bringing forest owners together to establish the Wicklow Private Woodland Owners Group, and his strong commitment to the initiative was deeply appreciated by all those involved. He successfully engaged with foresters and forest owners by talking through problems and finding practical solutions to the numerous problems that can arise in landscape sensitive areas. Although of a quiet disposition, Pat was very determined and he achieved much during his short life.

At national level, Pat played a key role representing the Forest Service and forestry sector perspectives on the Department of the Arts, Heritage and the Gaeltacht's National Landscape Strategy steering committee.

At a European and international level, Pat was a member of the Irish delegation to the UN Framework Convention on Climate Change. Under this remit, he made an important contribution to international negotiations surrounding the REDD+ process (Reducing

Emissions from Deforestation and Forest Degradation), successfully coordinating the EU input at the UNFCCC Bonn session in June 2013 during the Irish Presidency of the EU. This paved the way for the widely acclaimed international agreement on REDD+ concluded in Warsaw at the end of 2013. Pat also made a very significant contribution under the Irish Presidency during the meeting of the Ad Hoc Expert Group on Forest Financing in January in Vienna and again at the 10th session of the United Nations Forum on Forests in April in Istanbul. He was a hugely respected negotiator and brought his characteristic patience, pragmatism and capacity to propose innovative solutions to what, at times, appeared to be intractable problems. This can-do attitude and positive disposition won him many friends on both the European and international stages.

Pat joined the Society of Irish Foresters immediately after qualifying as a forester in 1983. He soon became an active and committed participant in its educational activities. His enthusiastic involvement culminated in his election as President of the Society of Irish Foresters in April 2009. During his term as President, Pat introduced many initiatives including the Augustine Henry Medal which is presented each year to the highest achieving student on both the UCD and WIT forestry courses. This innovation has since been extended to include medals for honorary members and former presidents. Pat always had a particular interest in encouraging and facilitating greater participation of students and young graduates in the activities of the Society. He recognised that this constant renewal and infusion of new members was the life-blood of a vibrant Society.

Pat was reared in the heart of Ireland's horse breeding country and was a keen horseman and successful breeder. He was also very committed to the Credit Union movement and served as Chairman of Blessington Credit Union. He was involved with Ballymore Eustace GAA Club and Naas Rugby Club. Pat established his own forest and was very proud of this achievement. He also encouraged his parents into tree planting, and they went on to become very enthusiastic tree growers.

To his wife Patrizia, daughter Emilia, son Daniel, parents Seán and Letty, sister Annmarie and brothers Fintan, Niall and Dermot, we offer our sincere sympathy on their sad loss.

Ar dheis Dé go raibh an anam álainn uasal!

John Mc Loughlin

Eddie O'Connor
1948-2013

News of the death of Eddie O'Connor, who died suddenly at his home in Riverstick, Co. Cork on 28th October 2013, came as a great shock to all those who knew him and especially to his family and his wide circle of friends.

Eddie was born into the family of Daniel and Mary O'Connor (nee O'Donoghue) on 15th February 1948, a farming family of four boys and three girls, in Coolegrane, Brosna, Co. Kerry. He received his primary education at Brosna National School and his secondary education at St. Ita's College, Abbeyfeale, Co. Limerick.

He began his career in forestry at Kinnitty Castle Forestry School on 1st October 1965 and graduated from Shelton Abbey Forestry College in 1968 with 27 other foresters. His first appointment was to Kilworth Forest, Co. Cork in 1968 before he was appointed to the Inventory of Private Woodlands team in 1970 where he worked in counties Cavan, Leitrim, Longford, Monaghan and Sligo. This team undertook an inventory of the private woodlands of Ireland which was published in 1973. While working on this project Eddie quickly became an expert in the identification of the many rare and exotic tree species he encountered. His next appointment was to Ennis, Co. Clare followed by Ballinglen Forest, Co. Wicklow in 1973. His final transfer was to Bandon Forest in 1978 and here he set up home in Riverstick with his wife, Brid.

When Coillte was established in January, 1989 Eddie was appointed Cost Controller in the Cork Region and in 1993 he became Region Accountant. In 1999, Eddie was awarded a M.Sc. (Agriculture) in UCD and his thesis "The economic impact evaluation of catastrophic storm damage in Irish Forestry" assessed the damage caused by the storms which hit the south of Ireland in December 1997. Two papers from his thesis were published subsequently in *Forestry*, the journal of the Institute of Chartered Foresters. Eddie was appointed manager of Coillte's Project Management Unit in 2005. This was the management vehicle which coordinated the work of part time contract staff that had availed of early retirement from Coillte. Eddie completed his career with Coillte in June 2012.

A quiet man, Eddie was a great listener who always went about his work in a diligent and professional manner while gaining the respect of all he had dealings with. Eddie's personality was ideally suited to the role of Cost Controller and Region Accountant as he had a ready grasp of detail, a vital ingredient in monitoring and managing income and expenditure.

Eddie had a great passion for sport and was a proud Kerry supporter. He played football with his native Knocknagoshel and won a county championship with them in 1969. Eddie played football for Shelton Abbey in the Wicklow senior championship. He also played rugby with Ennis Rugby Club while working in Ennis and with Arklow Rugby Club while working in Ballinglen Forest.

Eddie was an accomplished athlete and won many local and national titles. His first title came when he won the team event in the Wicklow cross country championship in 1967. When he was transferred to Bandon Forest, he joined Riverstick Athletic Club where he excelled at the long jump, the high jump, the triple jump and the javelin at local and national events. Eddie won a silver medal in the long jump and bronze medals in the high jump and triple jump in the 1995 National Veterans Track and Field Championships which were held in Belfast. At the 1996 National Veteran Championships held in Cork Institute of Technology, Eddie won gold in the long jump, silver in the high jump and silver in the triple jump. In 1997 the National Veterans Championships took place in Tullamore, Co. Offaly and Eddie again won gold in the long jump and silver in the triple jump and gold in the javelin event. His team mates in Riverstick Athletic Club remember him as a uniquely talented, natural athlete.

Eddie was interred in Ruan cemetery, Co. Clare. To his wife Brid and sons Eamon and Brian, brothers John, Donal and Denis, sisters Mary, Joan and Breda, we extend our sincere sympathy.

Ar dheis De go raibh a anam

Tim Crowley

Matthias (Tysie) Fogarty
1948 -2014

The sudden death at his home in Briarfield, Kilmyshall, Co. Wexford, of Tysie Fogarty, in his 66th year, was a shock to his family, friends and all those who worked with him throughout his years in forestry.

The older of two boys, he was born on 4th August 1948 to Matt Fogarty, a farmer from Briarfield, Newport, Co. Tipperary and Bridget (nee Mc Namara, Araglin, Cappamore, Co. Limerick). Tysie was to lose his father at a very young age and his mother then moved to Main Street, Doon, Co. Limerick where she bought a licenced premises. He received his primary education at Doon National School and his secondary education at St. Fintan's CBS, Doon.

On completing his secondary education in 1967 he spent a year at Pallaskenry Agricultural College and it was here that he learned about a career in forestry – a career that was tailor-made for him as he loved the outdoors. Tysie entered Kinnitty Castle Forestry School in September 1968 and completed his three year training programme at Shelton Abbey in 1971. During his early career working as an Assistant Forester, Tysie traversed the country. He completed five assignments in four years - Tinahely, Co. Wicklow; Kinnalea, Co. Cork; Muskerry, Co. Cork; Killarney, Co. Kerry; and finally in 1975 to Forth, Co. Wexford. This was typical of Tysie's generation of foresters as they bore the brunt of transferring as laid out in the 1972 Forester's Agreement. In early 1978 he was appointed Deputy Forester in Camolin, Co. Wexford and remained there until he became Forester-in-Charge at Bangor Erris Forest, Co. Mayo in 1982 where he managed huge ploughing and afforestation programmes. In 1987 he was appointed Forester-in-Charge in Cahir Forest, Co. Tipperary and remained there until 1990 when he became a Level 3 Forest Manager in the Callan/Rossmore area in counties Kilkenny and Carlow. For the last few years of his career he was Establishment Manager in Counties Carlow, Kilkenny and North Tipperary. In June 2002, at the age of 54, he availed of the Early Retirement package and went on to enjoy 12 happy years of retirement. Even though he retired at a relatively young age Tysie had achieved a lot and was very diligent about his work.

He exuded a zest for life that was evident to all who knew him and you were never long in his company before his sense of humour and storytelling made you feel at ease.

One of Tysie's great attributes was his admirable work ethic. His motto was "do it right the first time, no matter how long it takes". Anyone who ever worked with Tysie will readily acknowledge that he was an efficient and well organised person.

Anything that was needed for any job could always be produced from the cavernous boot of his car.

Tysie also had a strong sense of community and contributed hugely to the local area whether it was helping to organise the parish field day or collecting rubbish at Ryland Hill. People who spent time in Tysie's company will realise how knowledgeable he was. He had a great love of reading and poetry. If you visited his home you will know that when a conversation began and a difficult question was posed he would disappear quietly and return with a book on the topic.

Tysie's life with us will always be remembered as he was the perfect gentleman to everyone he came across. The song may have ended but the memory lingers on ……… he was laid to rest among the trees in Bunclody graveyard in his adopted County of Wexford.

We offer our sincere sympathy to his wife Frances and his brother Timmy.

Ní beidh a leithéid arís ann.

Ian Booth