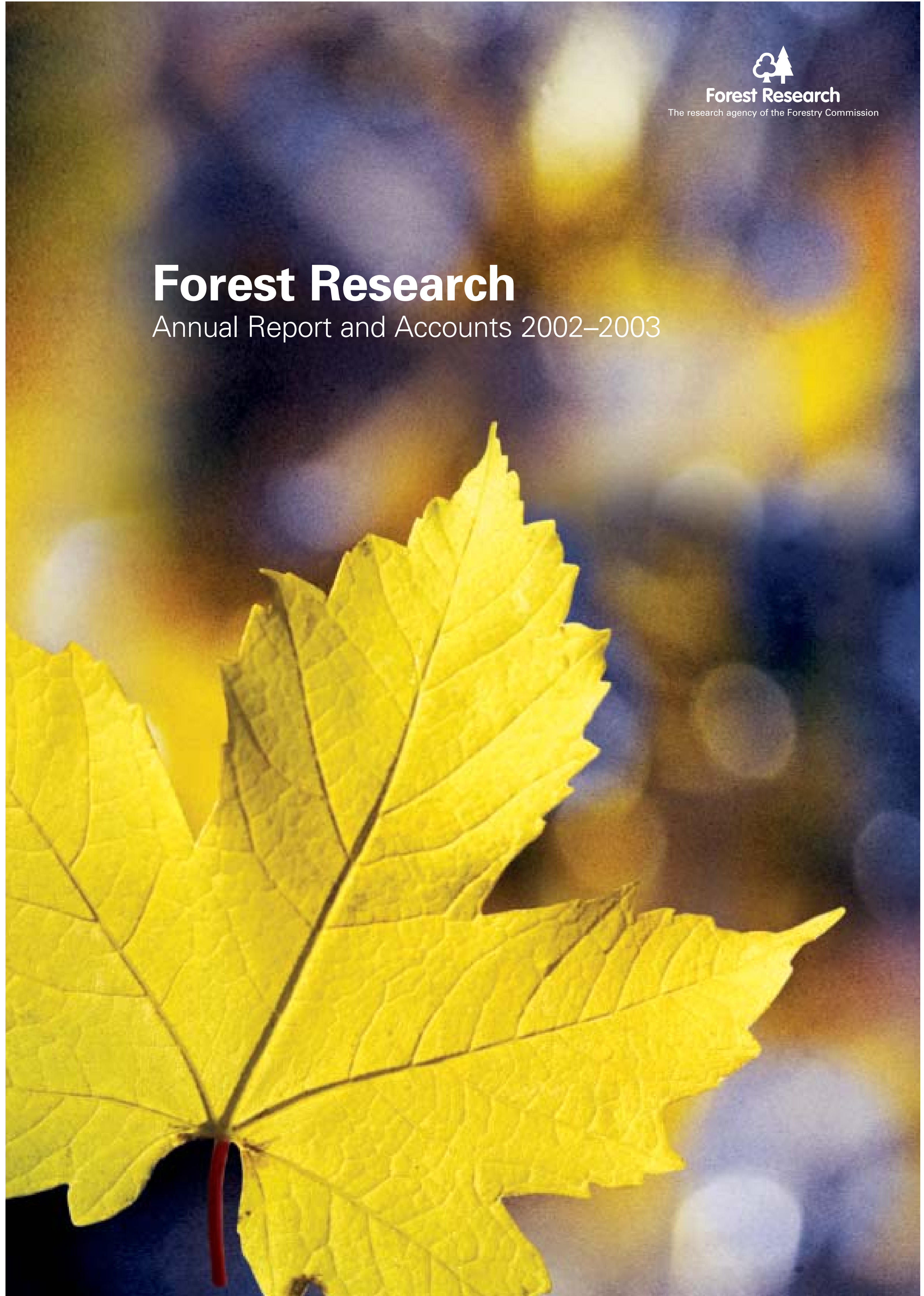
Forest Research
The research agency of the Forestry Commission

Forest Research
Annual Report and Accounts 2002–2003



Forest Research

Annual Report and Accounts 2002–2003

Together with the Comptroller and Auditor General's Report on the Accounts

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and Section 5 of the Exchequer and Audit Departments Act 1921

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Forest Research

The research agency of the Forestry Commission

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Director
Biomathematics and Statistics Scotland

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Forestry Commission
Forestry Group

* Rob Kempton died during the year: see page 11.

Forest Research Organisation Spring 2003

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Foreword

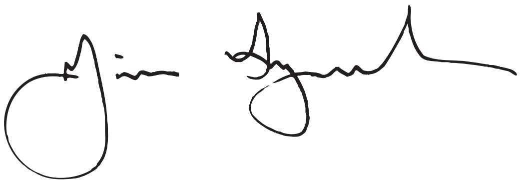
by Professor Jim Lynch, new Chief Executive

I have spent a career investigating the multiple interactions of soils, plants and micro-organisms in the context of agriculture and horticulture at research institutes of the BBSRC and various universities (Surrey, Kings College London, Oxford, Washington State and Oregon State). Before I joined Forest Research on 1 July 2003, I had been rather unfamiliar with the achievements of forestry research in the UK, even though I spent a period in the early 1980s teaching agriculture and forestry students in Oxford. It has been a revelation to me to learn of the quality of research in our agency, spreading over a broad range of natural and more recently social science disciplines, some of which are illustrated in this Annual Report of our activities. It also strikes me that so much of what we do can potentially have major impacts on the environment and society. It is my perception that fellow scientists, let alone politicians and the public at large, are not very aware of what we are doing. Clearly this must change and it will certainly be one of the first objectives in leading the agency.

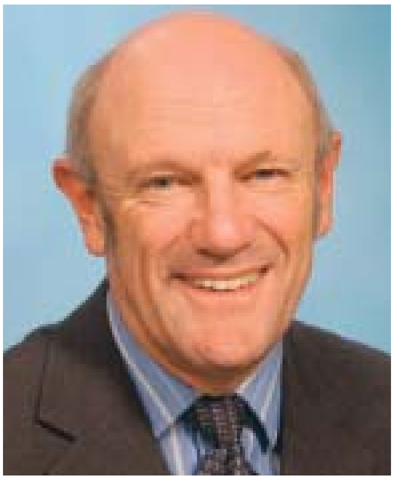
Of course, I hope that our principal stakeholders, the forestry industry, are aware of our work and I trust that we are responsive to their needs. However for the industry to flourish there must be innovation, a need which is increasingly recognised by our main customer for research, the Forestry Group of the Forestry Commission. Our scientific team therefore needs not just to be responsive to the current needs of the industry, but also to present innovative options to promote the sustainability and growth of the industry. Although we already have partnerships with universities, research council institutes and governmental departments, I feel that the further development of these relationships should focus on synergistic approaches to achieve the innovation that we need.

Forestry is clearly important on the international stage, as emphasised so emphatically at the series of UN conferences on the environment started at the Rio Summit in 1992. For my own part I have served on the Organisation for Economic Cooperation and Development Management Committee on Biological Resource Management for Sustainable Agricultural Systems as Co-ordinator since 1989. It is only in the past year that we have directly recognised the importance of forestry as an integrated approach to managing the sustainability of the environment. In realising our own objectives for GB forestry, I believe that increased international co-operation will be crucial, by building on our existing activities, particularly with Europe and further afield.

I am very excited about the opportunities that Forest Research presents for our stakeholders, which certainly includes the public, and I look forward to acting as facilitator to lead our staff into realising the opportunities offered by the forestry industry and their own potential.



Jim Lynch



Professor Jim Lynch joined Forest Research as Chief Executive on 1 July 2003. Prior to that, for ten years, he had been Head of the 5*A School of Biomedical and Life Sciences at the University of Surrey, following a career in BBSRC. He graduated with a BTech from Loughborough University in Chemistry, followed by a PhD and DSc at Kings College London in Microbiology. He is a Fellow of the Royal Society of Chemistry, The Institute of Biology, The International Institute of Biotechnology and the Royal Society of Arts. In 1993 he won the UNESCO Microbiology prize.

About Forest Research

Forest Research is an agency of the Forestry Commission and is the leading UK organisation engaged in forestry and tree related research.

Aims and objectives

The aims and objectives of Forest Research (FR) are to assist the Forestry Commission in achieving its high-level objective.

On behalf of all three administrations, to take the lead in development and promotion of sustainable forest management and to support its achievement internationally.

FR's Aims

To support and enhance forestry and its role in sustainable development, by providing high-quality research and development in a well-run organisation.

FR's Objectives

- To inform and support forestry's contribution to the development and delivery of the policies of the UK government and the devolved administrations.
- To provide research, development and monitoring services relevant to UK forestry interests.
- To transfer knowledge actively and appropriately.

Entrance to the Northern Research Station at Roslin

Alice Holt Lodge, Hampshire

Mixed oak and beech woodland in Buckinghamshire

Research funding

Much of FR's work is funded by the Forestry Commission with Forestry Group acting as purchaser of research and other services in support of forestry in Britain, including the particular needs of England, Scotland and Wales. Forest Enterprise was responsible for managing the FC estate during 2002–03, and purchased research, development and surveys specifically related to this estate. In recent years FR has successfully applied for external (non-FC) funding from government departments, the European Union, UK research councils, commercial organisations, private individuals and charities. Collaborative bids with other research providers and consortium funding have become increasingly important, placing emphasis on effective partnerships.

Activities

Research and development are essential components in delivery of the benefits of sustainable forestry in a multifunctional landscape. FR's research, surveys and related scientific services address the social, economic and environmental components of sustainability. There is a focus on providing new knowledge and practical solutions based on high quality science. Our projects provide understanding, policy advice and guidelines on implementation of best practice (e.g. on forest hydrology, continuous cover forestry, timber quality, land reclamation to woodland, and restoration of native woodlands). Much of the research is directed at increasing the biodiversity, landscape and recreational benefits of woodlands. Protection of GB woodlands from pests and diseases and predicting the impacts of environmental change are also overarching themes. FR works closely with the FC, the Commission of the European Communities and other international organisations to ensure compliance with international agreements on the sustainable management of forests and related subjects. The Agency also carries out work on genetic conservation, tree improvement, seed testing, method studies, product evaluation, crop inventory, surveys (*The national inventory of woodland and trees*) and monitoring.

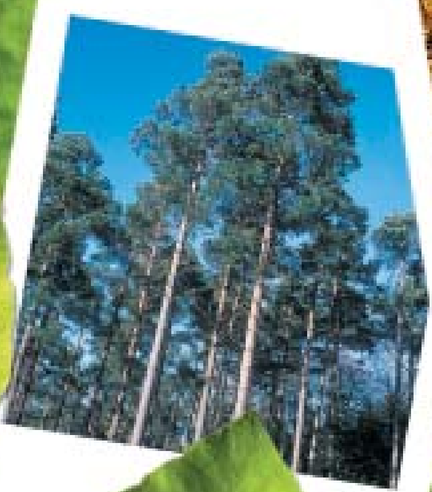
Resources

The Agency has two main research stations, Alice Holt Lodge in Hampshire and the Northern Research Station on the Bush Estate south of Edinburgh. The main office of Technical Development Branch is located at Ae in Dumfriesshire with subsidiary offices in the English Midlands and Wales. The Agency also has 10 field stations (the Technical Services) from which an extensive network of field trials, sample plots and monitoring sites is assessed. Contact information is given on the inside back cover. The Agency employs 280 staff, not including visiting scientists and sandwich students. FR has published a Corporate Plan for the period 2003–2006 and copies are available from the Library at Alice Holt Lodge.

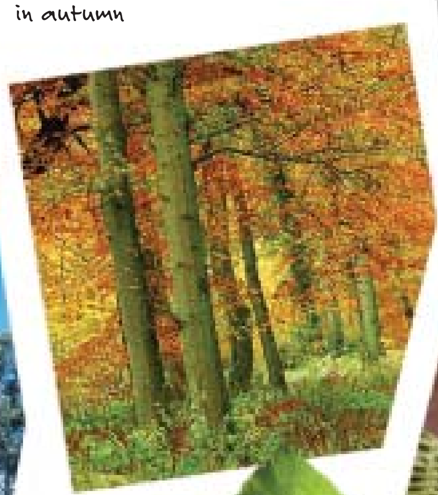
Acting Chief Executive's Introduction

2002–03 Major achievements

The year 2002–03 has been unusual but highly successful for FR and it is a great pleasure for me to introduce this year's Report on Forest Research. The Forestry Devolution Review (FDR) was agreed and we moved into the current implementation phase; the second report of FR's first Quinquennial Review was presented to Ministers in October 2002; and FR had an interim Chief Executive. Additionally the second FC-wide staff survey was conducted, and reported a general improvement in scores across all categories. Inevitably it has been an exceptionally busy year and one in which there have been opportunities to influence the outcome of major decisions. As a result of the work which has been done FR has moved into 2003–04 and the implementation of review recommendations with confidence and enthusiasm.



Scots pine stand



Lowland beechwood in autumn

Ringing a young nightjar in Sherwood Forest as part of long-term monitoring and landscape ecology research.

As Acting Chief Executive, it is very pleasing to me that FR's achievements over this year have exceeded expectations. This is quantifiable through the achievements of our key targets which cover science quality, full cost recovery and customer satisfaction. These targets are only met through members of staff initiating and conducting high quality research, submitting papers and other outputs on time, working to budget and liaising effectively with colleagues and funders. In a year of significant change for the Forestry Commission and within FR, it is very clear that our success resulted from hard work, a positive approach and a refusal to be distracted from personal and team obligations. I have seen this dedication at first hand for a number of projects and the pages that follow in this report provide specific examples from across the range of FR's 2002–03 programme.

As always there have been a number of important external influences during 2002–03. There has been a continuing focus, indeed pressure, on forestry globally: pressure to achieve sustainable forest management, to conserve forests as carbon sinks, and to conserve biodiversity and forest genetic resources. There are also international obligations to protect forests from new and established pests and diseases and to monitor forest condition. Against this background FR has to work closely with EU and other international colleagues. The EU has launched its 6th framework programme of research and development which offers an opportunity to maintain our good international collaborations. However the objective of the EU FP6 is to build capacity in Europe in order to consolidate Europe's position as one of a few major global research areas. The programme is likely to fund fewer, larger projects than previous FPs and these need to address directly the contents of the work programmes in which there is little mention of forestry. In response to these influences FR has developed a small number of high quality EU bids focused on key strategic issues and has worked closely with established and new partners in the UK and internationally.

Targets and achievements over the past five years

Performance measure		1998/99	1999/00	2000/01	2001/02	2002/03	
Customer satisfaction	Target	92%	95%	96%	96%	97%	**TARGET MET**
	Achieved	94%	96%	97%	97%	98%	
Peer-reviewed papers	Target	35	38	43	48	48	**TARGET MET**
	Achieved	40	43	48	48	48	
Unit cost/research day	Target	96	94	94	94	92	**TARGET MET**
(unweighted) 96/97=100	Achieved	94	86	82	81	79	
Unit cost of support services	Target	-	98	96	94	92	**TARGET MET**
	Achieved	100	95	92	86	84	
Cost recovery	Target	100%	100%	100%	99%	100%	**TARGET MET**
	Achieved	103%	100%	101%	100%	100%	

Quinquennial Review

Forest Research has completed its first five years as an agency and our first Quinquennial Review (FRQR) of performance and future objectives was concluded during 2002–03. This review included extensive consultation with stakeholders and it was pleasing to find strong support for FR's role, achievements to date and future. The review was particularly important not only as FR's first but also because it informed the Government's review of the role of the Forestry Commission post-devolution. It is a tribute to all FR staff that the review was so positive and that, based on the review, Ministers and the administrations in England, Scotland and Wales were able to endorse Forest Research as a GB agency of the Forestry Commission.

The first stage of the review concluded that there was a continuing need for the work of FR and that the best means of delivery was through an agency of the Forestry Commission – FR. The second stage report made a number of specific recommendations on the future aims, objectives, management and measurement of performance. In particular new approaches are recommended for the identification of research requirements, for the prioritisation of FR's research programmes and for the transfer of knowledge to forestry practitioners.

In these areas new arrangements which fit comfortably with the greater devolution of Forestry Commission activities to the three countries are now being implemented. A new *Framework Document* for Forest Research has been agreed, and the *Forest Research Corporate Plan 2003–2006* sets out in detail how we will meet our new aims over the next few years and describes the new performance targets for 2003/2004. (Copies of both publications are available from Alice Holt Library.) The aims and objectives set out on page 6 are those established in the new *Framework Document* which was formally effective from April 2003, but to which we have also addressed our efforts over the past year.

2002–03 Research highlights

This year's research highlights are presented by interdisciplinary theme. This reflects the way in which we have increasingly been working and also follows a steer on FR's Report on Forest Research provided in the Quinquennial Review. Eight reports by research theme follow here; themes similar to these will also be used on the new FR WebPages, and are team contributions intended to summarise the year's main findings, put them in the context of the overall programme and direct the reader to full accounts of the research. As in recent years this first section of the report is followed by six main articles which provide a comprehensive account of selected subjects where important issues have arisen and where major progress has been made.

FR currently has *c.*60 major research programmes (see page 91). It is interesting that an analysis of these conducted in May 2003 showed that some 24 began after 1998. This is a large proportion for research which supports forestry where rotation length and hence technical problems can remain current for significant periods – often decades. Many of our research programmes are thus new, or relatively new, and those which feature as major articles here are amongst those currently providing significant policy and practical advice. The main articles address pests and diseases, social forestry, managing the historic environment, genetic conservation of native trees, stem straightness in Sitka spruce and climate change. The redirection of FR's research in order to maximise its benefits is an ongoing task and, following FDR and the FRQR, along with Forestry Group, we have a newly established structure and procedure to achieve this. These new procedures will in particular take into account the research needs of England, Scotland and Wales.

As always there have been a number of circumstances which have influenced FR's work significantly during 2002–03. Among these have been the continuing concerns over *Phytophthora* *ramorum* (the fungus responsible for Sudden Oak Death in California and Oregon), the proposed changes to the *Dendroctonus Micans* Control Areas which result from the new outbreaks which have occurred, the loss of permethrin for the control of *Hylobius abietis*, and the planning for the new inventory of woods and trees. Over the year there has been close working with other parts of the FC, for example with Country Services on implementation of the new EU Forest Reproductive Materials Regulations. The continuing strong interest of UK forestry in moving to a larger area of continuous cover, in natural regeneration, conservation of biodiversity, restoration of native woodlands, timber quality, deer control, and in public involvement in forestry, have resulted in sustained demand for applied forest science and joint working with FR. Sound research is also essential to create the evidence base for well-founded policies. Current influences are contributing to a sustainable rural economy, urban renewal and forest landscape restoration. I believe that, in addition, forestry's response to climate change, the potential of woodfuel, and continuing improvements in data archiving, use and access will be important influences on our research programmes over the next few years.

Advisory Committee on Forest Research

The Advisory Committee provides guidance to FR and to the FC's Forestry Group on the quality and direction of FR's research. During the year the Committee discussed the Quinquennial Review of Forest Research and provided guidance on the development of FR's new Science Strategy. They also appointed visiting groups to look at the silviculture and entomology research programmes during 2003. The Committee visited the North York Moors in September 2002 to look at various aspects of FR's work: continuous cover forestry; cold hardiness (being conducted in the EU project called COLDtree); the control of *Hylobius*; long-term mixtures of birch and Scots pine; the regeneration of upland oakwoods.

We were sorry to hear of Rob Kempton's death in May 2003. Rob had been Director of BioSS since 1987, and also an enthusiastic and highly supportive member of the Committee since January 2000. He will be greatly missed.

Finance

Income in the year increased by 1% compared to the previous year. Within this a reduction in Forestry Commission income of £320,000 was offset by a significant increase in income from non-FC sources of £417,000 or 33%. Total expenditure was held within 0.3% of 2001–02 levels despite an increase of nearly 3% in staff costs.

The target net operating surplus for the year of £620,000 was exceeded by £8,000 resulting in a full cost recovery performance of 100.1% against the target of full cost recovery (100%).

Capital investment at £473,000 covered a wide range of scientific and technical equipment including, notably, state of the art ion chromatography and DNA sequencing facilities, as well as IT equipment and laboratory and office refurbishments. A continuing programme of capital investment in infrastructure, facilities and equipment is essential if we are to maintain the high quality and cost effectiveness of our research.

For the first time, the Agency took the lead co-ordination role in major EC research projects with the additional responsibility of managing the distribution of funds to partners across Europe. Some £1.4 million were successfully managed during the year.

People

The total number of staff employed by the Agency at year end excluding sandwich students and visiting scientists was 280 full-time equivalents.

Steve Petty, formerly of Woodland Ecology, was the first person to be awarded Research Associate status with Forest Research. Jonathan Humphrey (Woodland Ecology) was appointed Chair of the British Ecological Society Forest Ecology Group; Sam Evans (Mensuration) received an Honorary Senior Fellowship at the School of Biological and Biomedical Sciences, University of Durham; Juan Suárez (Silviculture North) was elected to the Council of the Association of Geographic Laboratories of Europe (AGILE).

Several staff were awarded higher degrees: Paul Taylor (Mensuration) received an MPhil in Hydrology and Sedimentology from Lancaster University; Peter Crow (Environmental Research) received an MSc in Geoarchaeology from Reading University; Matthew Griffiths received an MSc in Geographical Information Systems from Leicester University; Shaun Mochan (Silviculture North) was awarded an MSc in Forest Science from Edinburgh University.

Laetitia Laine and Daniel Rose (FR funded students, supervised by Entomology Branch) were each awarded a PhD by Imperial College London; Laetitia for 'Biological studies on two European termite species: establishment risk in the UK' and Daniel for 'Novel automated control of *Hylobius abietis*'. Elena Vanguelova (supervised by Environmental Research Branch) achieved a PhD from Reading University for her work on 'Soil acidification and fine root response of Scots pine'. Richard Jeffries (also supervised by Environmental Research Branch) was awarded a PhD from Southampton University for 'Investigating water and fine sediment transport in rivers with wooded floodplains'.

Professor Clive Brasier (Pathology) retired after 32 years of service, during which he made an outstanding contribution to our understanding of how tree pathogens behave and evolve, specialising particularly in Dutch elm disease and diseases caused by *Phytophthora*. In spring 2003 he was made fellow of the American Phytopathological Society. We are delighted that Clive has agreed to maintain an association with FR as an emeritus scientist at Alice Holt. Roger Boswell retired after 33 years of exceptional statistical support to many project leaders at Alice Holt, having co-authored over 40 publications and becoming Principal Statistician.

After more than 40 years with the Commission, John Budd (TSU South) retired in December 2002. For the last 12 years he worked at Headley Nursery running field trials. Jim Pratt MBE (Pathology) also retired after 42 years with the Commission, at both Alice Holt and Northern Research Station, working particularly on reducing chemical usage in forestry and on control of Fomes root and butt rot for which he is internationally renowned. Jim Dewar retired from the Forestry Commission in May 2002 after 33 years. Jim was FR's first Chief Executive after its constitution as an agency in 1997 and FR's success as an agency owes much to this energy and leadership.

New appointments to the Agency included: Dr Sandra Denman to work mainly on Phytophthoras; Victoria Stokes to work on environmental physiology; Dr Geoff Morgan to work as Principal Statistician at Alice Holt; Dr Stuart A'Hara to work initially on developing a molecular map of Sitka; David Georghiou to develop the FR website; Danielle Sinnett to work on land reclamation; Ewan Mackie to work on forest measurement systems; Christopher Vials to work as an analyst/programmer; Alexis Achim to work as a plant modeller.

Visitors and events

In April the Scottish National Inventory of Woodland and Trees was launched by the Scottish Deputy Minister for Environment and Rural Development.

Forestry Commissioners visited NRS in April; their visit included presentations on selected research programmes. The Queen's Jubilee celebrations were a summer highlight, and included a 'Queens and Punks' theme at NRS, and a 'Where were you in '52 or '77?' competition, woodland walks and a rocket display at Alice Holt. Autumn events included the Welsh Seminar: 'Establishing Quality and Native Woodlands' at Builth Wells in October.

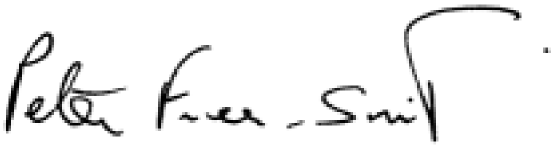
Chinese delegates from the State Forestry Administration visiting NRS in August 2002.

A variety of seminars and conferences were held at the research stations and on forest sites; these included Deer Management, Intranet Introductions and Internet Next Steps, FC England Grants Briefing. FR was well represented at many UK and international conferences and meetings, with staff providing presentations and posters. These covered Forest Restoration (IUFRO), Health and Well-being, Capercaillie LIFE bid, ForestSAT, Clonal Forestry, Silviculture and Wood Quality Modelling, Continuous Cover Forestry, Pinewood Nematodes, Globalisation of Forest Pests, Global Warming and the Health of Trees, Managing Woodlands and their Mammals.

FR's short Research Update Seminars, held regularly at NRS and AH, have proved very popular and informative.

The Agency maintained its links nationally and internationally by hosting groups and individual visitors. These included students from Imperial College London and Maurwood College and chinese visitors from the State Forestry Administration. In May Dr Ann Lynch from the US Forest Service in Arizona visited Alice Holt as part of a fact-finding tour to discuss spruce aphid in Radnor Forest.

Finally, I would like to thank FR for an excellent year, which I feel would have had a rather different outcome had it not been for the personal qualities of staff. I would also like to acknowledge the very significant contribution made by our collaborators particularly in UK and European forestry and science. The strength of our international links and the value placed on these are clear from the programmes listed on pages 91–96. I would also like to thank PPD (now part of the FC's Forestry Group) and FE, who have proved to be highly professional while also demanding of us, providing exactly the parent department/science provider relationship which is required to make FR's agency status as successful as it is.



Peter Freer-Smith

Acting Chief Executive, Forest Research

Research highlight

People, trees and woods

Paul Tabbush and Andy Moffat

- **Social forestry research**
- **Woodland history and heritage**
- **Woodland soils and archaeology**

Links between trees and woodland and the environmental, economic and social aspects of our lives are wide-ranging. Woods can contribute to human well-being by providing natural restorative spaces.

Children in Littlewood (Liverpool) involved in a community woodland event.

Social forestry research

During 2002, consultation days, focusing on the relationship between forests and health and well-being, were held in England, Scotland and Wales. These 'expert consultations' linked health and environmental professionals and culminated in the publication of *Health and well-being: trees, woodland and natural spaces.*

Investigation of values and meanings in relation to woodlands, originally conducted in northwest and southeast England by Liz O'Brien, was extended to Vermont, USA with a three-month study tour. Suzanne Martin and Paul Tabbush visited each of the FC National Offices to develop research on forest recreation. Action research on community involvement in forestry decision-making (Max Hislop) was extended to three Forest Enterprise districts.

The historic environment in woodlands

FR's historic environment research programme first began in 1999 by examining the issues and knowledge relating to the management of the archaeological resource in wooded landscapes. This involved extensive consultation with archaeologists in the form of a discussion document. Following this work, a significant part of 2002–03 was spent designing and producing a website on the Forestry Commission intranet to assist sustainable forest practice by the dissemination of information, research findings and advice.

The site also provides a forum to exchange ideas, with examples of FC-wide surveys and projects. A database was designed and incorporated into the website to enable information about ancient trees on FC land to be collected and mapped.

Grimes Graves: an English Heritage managed site in the heart of Thetford Forest. Many other archaeological features exist in the surrounding landscapes and require informed management by the FC.

The new information presented on this website significantly increases the ability of the FC to manage FE woodlands while fulfilling its commitment to preserve important heritage features. Many aspects of the internal website will be transferred to the wider FR internet during 2004 and thus will be accessible to the wider forest industry.

Woodland soils and archaeology

Woodland soils vary greatly in their chemistry and this in turn influences the longevity of different buried archaeological materials. In 1997, seven reference minerals were buried in 10 forest soils to examine weathering rates. During 2002–03, these were re-examined and further analysed to form part of a study into the longevity of archaeological materials in woodland soil environments. A simple method of determining preservation based on soil solution chemistry is being developed.

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Research highlight

Woodland biodiversity

Chris Quine

- **Developing guidance on HARPPS**
- **Biodiversity planning at landscape scale**
- **Technology transfer**

Conserving biodiversity has become one of the most important objectives of sustainable forest management.

Pearl-bordered fritillary butterfly

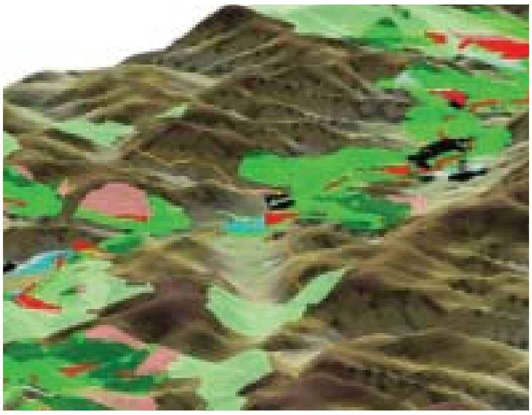
Development of a HARPPS pilot trial

First steps have been taken to develop a decision support system giving guidance on Habitats and Rare, Priority and Protected Species (HARPPS). A steering group representing main users has agreed the scope of the project and the development of a pilot trial. The system is being developed as a source of ecological advice for forest managers concerned with the requirements of particularly important species found within British forests. HARPPS will provide a source of general knowledge about the ecology of the species, their known distribution and habitat requirements, and their sensitivity to forest management. Managers will be able to use the information to assess the impact of particular operations and, conversely, to plan specific enhancement measures. HARPPS is being developed as computer software for possible access via the World Wide Web, and we would also like to establish direct linkage to information within the National Biodiversity Network.

HARPPS will ultimately provide a repository for the knowledge gained within a number of the other biodiversity programmes, including the projects relating to the Species Action Plans. For example, recent work in this area has included topics on juniper, twinflower, small cow-wheat, dormouse, red squirrel, capercaillie, the lime bark beetle, the chequered skipper and pearl-bordered fritillary, and a number of moths of coppice woodlands.

Biodiversity planning at landscape scale

A number of research strands are now tackling the broader scale of biodiversity planning – often termed the landscape scale. The Ecological Site Classification (ESC) has been developed in GIS form to link with the ArcView 'Forester' system and is being tested as a 'beta version' prior to general release. One of the difficulties of working at this scale is the acquisition of suitable data, and digital soils data of an appropriate resolution is particularly scarce. We have been exploring ways of predicting ESC soil variables (soil moisture regime and soil nutrient regime) from coarse resolution lithological and soil maps using relationships with topographic variables such as slope, aspect and convexity. In the first phase of the Landscape Ecology project, we explored the use of a number of summary landscape metrics.



Visualisation of native woodland expansion (green) and existing woodland (red).

Although the approach has promise, it is difficult to establish an ecological interpretation for the indices. The metric approach is now being complemented by a species-based approach. A prototype GIS-based Decision Support System (BEETLE – *Biological & Environmental Evaluation Tools for Landscape Ecology*) has been developed, which addresses the landscape requirements of a range of focal species. This will enable an analysis of landscapes with respect to the needs of particular representative (or focal) species and in time should provide a means of incorporating landscape ecology into the forest design planning process.

Technology transfer

There has been a substantial commitment to a wide variety of technology transfer activities, but two initiatives have required particular involvement. A series of training courses have been run supporting the publication of a guide to the provision and conservation of deadwood in forests, and there has been continuing demand for training in ESC.

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Research highlight

Protecting trees, woodlands and forests

Hugh Evans, Joan Webber and Chris Quine

- **Predicting potential threats**
- **Developing contingency plans**
- **Impacts of the grey squirrel**

The management of woodlands to provide a wide range of public benefits places even greater priority on their protection. Risks to trees and woodlands need to be properly understood and in many instances new threats need to be excluded or established pests and pathogens managed.

Horse chestnut leaf miner moth, *Cameraria ohridella*. (photo: P. Roose)

Potential threats: predicting and planning

There is often a fine line between our perception of woodland organisms as innocuous or beneficial and, at the other extreme, as damaging pests. Pest outbreaks have always occurred and it has been the aim of Forest Research to understand the reasons behind them and to develop ways of managing the problems they cause. There is considerable success in doing this but additional and increasing threats to our woodlands and forests are being noted as a result of the enormous expansion in international trade of woody and non-woody plant stock, of wood as a product in its own right and as packaging material associated with other products. Vigilance, both to predict potential threats and to develop contingency plans to manage incursions and establishments, is therefore essential. This is well illustrated by two recent threats, horse chestnut leaf miner moth and *Phytophthora ramorum* (the causal agent of sudden oak death) which were publicised through Exotic Pest Alerts and which have subsequently arrived in Britain.

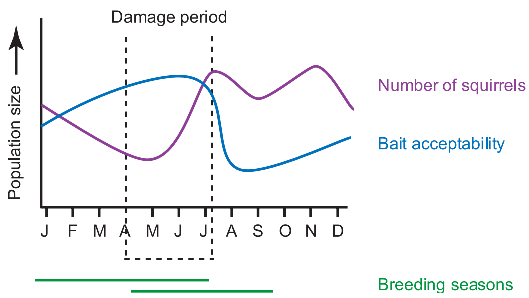
Research into the implications of these recent incursions is progressing and there is no doubt that additional threats will continue to occupy our attention. FR also works closely with Forest Health Group and Defra's Plant Health Branch to take effective action when incursions occur.

Grey squirrel impacts

The introduced North American grey squirrel and native and introduced deer species can cause very substantial damage in British woodlands; the latter featured in an article in last year's Annual Report. The focus of squirrel research has switched to field methods of reducing impacts, following the decision to stop field trials of immuno-contraception methods until further fundamental development work has been carried out.

A study tour to North America was undertaken by Brenda Mayle (FR) and Charles Critchley (FE) to liaise with researchers studying the squirrel in its native habitat and to consider whether there were new insights into the problem of managing squirrels in Britain. A number of useful contacts were made. There is increasing concern that grey squirrels may be impacting a wide range of woodland biodiversity, and not just trees (and timber quality). We are collaborating with the British Trust for Ornithology (BTO) to review the published evidence for such impacts – for example in affecting the breeding success of woodland birds. A new investigation has commenced to consider the prospects for targeting control efforts by index trapping. This method will distinguish years in which the overwinter survival of juvenile grey squirrels has been high, and damage is very likely, from those years in which damage is unlikely and control less necessary.

Grey squirrel (Sciurus carolinensis).



Tree seed availability influences grey squirrel population size and breeding success. Assessing seed availability and whether animals can be drawn to traps in early January (index trapping), followed by assessment of damage levels to vulnerable trees in late summer, will allow better prediction of damage risk in future years.

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Research highlight

Woodlands and forests in their wider environment

Andy Moffat and Sam Evans

- **Forest ecosystem monitoring**
- **Trees and drought**
- **Forest riparian management**
- **Climate change**
- **Forest carbon dynamics**

Climate change, pollutant depositions and other anthropogenic factors can have a major influence on forest condition and thus on terrestrial and aquatic ecosystems. The merits of effective, co-ordinated monitoring and research have become clear.

Rock sampling is part of the investigation of the effect of Corsican pine woodland on nitrate concentrations in groundwater.

Forest ecosystem monitoring and evaluation

The Level II intensive monitoring programme and the Environmental Change Network (ECN) have become highly valued sources of data. During the year, the number of Level II sites has been extended to 20, and now covers five species (Sitka spruce, Scots pine, Norway spruce, oak and beech). Ambient air quality is now measured using passive samplers at 13 plots. A rolling programme of intensive monitoring of air quality is providing data which will enable canopy exposure to ozone and other pollutants to be estimated from the passive sampler data. Litterfall measurements are undertaken at seven of the sites, and with chemical data these have been used as inputs to dynamic models for the prediction of critical loads and their exceedance for acidity and nitrogen.

At the Alice Holt ECN site, 2002–03 saw intensive vegetation monitoring (vascular plants, bryophytes, mosses and lichens) in 1750 quadrat plots. These data have been collated and will be evaluated in relation to forestry practices.

Hydrological research

There were some significant outputs from the hydrological research programme in 2002–03. The Final Report of the Trees and Drought Project on Lowland England (TaDPoLE), produced in association with the Universities of Newcastle and Loughborough, and ADAS, suggested that change of land use from grass to oak or pine woodland on the Sherwood sandstone aquifer will reduce groundwater recharge. The study also revealed higher nitrate concentrations under pine than was previously recognised and indicated that the establishment of pine woodland would exacerbate groundwater concentrations.

The effect of riparian forest management on the freshwater environment was reviewed for SNIFFER (Scotland and Northern Ireland Forum for Environmental Research). The Final Report of the project included an assessment of the impact of clearance of conifer crops from stream banksides on salmonid fish and/or benthic invertebrate populations at three study sites in Scotland and Wales, and made proposals for best management practice for riparian buffer areas.

Climate change research

Predictions of the effect of climate change on both production and suitability for native woodland have been made by incorporating the UK Climate Impacts Programme (UKCIP) 2002 climatic scenarios as the underlying dataset of ESC (Ecological Site Classification). For oak, commercial productivity is predicted by 2050s to fall significantly in the south and east of the UK, but to increase in parts of northern England and eastern Scotland.

Forest Research is in the process of establishing three phenology gardens, at Alice Holt, and Westonbirt and Bedgebury arboreta, as part of the International Phenology Garden (IPG) network. These will improve climate change monitoring significantly. A phenology garden which operated at Headley Nursery, near Alice Holt, between 1968 and 1981 provided valuable data for the calibration of the Forest Research oak budburst model, which has been further validated in 2002–03 using two new datasets.

Forest carbon dynamics

The role of trees and forests in carbon cycling is crucial to our understanding of how forests can help to mitigate climate change and how forest management practices can influence carbon dynamics. A new research programme: Forest Carbon Dynamics, jointly operated by Environmental Research and Mensuration Branches, was established in April 2002. At the Straits Enclosure carbon flux station in Alice Holt Forest, the carbon flux for 2002 was lower than preceding years, which may be the result of poor canopy development during a period of cold weather in late spring, as was also suggested by the low leaf litterfall.

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Research highlight

Sustainable forest and woodland management

Bill Mason, Paul Tabbush, Steve Smith, Bill Jones and Sam Evans

- **Continuous cover forestry**
- **Native woodlands surveys**
- **Alternative establishment systems**
- **Sustainable forestry and technical development**

The current emphasis on continuous cover forestry, native woodland and natural regeneration have called for new approaches to woodland establishment and management.

Continuous cover forestry in the Knightwood Inclosure, New Forest, Hampshire.

Advisory support for CCF initiatives

We continued to provide substantial advisory support to the range of continuous cover forestry (CCF) initiatives being developed throughout Great Britain. Much of this activity is concentrated upon the 12 demonstration sites identified by Forest Enterprise, and in conjunction with Forestry Training Services training courses on the principles of CCF management were run at Wykeham, Clocaenog, Glentress and Inshriach. Two seminars for the private sector were organised at Newton St Boswells in the Scottish Borders and at Evanton on the Black Isle.

Our close involvement with these initiatives has helped to identify where our current understanding is limited and research is necessary to provide improved knowledge. At Clocaenog Forest, for example, where we have joint plots with the School of Agricultural and Forest Sciences, Bangor, analysis of the 50-year-old Sitka spruce stands showed that these appear substantially more wind stable than would be predicted by the wind risk model ForestGALES. The reasons appear to be a combination of past thinning giving more resistant stand structures and some differences in wind climate, but we plan to test these assumptions in 2003–04.

New native woodland schemes: surveys to improve guidance

Since the early 1990s, there has been extensive new planting of native broadleaves and Scots pine as part of a policy of creating 'New Native Woodlands' in the uplands of Scotland. In both 2000 and 2001, a substantial number of advisory queries arose as a result of establishment failures in some of the schemes. To get a better idea of the extent of this issue and of the possible causes, a pilot survey of 10 Native Woodland Schemes in northern Scotland was carried out in late summer and early autumn 2002. The team included establishment specialists, a pathologist and a soil surveyor.

Findings indicated that the larger schemes tended to be on impoverished (ESC soil nutrient status of 'very poor') and moist site types with moderate to severe exposure. Such sites can require intensive management if satisfactory establishment is to be achieved. Problems of poor growth and unsatisfactory survival seemed to be most serious where wet microsites had not been adequately cultivated and/or inappropriate fertiliser regimes had been used. In some cases, there were also indications that the abiotic effects were being compounded by interactions with fungal pathogens. Preliminary survey results were presented to FC staff in December 2002 and further work during 2003 will provide improved guidance to woodland officers and other interested parties.

Monitoring, establishment and natural regeneration

The programme on Native Woodlands completed work on native coppice with the publication of *The silviculture and management of coppice woodlands*. A sampling system for monitoring the transformation of even-aged stands to continuous cover was developed and published in the journal *Forestry*. At the 4th International Vegetation Management Conference, papers were presented on Alternative Establishment Systems, the use of dye markers to reduce pesticide use, natural product herbicides, and the development (with the Canadian Forest Service) of a prototype web-based herbicide selection expert system .

Knowledge of seed biology and seed predation studies are being applied to the problem of obtaining reliable natural regeneration of the main broadleaved species and Corsican pine.

Sustainable forestry and technical development

Technical Development carries out research on operational methods, techniques and machinery, evaluating performance in terms of the quality of the work, environmental protection, economics of the operation and health and safety. Ongoing project work includes:

- *Ground preparation on restock sites.* Uniform and effective mounding with excavators can be difficult to achieve on restock sites due to brash residues and the difficulties operators can have in achieving consistent accurate spacing. Evaluation of different methods of dealing with brash has identified a reliable means of obtaining consistent mound production, with good soil to soil contact and regular spacing across the whole site. In addition, techniques to develop operator skill in mound spacing have been tested. A problem in soils such as clays and peats has been the difficulty of the spoil sticking in the bucket, causing delay and discomfort for the operator as the machine vibrates when shaking the bucket to release the spoil. We have designed and tested a bucket, which shows considerable promise in dealing with these problems – increasing output and improving the working conditions for the operator.

- *Other research programmes.* Alternatives to the use of herbicides (in partnership with the Woodland Trust); machine operator ergonomics (with EU partners); continuous cover forestry operations; woodfuel harvesting and supply; skyline operations; small scale forestry equipment; brash mat construction during harvesting.

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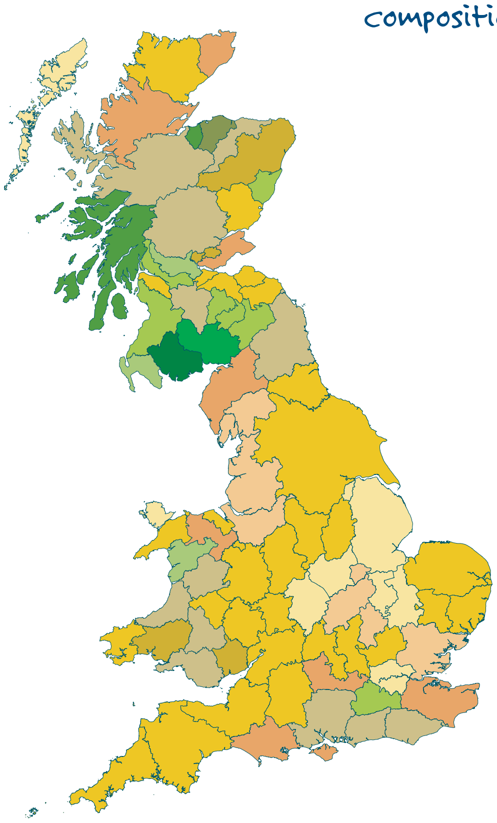
Research highlight

Collecting information about our forests and woodlands

Steve Smith and Sam Evans

- **National woodland inventory**
- **Potential woodfuel availability**
- **Modelling and evaluating our woodland resources**

A key requirement in monitoring the sustainable management of our forests and woodlands is to have up to date information on their extent, location and composition.



Woodland cover by county in 1998.

National Inventory of Woodland and Trees

The analysis of the primary data collected in the last round of the National Inventory was completed, and all remaining national, regional and county reports published. There were official launches for the three national inventory reports for England, Scotland and Wales.

- The England report was launched in November 2001, with Forestry Minister Elliot Morley claiming that it was the most accurate picture of England's forests and woodlands since the Domesday Book (1086).
- The Scotland report was launched by Forestry Minister Alan Wilson in April 2002. The message was that Scotland now has more trees than at any time since Robert the Bruce (early 14th century), with over 16% woodland cover.
- The launch of the Wales report followed in October 2002, by Rural Development Minister Michael German. Continuing the theme that woodland is in a period of expansion, the Welsh used the reign of the Prince of Wales, Owain Glyndwr, 600 years ago to compare when there was last this much woodland in Wales. Over the last 50 years alone, woodland cover has doubled to around 14%.

A Forestry Commission survey showed that over 60% of the public believes that GB woodland area is decreasing. This is clearly not the case, and inventory reports were used locally to try to dispel this impression. For example, in Essex, where woodland cover has increased by 27% since 1980, the local FC Conservancy put out the press release: 'When fact is better than fiction – woodland report explodes rural myth in Essex'.

Woodfuel availability. The data from the National Inventory of Woodland and Trees (NIWT) formed the basis of a variety of other studies. One example was the major project launched to estimate the size of the woodfuel resource available from British forests. The NIWT provided the basic dataset for the Private Sector, while Woodland Survey's Private Sector Timber Forecast System was adapted to forecast whole tree biomass. Results from this study are due to be published in 2004.

A major international conference, ForestSAT, on the use of remote sensing in forestry, was organised in Edinburgh in August 2002. Speakers from around the world gave presentations on operational systems and research projects covering the range from forest inventory to disease monitoring. The conference served to stimulate interest in the use of these technologies in British forestry.

Since work on data collection for the last round of the inventory finished, there have been several initiatives which will require different data in the future. For example, the development of national country forestry strategies, and the publication of the *UK indicators of sustainable forestry.* Work has begun on possible changes to the field data to be collected in the next round of the National Inventory, for example the need for more data on native woodlands and timber quality. Proposals will be put out for consultation next year.

Modelling and evaluating our woodland resources

Forest mensuration is the research discipline that develops and evaluates the theoretical basis and practical application of measurement systems which assess the growth and yield of trees and forest stands. Forest inventory techniques are underpinned by research on methods and approaches that process measurements to summarise current and future yield. Quantitative measurements provide the basis for standard procedures and conventions used by the forest industry.

- The *Forest mensuration handbook* has been extensively revised and will be published in spring 2004. Current research is developing standardised measurement conventions on 3-dimensional log scans to optimise wood processing in the forest industry.

- The sample plots research programme that characterises and quantifies UK growth trends of managed stands has been reviewed to provide new data to model the relationships between potential stand yield and site factors. By focusing on a larger number of single species or mixture sites to encompass the observed growth variability and range of management practice, the programme aims to achieve representation of the majority of forest conditions within 15 years.

- The interactive Sitka spruce yield model (ForestYield) will be released in spring 2004. As well as developing novel approaches to quantifying biomass, the model develops new single stand yield and volume curves for single species and mixtures representative of different management practices. Its structure provides the benchmark for future empirical models.

- Collaborative FC, EU and NERC projects have developed and validated process models of forest structure, growth and yield that can be used to simulate unobserved conditions. Models describing the water and carbon cycles in forest stands have been integrated with a catchment hydrology model to simulate the potential impacts of afforestation and management practice. This approach is being used to simulate the potential growth and quality of timber under scenarios of climate change.

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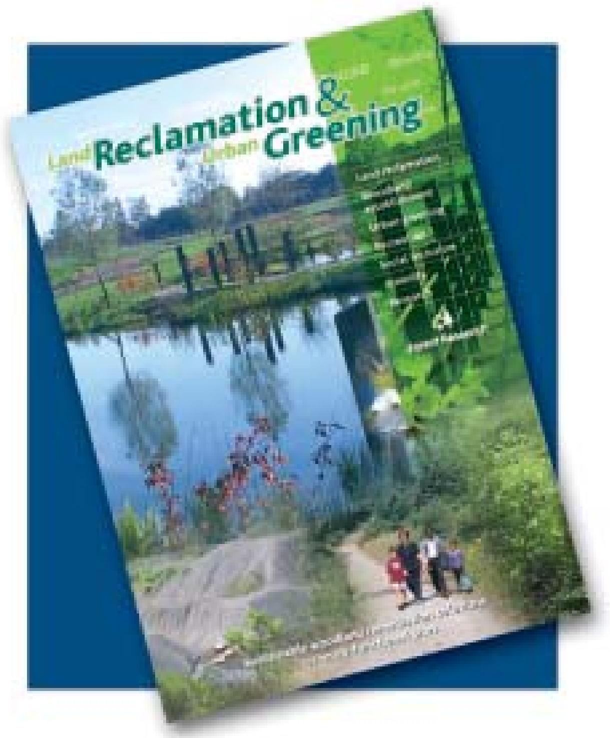
Research highlight

Land reclamation and urban greening

Andy Moffat

- **Site investigation of brownfield sites**
- **Assessing site fitness for woodland**
- **New soil cultivation technologies**

Woodland can provide a wide range of socio-economic, health and environmental benefits, including amenity, recreation and economic regeneration of deprived areas.



Promotional leaflet describing the expertise and capabilities of the Land Reclamation and Urban Greening Team.

Brownfield sites

Work activity has focused on meeting the expanding needs of colleagues in the Forestry Commission, especially the Land Regeneration Unit and those involved in the Northwest Development Agency Newlands Project and the Capital Modernisation Fund project in Thames Chase Community Woodland. Considerable effort has been spent in developing the methodology and formal specification for site investigation of brownfield sites. The Stage 1 (Preliminary Investigation) specification has been completed, and good progress has been made on Stage 2 (Reconnaissance Intrusive Survey). These methodologies have been adopted for the Newlands Project, and will be further developed for use across the portfolio of Forestry Commission brownfield sites where woodland establishment is sought.

Opportunities for woodland on contaminated land

During 2002, the Forestry Commission published guidance on the opportunities for woodland on contaminated land. Research continues to provide a sound scientific understanding on how trees grow on, and interact with, contaminated soil materials. In particular, an ecotoxicological, biomonitoring method for assessing site fitness for woodland establishment using cuttings of poplar and willow has been tested. Preliminary results demonstrate the potential of this method, and it will be further developed with support from CLAIRE (Contaminated Land: Applications In Real Environments).

Evaluation of new soil cultivation technologies

Research on the evaluation of new soil cultivation technologies has continued with assessments of tree response and soil condition in an important replicated experiment at Bramshill Forest. New ripping equipment, recently designed at Cranfield University, has been tested against conventional tackle and cultivation using a 360 degree excavator. The research has been set up to allow the modernisation of guidance on cultivation of restored substrates.

Work continues on the study of tree growth on containment landfill sites. A detailed examination of tree rooting was undertaken at the Waterford site, Hertfordshire. Results suggest that previous guidance on the need for an adequate thickness (>1.5 metres) of rootable soil material over a compacted mineral cap are well founded.

Strategic research issues in land reclamation and urban greening and how they are translated into research activities, and then presented in appropriate publications.

Research issue	Research activity	Recent publications [a]
Assessing land suitability for woodland establishment	Development of site investigation protocols for woodland establishment.	Foot *et al.* (2002) Report
	Reviewing issues relating to establishing trees on contaminated land.	Hutchings (2002) Information Note
	Assessing the plant availability and impacts of potentially toxic elements.	Hutchings (2003) Journal paper
Improving land restoration practice	Alleviation of soil compaction on restoration sites.	Foot (2002) Unpublished report Foot & Spoor (2003) Journal article
	Assessing the effects of incorporating soil forming materials on tree survival and growth.	Foot *et al.* (2003) Book chapter
	Assessing the effects of mycorrhizal inoculation on tree survival and growth.	Moffat (2002) Journal paper
Assessing the performance and implications of woodland planting	Woodland establishment on landfill sites.	Hutchings *et al.* (2001) Journal paper Foot (2002) Unpublished report
	Meeting ecological and environmental standards when planting woodland in urban areas.	Moffat (2001) Journal paper

[a] For further details of these publications, please contact andy.moffat@forestry.gsi.gov.uk

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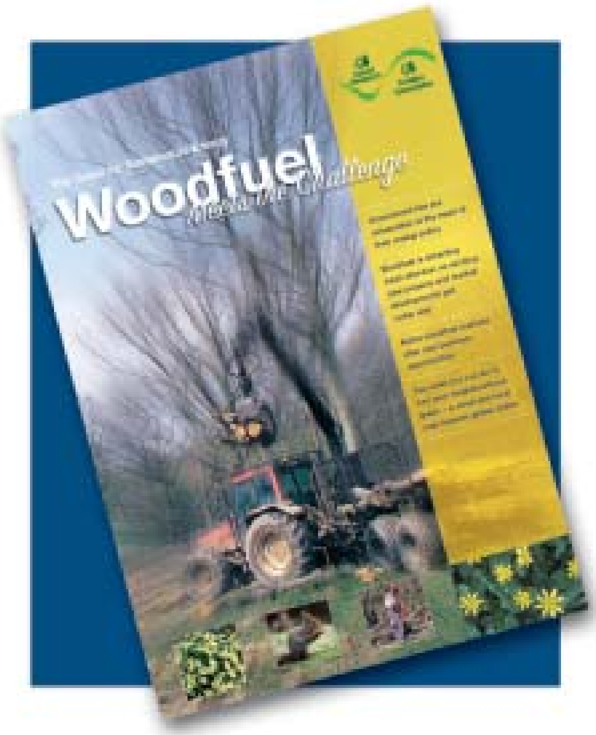
Research highlight

Enhancing economic value of forest and woodland resources

Andy Hall, Bill Mason and Sam Samuel

- **Biomass crops**
- **Assessing the risk of wind damage**
- **Marker-aided selection**

There is a wide range of ways in which research, particularly in partnership with the forest industry, can increase the competitiveness of British-grown forest products and their contribution to wealth creation.



'Woodfuel meets the Challenge' leaflet produced in conjunction with Forest Research/Forestry Commission woodfuel exhibition.

Biomass crops

Biomass is not new and comes in many forms. For many centuries, man has been using it in one form or another to heat his dwelling places. Over time, as new technologies have developed, interest in wood has been rekindled, but this resurgence of interest has often been misplaced and many opportunities for progress have come to nothing. However, today, reducing the use of fossil fuels to help mitigate the effects of climate change, present a very real social and economic opportunity for biomass, woods and forests to make a difference. The UK forest industry is being inundated with requests for information on woodfuel supply and we are already playing an essential role in the UK in support of this new and developing market sector.

Specific recent projects include:

- Woodfuel strategy review. This was primarily aimed at informing, supporting and prioritising future work within the woodfuel project area, as sponsored by the FC's Forestry Group and the forest industry. This work will benefit the industry and should help inform other market sectors which have an interest in wood beyond that as a fuel.

- Investigations into methods for achieving woodfuel specifications. These aim to identify the numerous factors affecting the sustainable development of a woodfuel supply industry in the UK.

- **Seminars and presentations on woodfuel production.** These have involved a significant amount of research which provided a unique overall characterisation of the woodfuel market and allowed us to establish ourselves as the 'honest broker' to the industry.

Ongoing projects include:

- **Woodfuel factsheets.** In conjunction with FE, this series of factsheets covers a wide range of information from the science of burning wood through to plumbing in wood burning systems. Written and presented with FC/FE forester staff in mind, they are also suitable for the wider audience.
- **Haulage and drying trials.** Bulk transport issues in relation to wood chip haulage, and long-term drying trials for short roundwood.

Assessing the risks of wind damage

In 2000 we released ForestGALES, a predictive model for assessing the risk of wind damage to forest stands. This is a Windows based package that can be used to calculate the risks to uniform conifer plantations anywhere in Britain. Several hundred copies of the model have been sold to end-users, many of whom have been trained in the use of the model in courses designed in collaboration with Forestry Training Services.

We have now made further improvements to the batch processing capability of the model and to the wind climate generator as a result of further analysis of anemometer datasets from forests throughout Britain. A beta version of the upgrade was released to the industry in late summer and the final version is due for release in late 2003. We have also developed an ArcView extension to the model so that it can be used with the GIS management systems being introduced to the private sector and Forest Enterprise. This is currently undergoing trials in a Forest District. The next steps proposed are to enhance our ability to use the model to predict the risks of damage in the irregular and mixed species stands which will be favoured under Continuous Cover Forestry regimes. This will be one consequence of the studies to be carried out at Clocaenog Forest previously mentioned, in 'Sustainable forest and woodland management'.

Marker-aided selection

In tree-breeding programmes, progeny testing is a vital part of assessing the genetic potential of trees to be selected for breeding. The problem for breeders is that the necessary field trials are expensive and need to be assessed over a number of years before conclusive information is available. A possible solution could be to employ the techniques available from molecular genetics to detect desirable characteristics in breeding material at an early age in the laboratory. Making the link between characteristics in the field and markers in the laboratory needs the most appropriate plant material to be established in the field.

Through vegetative propagation, Tree Breeders from Forest Research have now established clonal material of 1500 individuals within each of 3 full-sib families of Sitka spruce and plan to plant this in field trials on 3 different sites in 2005. Over the next 20 years this material will be assessed for a very wide range of characters relating to aspects such as growth and timber quality. Laboratory work has already begun to find molecular markers with which to construct a molecular map of the species. During later stages of this work, quantitative traits measured in the field trials will be linked to these markers. This will enable rapid early selection of superior genotypes in the laboratory.

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Pests and diseases

Hugh Evans and Joan Webber

The association between pests and diseases and their host trees is a dynamic and evolving process driven by a number of ecological, climatic and anthropogenic factors (Evans, 2001). Britain as an island has a flora and fauna that is relatively impoverished compared with mainland Europe but nevertheless has a wide diversity of plants and animals, most of which are of value from both biodiversity and social perspectives.

Red band needle blight in Corsican pine

Adult female pine looper moth, a periodic pest of various pine species in Britain

(photo: Robert Thompson)

Chlamydospores of Phytophthora ramorum, the pathogen causing the disease known as Sudden Oak Death in the USA

Introduction

Our island status does provides a degree of protection from the natural ingress of damaging organisms that could pose threats to our woodlands if they became established here. For example, the eight-toothed spruce bark beetle, *Ips typographus*, periodically reaches epidemic population levels in the spruce forests of Northern Europe. Despite numerous interceptions associated with imported wood, the beetle has not established in Britain and measures, including debarking or heat treatment of wood, are in place to reduce the risk of successful establishment. It is also interesting to note that the same beetle is on the prohibited lists of a number of countries including Australia, Canada, New Zealand, South Africa and the USA. This reflects the fact that numbers of new interceptions and establishments continue to rise in Great Britain and internationally and that concerted action is needed to reduce the rate of movement of damaging organisms in wood during international trade.

Despite the implementation of quarantine procedures under EU and National legislation, successful establishment of invasive damaging species does take place. In Great Britain this is evidenced by the appearance of *Phytophthora ramorum*, the cause of sudden oak death in the USA (Webber and Evans, 2002) and horse chestnut leaf miner, *Cameraria ohridella* (Evans and Webber, 2001; and the current report, page 33) in the past two years alone. Vigilance is vital in early detection of new incursions, particularly if there is to be any prospect of eradication of a pioneer population before it has become widely distributed. The strong international contacts established by staff in the Entomology and Pathology Branches have allowed them to recognise threats as they develop elsewhere and to provide early warning of potentially damaging organisms. Both *P. ramorum* and *C. ohridella* were flagged up as potential threats and publicised using Exotic Pest Alerts (EPAs) in paper and electronic forms, thus aiding the early detection of the two organisms soon after their arrival in Britain.

Technology transfer through written, electronic and, particularly, verbal presentations is, therefore, becoming increasingly important in making practitioners and members of the public aware of threats from invasive species. The value of well-illustrated articles and leaflets on pest and disease threats is clear and are increasingly being combined with electronic forms of publication. In addition to the two recent Exotic Pest Alerts already mentioned, a series of posters and an EPA for Asian longhorn beetle, *Anoplophora glabripennis*, have been produced and are available for download on the Forestry Commission Plant Health Service Website (http://www.forestry.gov.uk/forestry/hcou-4u4j4j). Other publications to aid identification of problems include books on Christmas tree pests (Carter and Winter, 1998), diseases and disorders of forest trees (Gregory and Redfern, 1998), tree hazards (Lonsdale, 1999) and diagnosis of ill-health in trees (Strouts and Winter, 2000) as well as a wide selection of scientific and popular articles on these subjects.

Increasingly, the importance of direct contact with practitioners is being recognised and staff from Entomology and Pathology are regular contributors to Forest Health Days and to meetings and seminars on the subject of plant health. During 2002, staff gave presentations and practical workshops at 12 locations, five in Scotland, two in Wales and five in England. Attendees came from a wide range of organisations and interests including Forest Enterprise, Forestry Commission, local authorities, the National Trust, English Nature and the Environment Agency. These presentations provided a valuable opportunity both to impart the latest information and also to interact directly with those who are most likely to spot pioneer infestations of new or, indeed, native pest organisms. Increasing awareness and expanding the number of individuals who have this awareness is one of the key elements in our continuing efforts to retain and enhance the health of woodlands. Further efforts to improve delivery of these aims will continue.

Figure 1a

Adult female *Lymantria dispar.*

(photo: Ronald S. Kelley, Vermont Dept of Forests, Parks and Recreation)

Figure 1b

A cluster of *Lymantria dispar* females laying eggs within hairy egg masses.

(photo: William M. Ciesla, Forest Health management International.)

Threats from abroad

Gypsy moth

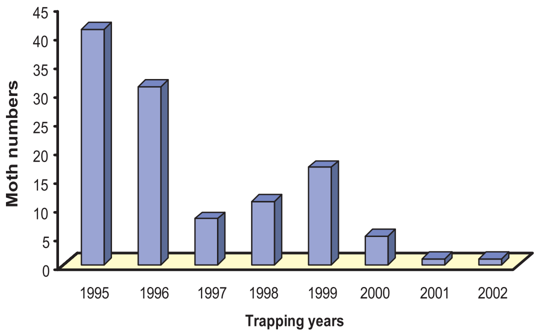
The small outbreak of the Gypsy moth, *Lymantria dispar* (L.), shown in Figure 1a and b, discovered in June 1995 in the South Woodford area of northeast London has persisted in the area despite eradication attempts. Although severe defoliation by the caterpillars is predicted as unlikely under current UK climate conditions, there is a potential threat of sporadic severe defoliation of important amenity trees in Epping Forest. Monitoring by use of pheromone traps again in 2002 has confirmed that the population is declining but has not been eliminated (Figure 2).

The marked decline in numbers in recent years indicates that the colony, which is the first breeding group in the UK since 1907, may be on the verge of extinction. Continued monitoring will show whether this is the case or just a phase of a natural population cycle.

In June 2002 Gypsy moth caterpillars were found feeding on young chestnut trees in the central south coast area of Jersey. Between 60 and 70 trees were found to be affected and a spraying operation was carried out in an attempt to eliminate these caterpillars. However, 200 pheromone traps set out during the adult flight period caught in excess of 500 adult male moths in just 3 weeks, indicating the possibility of a well-established population on the island. There have been regular catches of small numbers of male moths in the past, assumed to be migrants from the continent, but no signs of a breeding population on the island until now. For more information contact hugh.evans@forestry.gsi.gov.uk

Figure 2

Numbers of adult male gypsy moths caught in pheromone traps.



Horse chestnut leaf miner

The first finding in the UK of the horse chestnut leaf miner, *Cameraria ohridella*, was confirmed in July 2002 from a garden in the London Borough of Wimbledon (Figure 3). This moth was unknown in Europe before 1985 when it was found in Macedonia. Since then it has spread rapidly across Europe due mainly, it is thought, to the passive transportation of infested leaves on vehicles. Horse chestnut trees on the edge of Wimbledon common were found to be infested with *C. ohridella* but even higher populations of the moth were found in street trees in the centre of Wimbledon.

As its common name suggests, the larvae feed between the upper and lower surfaces of the leaves forming serpentine mines which, on heavily infested leaves, often merge together. This leads to browning and drying of the leaves and premature leaf fall that can affect 70–100% of the leaves on a single tree. Horse chestnut, *Aesculus hippocastanum,* is the main host but Norway maple, *Acer platanoides,* and sycamore, *A. pseudoplatanus,* are also reported to be susceptible. All three species are significant amenity trees planted in urban and suburban areas.

C. ohridella has several overlapping generations during the summer so numbers can build up rapidly; both the primary and secondary flush of leaves are affected. Three generations seems to be the average in Western Europe but up to five generations have been reported in hotter drier conditions. Trees heavily attacked by *C. ohridella* are reported not to die but the damage may prove, over time, to lead to an overall gradual decline in tree vigour. This is not the case with other species of leaf miners associated with UK trees, which have only a single generation in a year and therefore a limited damage period, and are merely regarded as disfiguring.

Apart from the removal and burning of infested leaves in autumn there is no other practicable form of control recommended at present. More information about this pest can be obtained from christine.tilbury@forestry.gsi.gov.uk

Figure 3

Early infestation by horse chestnut leaf miner on a tree in Wimbledon.

Phytophthora ramorum: cause of sudden oak death in the USA

This new pathogen has now been isolated at more than 200 nurseries in the UK, where it has been found infecting rhododendron and viburnum. Surveys have not detected *Phytophthora ramorum* on any trees but current research is assessing the potential susceptibility of a wide range of tree species. Tests on oak and other key woodland and forestry species have been carried out under a Ministry of Agriculture Licence in high security quarantine containment chambers at CABI, Silwood Park. The objective is to assess the risk posed by *P. ramorum* to UK/European tree species. In all, the following 23 hosts have been tested:

Quercus robur	*Prunus lauroseracus*
Alnus glutinosa	*Castanea sativa*
Quercus ilex	*Pseudotsuga menziesii*
Tilia cordata	*Picea sitchensis*
Quercus cerris	*Carpinus betulus*
Populus tremula	*Taxus baccata*
Quercus suber	*Betula pendula*
Ulmus procera	*Acer platanoides*
Quercus rubra	*Sequoia sempervirens*
Fraxinus excelsior	*Rhododendron ponticum*
Fagus sylvatica	*Aesculus hippocastaneum*
	Chamaecyparis lawsoniana

On the basis of these results, the various tree hosts have been categorised into more susceptible species, e.g. *Q. rubra* and *F. sylvatica*, less susceptible species, e.g. *Q. robur* and *A. hippocastanum,* and resistant, *e.g. T. cordata* (Figure 4). Some conifer species such as Douglas-fir and Sitka spruce have also proved to be highly susceptible in these tests, although all the tests involve wounding the bark so it does not indicate the effectiveness of the pathogen when infecting unwounded bark. The experiments have also indicated that there can be significant differences between the resistance levels of individual trees of the same species.

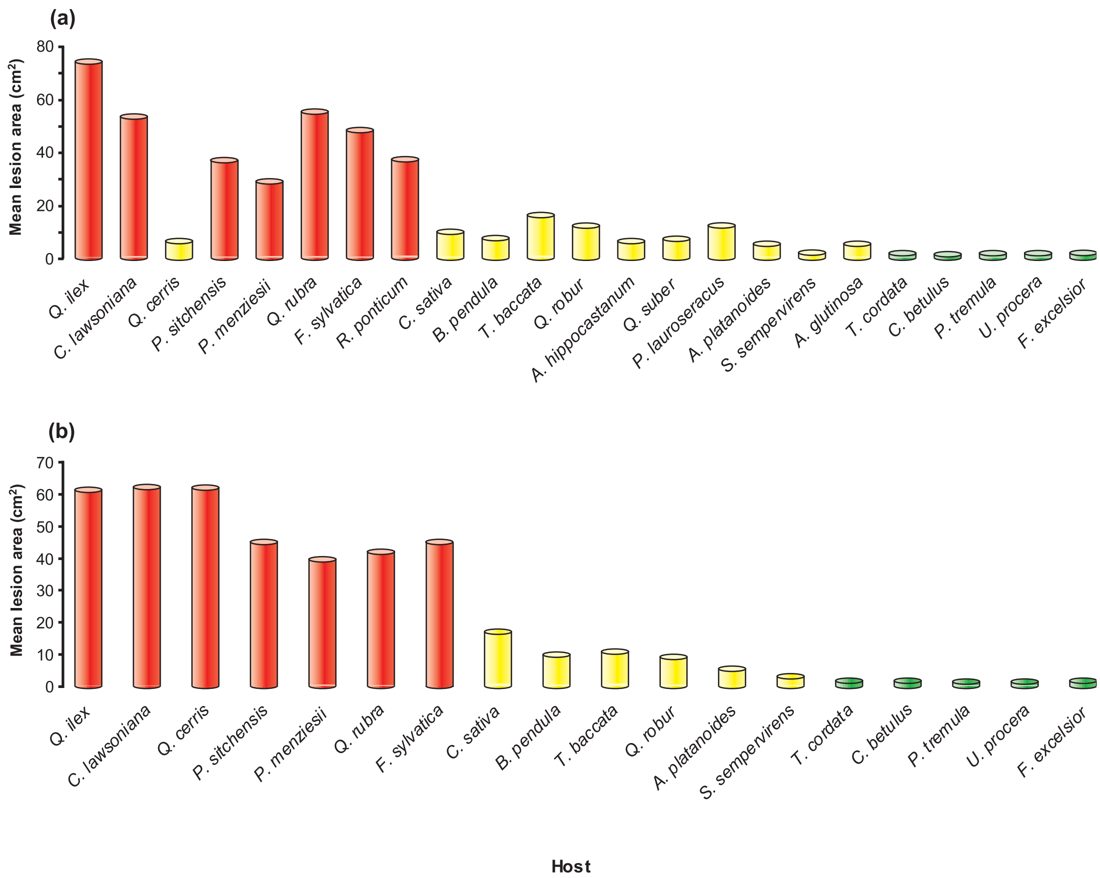
Tests also revealed that the USA populations of *P. ramorum* were much more variable than the European populations of the pathogen (Figure 4a and b). The latter were morphologically uniform, fast growing, highly pathogenic and of a single mating type (A1). American isolates showed a range of pathogenic behaviour and growth rates, a variable morphology and all consisted of the A2 mating type. However, when the A1 and A2 isolates were paired together, normal mating rarely if ever occurred, indicating that *P. ramorum* may not have a normally functioning breeding system, possibly as a result of genetic divergence in the two populations.

Recently, German workers have reported that they have isolated a single isolate of the A2 mating type in Europe but it is not clear whether this fits the profile of the American population or is capable of mating with A1 isolates from Europe.

For more information about this disease, contact joan.webber@forestry.gsi.gov.uk or look at www.forestry.gov.uk/pramorum

Figure 4

Susceptibility of a range of tree species to *P. ramorum* originating from (a) Europe and (b) North America. Red colours indicate more susceptible hosts, yellow columns less susceptible hosts and green resistant or tolerant.



Established pests and diseases

Pine looper moth, *Bupalus piniaria*: annual survey

The annual pupal surveys for pine looper moth, *Bupalus piniaria*, have continued in those forest districts with concerns about the potential impact of this damaging moth. As indicated in Webber and Evans (2003), increasing damage is being reported on lodgepole pine in the far north of Scotland and therefore the national pupal surveys remain relevant to the health of the affected forests.

Numbers of pupae recorded in most areas this year (Table 1) fell well within the limits considered normal for a resident population, ranging from less than 1 to between 4 and 5 pupae per square metre (m^{-2}). In the two areas where this was exceeded, shown in bold, numbers were still well below the level at which any further action would be advised (25 pupae m^{-2}).

Table 1

Pine looper moth: numbers of pupae recorded in annual surveys 1997–2002.

Forest District	Unit	1997	1998	1999	2000	2001	2002
North York Moors	Revised transects						
	Area 1[a]	3.6	1.2	1.2	2.0	n/s	2.4
	Area 2[b]	0.0	0.8	0.4	0.4	n/s	0.8
	Area 3[c]	1.2	1.2	2.0	4.0	n/s	2.0
	Area 4[d]	2.8	2.0	1.6	0.4	n/s	**6.8**
Midlands	Cannock	6.0	0.8	0.4	0.4	n/s	n/s
	Swynnerton	2.0	0.0	0.4	0.4	n/s	n/s
Sherwood	Sherwood III	0.8	4.0	0.0	0.4	0.4	0.4
	Sherwood IV	1.6	1.2	0.4	0.4	0.4	0.8
Inverness	Culloden	0.4	3.6	0.8	1.6	1.6	1.2
Moray	Culbin	6.0	2.0	3.6	13.6	7.2	2.4
	Lossie	0.4	1.6	6.8	18.0	14.8	**7.6**
	Roseisle	4.4	1.2	2.8	4.8	2.4	1.6
	Speymouth	30.0	20.4	4.0	2.0	2.8	2.4
Tay	Montreathmont	23.2	1.2	2.4	6.4	1.2	2.4
	Ladybank/Edensmuir	0.0	0.0	0.4	1.2	2.8	0.4
	Tentsmuir/Reres	32.8	2.8	1.2	4.4	4.0	2.0
	Reres	n/s	n/s	n/s	2.2	4.8	2.0
Scottish Lowlands	Devilla	n/s	n/s	n/s	3.2	1.6	0.4

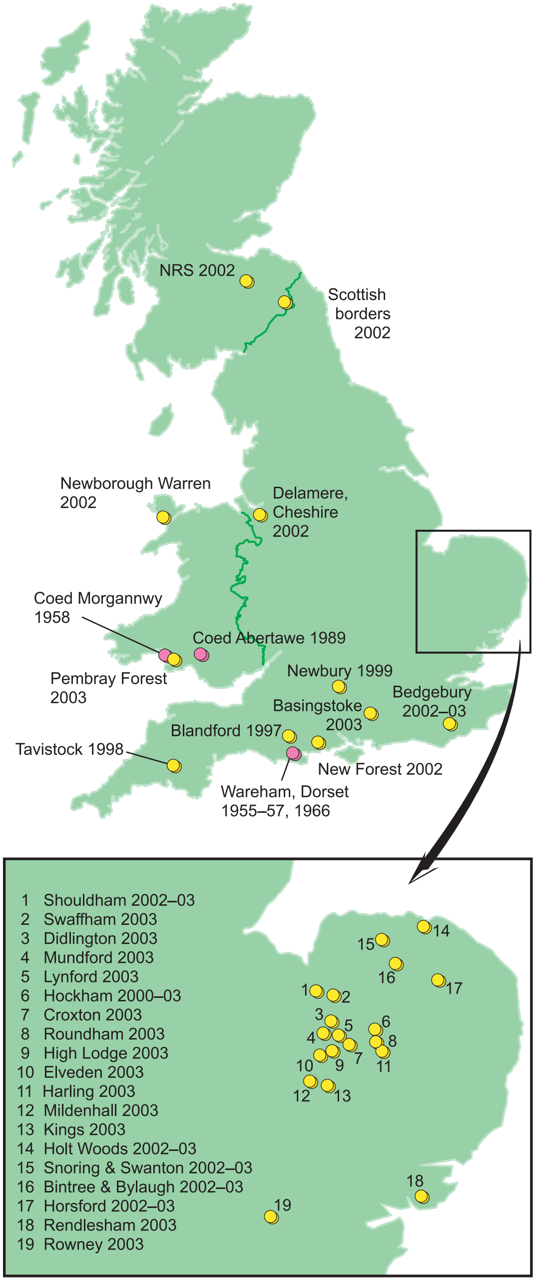
n/s: not surveyed.
[a]Area 1: Boltby/East Moor; Wass/Pry Rigg
[b]Area 2: Cropton; Dalby
[c]Area 3: Hardwood Dale/Broxa
[d]Area 4: Sneaton; Langdale/High Langdale

Shoot and needle diseases of pine

Several shoot and needle diseases of pine have been noticeable over the past year. Probably the most conspicuous example is red band needle blight, which has apparently been increasing in frequency for the past 4–5 years. The causal agent is the fungus *Dothistroma pini*, an introduced pathogen first seen in the UK in nursery stock in 1954 (see Brown *et al.,* 2003).

Figure 5

Accumulated records of *Dothistroma pini* in 2002.
Yellow = current survey.



Scots pine is relatively resistant to the disease but Corsican pine, *Pinus nigra* var. *laricicola*, is highly susceptible, so the main area affected by this disease has been in the East Anglia Forest District where Corsican pine is planted widely. The current distribution of the disease is shown in Figure 5 and it has recently been recorded in Scotland for the first time in two different locations. Within the East Anglia Forest District, it is now estimated that out of the total planted area of 15 000 ha of Corsican pine, trees over a 4000 ha area are suffering serious defoliation and some may have to be felled prematurely.

In addition to red band needle blight, there have been reports of scattered one-year-old shoots of two-needle pines (notably Corsican pine but also Scots pine) being killed by the fungus *Sphaeropsis sapinea*. The pathogen can be very damaging particularly if the host has already suffered shoot damage (hail and wind damage are frequently cited). This is recognised as a serious disease abroad, but in the UK the damage is usually slight and control is not considered necessary. However, during 2002 visible signs of shoot killing by *Sphaeropsis* have been common, particularly in Southern Britain, although there have not been enough records to estimate how widespread a problem this has become. The amount of damage cause by *Sphaeropsis* in areas such as Thetford Forest may also be masked by the damage already caused by red band needle blight.

Shoot and needle diseases have also become a feature of several New Native Woodland Grant Schemes in Scotland and this is causing concern because of the adverse affect on sustainability. In particular, *Lophodermium seditosum* has been frequently involved in outbreaks of needle browning and dieback on the Scots pine in young plantings. Three NNW schemes have suffered especially widespread damage from this pathogen with approximately 115 ha affected out of a total area of 200 ha.

Green spruce aphid, *Elatobium abietinum*

Reports of high numbers of the green spruce aphid, *Elatobium abietinum*, particularly on *Picea abies* and *P. sitchensis* were received from early spring onwards. Individual needles were yellow or showing yellow spots or bands where aphids had been feeding. By late spring, damage had become very obvious as yellowing needles became more abundant and many needles attacked earlier had turned brown and were completely dead (Figure 6). Trees looked at their worst in early summer, the damaged needles were falling and only the new growth at the tips of shoots remained relatively unaffected. Many were reported to resemble dead trees with soft new green growth at the ends of bare twigs. However, retention of the current year's growth usually allows trees to survive and recover but it will be several years before new shoots mask the damage as the defoliated parts of branches will not grow new needles. There are no insecticides approved for the control of the green spruce aphid in forest plantations and, although defoliation has been shown to cause a loss of increment, it is doubtful if chemical control could be justified in the forest on economic grounds.
For more information contact
nigel.straw@forestry.gsi.gov.uk

Figure 6

Damage to *Picea sitchensis* by *Elatobium abietinum*.

Alder disease and dieback in Scotland

Following the discovery in 1993 of a lethal disease of alder caused by a new species of *Phytophthora* which has now become widespread in England and Wales (Gibbs *et al.*, 2003) the disease has also been recorded at several locations in Scotland in recent years (Hendry, 2002). However, apart from *Phytophthora* disease, a serious dieback of native riparian alders has been observed in Scotland as long ago as the beginning of the last century. In contrast to alders affected with *Phytophthora* disease, trees with alder dieback do not show any evidence of tissue death at the root collar or in the structural and fine roots. Instead bark lesions occur on branches and commonly coalesce in the parent stem, resulting in girdling and branch and stem death. Underlying these lesions the wood is typically stained a dark brown and, on isolation, often yields the Ascomycete fungus *Valsa oxystoma*.

In 1999 a project was established to determine the severity of the problem via 11 permanent monitoring plots across mainland Scotland. In addition, the occurrence of *Phytophthora* disease was also assessed. *Phytophthora* disease appears to be largely confined to river catchments in the east of Scotland, with the disease recorded on the Avon, Tweed, Dee, Deveron, Duirinish and Spey. In contrast, the incidence of alder dieback tends to be confined to catchments in the north and west of Scotland. As the majority of western and northern Scottish rivers can be described as 'spate' systems which drain into small catchments, and in which water flow and water levels are inherently volatile, riparian alders in these areas, may be subjected to higher levels of environmental stress. These stresses, plus local site factors, are likely to contribute to the raised incidence of dieback, although there may be potential to manage affected stands of alder by encouraging regrowth via coppicing.
For more information about this research contact
steven.hendry@forestry.gsi.gov.uk

Oak pinhole borer, *Platypus cylindrus*

An increased number of reports of damage to felled timber and sawlogs in the south of Britain due to the oak pinhole borer, *Platypus cylindrus*, were received (Figure 7a and b). This insect is one of the few ambrosia beetles found in Britain; so-called because the larvae feed on specific ambrosia fungi that grow in the walls of tunnels bored into 'green wood' by the adult beetles. The presence of these fungi causes a blackening of the tunnels that is a characteristic of ambrosia beetle attack and helps to differentiate the damage from that caused by bark beetles.

The beetles can bore deep into the heartwood, making holes of about 1.6 mm in diameter, forming a branched gallery system that can reach a length of up to 1.8 m. They do not normally penetrate into the heartwood until the second year of their two-year life cycle. Infestation by ambrosia beetles will cease only when the wood has become too dry to support the growth of the fungi, i.e. between 30 and 40% moisture.

Logs can remain susceptible to attack by *P. cylindrus* for up to four years but are only at risk during the flight period of the adult beetle, from June to end of September. Prior to the hurricane of 1987 *P. cylindrus* was regarded as a rarity (British Red Data Books, 2 Insects: NCC, 1987). But by 1991, as a result of an abundance of breeding material, its numbers had increased dramatically in parts of Southern Britain. Numbers remained high for several years before falling back to a persistent but lower level. In spite of its common name, *oak pinhole borer* also attacks the timber of several other hardwoods. After oak they are most commonly found in sweet chestnut and beech and are also known to breed in ash, elm and walnut.

Figure 7

Damage by oak pinhole borer: (a) piles of fibrous frass marking entry points; (b) multiple attack of sweet chestnut log.

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Social science in forestry

Paul Tabbush, Liz O'Brien, Max Hislop and Suzanne Martin

The Social Research Unit came into being late in 2001, to consolidate an increasing programme of work, being carried out within the Silviculture Branches, which was concerned more with the relationships between people and trees than with the science of creating and managing woodlands. The main impetus for this work is based on the idea that sustainable forestry, derived from the 1993 Helsinki Conference, is the result of economic development that is positive in its implications for the environment and for society (Forestry Commission, 1998). Conversely, forestry development that is not properly positioned in its social context is unlikely to yield its full potential in terms of economic or environmental benefits. Our task, then, is to try to understand these social contexts and make recommendations for good practice.

Autumn colours in Vermont, USA

The importance of trees and green space within the urban environment: Soho Square, London

Families enjoying the walking trail at Bolderwood, New Forest

Introduction

One of the first activities was to draw together existing related work (funded partly by the Forestry Commission and carried out in universities) and to discuss possible future directions. This took the form of a seminar in 2000 and a conference in 2001 (O'Brien, 2001; O'Brien and Claridge, 2002; Figure 1a and b).

Figure 1

Publications of (a) the Social Forestry 2000 Seminar and (b) the Social Science Research 2001 Conference.

Our understanding of social forestry is continuing to develop, and our work now concentrates on the following central themes:

- Governance and public involvement
- Social and cultural values
- Health and well-being
- Education and learning
- Recreation, access and tourism.

Governance and public involvement

Public involvement in environmental decision-making is one of the central themes of Sustainable Development (UNCED, 1992). Although participation is focused here on poverty alleviation, it also accords with late 20th century thought on governance and democracy, especially in relation to environmental problems. The failure of representative democracy to take full account of local views and needs, especially in relation to developments affecting the environment, has led to a preoccupation with *deliberative democracy*, in which people's views are sought not in a simple vote, but through fair and well-informed debate. Max Hislop has devoted much of his time in the past two years to investigating methods for applying these ideas in a forestry context.

Forest managers, just like managers in many other industries, have to respond to societal changes. Increasingly they are faced with demands from the public and expectations from policy makers to involve stakeholders in forestry decisions. This presents the manager with many challenges:

- Who should be involved and how equitable is the decision-making process?
- What methods are best employed to involve people?
- What are the resource implications?
- How should we deal with conflicting demands?
- What are the objectives of public investment in forestry?

New ideas and approaches to environmental decision-making are being tested with Forest Enterprise planning teams in forest district pilot studies. Based on this research, guidance for managers suggests that:

- Public involvement should be recognised as a legitimate management activity in its own right, rather than just a part of a forest planning process.

- A planned approach to public involvement is advisable to ensure an equitable, open, honest and efficient decision-making process.
- Forest managers need intimate knowledge of the social issues associated with the forest prior to public engagement.
- Open and defendable means to prioritise between demands on limited resources need to be developed.

Social and cultural values

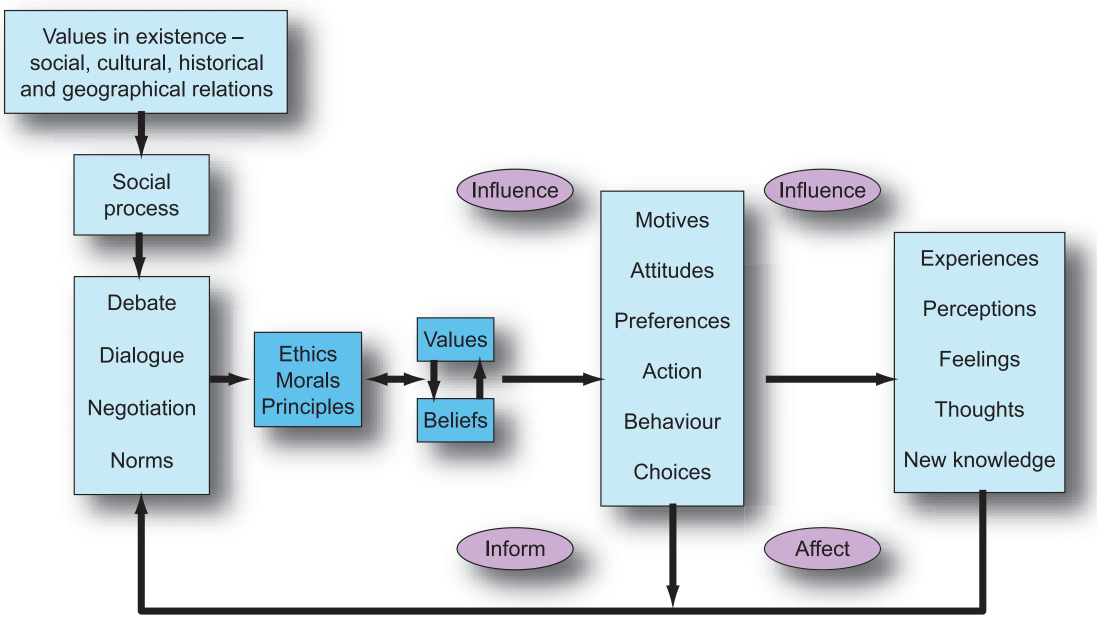
People's attitudes and behaviours are based on the values that they hold. These values collectively form the identity of individuals and communities, and are often spatially related. For example, local inhabitants of the Forest of Dean identify themselves as 'foresters' by association with the forest. Liz O'Brien has been conducting research into social and cultural values.

Values are the standards people use to judge how things 'ought to be'. They relate to ethical issues and our deeply held beliefs. Figure 2 illustrates how values are constructed within society through a social process of debate between individuals and institutions. Values can shift over time and be re-negotiated or reviewed through further deliberation. The aim of the research was to gain a greater understanding of the values and meanings people associate with woodlands and trees and draw out the implications for future forestry policy development. Data were collected in England and Vermont, USA in order to look at citizens' values in differing cultural contexts. In-depth interviews and discussion groups with members of the public were the main methods of data collection and included citizens from a range of age groups and socio-economic backgrounds. Key findings from the research include:

- The importance of personal memories and associations with particular trees and woods.
- Woodlands as a social setting for families, communities and friends to interact and undertake activities together.
- The significance of people's feelings of well-being associated with trees and woods: emotional, mental and physical.
- Publics' values for woodlands do not stand apart from wider issues of concern over changes in society and concerns over environmental and cultural change.

Figure 2

Schematic representation of value formation.



Health and well-being

The Forestry Commission, with its agency Forest Enterprise, represents the UK's largest single controller of public land. At the same time, community forests are being developed in and around centres of population, in recognition of the benefits of such initiatives in building social capacity, as well as providing much needed naturalistic public space. In 2002 the Forestry Commission hosted three expert consultations, in England, Scotland and Wales, in which environmental and health professionals were brought together to explore ways in which they could work towards increasing public health and well-being (Tabbush and O'Brien, 2003; Figures 3 and 4).

Inactivity is a significant factor in many of the most common major illnesses: obesity, heart disease, kidney disease, and some types of cancer and diabetes. Active involvement of people in outdoor activities in forests and green areas therefore has direct significance for health. There is growing understanding in health policy that sustainable health requires not only effective medical approaches, but also healthy environments and healthy lifestyles, to promote psychological/mental as well as physical health. This is the idea of health and well-being, as derived from contact with naturalistic environment; something more than just health as the absence of illness.

Figure 3

Health and Well-being publication: outcomes from expert consultations in England, Scotland and Wales during 2002.

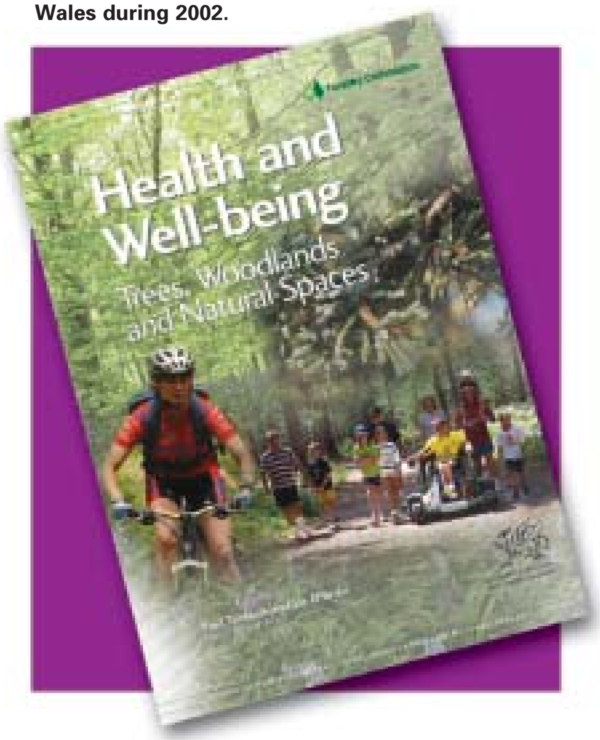


Figure 4

Personal development: the positive effects that outdoor activities can have on young people.

Education and learning

Forests offer a significant resource for learning, both in the sense of school learning and in the sense of social learning, in which publics, forest managers and experts learn from each other. This latter sense has implications for governance and public involvement.

Forest School

The idea of Forest School, which has Danish origins, has been championed in Britain by Bridgewater College. Their website (Bridgewater College, 2003) includes a definition:

> Forest School is a unique educational experience using the outdoor environment. Its principal purpose is to tailor an educational curriculum to a participant's preferred learning style (rather than vice versa) whilst using the outdoor environment as a 'classroom'. The majority of the Foundation Stage of the Early Learning Goals curriculum and the National Curriculum can be met in this unique learning setting. Its philosophy is to encourage and inspire individuals of any age and any group, through mastery of small achievable tasks in a woodland environment, to grow in confidence, self-esteem and independence. As the individual's self-esteem develops, the tasks become more complex but, at every stage, tasks are always achievable.

Forest Research is working with the New Economics Foundation to evaluate the outcomes of two Forest School projects in Wales, in terms of community benefits (Social Capital), self-esteem, and learning.

Recreation, access and tourism

For the public to benefit from recreational use of forests and woodlands, they must have access to these spaces. It follows that forestry can only be considered socially sustainable if the access needs of many different sections of society are catered for. This raises questions about who benefits from forest access and who does not.

Public access to the countryside and its associated recreation and tourism have in the past been marginalised around the primary production function. These days, recreation and tourism are being placed nearer to the centre of rural development. Tourism is an increasingly important element of the rural economy. However, the links between forestry and tourism are poorly understood. Suzanne Martin is exploring these links through in-depth local research within England, Scotland and Wales, using qualitative and quantitative social research techniques. This involves working with a range of key decision-makers as well as tourism and recreation businesses to investigate the current and potential role of forest and woodland environments in the tourism sector.

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Managing the historic environment in woodland: the vital role of research

Peter Crow

The historic environment is an important part of our heritage and contributes significantly to our understanding of the human past. This article provides a review of the management of the historic environment in woodlands, highlights important issues and reports on current and planned research.

Introduction

In woodland, as with other land uses, the conservation of the historic environment is highly important. This is reflected in a key Forestry Commission objective on sustainable forestry which includes the commitment that important historic environment features should be protected during woodland management and planning (Forestry Commission, 1998). There are many types of historic features in woodland and they provide a rich resource for study and research, including archaeological evidence, biocultural heritage such as veteran trees and historic landscapes such as wood pasture or ancient woodland. To maintain and enhance such features through informed management, we need improved understanding of how they interact with the surrounding environment and landscape. Such understanding is now being developed within a new research programme funded by the Forestry Commission.

The research programme began in 1999 by examining issues relating to the archaeological resource in British woodlands and these aspects are focused upon here. Archaeological evidence constitutes a major component of the historic environment and it is both finite and non-renewable. Within woodland environments, this evidence is often divided into two categories:

- Archaeology *in* woodland, where there is no relationship between the archaeological evidence and the woodland in which it occurs, for example, barrows.
- Archaeology *of* woodland, where the archaeological evidence is directly related to the history and management of the woodland, for example, saw pits, charcoal platforms and ancient woodland boundary banks. Here, the woodland itself is often an important part of, or setting for, the archaeological feature.

There are thousands of known archaeological sites in Great Britain (GB) ranging from extensive field systems and hillforts to single standing stones and sites of artefact finds. By their visual nature, earthworks are the most commonly known features, with sites of buried or less dramatic remains being harder to identify (Forestry Commission, 1995) while other archaeological evidence lies undiscovered. The total GB archaeological resource is therefore unquantifiable. Nevertheless, with over 2.7 million ha (27 000 km^2) of GB land currently under woodland management, it is inevitable that this will include many thousands of sites of archaeological interest.

Historically, forestry and archaeology have often been regarded as antagonistic. However, since the early 1980s, there has been an encouraging increased awareness of the historic environment reflected in government policy and an expanding dialogue between interested parties. This has led to a greater co-operation between foresters and archaeologists (Yarnell, 1999; Fojut, 2002).

A recent review of forestry and archaeological literature (Crow, 2004) has identified many ways in which tree presence or removal could be either benign or detrimental to archaeological evidence. The optimum management of a site is dependent upon many factors, all of which need to be considered when developing management plans, as described in Box 1. Indefinite preservation of archaeological evidence *in situ* is not possible, as it inevitably deteriorates with time. However, the rate of degradation can be greatly influenced by site management. Unfortunately, there is a limited understanding of the many complex interactions that influence the rates of change (Crow and Yarnell, 2002).

This article now looks at examples of three projects designed to help improve policy and management guidance. The first two examples concern new woodland establishment, while the third considers the management of sites already in a wooded environment. Other examples of research projects are listed in Box 2 (page 54).

Box 1

Examples of issues relating to historic environment features under woodland management.

- The high density of historic environment features and the large area of GB under woodland, inevitably means that in some areas both must co-exist
- Current government policy is to promote the establishment of woodland and short rotation coppice (SRC), but no planting should occur at the expense of important historic environment features
- Whether or not tree cover should be retained/cleared/established on areas of importance will need to be considered in a strategic approach to the management of archaeological features under woodland and forests
- Damage to archaeological sites could potentially occur in many ways including: cultivation, desiccation, root damage (from trees and other vegetation), visitor erosion, burrowing animals or chemical changes to the surrounding environment
- The type, composition, size and depth (if buried) of archaeological evidence combined with surrounding environmental factors will influence preservation
- The aesthetic setting of historic environment features should also be considered to place the site in a suitable context; past land use may also be relevant
- Less is known about historic environment features in woodland than under other land uses due to limited surveys and research
- Awareness, identification and mapping of historic environment features in woodland and forests is essential to aid management and minimise the risk of accidental damage

Floodplain forestry and wetland archaeology

Known archaeological site information is routinely sought as part of the Woodland Grant Scheme (WGS) consultation procedures. When important remains are identified, the land on which they are located is typically excluded from the scheme or incorporated into planned open spaces. However, certain landscapes possess favourable preservation environments and were suitable locations for former settlement but have no recorded archaeological evidence. Such land is regarded as having a high archaeological *potential*. Evaluation of the possible risk of damage caused by a change in land use is therefore required, so that informed decisions can be made.

Waterlogged deposits have yielded many well-preserved archaeological remains and so the impact of woodland establishment on floodplains is of particular interest. Various geotechnical, geophysical and archaeological site assessments can be used to detect buried evidence, but these are expensive. A recent WGS proposal formed the basis of an evaluation of site investigation methodologies and this is outlined below.

Site background and evaluation

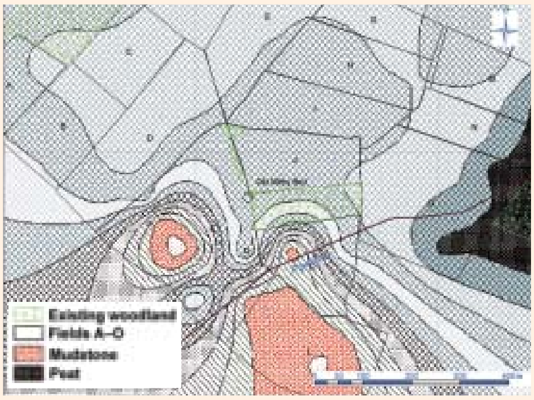
An application was made by a farm for a 67 ha mixed broadleaf community woodland on the Avon levels in South Gloucestershire. The water table of the floodplain deposits (<10 m above OD) is managed by a series of field drains which discharge into large ditches. The bedrock (Mercia Mudstone) below the alluvial deposit occurs at its shallowest depth (0.5 m below the surface) in the southeast of the farm and dips down as it extends northwest towards the Severn Estuary. However, towards the south of the farm it briefly rises again through the surrounding floodplain to form a small hill in one of the fields. The land use at the time of grant application was pasture, with three areas of existing woodland. During the installation of a gas pipeline across the site in 1997, Romano-British artefacts and deposits of peat (which may contain palaeoenvironmental evidence such as pollen grains) were identified.

Before the last phases of alluvial inundation and historic land claim, the Mercia Mudstone forming the small hill and rising towards the southeast of the farm would have formed higher, dry ground at the edge of the floodplain. These areas were therefore considered as sites of earlier settlement and land use with a high archeological potential. For these reasons, collaborative research involving the Forestry Commission, South Gloucestershire County Council and English Heritage was planned and undertaken using the following surveys and excavations:

Auger survey (Forest Research)
This was to a depth of 1.7 m of the entire application area to map the extent of the shallow Mercia Mudstone and the peat deposits. Figure 1 shows the extent of the mudstone (red) and the peat (black) at a depth of 1.4 m.

Figure 1

Auger survey to assess extent of mudstone and peat.



Soil examination pits (Forest Research)
These were dug to assess the typical rooting depths of the trees in the existing woodlands. Figure 2 shows the shallow nature of the lateral root growth and the depth of the water table.

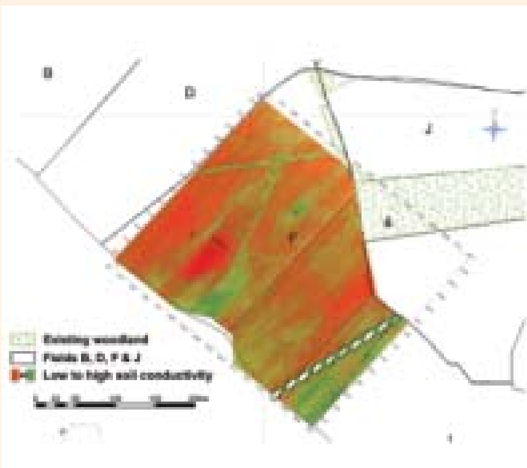
Figure 2

Soil examination pit revealing shallow lateral root growth.

Geophysical survey (Stratascan)
The field containing the small hill and location of Romano-British finds was surveyed, using various methods including electromagnetic (Figure 3), resistivity and magnetometry, tested for their ability to identify archaeological and geomorphological features. Survey costs ranged from £300 to £1000 per hectare.

Figure 3

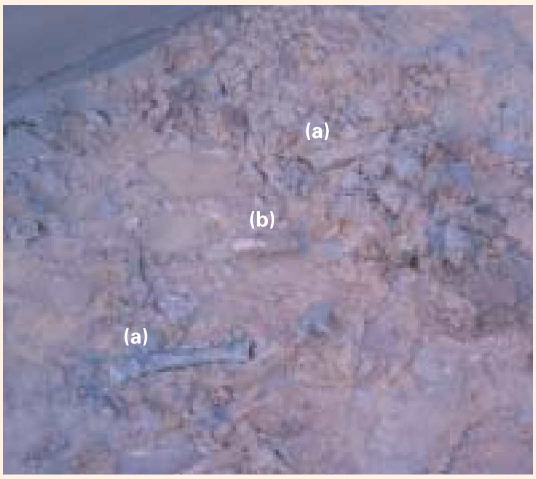
Geophysical survey using electromagnetic methods.



Trial excavations (Gwent Glamorgan Archaeological Trust)
These excavations were to examine features of interest identified by the geophysical survey and to re-examine the location of the previous Romano-British finds by expanding and developing the area exposed by the pipeline. Figure 4 shows the bones of domestic animals.

Figure 4

Trial excavations reveal bones of domestic animals (a); muddy trowel (b) added for scale.



Results

The excavations of areas of interest identified by the geophysical survey produced evidence of Romano-British occupation at the base of the alluvial deposits close to the surface of the Mercia Mudstone. These included bones of domestic animals, local pottery, charcoal and stone. This may have been the location of a simple Romano-British settlement, on low-lying but predominantly dry land on the margins of the floodplain. The full extent of the archaeological evidence at the site remains unknown but its topographical/marginal location is of importance in interpreting local Romano-British activity. The surrounding alluvial deposits, sampled during the excavations, were found to contain palaeoenvironmental information in the form of molluscs and some pollen grains. The peat deposits were not sampled, but it is probable that they contain a more complete pollen record. Palaeoenvironmental analysis of the peat was not in the remit of this study.

Woodland establishment and continued monitoring

The auger survey showed that most of the site was covered by at least 1.7 m of late or post-Roman alluvium and the threats of physical archaeological damage by tree roots was considered to be a very low risk. A revised planting scheme was therefore approved for the site. The areas that were considered to be the most archaeologically and palaeoenvironmentally sensitive were incorporated into open space to be maintained as grassland (Crow, 2003).

Observations during the above surveys showed that the water table occurred within 1.5 m of the soil surface. Throughout the site, the water table is managed by the field drainage system, but also influenced by climate and vegetation cover. As a precautionary measure, 12 months prior to the approval of tree planting, 24 dip wells were installed in three different areas, incorporating both open field and existing woodland. In all of the open fields containing the dip wells, trees have since been planted and the fortnightly monitoring of the water table is continuing. Results from this work will be published in a scientific journal once the trees have become fully established on the site.

This study has provided a valuable benchmark for future woodland proposals on alluvial floodplains. If woodland is to be considered on floodplains believed to have a significant archaeological potential, it gives an indication of the types and costs of the survey techniques that may need to be considered. Finally, it emphasises the need for good and early consultation and collaboration between foresters, surveyors and archaeologists.

Bioenergy and the expansion of short rotation coppice

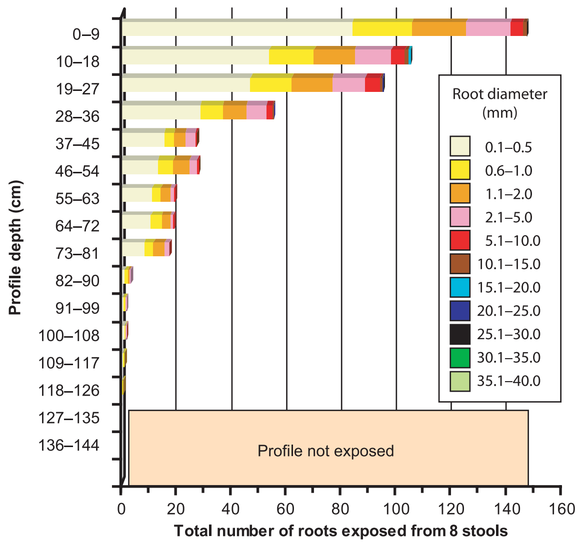
With a government commitment to reduce dependence on fossil fuels, some former agricultural land has been proposed for the establishment of short rotation coppice (SRC) as a biofuel crop. Despite regular agricultural ploughing, buried archaeological evidence may still survive below many fields and some SRC proposals have led to concerns over 'deeper rooting' tree species, often regarded as more intrusive and destructive than the former agricultural crop. The Forestry Commission has a responsibility to evaluate environmental risks from tree establishment, including SRC, and initiated the following study into rooting depth of this crop type.

Root evaluation method

To examine the typical rooting habit of biomass tree species, trenches were dug in a variety of established willow (*Salix* sp.) and poplar (*Populus* sp.) SRC plantations on a range of soils to assess the roots in profile. The diameter and location of each root exposed within the soil profile was recorded. This was repeated for eight stools within each trench. In total, 33 trenches were dug, 264 coppice stools assessed and over 18 000 roots were measured (Crow and Houston, in press). Figure 5 shows the mean root distribution data obtained for willow, plotted against a typical excavated trench profile.

Figure 5

Plot of mean root distribution for willow SRC.



The rooting habits were found to be influenced by many variables and too complex to predict accurately but the following conclusions could be made:

- Regardless of soil type, typically 75–95 % of willow and poplar SRC roots occurred within the topsoil (0–20/30 cm).
- SRC roots were found to a depth of over 1.3 m in some soils, but were few in number. (When grown in uncompacted soils many agricultural crops will produce roots to a depth of 1–1.5 m: Weaver, 1926.)
- Typically, at least two-thirds of the SRC roots were less than 1 mm diameter. Root diameters decreased with increasing depth.
- SRC poplars had larger stem and maximum root diameters than willows of the same age and management.
- A significant relationship was found between maximum root diameter and maximum stem diameter for poplars ($p<0.005$) and willows ($p<0.001$).
- SRC subject to greater exposure or less competition (e.g. at the plot edge) developed significantly larger root diameters ($p<0.001$).
- Poplars on well-drained soils had more and deeper roots than on other soil types. Wetter soils supported shallower root systems.

The depth of SRC root systems measured was very similar to common agricultural crops. Some SRC roots are clearly thicker than those of other crops, but regular harvesting of the coppice stems was found to inhibit large root development. The implications for any buried archaeological evidence will be site specific. However, where important archaeological evidence is known to exist just below the agricultural topsoil, SRC establishment would rarely be encouraged as the recommended cultivation usually involves deeper subsoiling to aid root growth and break any compacted soils (Ledin and Willebrand, 1996; Tubby and Armstrong, 2002).

This work has provided valuable information as the basis for guidance for landowners and archaeologists considering land for SRC establishment (Crow and Houston, in press).

Managing the vegetation cover of earthworks

In established forests and woodlands, tree retention may be acceptable on some types of archaeological site. However, what is usually poorly understood is the full extent of buried archaeological evidence on such a site, and how tree root growth may affect it.

While tree cover is managed to prevent windthrow, the long life of structural tree roots may provide a stabilising lattice to support the form of an earthwork such as a bank. Where appropriate and possible, coppice silviculture may offer long-term soil stability with reduced risk of windthrow compared with high forest management (Harmer and Howe, 2003). Knowledge of the rooting habits, water requirements and the environmental chemistry under different tree species can also be used to reduce risks of some potential impacts (Crow, 2004).

To maintain an archaeological site in open grassland, vegetation management will usually be required and possibly some measures to avoid erosion or to control burrowing animals. Nevertheless, the opening of areas through purposeful deforestation in the interests of both the archaeological evidence and their landscape setting has been successful in many places. However, preventing the re-establishment of scrub, bracken or other unwanted plant species on a site will always require some degree of active management.

Vegetation monitoring methods

To aid the development of effective scheduled ancient monument management plans within the Forestry Commission estate, vegetation monitoring is under way on a sample of earthworks in southern England at three surveying/monitoring levels. These are briefly outlined opposite, with an illustration of the data collected for each (Figures 6, 7 and 8).

During the past three years, some of the sample study sites have seen considerable changes in vegetation. For example, one enclosure with sycamore regeneration of up to 3 m, seen during the survey of 2001 (Figure 9a), was successfully cleared from the earthworks, as shown in Figure 9b. Annual mowing is now in place to maintain the site. These photographs clearly illustrate the need for continual vegetation management to maintain an earthwork, with the actual amount of work required being site-specific.

Where trees remain on a monument, such monitoring also provides a method of recording disease or damage. On another settlement site in Hampshire, this led to an assessment of wind firmness and general health of the trees, resulting in a selective thinning to prevent any damage to the earthworks through windthrow. On some monuments there are different floral communities associated with the banks and ditches. For example, below the canopy of the thinned monument, the initial spring survey showed parts of the bank to be dominated by bluebell (*Hyacinthoides non-scriptus*), while dog's mercury (*Mercurialis perennis*) was more abundant in the ditch. However, this pattern was not found across the whole monument and may simply reflect the natural occurrence of a different soil type. Whether or not such changes were due to bank/ditch induced environmental conditions (such as soil moisture) and could thus be used to map the location of any eroded features will require further study.

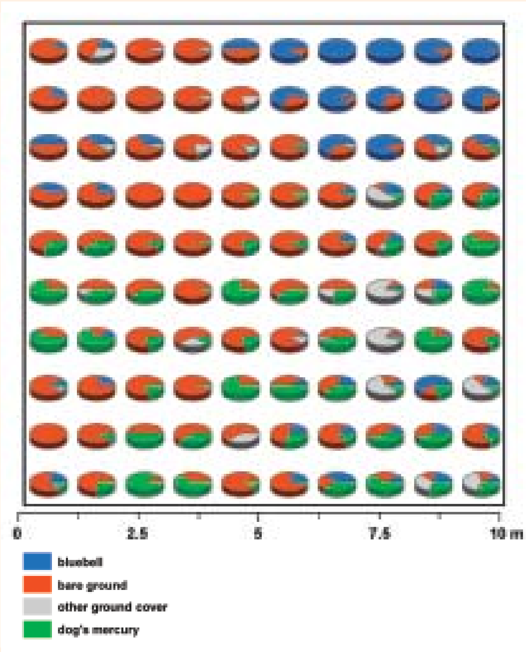
All archaeological earthworks will need an active management plan to prevent the establishment/proliferation of unwanted vegetation types and reduce the risk of site damage or enhance the monument setting. Vegetation monitoring (even in its simplest form) should be considered as it provides a method of assessing the effectiveness of such plans. And, when combined with GIS, it also allows longer term changes in both the condition of the monument and its environment to be examined.

Intensive survey

This examines a monument section (typically bank and ditch section) using a 10 m^2 survey grid divided into 100 quadrats. Each plant species is recorded as a percentage of the ground cover within each quadrat. Over successive surveys, this technique will allow very small vegetation changes to be resolved and is particularly well suited to smaller monuments such as barrows.

Figure 6

Intensive survey: suitable for smaller monuments.

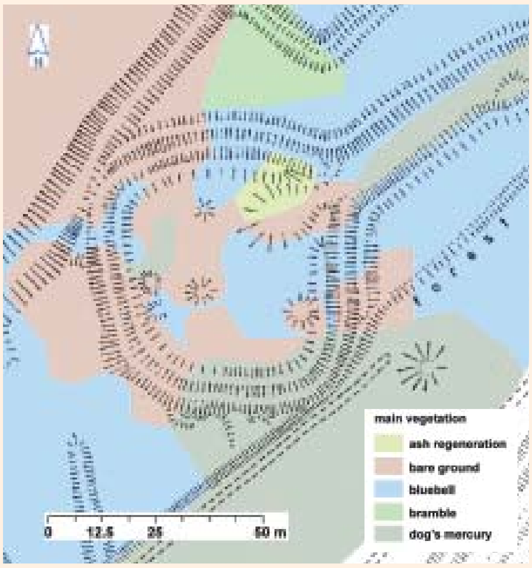


Walk-over survey

The main plant communities are recorded as areas drawn onto a map of the earthworks. This is unlikely to show gradual or minor changes but will enable differences to be mapped following active management or rapid vegetation succession. This method is more appropriate to larger monuments.

Figure 7

Walkover survey: suitable for larger monuments.



Photographic record

This is the simplest method and involves taking photographs of the monument from a selection of viewpoints. Subsequent photographs of the same views allow changes in vegetation to be monitored.

Figure 8

Monitoring by photographic record.

Figure 9

Vegetation cover on a Hampshire settlement enclosure (a) before and (b) after clearing.

The way ahead

Many current and proposed types of land use and management issues could potentially have implications for the preservation of the historic environment. Examples include:

- The increasing public awareness and interest in the historic environment.
- The government commitment to sustainable forest management and increased use of biofuels such as SRC.
- The Forestry Commission's commitment to increase the non-timber value of the estate by improving visitor access and social benefits, enhancing biodiversity and implementing conservation or restoration projects.

The research under this programme is essential in order to address these and other issues outlined in Box 1, through sustainable forestry. The varied nature of these issues and historic environment features is reflected by the range of research projects carried out under this programme. In addition to the three projects outlined above, Box 2 lists other examples of current and planned research projects.

Box 2

Ongoing and planned research projects.

- Continued research collaboration and communication with other organisations to increase awareness and understanding of the subject area
- Fundamental study of archaeological features in woodland environments to ascertain rooting impacts
- Hydrological monitoring of the Gloucestershire floodplain forestry case study site
- Monitoring of the Forestry Commission's management guidance and practice of both archaeological and biocultural features
- Evaluation of the preservation of the archaeological resource in woodland soils
- Development of GIS as a tool for the management and research of historic environment features
- Examination of the potential and practical applications of remote sensing as a tool for surveying woodland environments
- Development of a decision support guide to assist in the management of the historic environment
- Provision of advice through research on the management of existing and future veteran trees
- Study of the pollen production of different tree species under coppice silviculture and assessment of implications for palynology and palaeoenvironmental interpretation

This work will significantly improve our understanding of how woodland management influences the survival of historic environment and subsequently more informed decisions will be possible.

Considering the diverse variety of historic environment features and their different surroundings, more site-specific guidance is required. This will be taken forward in the forthcoming revision of *Forests and archaeology guidelines*, to be retitled *Forests and historic environment guidelines*, to reflect the wider heritage values and underpin *The UK forestry standard*. At a time when there are increasing demands on land use, sensitive woodland management can offer a setting in which archaeological evidence can be conserved, enhancing both the landscape and its value as well as the wider historic environment.

Acknowledgements

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Genetic conservation of native trees

Scott McG. Wilson[1] and C. J. A. Samuel

Over recent years, the genetic conservation of British native tree populations has become an increasingly important part of the work of Tree Improvement Branch (TIB). This has been in response to a greater interest from forestry policy-makers in the genetic basis of forest biodiversity conservation, both at the UK and, more especially, the European level.

[1]Consultant Forester and Forest Ecologist, 3 Thorngrove Crescent, Aberdeen, AB15 7 EH

Hornbeam at Brickett's Wood Common, Hertfordshire

Ash at Castle Eden Dene, Durham

Birch at Borrowdale, Cumbria

Introduction

The Forestry Commission (FC) recently published Technical Paper 31: *Genetic variation and conservation of British native trees and shrubs: current knowledge and policy implications* (Ennos *et al*., 2000) which is based on a literature survey carried out for the FC by the University of Edinburgh. One of the main conclusions was that there is a need to explore the extent and implications of genetic variation within the gene-pools of British native tree species. It was acknowledged that this is an area which has been under-researched in the past.

In 1999 the FC introduced a voluntary scheme which recommended the use of local-origin planting stock for native trees and shrubs, especially where these are being planted in or near existing ancient woodland. This scheme is set out in Practice Note 8 (Herbert *et al*., 1999). The scheme is based on a system of local seed zones, defined using topographical criteria. We do not yet have sufficient knowledge of actual genetic variation within individual tree species to delineate zones on any other basis, such as the 'biochemical zones' adopted earlier for Caledonian Scots pine. The new Forest Reproductive Material (FRM) Regulations, which came into force at the beginning of 2003, now cover a much wider range of British native tree species than was previously the case: 31 species relevant to forestry in Britain and 15 of these are native.

The FC is a member of EUFORGEN, a European organisation set up to co-ordinate research and policy on the conservation of forest genetic resources in Europe and participates in its Species Networks relevant to British forestry.

Biochemical and molecular research

Tree Improvement Branch (TIB) has previously participated in a small number of biochemical research projects to explore the nature of variation in selected British native tree species. This variation reflects the long-term genetic structure of tree populations, largely defined by their refugial distributions during the periods of Quaternary glaciation, and the spread out from these refugia thereafter.

Research led by Ian Forrest in the 1970s and 1980s on Caledonian Scots pine (*Pinus sylvestris* var. *scotica*) showed that the Scottish gene-pool was made up of a number of distinct regional-scale genetic units, based on the monoterpene composition of resin. Those on the north-west coast of Scotland were particularly divergent, and might indicate descent of populations in these areas from oceanic as opposed to continental glacial refugia. This work led to the establishment of a system of biochemical seed zones which have guided the sourcing of seed stock for the extensive Native Pinewood Scheme planting programme. Currently Scots pine is the only species for which we have this level of genetic understanding.

More recently, Joan Cottrell has led research into the genetic structure of British native oak populations, as part of a wider European investigation of post-glacial migration routes of oak species from glacial refugia. This work was described in the *Forest Research annual report and accounts* 1999–2000 (Cottrell, 2001). Chloroplast DNA investigations have continued and include work on veteran oak trees and the refugial origins of black poplar (*Populus nigra* var. *betulifolia*).

Population inventory project

Biochemical and molecular research make use of neutral markers which are unlikely to be affected by local selection pressures. With the publication of Technical Paper 31, it became clear that it was necessary to initiate work on *adaptive* genetic variation in British native trees. This is the type of genetic diversity that allows individual populations of native trees to become well adapted to their local environmental conditions. Knowledge of such variation is essential to inform seed sourcing and zonation regimes and to ensure the use of well-adapted planting stock for new native woodland planting schemes in the future. It should help to address the question, 'How local is local?' that is often asked by practitioners in this area.

Adaptive variation must be examined by carrying out *provenance trials* or *common garden experiments* which test the performance of material derived from a range of seed origins of a particular tree species under a range of environmental conditions. These are usually rather long-term studies due to the slow growth rates and long life cycles of native trees.

The first task was to identify suitable source populations of each native tree species for testing in such trials as there was no such list for any species other than Caledonian Scots pine. A comprehensive inventory database of natural tree populations throughout Great Britain was thus required. It was also intended that the creation of such an inventory of potential seed source populations would support the adoption of the voluntary local-origin scheme set out in Forest Practice Note 8 and the compliance with the terms of the new FRM regulations where these apply.

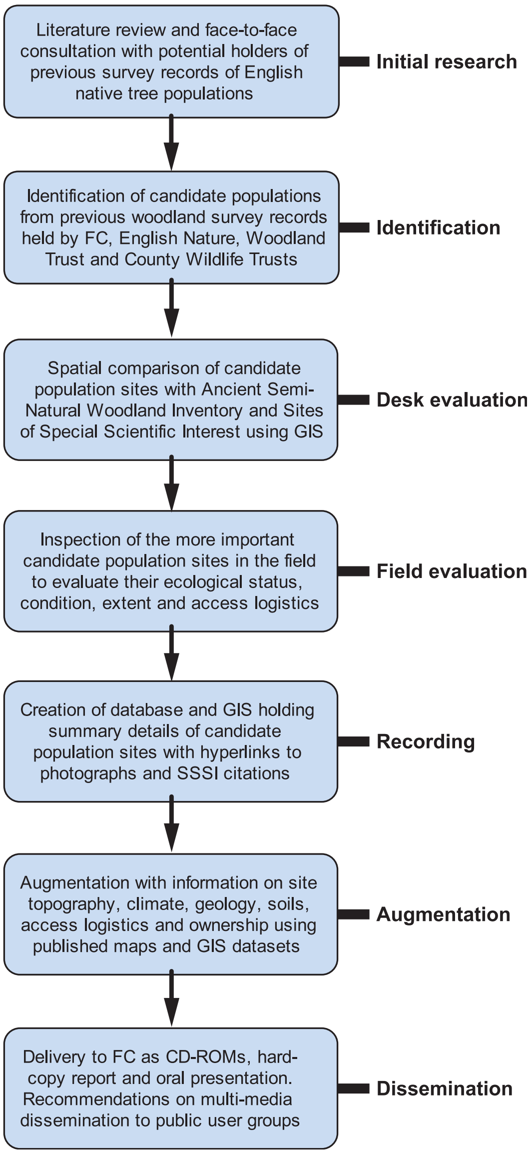
Fortuitously, such an inventory database had already been created for Scotland between 1998 and 2000 by Dr Scott Wilson, as a research project funded by the Scottish Forestry Trust. In 2000 the FC had supported the extension of this work to cover Wales, and between 2001 and 2003, coverage was also extended to include England, thereby providing a GB-wide inventory prepared to a common standard.

The inventory database comprises a register of important populations of each of the native tree species that are thought to be site-natural. The species on the database include all the native trees in each region, and some important bush/shrub species. Populations were selected, where possible, which have sufficient breeding individuals to ensure genetic sustainability (usually more than 30 trees is considered sufficient).

A summary of the stages involved in developing the inventory is presented in Figure 1.

Figure 1

From initial research to dissemination: the seven stages of the population inventory project.



The populations for inclusion on the inventory database were initially identified from existing sources of woodland survey information held by conservation bodies such as Scottish Natural Heritage, English Nature and the Countryside Council for Wales. A variety of independent organisations (such as Wildlife Trusts) and research workers also suggested appropriate populations. Following this initial review of existing resources, intensive fieldwork was carried out throughout the UK, visiting most significant areas of ancient semi-natural woodland to locate and assess native tree populations for inclusion. As a result the database includes tree populations at more than

Figure 2

Oak - Sharpnage Wood, Herefordshire.

Figure 3

Beech - Workman's Wood, Cotswolds.

2000 locations throughout the country, and covers 25 species ranging from major broadleaves such as oak and ash to mature cherries and limes. Some examples of individual populations included in the inventory for a range of species appear in Figures 2, 3 and 4 and on the title page (page 56).

As well as the map locations and native tree species present, the database records a range of site ecological details (e.g. climate, geology and soils). This will be of value in selecting a representative portfolio of source populations for provenance trials or in matching the ecological needs of particular planting schemes with potential seed sources. The database also contains appraisals of the accessibility of the individual sites for seed collections and of their conservation designations and ownership. A large catalogue of digitised site photographs can also be accessed from the database.In addition it is equipped with a Geographical Information System (GIS) map interface which makes it straightforward to carry out spatial analyses of population distribution, clustering and proximity.

Figure 4

Alder - New Forest, Hampshire.

Examples of population distribution of two species (bird cherry and hornbeam) in England are given in Figure 5a and b.

Figure 5

Distribution of (a) bird cherry and (b) hornbeam populations in England; black dots are key populations.

(a)

(b)

One of the main research challenges which the inventory work has highlighted is the difficulty in establishing objectively whether native tree populations are indeed site-natural. Given the very long record of tree planting in this country, frequently using seed or plants imported from mainland Europe, it is often impossible to be certain from site inspections that populations of mature trees are natural. A variety of spatial analysis techniques have been used to attempt to deal with this, such as comparing the population site locations with the Ancient Woodland Inventory and the boundaries of Sites of Special Scientific Interest. Coincidence with this type of record was used to support identification of material as site-natural. However it is recognised that in many cases only a 'balance of probability of naturalness' can be established. A pilot evaluation of the use of detailed historical archives (e.g. estate papers) was undertaken by the first author to assess the naturalness of tree populations, but this proved extremely time consuming and rarely yielded the degree of certainty sought.

At a more logistical level it has also become apparent that seed collection from many natural woodlands may raise potential practical difficulties and incur increased costs. In the lowlands, the density of many former coppice woodlands almost certainly limits seed production and may make it physically arduous to collect seed. In some woodlands on designated sites seed collection may conflict with conservation objectives (e.g. when cutting back undergrowth for access). For these reasons it may be necessary to consider arranging single collections of seed or vegetative material which could be used to generate seed production on another site in a seed orchard or other specific plantation.

Future work

The Forestry Commission intends to develop the work by making the inventory database contents more widely available to the research, seed-collecting, nursery and tree-planting sectors throughout Great Britain. In Scotland this process was initiated by a publication by the Scottish Forestry Trust (Wilson *et al.*, 2000). In Wales the Forestry Commission has now established an advisory contact who can deal with seed sourcing queries, making reference to the inventory database (Wilson and Jenkins, 2001). Consideration is now being given to how this can best be handled for England, and for GB as a whole, recognising that both printed and electronic media approaches could be used. Before this can proceed it is necessary to consult with population site owners and to make provision for future updating and revision of the inventory database as required.

With the completion of the inventory work in 2003, TIB is now much better placed to initiate the establishment of the planned provenance trials for selected native tree species. Work is already under way on silver birch, in which trials of over 60 natural populations sampled throughout Great Britain have been laid out in 10 contrasting and widely distributed sites, including one in the south of the Republic of Ireland. The approach follows the objectives of the British and Irish Hardwood Improvement Programme (BIHIP) Silver Birch Group and the database has been used to identify candidate populations. The BIHIP Ash Group has also benefited in searching for populations in which to select superior candidate trees for breeding work. TIB is currently evaluating the best way forward for establishing provenance trials for other native tree species, for which seed collections from populations on the inventory database are likely to be made in due course. As with many topics in forestry research this is inevitably a long-term programme.

The Forestry Commission is currently reviewing its policy on encouraging the use of local-origin planting material for creating new woodlands of native species. The overall objective is to reduce the proportion of planting material which comes from geographically distant locations or from overseas.

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Stem straightness in Sitka spruce

Jason Hubert, Barry Gardiner, Elspeth Macdonald and Shaun Mochan

The successful large-scale establishment of Sitka spruce has lead to this species becoming the predominant source of timber in many parts of the UK. The pace of establishment increased in the 1960–70s, bringing with it the need to plant on more demanding sites; at the same time wider initial spacings were being used, more fertiliser was needed for establishment and, latterly, a greater proportion of sites managed under a non-thin regime. As these sites come to be felled increased concern has been voiced by the sawmilling industry that the quality of timber coming onto the market has been declining and that this trend is set to continue for the next 10 years. Given this concern and the opportunities afforded by restocking to alter basic silviculture, growers need to become more aware of the potential to improve timber quality through silvicultural management.

Inspecting dried spruce timber at a sawmill in Aboyne, Scotland

Using a medical CT scanner to measure the density of Sitka spruce discs

Logs from experiment on timber quality of wind blown spruce at a sawmill in Carrbridge, Scotland

Introduction

The objective for improvement of quality is to increase the amount of construction grade material available from the forest since this is a market with potential to grow, and within which market penetration by UK timber is still relatively weak. The market for lower quality timber, used in fencing and pallets, is currently close to saturation and unlikely to expand sufficiently to absorb the predicted increase in volume becoming available (McIntosh, 1997). The main criteria for construction grade timber are that it should be straight, strong and competitive economically. These three broad criteria are a function of a myriad of other factors ranging from the cellular structure of the wood to management decisions such as rotation length, most of which can be altered either by silviculture or genetic manipulation (Macdonald and Hubert, 2002). However, for a stand that is about to be felled there is little opportunity to alter the state of the crop and the assessment of quality commonly undertaken is subjective. For Sitka spruce this is essentially an estimate of the proportion of straight stems in the crop since branch size, and hence knots in the timber, is rarely a problem (Forestry Commission, 1993).

Methley (1998) initially developed an objective method of assessing stem straightness in Sitka spruce based on visually estimating the number and length of sawlogs that could be cut in the first 6 m of the tree. The definition of sawlog used was based on the green log classification; namely that bends must be less than 1 cm deviation in a metre length (Forestry Commission, 1993). The minimum log length was 2 m and the maximum was 4 m. Her initial work demonstrated that consistent results could be obtained from different assessors and that assessments undertaken in the field provided a reasonable method of predicting relative out-turns from stands once processed at a sawmill. Macdonald *et al.* (2001) further developed the methodology, adding another log class, 5 m, and undertook a number of trials to establish a fast, consistent method of assessment that could be used for surveying a large number of sites.

Survey methodology

Three surveys of stem straightness in Sitka spruce have been undertaken using the assessment protocol developed by Macdonald *et al.* (2001). The first surveyed South Scotland, Dumfries and Galloway, and the Borders; the second covered Kielder Forest District, Argyll, Grampian and Highlands regions, and the third covered Wales (Stirling *et al.*, 2000; Mochan *et al.*, 2001; Mochan *et al.*, 2002); see Figures 1 and 2. In all the surveys site selection was undertaken randomly after stratification by planting year, yield class, thinned or not and, where available, initial stocking. The area surveyed in each stratum was balanced so that the survey as a whole assessed a similar percentage of the total cover of Sitka spruce regardless of age or ownership types (e.g. FC or private). The stratification criteria are listed in Table 1. For all the surveys, sites were selected to allow replication within each stratum to facilitate statistical modelling of the data. In some instances certain combinations of planting year, yield class and thinning history could not be found.

Figure 1

Survey sites in Scotland and northern England. The first survey covered Dumfries and Galloway and the Borders, and the second the other regions.

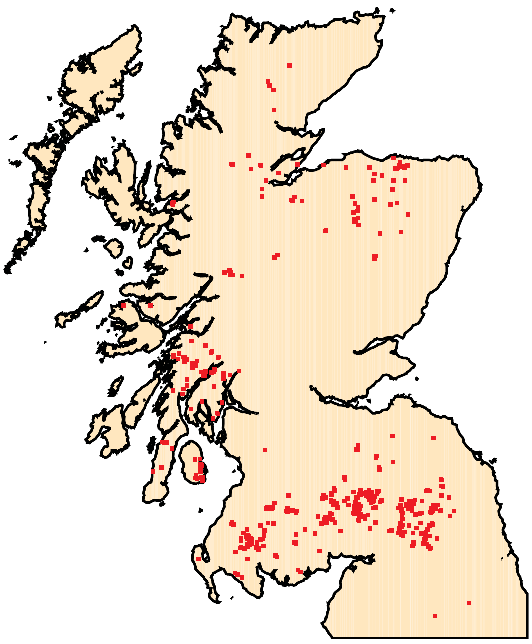
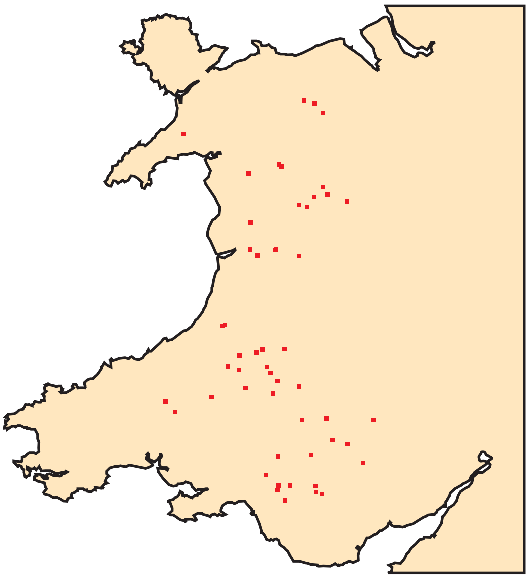


Figure 2

Sites for the third survey in Wales.



At each stand stem straightness was assessed using randomly located 3 m wide linear transects following random bearings. Each linear plot consisted of the first 10 trees encountered with diameters greater than a set minimum. The minimum diameters were based on assumptions of growth for an average stand of YC 14 such that at felling age (estimated to be 55 years) the trees assessed would all be of sufficient size to yield a 6 m sawlog. Each site contained 8 or 10 plots depending on its area. In addition to assessing stem straightness the sites were measured for dbh, forking, top height, between and within row spacing plus slope for correction, and thinning history. Additional information on elevation and DAMS (windiness) was obtained using the grid reference. In order to provide consistent scoring across the survey the number of assessors was kept to a minimum and a sub-sample of sites was reassessed by the person who had originally trained all the assessors.

Results and discussion

The scale of the surveys can be judged from Table 2. The South Scotland survey was the most intensive and replication was higher than in the subsequent two surveys in order to provide sufficient data for modelling. The Rest of Scotland survey data were used to validate the model developed in South Scotland, but it was found that regional differences were too great and hence different regional models needed to be developed.

Table 1

Survey stratification criteria.

Survey	Location	Stratification criteria
South Scotland	Dumfries and Galloway; Borders	Pyear: Pre-1961, 1961–70, 1971–75 YC: >6≤12, 14–16, ≥18 Thinning: thinned, non-thin Initial spacing: ≤1.7 m, 1.8–2.0 m, ≥2.1 m
Rest of Scotland	Argyll, Grampian, Highland and NE England	Pyear: Pre-1961, 1961–70, 1971–75 YC: >6≤12, 14–16, ≥18 Thinning: thinned, non-thin
Wales	All regions of Wales	Pyear: Pre-1961, 1961–70, 1971–75 YC: >6≤12, 14–16, ≥18 Thinning: thinned, non-thin

Table 2

The number of sites, trees and the percentage of Sitka spruce surveyed in each survey of stem straightness.

Survey	Number of sites	Number of trees	Area of Sitka surveyed (ha)	% area of Sitka cover assessed
South Scotland	257	23 100	FC: 1,618 Private: 1,160	FC: 3.9 Private: 2.5
Rest of Scotland Argyll, Highlands NE England and Grampian	212	18 319	FC: 1,897 Private: 915	FC: 1.9 Private: 1.9
Wales	54	4 490	FC: 614 Private: 279	FC: 1.9 Private: 1.8

Planting year and diameter

In all the surveys planting year was the factor most strongly associated with stem straightness. In all cases the more recent planting years were linked to poorer form trees. When looked at in terms of dbh, smaller trees tended to have poorer form than larger diameter trees. Interestingly, this could be observed both between stands and within a stand. This apparent connection between dbh and stem straightness in Sitka spruce suggests two possible mechanisms. Either that leader loss was the cause of bending in Sitka, having lost a leader the tree was less able to compete with its straighter neighbours, or that as trees become suppressed they tend to bend towards gaps in the canopy. Once competition had started in the stand the shorter, bent trees would become suppressed and hence lead to the observation. Since the survey was assessing trees of a minimum diameter size the suppression of poorer form trees would provide a strong link between form and planting year, with the older stands having experienced a longer period of within-stand suppression and mortality. This raises the possibility that stands might improve with age but as yet this hypothesis has not been tested.

Thinning

For all the surveys thinning had a positive effect on the overall stem straightness of a stand. This is as expected since some of the thinning was selective in nature. Interestingly, when modelled with all the other factors there was a negative interaction with DAMS, i.e. exposure (Quine and White, 1993), for the rest of Scotland survey. This suggests that on more exposed sites thinning can reduce stem straightness, possibly by increasing the exposure each individual tree experiences and increasing the overall risk of leader loss.

Yield class

The association between yield class and stem straightness is not clear except in Wales where there is a positive correlation between increasing yield class and better stem form. The fact that this is not the case further north, and indeed in some areas the reverse is true, suggests that other environmental factors are dominant. For instance it is possible that the more severe wind climate or earlier autumn frosts are causing greater damage to the faster growing leaders of higher yield class stands in Scotland than in Wales, where the trees are growing in a generally more favourable environment.

Initial spacing

Again the association between initial spacing and stem straightness is not clear-cut. In general, for Scotland and northern England, where there is a clear trend, it appears that higher initial stocking densities provide straighter trees. However, this is not uniformly the case, for instance in Argyll it appears that higher stocking densities are associated with poorer form. In Wales there is no statistically significant relationship between initial stocking density and form. Where stocking does contribute towards a model it is always a very minor contributor to the overall prediction of mean stem straightness for a site.

Wind exposure and altitude

Wind exposure and altitude are significant factors for the two surveys conducted in Scotland and Northern England but not for the survey in Wales. In all the cases where they were significant factors, an increase in wind exposure or altitude was associated with a decrease in stem form. The most likely explanation for this observation is that increased exposure, especially to summer gales when new growth is less lignified, will lead to greater leader damage or loss resulting in the promotion of a branch to a leader. This will cause a permanent kink in the stem. The effect of a summer gale on a fast growing plantation of Sitka spruce was reported by Baldwin (1993) who examined the levels of leader loss at a fertiliser experiment. He found significantly greater damage in the fertilised plots than the non-fertilised control plots, indicating one of the controlling factors for stem straightness and also the potential drawback of a high yield class site in an exposed location.

Forecasting quality in Sitka spruce

At present the Forestry Commission provides long-term production forecasts, which allow users to estimate the volumes (broken down by species and size categories) of timber coming on to the market over the next 20 years; see for example, Rothnie and Selmes (1996). One drawback of the current forecasts is that they cannot predict the quality of the timber that will be produced. This is particularly important for sawlog size timber since this is the largest fraction produced and also the most valuable. Providing an estimate of both the volume and the quality of the timber coming onto the market, and hence an estimate of the value, will assist the industry when making long-term investment decisions.

The stem straightness surveys produced a variety of statistical models that allow the mean straightness score of a stand to be predicted from factors such as planting year, yield class, thinning

Figure 3

Relationship between estimated % green log volume per plot and plot mean standing straightness score from work at four different sites: Wauchope, Rosarie, Clatteringshaws and Tywi.

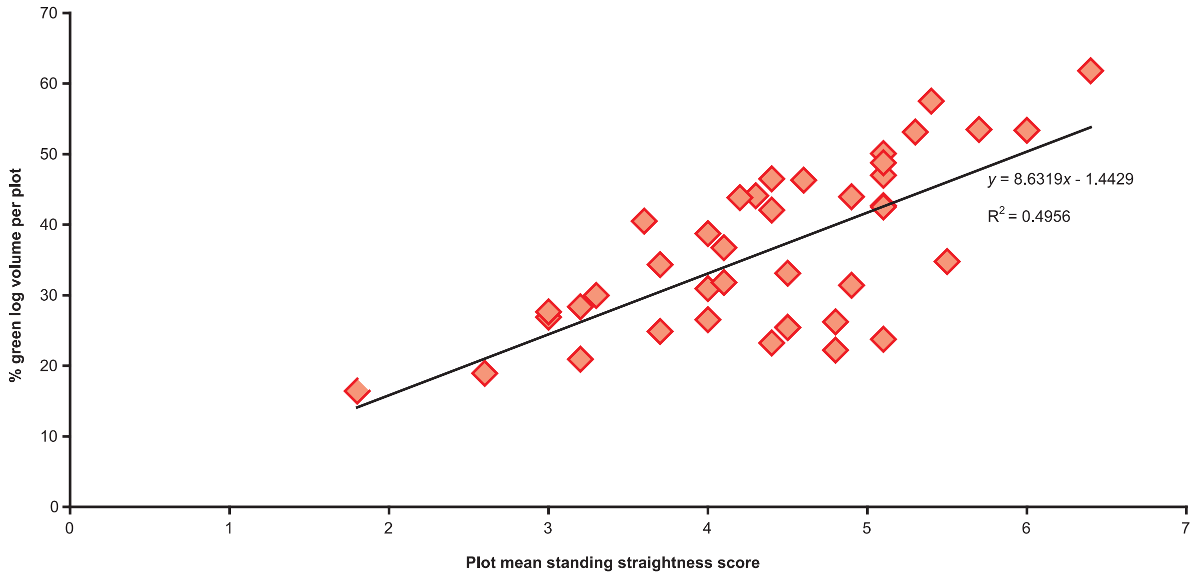


Figure 4

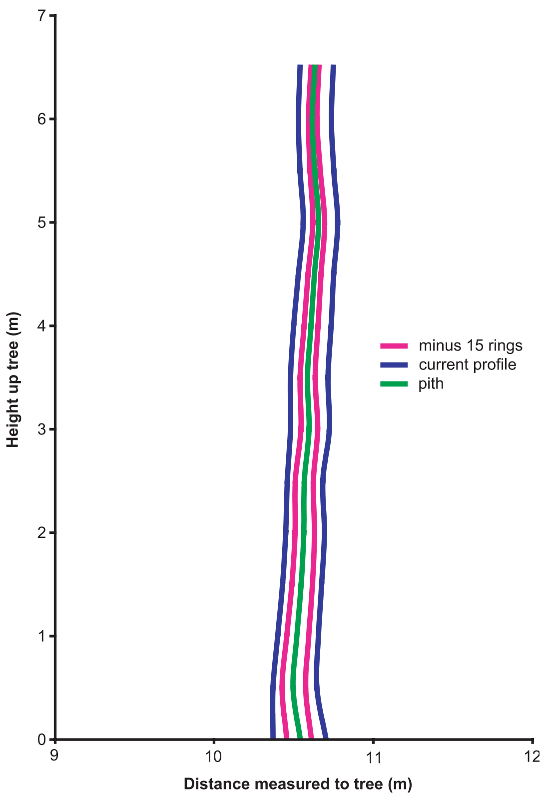
Using a laser relascope to create an accurate external profile of the tree on two sides (north and west).

history, stocking density and wind exposure (DAMS score). Since the mean straightness score of a stand is based on the assessment of green logs in the first 6 m of the tree, it should be linked to the proportion of green log volume in the stand. Work undertaken at four sites of different quality and located in different parts of the country has shown that this is the case (Figure 3). Hence it should now be possible, within the limits of the accuracy of the statistical models, to estimate the proportion of green logs as part of the total volume for any stands of Sitka spruce planted prior to 1975. However, one limitation of the models is that they provide an analysis of the situation at the time of the survey. Hence using them to predict stem straightness in the future requires the assumption that the trees themselves do not alter form over the period of the forecast and that the quality of the stand as a whole does not alter due to stand dynamics.

In order to test the first assumption, that the individual trees do not alter shape sufficiently to change their straightness score over 10–15 years, a pilot study was carried out (Macdonald and Barrette, 2001). This study examined 10 trees of differing straightness score in a stand using a laser relascope to create an accurate external profile of the tree on two sides (north and west; Figure 4). The trees were then felled and disks taken at 0.5 m intervals up the trunk to coincide with the laser measurement points.

Figure 5

Recreating the shape of the trunk at half-metre intervals up the stem.



Accurate measurement of ring widths from pith to bark along the two perpendicular radii (north and west) made it possible to recreate the shape of the trunk at 5 yearly intervals in the past (Figure 5). Analyses of these profiles showed that in all but one case the trees did not straighten sufficiently to alter the straightness score over 15 years of growth and the single tree that did improve did so by only one score. This suggested that on an individual tree scale it was possible to predict stem quality 15–20 years in the future.

The second assumption, that stands will not alter their mean straightness score over the forecast period, is still undergoing testing. The fact that there is a pronounced association between planting year and stem straightness and a similar link both between and within stands for dbh indicates that suppression and mortality is more common for trees of poorer form. Since poor form in Sitka spruce is likely to be due to leader loss and hence a loss of a season's growth there exists a plausible mechanism to explain the observation. Currently research is ongoing to explore the rate at which this occurs and hence the time-scale over which a forecast would be valid.

Conclusions

For all the surveys, the main observation is a very strong link between planting year and stem straightness, with the more recent planting years showing poorer straightness. The survey provides a snapshot of the situation at present but this is unlikely to alter greatly over the next 5 years. Hence, as a greater number of these more recent plantings are harvested, the general trend in log out-turn will be to see an increase in the proportion of red logs and short green logs in the total production volume. One of the challenges for the forest industry will be to market short green logs. However, as the total volume is currently predicted to increase until 2020 the actual volume of green logs is also likely to increase in this period.

Managers should aim to extend rotations and thin where possible, although the wind climate in some regions will place obvious limits to these options. Another factor to consider when restocking is to design felling and restocking coupes to maximise shelter in the restock sites using existing crops. This, and striving to attain full stocking for mutual shelter, should reduce the extent of wind damage to the leaders and therefore reduce the level of stem defects.

Acknowledgements

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Climate change and British woodland: what does the future hold?

Mark Broadmeadow, Duncan Ray, Louise Sing and Liz Poulsom

There is now convincing evidence that the climate is changing at an unprecedented rate for modern times, at both a global and a national scale. Models predict that this change will continue, causing parts of the UK to be subject to climatic extremes beyond those experienced since before the last ice-age. The potentially serious consequences of predicted climate change for British woodland are reviewed here, together with their implications for future species suitability.

Open-top chamber used for air pollution and climate change research

Frost damage to Norway spruce

Forest fires may be more of a cause for concern in the future

Background

In 2001, the Intergovernmental Panel on Climate Change (IPCC) stated that *'the earth's climate system has demonstrably changed on both global and regional scales since the pre-industrial era, with some of these changes attributable to human activity'* (IPCC, 2001). Although the magnitude of the global rise in temperature of 0.6 ^{o}C may seem small, the rate of change is unprecedented. The global temperature increase has been accompanied by a similar change in the UK, with the 1990s the warmest decade on record (about 0.5 ^{o}C above the 1961–90 average), and six of the seven warmest years since 1659 having occurred between 1989 and 2002 (the Central England Temperature Record: CET). The rise in global temperature has been attributed to the emission of carbon dioxide (CO_2) and other greenhouse gases resulting from human activities including deforestation and fossil fuel burning, and is expected to continue.

The predictions of ongoing climate change are based on global development 'story-lines' linked to emissions scenarios which range from an environmentally sustainable global future with the rapid uptake of renewable energy, to a continuing reliance on fossil fuels and a global market economy (IPCC, 2000; IPCC, 2001). In turn, these emissions scenarios are used as input to global climate models (GCMs), with the output of one (HADCM3: developed by the UK Meteorological Office) used to generate climate change scenarios for the UK.

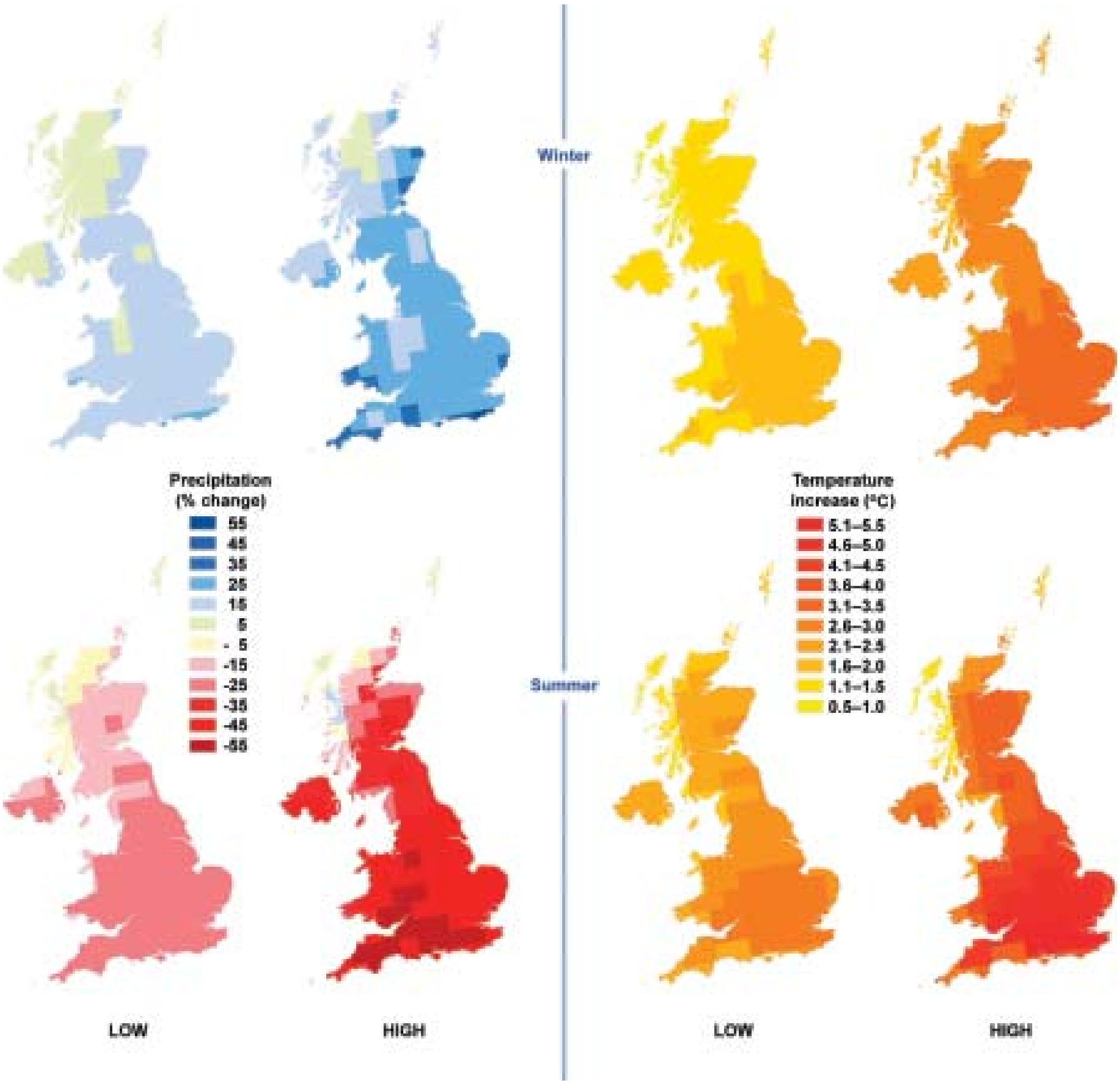
The UKCIP02 scenarios

New climate scenarios for the UK were produced by the Tyndall and Hadley Centres on behalf of Defra and published in May 2002 (Hulme *et al.*, 2002). These new scenarios include a better spatial representation of the UK than the earlier UKCIP98 scenarios (Hulme and Jenkins, 1998), being based on a series of 96 50 x 50 km grid squares covering the UK land-mass. The scenarios provide predictions of mean climate, together with an indication of inter- and intra-annual variability in some variables over 30 year time-slices centred on the 2020s, 2050s and 2080s. For each time-slice, data are presented for four of the emissions scenarios given in IPCC (2000), and it is recommended that any assessment of the consequences of climate change covers the full range of scenarios. The scenarios are qualitatively similar to the earlier scenarios, although the magnitude of change is slightly larger. The climate of the late 21st century is predicted to be hotter and drier in summer, and milder and wetter in winter. The drier summer climate is now predicted to extend across the entire country, with the most extreme changes occurring in the south and east of England.

The global climate model on which the UKCIP02 scenarios are based has a detailed representation of the ocean currents, including an assumed weakening of the Gulf Stream. It is thought unlikely that the Gulf Stream will switch off completely, and that over the coming century the greenhouse gas forcing of the climate will outweigh any effects of changing ocean currents in the Atlantic. Maps showing changing temperature and precipitation patterns are shown in Figure 1 and a summary of changes to key meteorological variables for the northwest and southeast of Great Britain is given in Table 1.

Figure 1

Maps showing the UKCIP02 seasonal rainfall and temperature predictions for the 2080s Low and High emissions scenarios relative to the 1961–90 baseline. [Source: Hulme *et al.* (2002), produced by the Tyndall and Hadley Centres on behalf of Defra.]



The predictions of a 2 °C to 4.5 °C rise in temperature by the 2080s may seem small, but the magnitude of these predicted changes needs to be placed in context. Figure 2 shows summer and winter climate data for the UK Meteorological Office affiliated weather station at Alice Holt Research Station, Hampshire, together with the predictions of mean climate under the 2080s Low and High emissions scenarios. Over the past 50 years, the average summer temperature predicted for the Low emissions scenario in the 2080s has not been approached, including the extreme years of 1976, 1995 and 2003. The predictions for changes to winter temperatures are less extreme, but still highly significant. As a result of the high inter-annual variability in rainfall, predicted changes to winter rainfall are difficult to distinguish from natural variability, while for summer rainfall, a number of years (including 1976 and 1995) would fall into the 'normal' category for the 2080s under both the Low and High emissions scenarios.

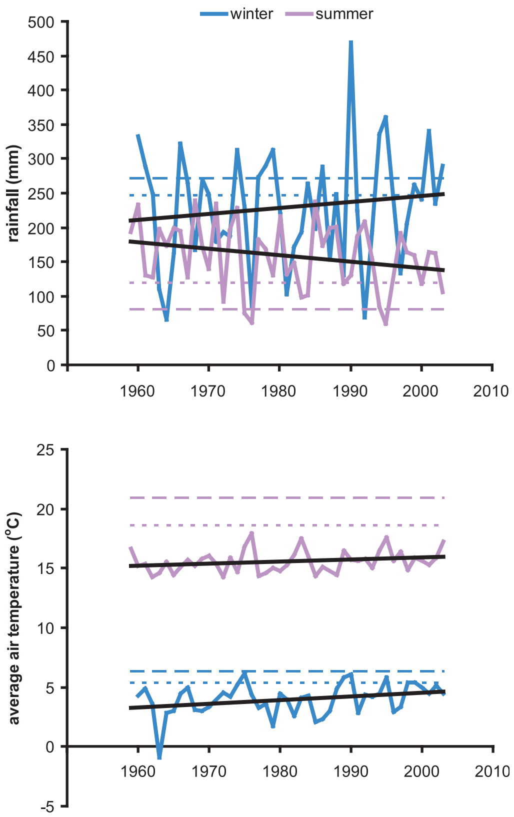
Table 1

UKCIP02 climate change predictions for the 2050s and 2080s for the Low and High emissions scenarios. Units of temperature change are degrees Celsius relative to the 1961–90 baseline, while all other variables are given as percentage change relative to the baseline. Southeast values are for the 50 km x 50 km grid-square in which Alice Holt Research Station, Hampshire is situated, while the northwest grid-square is centred on Fort William, Highland Region.

2050s	Low emissions scenario				High emissions scenario			
	winter		summer		winter		summer	
	northwest	southeast	northwest	southeast	northwest	southeast	northwest	southeast
Minimum temp. (°C)	+1.0	+1.2	+1.2	+1.8	+1.6	+1.9	+1.9	+2.8
Maximum temp. (°C)	+0.9	+1.2	+1.4	+2.3	+1.5	+1.8	+2.2	+3.7
Precipitation (%)	+4.3	+8.4	-7.6	-18.0	+6.8	+3.4	-12.1	-28.6
Snowfall (%)	-26.2	-40.0	-	-	-41.7	-63.6	-	-
Wind speed (%)	+0.6	+2.3	-1.0	+0.3	+0.9	+3.7	-1.6	+0.5
Soil moisture (%)	+2.0	-1.5	-2.4	-16.7	+3.1	-2.4	-3.9	-28.6
Relative humidity (%)	-0.3	-0.9	-1.0	-5.1	+0.5	+1.5	-1.6	-8.1
Absolute humidity (%)	+6.6	+7.5	+7.1	+4.4	+10.6	+11.9	+11.2	+7.0
Cloud cover (%)	+0.4	0	-1.7	-5.6	-0.9	0	+2.0	-9.0.
2080s	**Low emissions scenario**				**High emissions scenario**			
	winter		**summer**		**winter**		**summer**	
	northwest	**southeast**	**northwest**	**southeast**	**northwest**	**southeast**	**northwest**	**southeast**
Minimum temp. (°C)	+1.4	+1.7	+1.7	+2.5	+2.7	+3.3	+3.3	+4.8
Maximum temp. (°C)	+1.3	+1.6	+1.9	+3.3	+2.6	+3.2	+3.7	+6.4
Precipitation (%)	+6.1	+11.9	-10.8	-25.5	+11.8	+23.1	-21.0	-49.5
Snowfall (%)	-37.2	-56.8	-	-	-72.1	-100	-	-
Wind speed (%)	+0.8	+3.3	-1.4	+0.5	+1.6	+6.3	-2.8	+0.9
Soil moisture (%)	+2.8	-2.1	-3.5	-23.6	+5.5	-4.1	-6.7	-45.8
Relative humidity (%)	-0.4	-1.3	-1.5	-7.2	-0.8	-2.6	-2.9	-14.0
Absolute humidity (%)	+9.4	+10.6	+10.0	+6.3	+18.3	+20.6	+19.5	+12.2
Cloud cover (%)	+0.6	0	-2.4	-8.0	+1.1	0	-4.7	-15.4

Figure 2

Average summer and winter temperature (top) and rainfall (bottom) for Alice Holt Research Station, Hampshire. In each case, the general trend over the period 1959–2003 is indicated by the linear regression (solid line). The dotted and dashed lines represent the UKCIP02 Low and High emissions scenarios for the 2080s.



The likely effects of climate change on woodland in the UK

A changing climate has the potential to affect a woodland ecosystem in many ways, as summarised in Table 2. However, before the effects of a changing climate are considered, it is important to note that the atmospheric concentration of carbon dioxide – the main driver of human-induced climate change – affects the growth of trees directly. Current levels of CO_2 do not saturate photosynthesis, and so CO_2 emissions would be expected to enhance growth rates assuming all other environmental conditions remained constant. Experiments with young trees indicate that a doubling of the CO_2 concentration in the atmosphere may increase biomass production by 30–50%. Although mature trees are unlikely to respond as much in a forest environment (Oren *et al.*, 2001), some increase in productivity is likely and will be accompanied by a range of other effects including lower stomatal conductance and thus water use on a leaf area basis (Medlyn *et al.*, 2001), an increase in leaf area (Broadmeadow and Randle, 2002) and possible changes to timber quality (Savill and Mather, 1990) and the nutritional quality of foliage to insect herbivores (Watt *et al.*, 1996). Other important elements of atmospheric change that may affect trees and woodland are predicted increases in the concentration of ground-level (tropospheric) ozone, and changes to the pattern of nitrogen deposition.

Ozone is a phytotoxic pollutant which reduces forest productivity across Europe by up to 10% at current concentrations. The complex chemical reactions in the atmosphere which lead to its formation are linked to climate and global emissions of nitrogen oxides and volatile organic compounds (VOCs). Predictions are for an approximate doubling of concentrations by the end of this century (NEGTAP, 2001). At low levels of deposition, nitrogen enhances growth, but at higher concentrations it can affect woodland ecosystems by altering the competitive balance between species comprising the ground vegetation and by altering the susceptibility of trees to a number of factors including insect herbivory and frost damage (Kennedy, 2003). The effects of a narrow definition of climate change should thus not be viewed in isolation, but as one element in the wider process of environmental change.

Climatic and site factors determine which plant species will grow in a given location thus influencing the community structure and the identity of native woodland types, as well as the productivity of timber plantations. Climate change also has the potential to affect forestry activities by altering site conditions as summarised below.

Winter rainfall

In recent years, heavy winter rainfall has been suggested as indicative of a changing climate. For forestry, winter waterlogging affects the trafficability of forest soils and limits access of harvesting machinery for forestry operations if soil sustainability is to be maintained (Nisbet, 2002). Stands on waterlogged soils are more prone to windthrow (Ray and Nicholl, 1998), while waterlogging leads to the death of fine roots (Coutts and Philipson, 1978) thus accentuating the effects of high summer soil water deficits. Infection by various soil-borne pathogens including species of *Phytophthora* is promoted by fluctuating water tables (Lonsdale and Gibbs, 2002). Phytophthora diseases would thus be expected to become more prevalent on the basis of the predictions of wetter winters and drier summers.

Water availability in summer

In contrast, significantly less summer rainfall is predicted in southern England. Longer growing seasons and shorter winter recharge periods, together with higher evapo-transpiration during warmer summer months, will enhance soil moisture deficits in summer, with drought conditions becoming more severe and frequent. In addition to affecting some tree species directly, stress caused by drought will make trees more susceptible to pathogens, especially weak pathogens such as sooty bark disease of sycamore, and thus mortality is likely to increase. The effects of drought are likely to be observed initially on the establishment of young trees and trees in hedgerows and the urban environment. As climate change progresses, even established trees may be affected and thus the suitability and distribution of some species will change.

A further consequence of the predicted increase in the incidence and severity of summer droughts is a likely increase in forest fire damage (Nisbet, 2002). Although the majority of forest fires occur in early summer, severe and extended droughts can result in significant fire outbreaks in late summer, as was the case in 1976 (Cannell and McNally, 1997).

Snow and winter cold

Snowfall and thus snow damage will become less frequent as a result of rising temperatures. However, concerns have been raised that wetter snow and heavier falls will occur, potentially counteracting the benefits of climate change. Winter cold injury will become less frequent, but there is evidence to suggest that a predicted advance in flushing of up to one month could make some species more susceptible to spring frost damage. Higher temperatures in autumn may delay hardening and again make tissue, particularly the lammas growth of conifers, more susceptible to frost damage.

Wind climate

Predictions of the changes in the wind climate are among the least certain of the UKCIP02 scenarios. They do, however, indicate that the largest increases are likely to be in autumn in the south of the UK, contrasting with the earlier predictions of the largest changes in northwest Scotland. This is because the storm track is predicted to move further south together with an increased frequency of deep depressions crossing the UK in winter. Most damage to forests is caused by extreme events, and the frequency of these is still more difficult to predict. It should, however, be noted that a small change in mean wind speed can have a significant effect on the DAMS (Detailed Aspect Method of Scoring: Quine and White, 1993) wind exposure classification. Therefore, although the predictions for wind speed are far from robust, a changing wind climate in the uplands could impact on forestry.

Effects on pests and diseases

The effects of climate change on the incidence of pest and disease outbreaks are more difficult to predict because of the number of potential interactions. However, it is clear that existing pests such as the green spruce aphid are likely to become more prevalent as a result of lower winter mortality and increased fecundity and number of generations in a single year (Straw, 1995; Straw *et al.*, 2000). Potentially more worrying is the threat from insect pests and disease-causing agents which currently are not established in the UK. Both the Asian longhorn beetle *(Anoplophora glabripennis)* and the eight-

Table 2

Summary of the effects of predicted climate change on woodland and forestry. Indicative responses to changes in each environmental variable are given, but specific cases may differ from the general responses outlined.

Variable	Beneficial effects	Detrimental effects
Atmospheric CO_2	Increase in growth rate Reduction in stomatal conductance and lower water use on a leaf area basis	Reduction in timber quality Increase in leaf area and thus higher wind resistance and water use; lower light transmission also affects character of ground vegetation Possible nutrient imbalances
Ozone pollution		Reduction in growth rate Impaired stomatal function and thus increased susceptibility to drought
Temperature	Longer growing season Higher potential productivity Lower risk of winter cold damage Less snow damage Potential for use of species which are not hardy at present	Delayed hardening Risk of spring and autumn frost damage possibly increased Longer growing seasons reducing winter soil water recharge period Reduced winter mortality of insect and mammalian pests More rapid development and increased fecundity of insect and mammal pests Potential for exotic/alien pests to spread to the UK
Rainfall	Reduced intensity of some foliar pathogens	Winter waterlogging limiting access for forest operations and reducing stability Root death increasing susceptibility to drought and soil-borne pathogens Summer drought-induced mortality Facultative pathogens more damaging in stressed trees Possible increase in forest fires
Wind		Increased number of deep depressions increasing risk of wind damage, particularly in England
Cloud cover	Increased potential productivity	Increased diurnal temperature range in autumn increasing risk of frost damage

toothed spruce beetle *(Ips typographus)* have been recorded in recent years, while the recently discovered *Phytophthora ramorum* (the cause of sudden oak death in the USA) has been identified in nurseries and some isolated trees in Britain. Although the global nature of the timber trade rather than climate change may be the main factor behind their arrival, predictions are for the climate of the UK to be more favourable for the establishment of populations of some insect pests and pathogens. The potential interactions between pests, diseases and climate change are further explored by Evans *et al.* (2002) and Webber and Evans (2003).

Predictions of future species suitability

Predictions of future species suitability have been made using the knowledge-based spatial decision support system, Ecological Site Classification within a Geographical Information System (ESC-GIS: Ray and Broome, 2003). ESC has been developed to support the UK forestry industry in commercial species selection and the restoration and expansion of native woodland. It is a knowledge-based model in which suitability or yield class is predicted on the basis of four climatic (accumulated temperature, wind exposure, moisture deficit and continentality) and two edaphic (soil moisture regime and soil nutrient regime) factors. In the case of commercial suitability as defined here, accumulated temperature (AT) is assumed to be the principal determinant of yield, with the product of AT and the next most limiting factor providing a site level assessment of suitability (see Ray and Broome, 2003). A full description of ESC is given by Pyatt *et al.* (2001). The 2050s High and Low emissions scenarios of UKCIP02 have been incorporated as the underlying climate data, replacing the UKCIP98 climate scenarios reported by Ray and Broome (2003). A number of assumptions and simplifications have been made that should be considered when interpreting the suitability maps in the context of climate change predictions (see Ray *et al.*, 2002). In particular, the following have not been considered:

- The direct effects of rising atmospheric CO_2 concentrations on growth and evapo-transpiration.
- The effects of a possible change in the frequency of severe pathogen or insect pest outbreaks.
- Changes to the frequency of extreme climatic events.
- The predicted increase in **winter** wind speed; the DAMS wind hazard classification system is based on mean **annual** wind speed and thus the effects of changing exposure may be underestimated.
- Changing soil moisture quality index; although a changing soil moisture deficit is included in the analysis (one of the four climatic factors), the edaphic soil moisture (wetness) factor has not been adjusted to account for climate change in these simulations.
- Spatial scales finer than the 5 km grid are not explored; variability in soil quality means that these maps cannot be applied to site-based assessments and should only be used to indicate general trends.

Keeping in mind the assumptions outlined above, the maps of species suitability given in Figures 3–5 represent changes to the potential suitability for commercial forestry as a result of changes to meteorological variables alone. Rising atmospheric CO_2 concentrations will ameliorate the negative effects and reinforce the positive effects of climate change on species suitability to some degree. In contrast, ozone pollution together with predictions for extreme climatic events to become more commonplace and the likelihood that pest and pathogen outbreaks will become more significant, may mean that the effects of environmental change could be more far-reaching than the simulations indicate.

Figure 3

Effects of climate change on the potential suitability of broadleaf species as predicted by ESC for the UKCIP02 2050s (2041-2060) High and Low emissions scenarios. (a) The broadleaf species most suited to the ESC climatic and edaphic factors for each scenario and (b) the productivity class (GYC: m^3 ha^{-1} yr^{-1}) of that species.

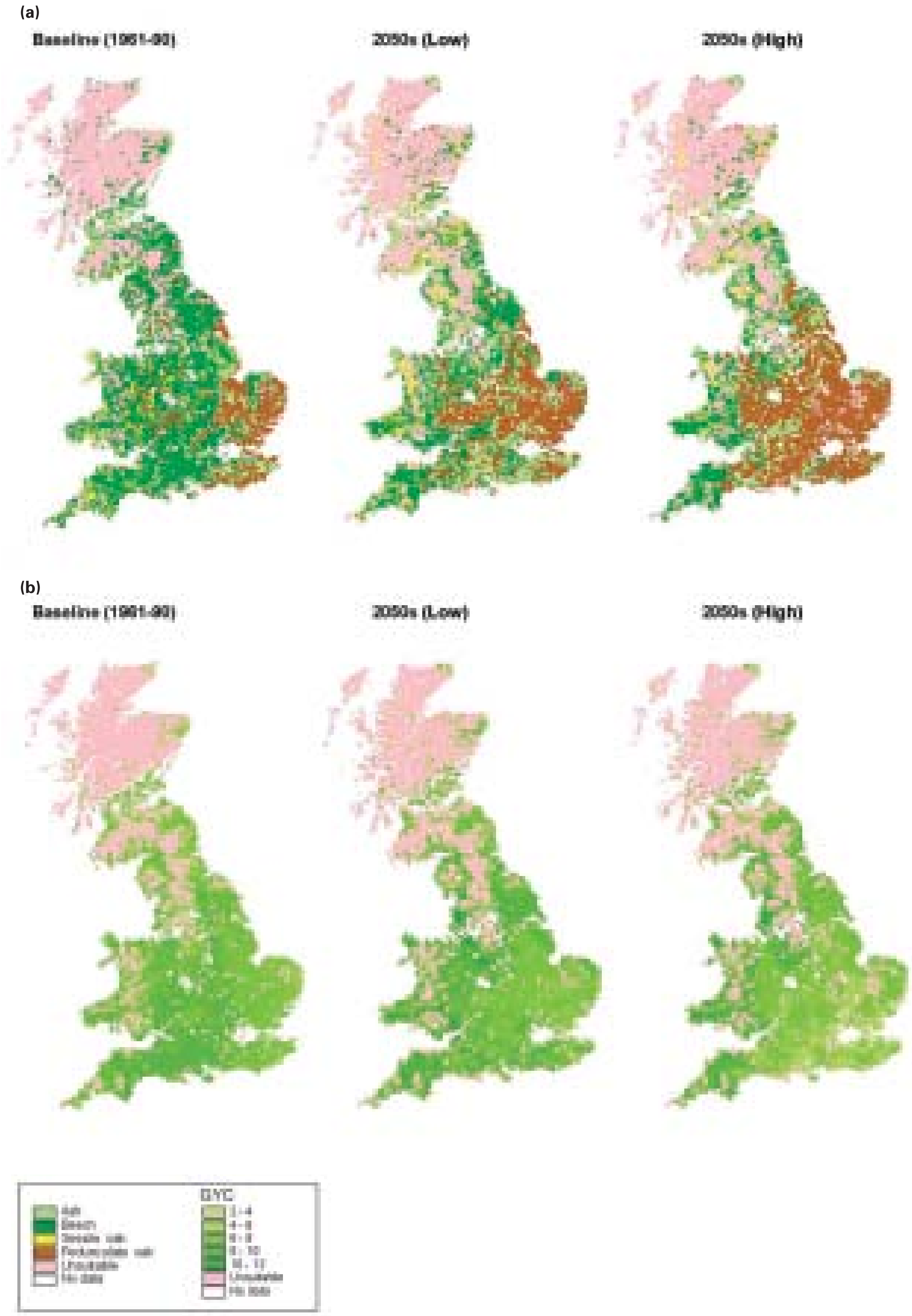
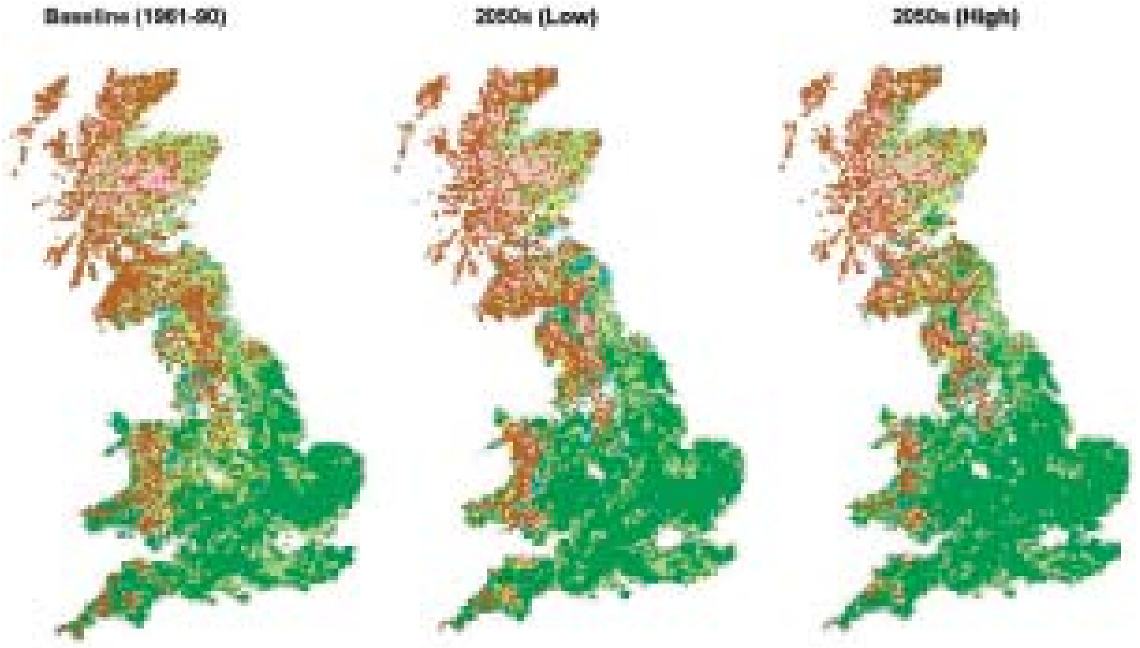


Figure 4

Effects of climate change on the potential suitability of conifer species as predicted by ESC for the UKCIP02 2050s (2041-2060) Low and High emissions scenarios. (a) The conifer species most suited to the ESC climatic and edaphic factors for each scenario and (b) the productivity class (GYC: m^3 ha^{-1} yr^{-1}) of that species.

(a)



(b)

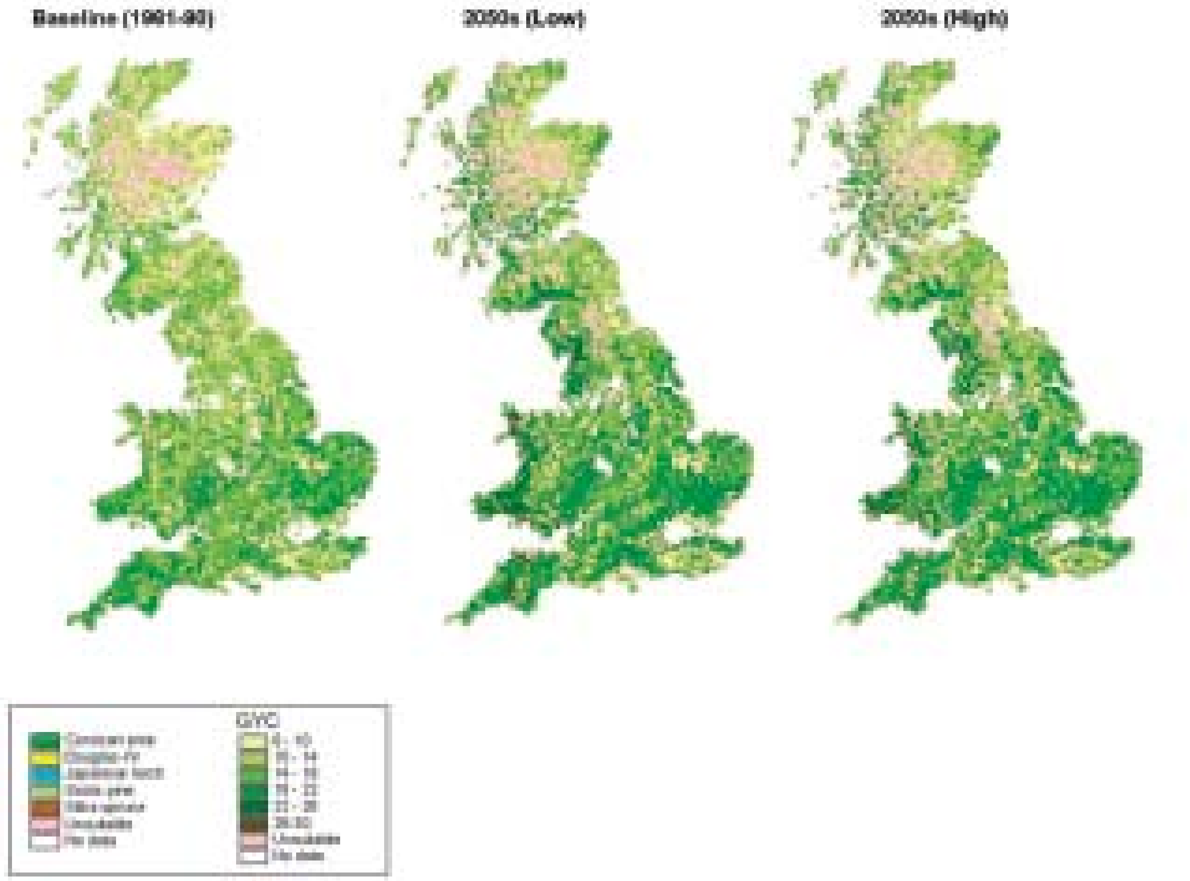


Figure 5

Effects of climate change on the identity of the most productive conifer species as predicted by ESC for the UKCIP02 2050s (2041-2060) Low and High emissions scenarios.

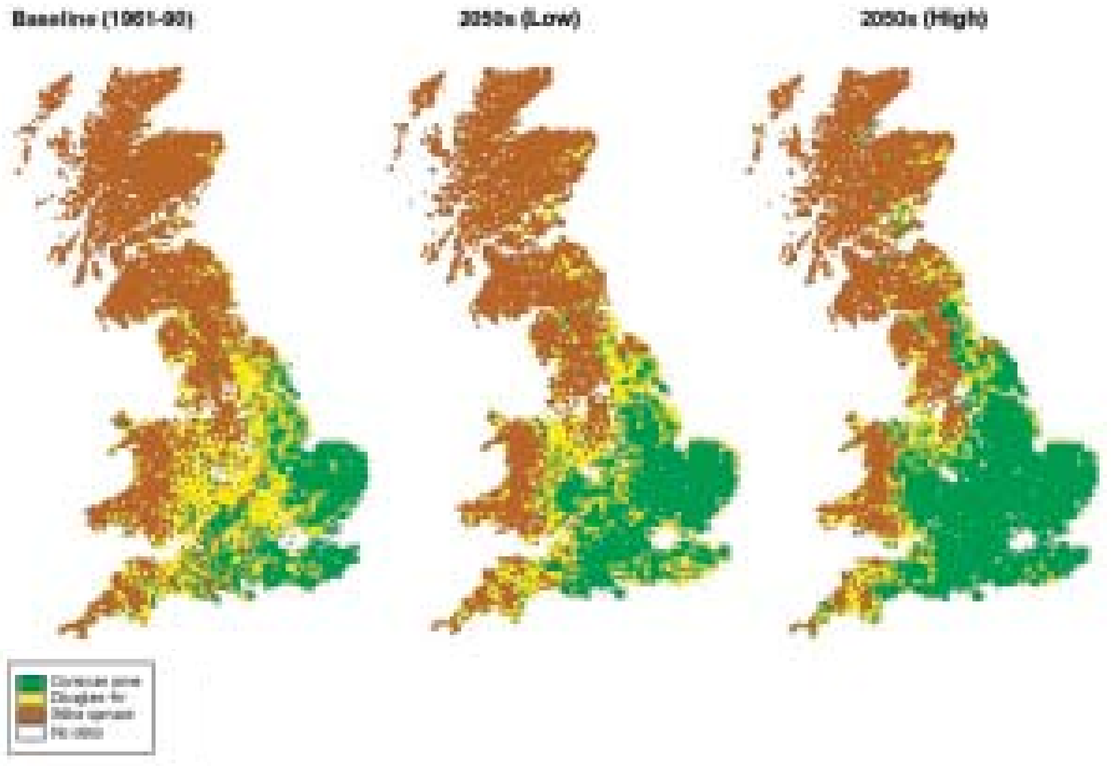


Figure 3a presents simulations of the most suitable broadleaf species for a given locality, where suitability is defined as the ratio of general yield class (GYC) to maximum GYC for that species in the UK, i.e. the species best suited to the site conditions but not necessarily the most productive species. In the baseline scenario (i.e. for the climate of 1961–90), the area where pedunculate oak *(Quercus robur)* is the most suitable species is restricted largely to East Anglia, Kent and Sussex. A regional basis for the distribution of ash is less clear, presumably on the basis of soil quality rather than climatic factors limiting its suitability. Sessile oak *(Quercus petraea)* is the most suitable species in upland areas across most of western England and Wales and southern Scotland, while beech *(Fagus sylvatica)* is predicted to be the most suitable species in lowland areas across all but the driest parts of England. In the 2050s Low scenario, the area in which beech is the most suitable species retreats north and westwards, such that in the High emissions scenario, this area is largely restricted to Wales and the southwest peninsula. Sessile oak shows a similar westwards retreat. In central and southern England, beech is replaced by ash *(Fraxinus excelsior)* and pedunculate oak as the most suitable species in the 2050s, with ash predominating in the Low emissions scenario, and pedunculate oak in the High emissions scenario. In northern England and southern Scotland, beech gives way to a combination of ash and sessile oak by the 2050s under both scenarios. Changes in the suitability distribution in Wales and west England are less obvious. In terms of the productivity of the most suitable species (Figure 3b) ESC predicts a slight reduction in GYC across southeast England, but an increase in the west country, west Wales, northwest England and eastern and central Scotland. It is clear that the climate change scenarios are predicted to have little effect on where broadleaf species can be grown on a commercial basis. However, species selection is likely to become increasingly important across much of England.

Less change is predicted to the suitability distribution of conifer species than for broadleaf species (Figure 4a). The area where Corsican pine *(Pinus nigra)* is the most suitable expands to the north and west, in most places replacing Scots pine *(Pinus sylvestris)*. Scots pine is also replaced as the most suitable species by a combination of Sitka spruce *(Picea sitchensis)* and Corsican pine across much of Wales. Douglas-fir *(Pseudotsuga menziesii)* becomes the most suitable species over large areas of eastern Scotland in the 2050s High emissions scenario, but is largely replaced by a variety of species in central and northern England. Of most concern to the forest industry is the ESC prediction that the Sitka spruce heartland of western Scotland becomes less favourable through the 21st century, while there is also an increase in the area classed as unsuitable in upland Scotland and northern England as a result of increased wind exposure. When species suitability is mapped on the basis of absolute productivity rather than ESC suitability class (Figure 5), changes in suitability become clearer with the range of Corsican pine expanding dramatically to the north and west, largely replacing Douglas-fir. The areas in which Sitka spruce is the most productive species also contract to a small extent, being replaced by Douglas-fir. In terms of productivity of the most suitable species (Figure 4b) there is a general increase in productivity across the whole of Great Britain for commercial conifer species.

Conclusions

It is clear that climate change has the potential to dramatically affect forestry in the UK. Predictions of the impacts of storms and severe pest and disease outbreaks cannot be made because of their near random nature, although general guidance can be given and inferences made. Rising concentrations of carbon dioxide in the atmosphere will be beneficial to tree growth, as will increasing temperatures and thus longer growing seasons in the uplands. Snow damage and winter cold injury will become less important with time. However, the most serious consequences of climate change are likely to be related to moisture availability. In England, species suitability will change over large areas, not necessarily resulting in widespread mortality but, certainly, reduced productivity in some species and a greater susceptibility to other environmental factors. ESC can provide general guidance on future species suitability, but this knowledge should be used in conjunction with an assessment of on-site conditions. Given the magnitude of potential changes described here, it is advisable for climate change predictions to be considered in current forest design plans. At this stage, it would be prudent to avoid species monocultures, providing some protection against uncertainty in the responses of woodland to climate change, and in the predictions of climate change itself. In addition, the possibility of further and more extreme changes to the climate in the latter half of the century should be considered and, where possible, accommodated.

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Publications by Forest Research staff

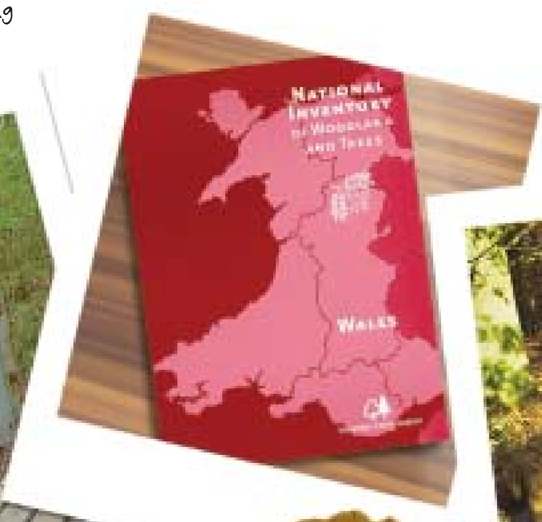
Major research programmes undertaken by Forest Research

Research contracts awarded by Forest Research

Forest Research people

Woodland carbon exchange: monitoring part of an ongoing enviromental research programme

New publication: inventory report for Wales



Acorn collection in the New Forest, Hampshire, featured in Practice Note 12

Forestry Commission technical publications

The following titles were published during the year ending 31 March 2003.

Reports and Plans

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Website: www.forestry.gov.uk/inventory

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Major research programmes undertaken by Forest Research

Programmes funded by the Forestry Commission

Entomology Branch

Plant health

Hugh Evans, Nick Fielding and Christine Tilbury

Research into the risks from indigenous and non-indigenous forest insect species. Co-ordination and implementation of surveys in relation to retention of EU Protected Zone status for named bark beetle pests. The use of Pest Risk Analysis techniques to determine contingency options for potential pests. Research into alternatives to methyl bromide as a quarantine and remedial treatment against exotic pests (part EU-funded).

Restocking pests

Stuart Heritage

Research into the effective use of chemical pesticides for control of restocking pests, notably *Hylobius abietis*. Research into and development of insect parasitic nematodes for biological control of larval stages in stumps and provide direct intervention options within the Integrated Forest Management programme being developed in the Branch.

Impact of insects on tree growth

Nigel Straw

Investigate quantitative relationships between insect population pressure and the growth of trees attacked by those insects. An important aim is to separate the direct effects of damage from other biotic and abiotic variables that might mask the impacts of pest insects. The target species is green spruce aphid, *Elatobium abietinum*, which severely defoliates both Norway and Sitka spruces.

Integrated Forest Management

David Wainhouse, Roger Moore and Hugh Evans

Develop the concepts and science of Integrated Forest Management (IFM) to underpin sustainable forestry with particular emphasis on reductions in chemical pesticides. Study the population dynamics of *Hylobius abietis* and use the data to develop decision support systems for management of the restocking problem. Investigate the variability in quality of both stumps and transplants in relation to performance of *H. abietis* and use the data to refine management options within the IFM programme. Develop a decision support system for sustainable reduction of *H. abietis* populations towards the acceptable damage threshold predicted by the population dynamics models.

Mechanisms of tree resistance to insect attack

David Wainhouse

Investigate mechanisms of resistance of young conifers to the pine weevil. Determine the relative importance of genetic and environmental factors in resistance expression. Develop these aspects to contribute to an Integrated Forest Management (IFM) approach for control of pine weevil.

Advisory services

Christine Tilbury

Provide identification services for both pest and beneficial insects and provide advice on pest management and control.

Environmental Research Branch

Soil sustainability

Fiona Kennedy and Elena Vanguelova

Research to identify and evaluate the potential impacts of both forest management and air pollution on soil status and dynamics. Develop and advise upon sustainable practices.

Reclamation of man-made sites for forestry

Andy Moffat, Kirsten Foot and Tony Hutchings

Improve methods of establishing woodland and management practices on disturbed (brown field) sites, taking into account changes in forestry and land-use policy, planting opportunity, environmental impacts, mining practices and technology. Develop best practice guidelines.

Forest hydrology

Tom Nisbet

Study the impacts of forests and forestry management practices on water quality and quantity. Develop and assess guidance on best management practice for the protection of the freshwater environment within forests. Provide expert advice on forestry–water issues.

Effects of air pollution on trees

Dave Durrant and Andy Moffat

Determine the role of air pollution in forest condition and growth through long-term intensive environmental monitoring in forest ecosystems, in compliance with EC regulations. Provide data under the Convention on Transboundary Air Pollution for the calculation and mapping of critical loads.

Climate change

Mark Broadmeadow

Predict and model the impacts of climate and wider environmental change on tree growth by experimental work in open-top chambers and in forest stands. Interpret published climate change scenarios and develop guidance on future species suitability, both for production woodland management and native woodland restoration. Identify interactions between forests, woodland management and the changing global environment.

Carbon
Mark Broadmeadow
Develop a network for monitoring carbon stocks and stock changes of woodland in the UK. Maintain one of only three long-term carbon flux monitoring stations in woodland in the UK, measuring carbon fluxes and constructing a carbon budget for a stand of lowland broadleaf woodland. Research the contribution that wood (including bioenergy production) and wood products can make to climate change mitigation.

Environmental change network
Sue Benham
Monitor and understand environmental change and its impact on terrestrial ecosystems. Manage one of the national ECN terrestrial sites.

Historic environment
Peter Crow
Develop methods, tools and guidance to aid the day to day management of historic environment features such as archaeological evidence, veteran trees and historic woodlands/landscapes.

Mensuration Branch

Sample plots
John Proudfoot
Develop and maintain national reserve of periodic growth and yield data to support measurement, growth and yield studies using a network of permanent and temporary sample plots. Current focus: contemporary silvicultural practices, uneven-aged planting mixtures, modern planting and harvesting systems, long-term environmental change monitoring.

Yield models
Robert Matthews
Improve methods and models for forecasting growth and yield of forests. Current focus: development of interactive stand-level yield model software, site:yield relationships, biomass yield models.

Measurement
Ewan Mackie
Develop and promote measurement systems and instruments for the accurate and efficient measurement of trees and timber to support industry, national and international standards. Provide independent expert advice in cases of measurement dispute.

Core model
Sam Evans
Integrate modelling initiatives within Forest Research by developing a framework of existing and new models and relevant datasets. Taking growth models as a starting point, the core model programme aims to provide modelling tools at appropriate scales of resolution to support and promote the implementation of multi-purpose sustainable forestry policy in the UK.

Pathology Branch

Tree diseases: diagnosis and provision of advice
David Rose and Sarah Green
Diagnose disease in trees and provide advice and information on disease identification, management and control. Provide information on decay in standing trees, and on management of veteran trees.

Tree health monitoring
Steven Hendry
Monitor the health of the nation's trees and raise awareness of tree health issues.

Risks from altered pathogens
Clive Brasier
Investigate changes in pathogen behaviour and evaluate the potential impact of such changes in relation to plant health and Pest Risk Analysis.

Non-chemical protection
Joan Webber
Research and evaluate the potential for biological control of tree diseases, with special emphasis on root rot pathogens and the fungi that cause vascular wilts and stain and decay.

Fomes root and butt rot of conifers
Katherine Thorpe
Conduct research on root and butt rot of conifers caused by *Heterobasidion annosum* and investigate approaches to management and control.

Phytophthora diseases of trees
Clive Brasier and Joan Webber
Investigate pathogenic *Phytophthora* species of alder and oak to determine their impact and the opportunities for management and control.

Silviculture (North) Branch

Integrated establishment systems for the uplands
Alan Harrison, Mike Perks and Colin McEvoy
Integrated studies of the effect of nursery practice, seedling physiology, plant handling methods, site preparation and maintenance upon tree establishment.

Silvicultural effects upon timber quality
Barry Gardiner, Jason Hubert, Elspeth Macdonald and Shaun Mochan
Investigate the impact of silvicultural practices on timber quality in conifers, especially spruce. Main emphasis is impact of site factors (e.g. exposure, fertility) on quality.

Silviculture of upland native woodlands
Richard Thompson and Colin Edwards
Research into the structure, dynamics and silviculture of native woodland ecosystems in northern and western Britain to support restoration and extension for ecological and economic benefits. Emphasis is on Scots pine forests, birchwoods and the Atlantic oakwoods.

Alternative silvicultural systems in conifer forests
Bill Mason, Colin Edwards and Sophie Hale
Evaluate canopy structure manipulation to promote suitable microclimates for seedling establishment and facilitate natural regeneration to enable wider use of alternative silvicultural systems to patch clearfelling (continuous cover forestry).

Stability of stands
Barry Gardiner, Bruce Nicoll, Alexis Achim and Juan Suárez
Research to reduce wind damage to British forests using a GIS-based windthrow risk model for predicting the probability of windthrow in Sitka spruce forests. Carry out studies of root development and architecture in support of the model.

Remote sensing
Juan Suárez
Evaluate the potential of remote sensing techniques for operational use in British forest management.

Silviculture and Seed Research Branch

Alternative establishment systems
Ian Willoughby and Richard Jinks
Investigate alternatives to conventional establishment systems for new planting and regenerating existing woodlands, including vegetation management, reducing synthetic chemical inputs and direct seeding.

Energy coppice and poplar research
Ian Tubby
Investigate dry matter yields of willow and poplar coppice grown for renewable energy.

Lowland native woods
Ralph Harmer
Examine methods for managing, regenerating and extending lowland native woodlands.

Silvicultural systems
Gary Kerr
Examine the potential for diversifying the range of silvicultural systems used in native woodlands.

Seed and seedling biology
Peter Gosling and Richard Jinks
Improve tree seed quality and performance to reduce costs and increase reliability of direct seeding and natural regeneration.

Social research unit (inter-Branch)

Paul Tabbush and Elizabeth O'Brien (SSRB, Alice Holt)
Max Hislop and Suzanne Martin (Silv(N), NRS)
Examine relationships between communities and woodlands in support of FC policies on sustainable forest management. Work concentrates on community involvement, publicly held values, health and well-being, criteria and indications of sustainability, recreation, access and rural development.

Technical Development Branch

Large-scale forestry harvesting
Colin Saunders
Evaluate machinery and equipment, produce output guidance and investigate operational techniques relevant to large-scale forestry work in harvesting.

Large-scale ground preparation, seed sowing and planting
Steve Morgan, Andy Hall and Bill J. Jones
Evaluate machinery and equipment, produce output guidance and investigate operational techniques relevant to large-scale forestry work in ground preparation and planting.

Farm and small-scale silviculture/harvesting and utilisation of small woodlands
Andy Hall
Develop methods and assess equipment with low environmental impact suitable for use in small, generally broadleaved woodlands, and suitable for use by farmers and small contracting firms.

Forestry operations on derelict and reclaimed land
Bill J. Jones
Undertake focused research into the cost-effectiveness of restoration techniques, with an emphasis on system and cost advice on techniques recommended by scientists.

Wood for energy
Andy Hall and Paul Webster
Develop methods for using short rotation coppice, single-stemmed short rotation forestry, forestry residues and existing undermanaged woodlands for small-scale heating and small- or large-scale electricity generation.

Chemical weeding
Bill J. Jones
Evaluate equipment, application techniques and safety.

Reduction in the use of chemicals
Bill J. Jones and Paul Webster
Examine equipment and methods that offer opportunities for non-chemical weed control.

Health and safety
Bill M. Jones and Colin Saunders
Review techniques and procedures for management of health and safety of machine operators.

Tree Improvement Branch

Selection and testing of conifers
Steve Lee
Undertake plus-tree selection, progeny testing. Breeding/production populations. Demonstration of realised gain. Development of techniques for marker aided selection. Species: Sitka spruce, Scots pine, Corsican pine, Douglas fir, larch.

Breeding and production of conifers
Steve Lee
Clonal archives: conservation, advanced breeding material. Improved seed: controlled pollination, seed orchards.

Improvement of broadleaves
Ned Cundall
Selection/testing of selections at population, family and clonal level: oak, ash, sycamore, beech, birch.

Origin and provenance of conifers
Sam Samuel
Identification of suitable origins of conifer species. Key species: Sitka spruce, Douglas fir.

Genetic Conservation
Joan Cottrell
Study of genetic variation and gene flow in natural populations. Assessing the level of adaptive variation in the field trials of populations of native species.

In vitro propagation and phase-change biotechnologies
Allan John
Investigate tissue culture systems for multiplication of Sitka spruce.

Forest Reproductive Material Regulations
Sam Samuel
Devise methods for inspection of material proposed for registration. Maintain the National Register of Basic Material.

Woodland Ecology Branch

Biodiversity evaluation and indicators
Jonathan Humphrey
Synthesise datasets from the biodiversity assessment project, identify potential biodiversity indicators, and disseminate findings.

Forest habitat management
Jonathan Humphrey, Russell Anderson and Helen Armstrong
Investigate and provide guidance on the management of forests for biodiversity through developing old growth stands, utilising cattle grazing and managing open ground habitats.

Species Action Plans
Alice Broome, Roger Trout, Chris Quine and Brenda Mayle
Undertake research in support of Forestry Commission commitments to the species Biodiversity Action Plans and provide advice on appropriate management of woodland habitats for these species.

Landscape ecology
Kevin Watts and Chris Quine
Improve understanding of how biodiversity responds to management at the landscape scale, and translate this into practical management guidance for forest design.

Ecological site classification and decision support systems
Duncan Ray
Research, build and test models that predict the effect of forest management on forest ecology, and develop decision-making tools for ecological site classification and forest biodiversity.

Squirrel management
Brenda Mayle
Develop cost-effective means of managing the impact of grey squirrels on timber production. Investigate the impact of grey squirrels on woodland biodiversity.

Deer population ecology and management
Robin Gill, Helen Armstrong and Brenda Mayle
Provide a sustainable basis for deer management in UK woodlands by investigating and developing new techniques and models of impacts and damage, population dynamics of deer, and deer density assessment.

Tree protection
Roger Trout
Develop techniques and materials for cost-effective protection of trees and woodlands from vertebrate damage.

Woodland Surveys Branch

National inventory of woodlands and trees
Steve Smith
Undertake the FC national survey of woodlands and trees, assessing the woodland cover. Update key statistics on forest type, species, age-class, management and ownership.

Inventory GIS development
Graham Bull
Create the digital woodland map for Britain. Develop the use of GIS for providing spatially referenced data on the woodland cover of Great Britain.

Private sector production forecast
Justin Gilbert
Develop and produce the private sector production forecast incorporating new woodland data from the national inventory.

Programmes funded by the European Commission

Alternatives to methyl bromide for quarantine treatment.

Application of cDNA Microarray Technology for unravelling molecular events underlying dormancy and cold hardiness in forest tree seedlings.

Bark and wood boring insects in living trees.

Ash for the future: defining European ash populations for conservation and regeneration.

Compression wood in conifers.

Control of decay.

Demonstration of sustainable forestry to protect water quality and aquatic biodiversity.

Development of guidance for health management of harvesting machine operators.

Development of improved pest risk analysis techniques for quarantine pests, using pinewood nematode *Bursaphelenchus xylophilus* in Portugal as a model system.

Eco-engineering and conservation of slopes for long-term protection from erosion, landslides and storms.

Forecasting the dynamic response of timber quality to management and environmental change.

Forest condition surveys.

Gene flow in oaks.

Improving ash productivity for European needs by testing selection, propagation and promotion of improved genetic resources.

Improving protection and resistance of forests to the spruce aphid.

Integrating ecosystem function into river quality assessment and management.

Intensive monitoring of forest ecosystems.
Larch wood chain.

Modelling of *Heterobasidion* infection in European forests.

Native black poplar genetic resources in Europe.

Natural regeneration of oak.

Phytophthora in European oak decline.

Urgent conservation management fpr Scottish capercaillie.

Upgrading the Level II protocol for physiological modelling of cause–effect relationships: a pilot study.

Visualisation tools for public participation in the management of landscape change.

Programmes funded by individual organisations

Cranfield
Development of heat penetration models to predict the rate of heating in wood during quarantine treatment.

Office of the Deputy Prime Minister
Monitoring the health of non-woodland trees.

Potential for woodland establishment on landfill sites.

Department for the Environment, Food and Rural Affairs/Loughborough University
Trees and drought in lowland England.

Department for the Environment, Food and Rural Affairs/Natural Environment Research Council
Cause–effect relationships for pollutant inputs to UK woodland ecosystems.

Department of Trade and Industry
Yield models for energy coppice of poplar and willow.

EC/Highland Birchwoods
Conservation of native oakwoods.

EC/Scottish Natural Heritage
Restoration of wet woods.

English Nature
Woodland restoration - comparison of inventory data.

Brash management.

Environment Agency
Phytophtora disease of alder.

Health and Safety Executive
Development of guidance on the use of mobile elevated platforms in arboriculture.

Health and Safety Laboratories
Vibration exposure of chainsaw operators.

ITE
Terrestrial effects of acid pollutants.

UK emissions by sources.

Kemira Fertilisers
Slow release fertilisers for cell-grown seedlings.

Macfarlane Smith
Vertebrate repellents.

Madeira National Park
Mammal control.

Department for the Environment, Food and Rural Affairs
Development of a site-specific yield model for ash in lowland England and Wales.
Provenance testing of broadleaved species in farm forestry.

Yield models for energy coppice of poplar and willow.

Natural Environment Research Council/Imperial College
Variation in the Dutch elm disease pathogens.

Terrestrial carbon dynamics.

National Forest Company
Research and demonstration in the National Forest.

Raleigh International
Huemul ecology research for the conservation planning in Southern Chile.

Southampton University
Short rotation coppice (poplar).

Scotland and Northern Ireland Forum for Environmental Research
A coupled soil–forest–atmosphere dynamic model for predicting evapotranspiration demands at the plot and landscape scales in the UK.

Effect of riparian forest management on the freshwater environment.

Scottish Forestry Trust/UK Forest Products Association/Tilhill Economic Forestry/Scottish Woodland Owners Association
Assessing log quality in Sitka spruce.

Scottish Natural Heritage
Balancing upland and woodland strategic priorities.

Testing methods for monitoring beaver impacts on terrestrial vegetation in Knapdale.

Woodland Trust
Weed control using non-chemical methods.

Research contracts awarded by Forest Research

Avon Vegetation Research
Forestry herbicide evaluation.

Butterfly Conservation
Study of small pearl-bordered fritillary populations in Clocaenog Forest.

Cranfield University, BHR Group
Development and production of prototype systems to separate insect parasitic nematodes from rearing media.

Environment Agency (Wales)
Effects of forestry on surface water acidification.

Fountain Forestry
Water monitoring, Halladale.

Freshwater Fisheries Laboratory
Effects of riparian forest clearance on fish populations.

Imperial College, London
Control of decay in utility poles.
Development of a biological control agent for Dutch elm disease.

Macaulay Land Use Research Institute
Sustainability of afforestation development, Halladale.

Mountain Environments
Investigation of the long-term effects of forest management on upland catchments (Balquhidder).

Scottish Environment Protection Agency
Effects of forestry on freshwater fauna.

University of Abertay, Dundee
Cryopresentation of Sitka spruce tissues.

University of Birmingham
Woody debris in forest aquatic habitats.

University of Leeds
Atmospheric boundary layer over forests.
Chemical transport in forests.

University of Reading
Tree root response to acidification.
Soil variability.

University of Southampton
Water and fine sediment transport in rivers with wooded floodplains.

University of Stirling
Habitat use of working forest by capercaillie.
Paleoecology of Glen Affric.

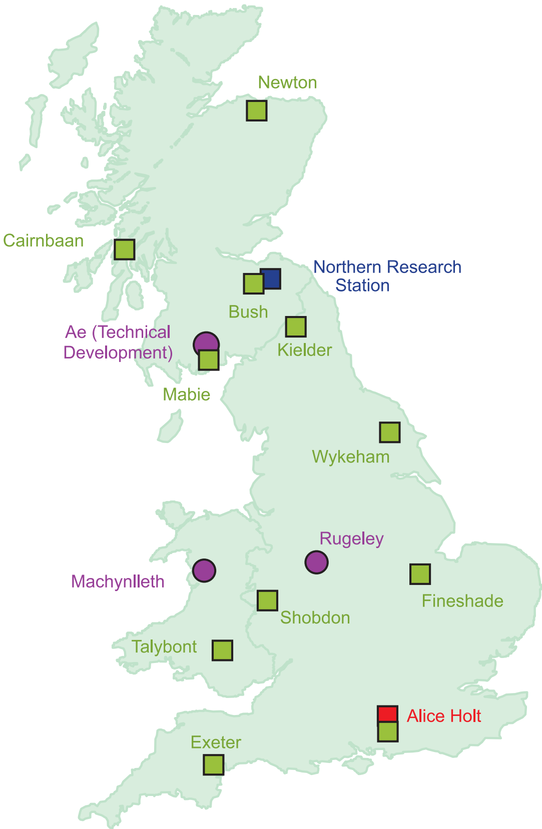
University of Sussex
Biochemical mechanisms for plants to act as sinks for atmospheric pollutants.
Drought tolerance in poplars.

University of Ulster
Feeding ecology of the large pine weevil.
Impact of defoliating insects on forests.

Forest Research people

Staff as at 31 March 2003, in Branches, Sections and Technical Services based at:

- **Alice Holt**
- **Northern Research Station**
- **Ae Village, Midlands and Wales**
- **Field Stations**



Chief Executive
up to May 2002
- Jim Dewar, BSc, MICFor

Chief Research Officer
and **Acting Chief Executive** from May 2002
- Peter Freer-Smith, BSc, PhD, DSc

Personal Secretary
- Claire Holmes*
- Sue Jones, BA, MA*

Head of Northern Research Station
from May 2002
- Bill Mason, BA, BSc, MICFor

Personal Secretary
- Madge Holmes

*Denotes part-time.

Administration Branch

- Ken Charles, FMS, *Personnel and Administration Officer*, *Head of Branch*

Central Services
- Mike Wheeler
- Mandy Sennet*
- Amanda Smith*
- Mike Young

Personnel
- Wendy Groves
- Janet Lacey
- Hayley Oldale

Typing
- Sue Stiles*, *Head of Section*
- Sally Simpson*
- Heather Russell*

Administration, NRS
- Martin Abrahams, *Head of Section*
- Gerry Cockerell
- Evelyn Hall
- Esther Kerr
- Heather Moreland*
- Linda Legge*
- Gill Mackintosh*
- Roz Shields*

Finance and Planning Branch

- Tony Cornwell, FCMA, *Head of Branch*
- Gilly Anderson*
- Laura Caless
- Peter Filewood
- David Georghiou, BA
- Carol Knight*
- Carole Martin
- Alison Melvin, BA
- Janet Turner

Communications Branch

Photography and Publications
- George Gate, *Head of Section and Acting Head of Branch*
- Glenn Brearley
- Jenny Claridge, BSc, ARCS
- Sally Taylor *(also with Library and Information)*
- John Williams

Library and Information
- Catherine Oldham, BA, MA, DipLib, MCLIP, *Head of Section and Librarian*
- Eleanor Harland, MA, DipLib, *Assistant Librarian*
- Kirsten Hutchison, MA
- Thelma Smalley

Entomology Branch

- Hugh Evans, BSc, DPhil, FRES, *Head of Branch*
- Gillian Green, BSc*
- Martin Jukes, CBiol, MIBiol
- Shirley Stephens*
- Nigel Straw, BSc, PhD, FRES
- Christine Tilbury, BSc
- David Wainhouse, MSc, PhD, FRES
- Stuart Heritage, MBA, CBiol, MIBiol, *Head of Section*
- Roger Moore, BSc, PhD

Environmental Research Branch

- Andy Moffat, BSc, PhD, *Head of Branch*
- Lorraine Adams, BSc
- Sue Benham, BSc
- François Bochereau, BSc, MSc
- Caroline Bristoll, BSc
- Mark Broadmeadow, BSc, PhD
- Samantha Broadmeadow, BSc, MSc
- Sylvia Cowdry*
- Peter Crow, BSc, MSc
- Dave Durrant, BA
- Kirsten Foot, BSc, MSc, EngD
- Tony Hutchings, MSc
- Elizabeth Luttrell, BSc *(also with Woodland Ecology Branch)*
- Anthea McIntyre, BSc
- Tom Nisbet, BSc, PhD
- Rona Pitman, BSc, PhD
- Danielle Sinnett, MSc
- Victoria Stokes, BSc, PhD
- Ernest Ward, BSc, MSc, CChem, MRSC
- Christine Whitfield*
- Matthew Wilkinson BSc, MSc

Mensuration Branch

- Professor Sam Evans, MA, PGDip, PhD, PhD, *Head of Branch*
- Catia Arcangeli, MSc, PhD
- Miriam Baldwin, HND, BSc, MSc
- June Bell
- Eric Casella, MSc, PhD
- Tim Cooper
- Ian Craig
- Paul Henshall, BSc
- Tracy Houston, BSc, MIS
- Ewan Mackie, BSc, MSc
- Robert Matthews, BSc, MSc
- John Proudfoot
- Tim Randle, BSc
- Paul Taylor, MA, MSc, MPhil

Pathology Branch

- Joan Webber, BSc, PhD, *Head of Branch*
- Professor Clive Brasier, BSc, PhD, DSc, Emeritus
- Anna Brown, BSc, PhD
- Sandra Denman, BSc, MSc, PhD
- Anthony Jeeves
- Susan Kirk
- Carol Lishman*
- David Rose, BA
- Joan Rose
- Katherine Thorpe, BA, MSc, DPhil
- Sarah Green, BSc, PhD, *Head of Section*
- Steven Hendry, BSc, PhD
- Grace MacAskill
- Heather Steele, BSc*

Silviculture & Seed Research Branch

- Paul Tabbush, BSc, FICFor, *Head of Branch*
- Vicky Cunningham, BSc
- Peter Gosling, BSc, PhD
- Ralph Harmer, BSc, PhD
- Andrea Kiewitt, BSc, MSc
- Richard Jinks, BSc, PhD
- Gary Kerr, BSc, FICFor, PhD
- Liz O'Brien, BSc, PhD
- Matt Parratt, BSc
- Ian Tubby, BSc
- Ian Willoughby, BSc, MBA, MICFor
- Christine Woods, BA

Silviculture North Branch

- Bill Mason, BA, BSc, MICFor, *Head of Branch*
- Alexis Achim, BSc
- Colin Edwards, BSc
- Professor Barry Gardiner, BSc, PhD, FRMetS
- Sophie Hale, BSc, PhD
- Alan Harrison, BSc
- Max Hislop, MICFor
- Jason Hubert, BSc, PhD
- Elspeth Macdonald, BSc, MSc
- Colin McEvoy, BA
- Suzanne Martin, BSc, PhD
- Shaun Mochan, MSc
- Bruce Nicoll, BSc
- Mike Perks, BSc, MSc, PhD
- Stephen Smith, BSc, MICFor
- Juan Suárez-Minguez, BSc, MSc
- Richard Thompson

Statistics and Computing Branch

- Jane Smyth, BSc, *Head of Branch*
- Carol Foden*
- Dai Jeffries, BSc
- Dan Johnson, BSc
- Timothy Knight, BSc
- Geoff Morgan, BSc, MSc, PhD
- Andrew Peace, BSc
- Lyn Pearce
- Chris Vials, BSc
- Wayne Blackburn, BSc, *Head of Section*
- Lynn Connolly*
- Tom Connolly, BSc, PhD
- Alec Gaw, BSc*
- Alvin Milner, BSc, PhD
- Lynn Rooney*

*Denotes part-time.

KEY: ■ **Alice Holt** ■ **Northern Research Station** ● **Ae, Midlands and Wales** ■ **Field Stations**

Tree Improvement Branch

- Sam Samuel, BSc, PhD, *Head of Branch*
- Stuart A'Hara, BSc, MSc, PhD
- Cathleen Baldwin
- Joan Cottrell, BSc, PhD
- Ned Cundall, BSc, PhD
- Allan John, BSc, PhD
- Steve Lee, BSc, PhD, MICFor
- Margaret O'Donnell*
- Rob Sykes

Woodland Ecology Branch

- Chris Quine, MA, MSc, MICFor, PhD, *Head of Branch*
- Russell Anderson
- Helen Armstrong, BSc, PhD
- Alice Broome, BSc
- Jonathan Humphrey, BSc, PhD
- Margaret Plews *(also with Technical Services Unit North)*
- Liz Poulsom, MSc
- Duncan Ray, BSc
- Louise Sing, BA, MSc
- Brenda Mayle, MSc, *Head of Section*
- Andy Brunt
- Mark Ferryman
- Robin Gill, BSc, MSc, PhD
- Matthew Griffiths, BSc, MSc
- Elizabeth Luttrell, BSc *(also with Environmental Research Branch)*
- Ruaraidh Milne, BSc
- Roger Trout, BA, PhD
- Kevin Watts, BSc, PhD

Technical Development Branch

- Bill Jones, *Head of Branch*
- Bill J. Jones
- Steve Morgan
- Derry Neil
- Rosemary Nicholson*
- Joyce Rammell, BSc
- Colin Saunders
- Aileen Wallace*

Midlands
- Andy Hall
- Duncan Ireland, BSc
- Martin Lipscombe
- Paul Webster

Wales
- David Jones, EngTech, AMIAgrE

Woodland Surveys Branch

- Steve Smith, BSc, BA, MBA, *Head of Branch*
- Rab Beck
- Graham Bull
- Christine Brown
- Justin Gilbert, BSc
- Shona Macintosh
- Esther Whitton

Field Stations

Technical Services (North)

- Kate Fielding, *Head of Branch*

Engineering Services
- David Brooks, *Head of Engineering Services*
- James Nicholl
- John Strachan

Bush, Inver and Bush Nursery
- David Anderson, *Head of Stations*

Bush
- Colin Gordon
- Hamish Howell
- Nelson Innes
- Gavin Mackie
- Martin Mackinnon, BSc
- Steven Osborne, BSc
- Steven Sloan

Inver
- Nick Evans
- Bill Rayner

Bush Nursery
- David Clark, *Nursery Manager*
- John Armstrong
- Graeme Crozier
- Alan Purves

Cairnbaan
- Dave Tracy, BSc, *Head of Station*
- Pauline Simson, BSc
- Elma Wilson, BSc
- James Wilson

Kielder and Mabie
- Dave Watterson, *Head of Stations*

Kielder
- Terry Gray
- Mike Ryan
- Len Thornton

Mabie
- James Duff
- Joanne McGregor*
- Hazel MacLean
- Harry Watson
- James White

*Denotes part-time.

KEY: ■ **Alice Holt** ■ **Northern Research Station** ● **Ae, Midlands and Wales** ■ **Field Stations**

Newton and Lairg
- Alistair MacLeod, *Head of Stations*

Newton
- Hazel Andrew*
- Gillian Bowden
- Allison Cowie
- Andrew Kennedy, BSc
- Fraser McBirnie
- Stuart McBirnie
- Hugh MacKay, BSc
- Colin Smart
- Linda Tedford

Lairg
- Alexander Bowran
- Calum Murray
- Duncan Williams

Technical Services (South)

- Norman Day, *Head of Branch*

Alice Holt
- Nick Tucker, *Head of Station*
- Jamie Awdry
- Bob Bellis
- Tony Bright
- Kate Harris
- Steve Coventry
- Ian Keywood
- Vicky Lawrence
- Tony Martin
- Ralph Nickerson
- Doug Nisbet
- Jim Page
- Bill Page
- Sue Bellis

Alice Holt Workshop
- John Davey
- Mike Johnston

Exeter
- Dave Rogers, *Head of Station*
- Alan Ockendon
- Dave Parker
- Anthony Reeves
- Barnaby Wylder*

Fineshade and Thetford
- Dave West, *Head of Stations*
- Elizabeth Richardson

Thetford
- John Lakey
- Paul Turner
- Alistair Whybrow
- Steven Whall

Shobdon
- Nick Fielding, *Head of Station*
- Nigel Connor
- Brian Hanwell, BSc
- Jason Jones
- John Price
- Sharon O'Hare*
- Richard Nicoll

Talybont
- Chris Jones, BSc, *Head of Station*
- Lyn Ackroyd*
- Justin Chappell
- Dai Evans
- Carl Foster
- Richard Keddle
- Tony Price
- Rachel Sparks
- Ken Williams
- Colin Clayton

Wykeham
- Davey Kerr, *Head of Station*
- Ian Blair
- Lee Cooper
- Alex Hill
- Patricia Jackson*
- William Riddick

PhD students linked with Forest Research
Helen Billiald (Sussex University)
Lois Canham (University of Stirling)
Lauren Crawford (Imperial College)
Richard Curtis (University of Gloucester)
Luis Dieguez (Salford University)
Hannah Drewitt (University of Durham)
Sharon Flint (Manchester Metropolitan University)
Samantha Gale (Abertay University)
Caroline Hacker (Imperial College)
Joe Hope (University of Stirling)
Jack Johnston (Colraine University)
Amanda Lloyd (Newcastle University)
Anna Manoukiants (University of Brighton)
Tanya Ogilvy (Edinburgh University)
Vini Pereira (Imperial College)
Pernille Schiellerup (University College London)
Helen Sellars (University of Liverpool)
Helen Shaw (University of Stirling)
Suzanne Swanwick (Cranfield University)
Louise Timms (Imperial College)
Alessandra Timarco (Reading University)
Elena Vanguelova (Reading University)
Georgios Xenakis (Edinburgh University)
Liz Young (University of Portsmouth)

Research associate
Steve Petty, PhD

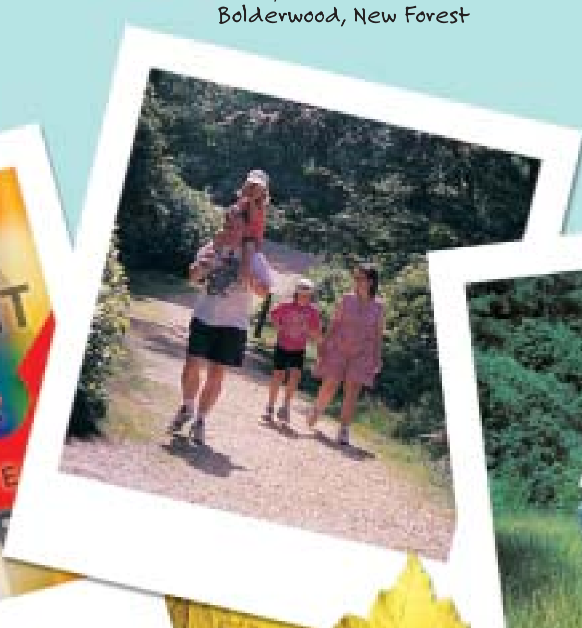
*Denotes part-time.

KEY: **Alice Holt** **Northern Research Station** **Ae, Midlands and Wales** **Field Stations**

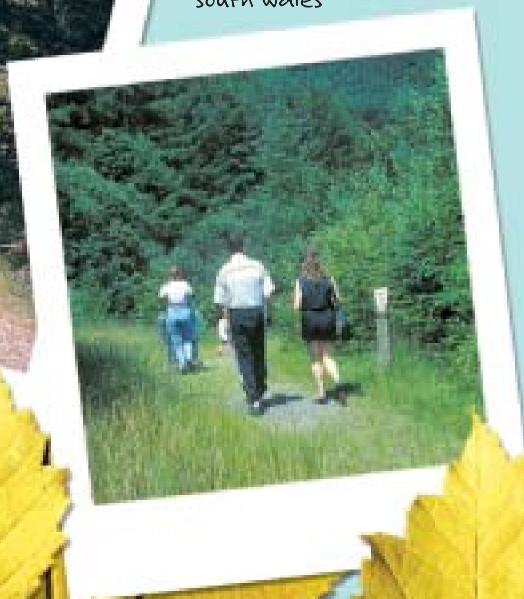
Accounts for the year ended 31 March 2003

Managing Forest Research finances

Family on a trail in Bolderwood, New Forest



Walkers on a trail through a restored open-cast site at Cyner Afan, south Wales



Contents

Foreword

1. Basis of Accounts

These accounts are prepared in accordance with a direction given by HM Treasury in pursuance of section 7 of the Government Resources and Accounts Act 2000.

2. Status

Forest Research became an Executive Agency of the Forestry Commission with effect from 1 April 1997. It undertakes the major part of the Commission's research and development programmes as well as providing survey, monitoring and scientific services.

Forest Research remains part of the Forestry Commission, which is a cross border Government Department responsible for forestry throughout Great Britain. The relationship between Forest Research, the Forestry Commissioners and Forestry Ministers was described in the Framework Document published February 1997.

Prior to April 1997, Forest Research was managed as a Division of the Forestry Commission and its assets and financial transactions were included in the departmental accounts presented in the Forestry Commission Annual Report and Accounts.

From 1 April 1997, the Agency assumed ownership of and responsibility for the assets and liabilities appropriate to the research activity which were included in the Forestry Commission Statement of Assets and Liabilities as at 31 March 1997. It also assumed ownership of the building assets it occupies, which were previously owned and managed on behalf of the Forestry Commission by the Forest Enterprise agency, with appropriate intra-departmental charges made, and recorded on the Forest Enterprise balance sheet as at 31 March 1997.

Two organisational reviews took place during 2002 and 2003 that impact on the Agency's status and operational arrangements.

In line with normal arrangements for agencies Forest Research underwent a Quinquennial Review, stage one of which was completed in January 2002 whilst between May 2001 and August 2002 an interdepartmental group carried out a review of the Forestry Commission. This reviewed the devolution arrangements for delivering sustainable forestry policies in England, Scotland and Wales and the UK's international forestry commitments.

On conclusion of stage one of the Forest Research Quinquennial Review Forestry Ministers decided that the Agency should retain its executive agency status for a further five years. The devolution review concluded that Forest Research should continue as a GB-wide agency of the Forestry Commission but new arrangements should be set up, with an enhanced role for the devolved administrations through the National Offices in England, Scotland and Wales in determining research priorities and specifying programmes.

The stage two report of the Agency's Quinquennial Review, which addresses the issues raised in the stage one review and the devolution review and makes recommendations for their implementation, received final Ministerial approval in January 2003. A new Framework Document has been agreed and is now in place*. A timetable for meeting the stage 2 recommendations was put in place in January 2003 and implementation is under way.

Under the Framework Document, Forest Research is funded from the sale of its services to both the Forestry Commission and external customers. Any annual surplus or deficit is counted in the Forestry Commission's net funding requirement.

*Editorial update: published October 2003.

Forest Research has been designated a GB entity. For Resource Accounting purposes Forest Research is within the departmental boundary. Its accounts are one of a number of separate accounts produced and audited by the Commission and are consolidated into the overall Forestry Commission England/GB accounts.

3. Aims and Objectives

The aim of Forest Research as set out in the new Framework Document is:

- to support and enhance forestry and its role in sustainable development, by providing high quality research and development in a well run organisation.

The objectives of Forest Research are listed on page 6 in the Annual Report.

4. Review of Activities

This is Forest Research's sixth year of operation as an Agency. Forest Research produced a net operating surplus of £628,000 on its Income and Expenditure Account, excluding the notional cost of capital. A comparison of income and expenditure with the previous year's results shows that:

- staff costs increased by £208,000 (3%)
- other management costs increased by £14,000 (0.7%)
- materials and service costs reduced by £184,000 (7%)
- income from Forestry Commission customers reduced by £320,000 (3%)
- income from external customers increased by £417,000 (33%).

The net surplus for the year after cost of capital of £620,000 and adjusting for the over provision of depreciation in previous years, was £8,000, representing a cost recovery rate of 100.1%.

After adjusting the total surplus for items not involving the movement of cash and for capital expenditure and income, the net cash inflow for the year was £501,000.

Additions to fixed assets in the year were £505,000.

5. Financial Objective

Forest Research's financial objective set out in the Framework Document is to recover the full economic costs, including cost of capital, of its operations from the sale of services to customers.

6. Post Balance Sheet Events

There are no post balance sheet events other than the outcome of the Forestry Devolution Review noted at paragraph 2.

7. Supplier Payment Policy

Forest Research observes the principles of the late payment of commercial debts (interest) Act 1998. Unless otherwise stated in the contract, we aim to pay within 30 days from the receipt of goods and services, or the presentation of a valid invoice, whichever is the later. An analysis for 2002–03 indicates that 99.3% of payments to suppliers, including those made using the Government Procurement Card, were paid within the due date. Arrangements for handling complaints on payment performance are notified to suppliers on orders.

8. Employment Policies

Forest Research is committed to the principle of equality of opportunity for employment and advancement for all eligible people on the basis of their ability, qualifications and fitness for the work. Forest Research has systems to ensure that all permanent appointments are made on the basis of fair and open competition and in accordance with the guidance laid down by the Civil Service Commissioners. Further information on the employment of persons with disabilities, the provision of information to, and consultation with, employees, and the promotion of equal opportunities is available on request.

9. Management

The Ministers who had responsibility for the Commission during the year were:

Rt. Hon. Margaret Beckett MP	*Secretary of State for the Department for the Environment, Food and Rural Affairs*
Elliot Morley MP	*Parliamentary Secretary (Commons) for the Department for the Environment, Food and Rural Affairs*

Members of the Management Board of Forest Research during the year were:

Jim Dewar	*Chief Executive (until 31 May 2002)*
Peter Freer-Smith	*Chief Research Officer and Acting Chief Executive (from 1 June 2002)*
Ken Charles	*Personnel and Administration Officer*
Tony Cornwell	*Head of Finance and Planning*
Bill Mason	*Acting Head, Northern Research Station (from 1 June 2002)*

The Chief Executive is appointed following public advertising of the post. Professor J.M. Lynch was appointed Chief Executive for a five-year period from 1 July 2003.

10. Auditors

These accounts are prepared in accordance with a direction given by the Treasury in pursuance of Section 7 of the Government Resources and Accounts Act 2000. They are audited by the Comptroller and Auditor General.

Professor J.M. Lynch
Chief Executive and Agency Accounting Officer
25 November 2003

Statement of Forestry Commission's and Chief Executive's Responsibilities

Under Section 7 of the Government Resources and Accounts Act 2000 the Treasury has directed the Forestry Commission to prepare a statement of accounts for Forest Research for each financial year in the form and on the basis set out in the accounts direction. The accounts are prepared on an accruals basis and must give a true and fair view of the Forest Research state of affairs at the year end and of its income and expenditure, recognised gains and losses and cash flows for the financial year.

In preparing the accounts the Forestry Commission is required to:

- observe the accounts direction, including the relevant accounting and disclosure requirements, and apply suitable accounting policies on a consistent basis;
- make judgements and estimates on a reasonable basis;
- state whether applicable accounting standards, as set out in the *Resource accounting manual,* have been followed, and disclose and explain any material departures in the financial statements;
- prepare the financial statements on the going concern basis, unless it is inappropriate to assume that Forest Research will continue in operation.

The Director General of the Forestry Commission, as Departmental Accounting Officer, has designated the Chief Executive of Forest Research as the Accounting Officer for the Agency. His relevant responsibilities as Accounting Officer, including his responsibility for the propriety and regularity of the public finances and for the keeping of proper records, and for safeguarding the Agency's assets, are set out in the Accounting Officers' Memorandum, issued by the Treasury and published in *Government accounting* (The Stationery Office).

Statement on Internal Control

1. As Agency Accounting Officer I have responsibility for maintaining a sound system of internal control that supports the achievement of the Agency's policies, aims and objectives, set by the Agency's Ministers, whilst safeguarding the public funds and assets for which I am personally responsible, in accordance with the responsibilities assigned to me. Control of certain activities is carried out by the Forestry Commission on the Agency's behalf, and in respect of those areas I place reliance on the Forestry Commission's Statement on Internal Control.

2. The system of internal control is designed to manage rather than eliminate the risk of failure to achieve policies, aims and objectives: it can therefore only provide reasonable and not absolute assurance of effectiveness.

3. The system of internal control is based on an ongoing process designed to identify the principal risks to the achievement of the Agency's policies, aims and objectives, to evaluate the nature and extent of those risks and to manage them efficiently, effectively and economically. This process has been in place for the year ended 31 March 2003 and up to the date of approval of the Annual Report and Accounts and accords with Treasury guidance.

4. We have agreed and promulgated a risk management policy. Working with responsible managers, we have developed a risk register for the principal risks to the achievement of Agency policies, aims and objectives. These identify the risks, the adequacy of the controls and any corrective action required. This has been endorsed by the Agency's Management Board and we have carried out a full risk and control assessment before reporting on the year ended 31 March 2003.

5. As Agency Accounting Officer I also have responsibility for reviewing the effectiveness of the system of internal control. The Agency has established the following processes which operated during the financial year:

- The Management Board met monthly to consider the plans and strategic direction of the Agency. The Management Board received regular reports from managers on the steps taken to manage risks in their areas of responsibility including progress on key projects. The risk management policy ensures that the Board includes risk management within its remit and formally tasks it with its review.
- The Agency has an Audit Committee, which reviewed matters concerning risk and internal control within the Agency. The Forestry Commission had an overarching Audit Committee chaired by a non-executive Forestry Commissioner. Its remit included advice on the effectiveness of risk management and control throughout the Commission and its Agencies, including Forest Research. The work of the internal and external auditors is currently reported annually to the full Board of Commissioners; in future this will be expanded to cover the full business of the overarching Forestry Commission Audit Committee.
- The Forestry Commission has an Internal Audit Unit, which operates to Government Internal Audit Standards. They submit regular reports, which include the Head of Internal Audit's independent opinion on the adequacy and effectiveness of the Agency's system of internal control together with recommendations for improvement.
- The topic of risk management was introduced into a series of financial awareness seminars attended by staff of all grades with financial responsibilities. The series was completed by December 2002 and the seminar has now become part of the internal training prospectus available to all staff.

6. My review of the effectiveness of the system of internal control is informed by the work of the internal auditors and the executive managers within the Agency who have responsibility for the development and maintenance of the internal control framework, and comments made by the external auditors in their management letters and other reports.

7. From 1 April 2003 the system of internal control has been redesigned, primarily to reflect the change in structure across the Commission following the Forestry Devolution Review. This will involve the ongoing work of the overarching Audit Committee, on which the Agency will have a representative, and the introduction of an Internal Control Committee for the Agency to advise the Accounting Officer on the effectiveness of risk management and control.

Professor J.M. Lynch

Chief Executive and Agency Accounting Officer

25 November 2003

The Certificate and Report of the Comptroller and Auditor General to the House of Commons

I certify that I have audited the financial statements on pages 112 to 124 under the Government Resources and Accounts Act 2000. These financial statements have been prepared under the historical cost convention as modified by the revaluation of certain fixed assets and the accounting policies set out on pages 115 to 116.

Respective responsibilities of the Agency, the Chief Executive and Auditor

As described on page 105, the Agency and Chief Executive are responsible for the preparation of the financial statements in accordance with the Government Resources and Accounts Act 2000 and Treasury directions made thereunder and for ensuring the regularity of financial transactions. The Agency and Chief Executive are also responsible for the preparation of other contents of the Annual Report. My responsibilities, as independent auditor, are established by statute and guided by the Auditing Practices Board and the auditing profession's ethical guidance.

I report my opinion as to whether the financial statements give a true and fair view and are properly prepared in accordance with the Government Resources and Accounts Act 2000 and Treasury directions made thereunder and whether in all material respects the expenditure and income have been applied to the purposes intended by Parliament and the financial transactions conform to the authorities which govern them. I also report if, in my opinion, the Foreword is not consistent with the financial statements, if the Agency has not kept proper accounting records or if I have not received all the information and explanations I require for my audit.

I read the other information contained in the Annual Report and consider whether it is consistent with the audited financial statements. I consider the implications for my certificate if I become aware of any apparent misstatements or material inconsistencies with the financial statements.

I review whether the statement on pages 108 to 109 reflects the Agency's compliance with Treasury's guidance 'Corporate Governance: Statement on Internal Control'. I report if it does not meet the requirements specified by Treasury or if the statement is misleading or inconsistent with other information I am aware of from my audit of the financial statements.

Basis of audit opinion

I conducted my audit in accordance with United Kingdom Auditing Standards issued by the Auditing Practices Board. An audit includes examination on a test basis of evidence relevant to the amounts, disclosures and regularity of financial transactions included in the financial statements. It also includes an assessment of the significant estimates and judgements made by the Agency and Chief Executive in the preparation of the financial statements and of whether the accounting policies are appropriate to the Agency's circumstances consistently applied and adequately disclosed.

I planned and performed my audit so as to obtain all the information and explanations which I considered necessary in order to provide me with sufficient evidence to give reasonable assurance that the financial statements are free from material misstatement whether caused by error or by fraud or other irregularity and that in all material respects the expenditure and income have been applied to the purposes intended by Parliament and the financial transactions conform to the authorities which govern them. In forming my opinion I have also evaluated the overall adequacy of the presentation of information in the financial statements.

Opinion

In my opinion:

- the financial statements give a true and fair view of the state of affairs of Forest Research at 31 March 2003 and of the surplus, total recognised gains and losses and cash flows for the year then ended and have been properly prepared in accordance with the Government Resources and Accounts Act 2000 and directions made thereunder by Treasury; and
- in all material respects the expenditure and income have been applied to the purposes intended by Parliament and the financial transactions conform to the authorities which govern them.

I have no observations to make on these financial statements.

John Bourn

Comptroller and Auditor General

11 December 2003

National Audit Office
157–197 Buckingham Palace Road
Victoria
London SW1W 9SP

Income and Expenditure Account for the year ended 31 March 2003

	Notes	2003 £000	2002 £000
Income			
Income from research, development and survey services			
Forestry Commission customers	2	**10,833**	11,153
Non-Forestry Commission Customers			
European Union		**510**	556
Other		**1,165**	702
Total income		**12,508**	12,411
Expenditure			
Staff costs	3	**7,528**	7,320
Other management costs	4 & 5	**1,899**	1,885
Materials and services	5	**2,453**	2,637
Total expenditure		**11,880**	11,842
Net operating surplus/(deficit)		**628**	569
Notional cost of capital	7	**(620)**	(556)
Net surplus/(deficit) for the year		**8**	13
Transferred to General Fund		**8**	13

Statement of Total Recognised Gains and Losses for the year ended 31 March 2003

	2003 £000	2002 £000
Net surplus/(deficit) for the year	**8**	13
Revaluation surplus/(loss) for the year	**500**	1,280
Total recognised gains/(losses)	**508**	1,293

The notes on pages 115 to 124 form part of these accounts.

Balance Sheet as at 31 March 2003

	Notes	**31 March 2003 £000**	31 March 2002 £000
Fixed assets			
Tangible assets	6	**10,378**	9,768
Current assets			
Stocks and Work In progress	8	**162**	259
Debtors	9	**1,031**	471
Cash at banks and in hand	10	**518**	1
		1,711	731
Current liabilities			
Creditors – amounts falling due within one year	10	**1,178**	742
Net current assets/(liabilities)		**533**	(11)
Total assets less current liabilities		**10,911**	9,757
Taxpayers Equity			
General Fund	11	**6,523**	5,869
Revaluation Reserve	12	**4,388**	3,888
Total Taxpayers Equity		**10,911**	9,757

Professor J.M. Lynch
Chief Executive and Agency Accounting Officer
25 November 2003

The notes on pages 115 to 124 form part of these accounts.

Cash Flow Statement for the year ended 31 March 2003

	Notes	2003 £000	2002 £000
Reconciliation of net surplus to net cash flow from operating activities			
Net surplus/(-) deficit for the year		**8**	13
Notional cost of capital	7	**620**	556
Depreciation	4 & 6	**389**	405
(Profit) / loss on disposal of assets		**5**	
Decrease/(-)Increase in stocks and work in progress		**97**	(228)
Decrease/(-)Increase in debtors		**(560)**	133
Increase/(-)Decrease in creditors		**436**	481
Net cash inflow from operating activities		**995**	1,360
Capital expenditure			
Payments to acquire tangible fixed assets		**(503)**	(513)
Non-cash inter-country transfers		**9**	9
Total net cash inflow		**501**	856
Financing			
Cash Surplus transferred to Forestry Commission		**501**	856
Reconciliation of net cash flow to movement in net funds			
Increase in cash and bank		**517**	
Net funds at 1 April 2002		**1**	1
Net funds at 31 March 2003		**518**	1

The notes on pages 115 to 124 form part of these accounts.

Notes to the Accounts

Note 1. Accounting Policies

1.1 Form of Accounts

In accordance with Section 7 of the Government Resources and Accounts Act 2000, the accounts are drawn up in a format agreed and approved by Treasury. They are prepared in accordance with the 2002–03 *Resource accounting manual* (RAM) issued by HM Treasury, under the historical cost convention modified by the inclusion of the valuation of assets.

The accounting policies contained in the RAM follow UK Generally Accepted Accounting Practice for companies (UK GAAP) to the extent that it is meaningful and appropriate to the public sector.

The particular accounting policies adopted by the Agency are described below. They have been applied consistently in dealing with items considered material in relation to the accounts.

1.2 Tangible Assets

Where the Agency is the principal beneficial user of assets of the Forestry Commission estate, they are treated as a fixed asset of the Agency although legal ownership is vested in the Forestry Ministers.

The normal threshold for the capitalisation of assets is £1,500, but all IT equipment costing £250 or more is capitalised as a pooled asset, the amount involved being material.

1.3 Valuation of Assets

Land and buildings were subjected to a triennial revaluation as at 31 March 2002 by professionally qualified land agents employed by the Forestry Commission following the principles set out in the *Royal Institute of Chartered Surveyors Appraisal and Valuation Manual*. Research and office equipment is revalued every three years using prevailing current prices for replacement items. Between revaluations, tangible asset values are updated annually using appropriate indices.

All revaluation surpluses and deficits are taken to the Revaluation Reserve.

1.4 Depreciation

Freehold land is not depreciated.
Depreciation is provided on all other tangible assets at rates calculated to write off the valuation, less estimated residual value, of each asset evenly over its expected useful life.
Freehold buildings – 20 to 80 years
Research and office equipment – 4 to 20 years

1.5 Intangible Assets

There are no intangible assets in the accounts. Purchased software and software licences are charged to the Income and Expenditure Account in the year in which they occur.

1.6 Stocks and Work in Progress

Work in progress on long-term projects is valued at the cost of staff time and other direct costs plus attributable overheads based on the normal level of activity.

1.7 Provision for Bad and Doubtful Debts

Specific provision for bad and doubtful debts are set aside on the basis of a review of individual debts at the end of the year.

1.8 Research and Development

As a provider of research services, all income and expenditure on research and development is written off to the Income and Expenditure Account.

1.9 Cost of Capital Charges

Charges, representing the cost of capital utilised by the Agency, are identified on the Income and Expenditure Account. The charge is calculated at the Government's standard rate of 6% in real terms on the average carrying amount of all assets, less liabilities. This rate has been reduced to 3.5% with effect from 1 April 2003.

1.10 Corporation Tax

Forest Research is not subject to corporation tax.

1.11 Value Added Tax (VAT)

The Forestry Commission is registered for VAT and accounts for it on a Great Britain basis, including any Agency activity. Income and expenditure shown in the accounts is net of any recoverable VAT. Non-recoverable VAT is charged to the accounts in the year in which it is incurred.

1.12 Foreign Currencies

Transactions in foreign currencies are recorded at the rate ruling at the time of the transaction. Exchange differences are taken to the Income and Expenditure Account. Exchange rate gains as at 31 March 2003 amounted to £30,000.

1.13 Insurance

In accordance with normal Government accounting practice, the Forestry Commission carries its own insurance risks.

1.14 Pensions

Past and present employees are covered by the provisions of the Principal Civil Service Pension Scheme (PCSPS), which is a defined benefit scheme and is unfunded. The Forestry Commission recognises the expected cost of providing pensions on a systematic and rational basis over the period during which it accrues benefits from employees' services by payment to the PCSPS of amounts calculated on an accruing basis. Liability for payment of future benefits is a charge on the PCSPS.

1.15 Compensation Scheme

The Forestry Commission is required to meet the additional cost of benefits beyond the normal pension scheme benefits in respect of employees who retire early. For Agency staff leaving after 1 April 1999, excepting those who left during 2000–01 under the provisions of the Modernising Government Fund, future liabilities for monthly 'compensation' payments will be shown in the Agency's accounts. To date, there have been no early retirements meeting this criterion.

Note 2. Income from Forestry Commission and Forest Enterprise

The Agency undertakes a significant proportion of the Forestry Commission's overall annual research programme in the form of specifically commissioned projects to deliver agreed outputs. A separate annual charge is agreed for each project based on full cost recovery. These charges amounted to £9.5 million. Costs established in one year are used to determine project charges for future years. The Agency also provides research and survey services for Forest Enterprise and other parts of the Forestry Commission on a full cost recovery basis.

Total income from Forestry Commission customers consisted of:

	2003	2002
	£000	£000
Research, development and other services to:		
Forestry Commission	**9,797**	10,096
Forest Enterprise	**1,036**	1,057
	10,833	11,153

Note 3. Staff Costs and Numbers

3.1 Employee costs during the year amounted to:

	2003	2002
	£000	£000
Wages and Salaries	**6,285**	5,999
Social Security Costs	**424**	424
Employer's Superannuation Costs	**797**	894
Agency Staff Costs	**22**	3
	7,528	7,320

To comply with RAM 2002–03 agency staff costs have been included with staff costs.

Until 30 November 2002 the Agency's staff were covered by the Forestry Commission Pension Scheme which was an unfunded defined benefit pension scheme. Employer's superannuation contributions, calculated as a percentages of pensionable pay, were paid to the Forestry Commission Pension Scheme and included in the Income and Expenditure Account. The employer's contribution rates were set at 15% to 22% according to grade, as determined by the Government Actuary. A full actuarial valuation was carried out at 31 March 1999.

From 1 December 2002 the Forestry Commission Pension Scheme was subsumed into the Principal Civil Service Pension Scheme (PCSPS) which is an unfunded multi-employer defined benefit pension. Employer's superannuation contributions, calculated as percentages of pensionable pay, are paid to the PCSPS and included in the Income and Expenditure Account. The employers contribution rates are set at 12%–18.5%, according to salary band. For 2002–03 employers contributions of £797,000 were payable (2001–02: £894,000).
Employees joining after 1 October 2002 can opt to open a partnership pension account, a stakeholder pension with an employer contribution. No Agency staff have yet taken this option.

3.2 Jim Dewar retired from the post of Chief Executive on 31 May 2002. The total remuneration, excluding pension contributions, of Peter Freer-Smith, Acting Chief Executive from 1 June 2002, the highest paid member of the management board, was £61,228.72 (2001–02: £50,579). The Acting Chief Executive is an ordinary member of the Pension Scheme.

3.3 The salary and pension entitlements of the management board members is shown below.

	Age	Salary	Real increase in pension at age 60	Total accrued pension at age 60 at 31 March 2003	Benefits in kind
2002–03	Years	£000	£000	£000	£000
Jim Dewar (retired 31May 2002)	55	10–15	0–2.5	25–30	–
Peter Freer-Smith[a]	47	60–65	0–2.5	10–15	800
Ken Charles[a]	57	35–40	0–2.5	15–20	–
Tony Cornwell[b]	59	35–40	0–2.5	0–5	–
William Mason[a]	54	40–45	0–2.5	10–15	–
2001–02	Years	£000	£000	£000	£000
Jim Dewar	54	60–65	0–2.5	25–30	–
Peter Freer-Smith	46	50–55	0–2.5	10–15	1800
Ken Charles	56	35–40	0–2.5	15–20	–
Tony Cornwell	58	35–40	0–2.5	0–5	–

[a]Opted to join classic scheme. [b]Opted to join premium scheme.

Salary

Salary includes gross salary and performance bonuses.

Pension

Pension benefits for the management board are consistent with other Forestry Commission employees and are provided through the Principal Civil Service Pension Scheme (PCSPS).

Benefits in kind

The monetary value of benefits in kind shown in the table above covers benefits provided by the employer that are treated as taxable income by the Inland Revenue. They are in respect of the Car Provision for Employees Scheme.

3.4 Pension schemes

From 1 October 2002, civil servants may be in one of three statutory based ‘final salary’ schemes– classic, premium or classic plus. New entrants after 1 October 2002 may choose between membership of premium or joining a good quality ‘money purchase’ stakeholder-based arrangement with a significant employer contribution (partnership pension account).

(a) *Classic scheme*

Benefits accrue at the rate of 1/80th of pensionable salary for each year of service. In addition, a lump sum equivalent to three years pension is payable on retirement. Members pay contributions of 1.5% of pensionable earnings. On death, pensions are payable to the surviving spouse at a rate of half the member’s pension. On death in service, the scheme pays a lump sum benefit of twice pensionable pay and provides a service enhancement on computing the spouse’s pension. The enhancement depends on length of service and cannot exceed 10 years. Medical retirement is possible in the event of serious ill health. In this case, pensions are brought into payment immediately without actuarial reduction and with service enhanced as for widow(er) pensions.

(b) *Premium scheme*

Benefits accrue at the rate of 1/60th of final pensionable earnings for each year of service. Unlike the classic scheme, there is no automatic lump sum, but members may commute some of their pension to provide a lump sum up to a maximum of 3/80ths of final pensionable earnings for each year of service or 2.25 times pension if greater (the commutation rate is £12 of lump sum for each £1 of pension given up). For the purposes of pension disclosure the tables assume maximum commutation. Members pay contributions of 3.5% of pensionable earnings. On death pensions are payable to the surviving spouse or eligible partner at a rate of 3/8ths of the members pension (before any commutation). On death in service, the scheme pays a lump sum benefit of three times pensionable earnings and provides a service enhancement on computing the spouse’s/partner’s pension. The enhancement depends on length of service and cannot exceed 10 years. Medical retirement is possible in the event of serious ill health. In this case, pensions are brought into payment immediately without actuarial reduction. Where the member’s ill health is such that it permanently prevents them undertaking any gainful employment, service is enhanced to what would have been accrued at age 60.

(c) *Classic plus*

This is a variation of premium, but with benefits in respect of service before 1 October 2002 calculated broadly as classic.

(d) *Partnership pension account*

This is a stakeholder-type arrangement where the employer pays a basic contribution of between 3% and 12.56% (depending on the age of the member) into a stakeholder pension product. The employee does not have to contribute but where they do, these will be matched by the employer up to a limit of 3% in addition to the employer's basic contribution. Employers also contribute a further 0.8% of pensionable salary to cover the cost of risk benefit cover (death in service and ill health retirement). The member may retire at any time between the ages of 50 and 75 and use the accumulated fund to purchase a pension. The member may choose to take up 25% of the fund as a lump sum.

3.5 The average number of employees (full time equivalents) during the year was 280 (2002: 280).

3.6 Benefits in kind are provided under the following schemes:

(i) Advances of Salary for House Purchase

(ii) Advances of Salary for Purchase of Season Tickets and Bicycles

(iii) Car Provision for Employees Scheme.

Each scheme is subject to conditions and financial limits.

The Advances of Salary for House Purchase scheme had 9 loans with an outstanding balance of £2,500 or more to individual members of staff at 31 March 2003. The total value of all loans (15) was £85,340.

Note 4. Other Management Costs

Other management costs are stated after charging:

	2003	2002
	£000	£000
Loss on disposal of fixed assets	**5**	–
Auditors' Remuneration	**19**	22
Depreciation of Fixed Assets	**389**	405
Travel and Subsistence	**460**	464
Staff Transfer Expenses	**68**	59
Training	**134**	120
Building Maintenance	**431**	382
Utilities	**220**	230
Computer Supplies	**96**	101

Note 5. Charges from the Forestry Commission

Included within Other Management Costs and Materials and Services are charges from the Forestry Commission and Forest Enterprise amounting in total to £1,018,580 (2002: £1,118,597).

Charges are made to Forest Research from the Forestry Commission and Forest Enterprise, as appropriate, for assistance with field experiments, hire of machinery and equipment and for personnel, business management, financial and other support services at Silvan House, Edinburgh.

Note 6. Fixed Assets

	Freehold Land and Buildings £000	Machinery and Equipment £000	Total £000
Valuation:			
At 1 April 2002	**8,650**	**5,033**	**13,683**
Additions	114	391	505
Disposals		(112)	(112)
Transfers		26	26
Revaluation adjustment	500		500
At 31 March 2003	**9,264**	**5,338**	**14,602**
Depreciation:			
At 1 April 2002	**331**	**3,584**	**3,915**
Provided in year	168	221	389
Disposals		(107)	(107)
Transfers		27	27
At 31 March 2003	**499**	**3,725**	**4,224**
Net book value:			
At 31 March 2003	8,765	1,613	10,378
At 31 March 2002	8,319	1,449	9,768

Fixed assets were revalued as at 31 March 2003 in accordance with accounting policies. The valuation includes the principal research stations at Alice Holt Lodge near Farnham in Surrey and the Northern Research Station, Roslin near Edinburgh, with net book values of £5.8 million and £2.6 million respectively at 31 March 2003.

Depreciation costs on machinery and equipment have been reduced by £54,000 to adjust for over provisions in earlier years.

Note 7. Cost of Capital

Notional cost of capital based on 6% of average total assets less current liabilities employed in 2002/03 amounted to £ 620,068.

Note 8. Stocks and Work in Progress

	2003	2002
	£000	£000
Research Work in Progress	**162**	259
	162	259

Note 9. Debtors

	2003	2002
	£000	£000
Amounts falling due within one year		
EC debtors	**457**	242
Other Trade debtors	**350**	126
Other debtors	**51**	30
Prepayments	**100**	2
	958	400
Amounts falling due after one year – house purchase loans	**73**	71
	1,031	471

Note 10. Creditors: amounts falling due within one year

	2003	2002
	£000	£000
Payments received on account	**350**	280
Trade creditors	**311**	454
Sums held on behalf of partners in EC projects	**517**	
Other creditors including taxation and social security costs		8
	1,178	742

Forest Research acts as co-ordinator for a number of projects partially funded by the European Commission (EC). The duties of co-ordinators include receiving EC funds on behalf of partners for onward transmission once work programmes have been approved. These sums are recorded on the face of these accounts as creditors and bank balances. At 31 March 2003 the amount held in Forest Research Bank accounts on behalf of partners was £517,386.92. This has subsequently all been transferred to the partners concerned.

Note 11. General Fund

	2003	2002
	£000	£000
Balance brought forward	**5,869**	6,160
Movement in year		
Net surplus/(-) deficit for year	**8**	13
Transfer of fixed assets from/(-) to other Forestry Bodies	**1**	(13)
Cash surplus to Forestry Commission	**(501)**	(856)
Monies held on behalf of partners	**517**	9
Non-cash inter-country transfers	**9**	
Notional cost of capital	**620**	556
Balance carried forward	**6,523**	5,869

Note 12. Revaluation Reserve

	2003	2002
	£000	£000
Balance brought forward	**3,888**	2,608
Revaluation surplus for the year ended 31 March 2003		
Land and Buildings	**500**	1,280
Balance carried forward	**4,388**	3,888

Note 13. Contingent Liabilities

Contingent liabilities have been recognised at 31 March 2003 in respect of claims for compensation for personal injury from two employees. One claimant is seeking damages of £43,000 and no detailed schedule of loss has yet been received in the other case. Both cases are ongoing. The information usually required by FRS12 is not disclosed, in line with DAO/GEN 19/02, on grounds that it can be expected to be prejudicial.

Note 14. Related Party Transactions

During the year, Forest Research has had a significant number of material transactions with the Forestry Commission and Forest Enterprise agency who are regarded as related parties.
In addition, Forest Research has had various material transactions with other Government Departments and other central Government bodies. Most of these transactions have been with the Department of Trade and Industry and the Department for Environment, Food and Rural Affairs.

Note 15. Financial Instruments

FRS 13: *Derivatives and other financial instruments* requires disclosure of the role which financial instruments have had during the period in creating or changing the risks an entity faces in undertaking its activities. Because of the way in which government departments are financed, the Agency is not exposed to the degree of financial risk faced by business entities. Moreover, financial instruments play a much more limited role in creating or changing risk than would be typical of the listed companies to which FRS 13 mainly applies. The Agency has no powers to borrow or invest surplus funds and financial assets and liabilities are generated by day-to-day operational activities and are held not to change the risks facing the Agency in undertaking its activities.

Liquidity risk

The Agency is not exposed to significant liquidity risks because its net revenue and capital resource requirements are financed by resources voted annually by the UK Parliament.

Interest rate risk

The Agency is not exposed to interest rate risk.

Foreign currency risk

The agency has commercial relations with foreign customers and the European Commission, having dealings in foreign currencies and the Euro as well as Sterling. The treatment of gains and losses arising from transactions in foreign currencies is described at Note 1.12 to the accounts. The Agency is therefore exposed to foreign currency risk, but the risk is not significant, income from these sources being no more than 4% of the Agency's total income.

Note 16. Financial Performance Measures

The target to recover full resource costs, including capital, from internal and external customers was achieved. The Agency achieved an operating surplus of £628,000 which, after allowing for the cost of capital, represented a cost recovery of 100.1% (2002: 100%).

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Contact addresses

Forest Research
Alice Holt Lodge
Farnham
Surrey, GU10 4LH
Tel: 01420 22255
Fax: 01420 23653
E-mail: research.info@forestry.gsi.gov.uk

Forest Research
Nothern Research Station
Roslin, Midlothian, EH25 9SY
Tel: 0131 445 2176
Fax: 0131 445 5124
E-mail: research.info@forestry.gsi.gov.uk

Technical Development Branch
Forest Research
Ae Village, Dumfries
DG1 1QB
Tel: 01387 860264
Fax: 01387 860386
E-mail: research.info@forestry.gsi.gov.uk

Website
http://www.forestry.gov.uk/forest_research

Advisory services

Disease, Diagnosis and Advisory Service - E-mail: ddas@forestry.gsi.gov.uk
Plant Quality Testing - E-mail: colin.edwards@forestry.gsi.gov.uk
Seed Testing - E-mail: seedtesting@forestry.gsi.gov.uk
Foliar Analysis/Fertiliser Prescription Service - E-mail: foliar@forestry.gsi.gov.uk
Library, Photographic and Information Services - E-mail: library@forestry.gsi.gov.uk

Editing and production management: Jenny Claridge, Forest Research
Graphics: George Gate, Forest Research
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Forest Research

Northern Research Station
Roslin, Midlothian EH25 9SY
Tel: 0131 445 2176
Fax: 0131 445 5124
http://www.forestry.gov.uk/forest_research

Alice Holt Lodge
Farnham
Surrey GU10 4LH
Tel: 01420 22255
Fax: 01420 23653

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