

FORESTRY COMMISSION RESEARCH ACTIVITY

Research by the Forestry Commission is undertaken to implement the *Science and Innovation Strategy for British Forestry*. The Strategy was developed by a Research Strategy Management Board representing both the Forestry Commission and the Northern Ireland Forest Service. In the Forestry Commission, research is commissioned on behalf of the Board by a team within Corporate and Forestry Support Division located at Silvan House, 231 Corstorphine Road, Edinburgh.

Research is organised by topic under the following strategic themes

- **Social and economic development** – research into social science, cultural heritage and economics (including some aspects of economic valuation).
- **Products and resources** - yield modelling, market development; research into timber quality, carbon, wood and non-wood forest products.
- **Environment, ecosystems and biodiversity** – research covering topics such as adaptation to climate change, tree health, landscape ecology, biological sustainability and the interactions between woodlands and water, soil and wildlife.
- **Sustainable management and protection** – research to develop and improve silviculture, forest operations, decision support and the practical management of pests and diseases.
- **Biometrics, monitoring and data management** – the development of indicators, the National Inventory of Woods and Trees, the Forest Condition Survey, some aspects of forest modelling and long-term data collection.

The bulk (approximately 90%) of research funded by the Forestry Commission is purchased from its Agency, Forest Research. Projects commissioned from external providers are often linked to the larger Forest Research programmes and these are mentioned briefly with the programme. Some larger purchases are described as programmes in their own right.

Social and economic development

Programmes

Economic research
Forest industry surveys
Forest visitor surveys and monitoring
Heritage & archaeology
Indicators of sustainable forestry
Public Attitudes Surveys
Social forestry

Programme title ***Economic research***

Location: External providers, Corporate and Forestry Support and Forest Research

Prior to 2005, economic and socio-economic research was commissioned as a series of studies from external providers. From 2005 we will also institute a longer-term programme of economic research from the Social Research Unit in Forest Research. This will add to the Forestry Commission's capacity in economic research and, in particular, will allow Forest Research to integrate economics into research on sustainable forest management. The details of this programme are still being planned.

Externally provided research will continue and includes projects on:

Valuing forest recreation. A major study is underway to value different forms of forest recreation in England, Scotland and Wales. The study will estimate the public benefit and economic impacts of different types of forest recreation activity and user, and provide profiles of visitors engaged in different types of forest-related recreation. Fieldwork at six forest sites in England, Scotland and Wales will be completed by the autumn. The final report is due at the end of 2005. The study is being overseen by a steering group comprising representatives of the Forestry Commission, Defra, the Scottish Executive and VisitScotland.

Economic Benefits of Accessible Green Space for Physical and Mental Health: Scoping Study. A consortium of government agencies, co-ordinated by the Forestry Commission, has commissioned a scoping study to investigate the economic benefits, in terms of physical and mental health, of changes in the provision of accessible green space. The results of the study will be used to consider whether a more substantial piece of research may be required to provide a fuller understanding of the extent to which green space (including woodland) generates beneficial health outcomes, and the policy interventions that may be needed to achieve these outcomes.

Programme title ***Forest Industry Surveys***

Location: External providers and Corporate and Forestry

Support

Annual surveys of sawmills and other wood processing industries are carried out by the Economics & Statistics Unit, to provide statistics on the volume of British timber used by these industries. A survey of employment related to forestry and wood processing was carried out at intervals of 5 years, with results for 1998/99 published in January 2001, but it has been decided not to run a survey in 2004. Research was commissioned in 1999/2000 to assess the health and vitality of forestry businesses, to establish a baseline for future monitoring; a further survey was carried out in 2004. A survey of domestic woodfuel use in Scotland was run in 2005, to update and expand a similar GB-level survey run in 1997. The survey is one of 3 projects aimed at evaluating woodfuel use in Scotland.

Programme title **Forest visitor surveys and monitoring**

Location: External providers

Until 2001, visitor surveys were carried out at 20-30 Forestry Commission visitor sites each year, about half as part of a national programme and the rest to meet local management needs. The national programme also used surveys to investigate one particular type of user each year - cyclists, special needs, horse riders and "local use" (dog walkers and others from the immediate vicinity). Until the end of 2002 trends in Forestry Commission visitor numbers were estimated using data from traffic counters and other sources. During 2002, the methodology for Forestry Commission visitor counts and surveys was reviewed. Selected districts piloted new methods, which can be applied to GB as a whole, or to individual countries. There is unlikely to be a GB FE co-ordinated programme in future, but the new methodology has been implemented in rolling programmes for Forestry Commission woodlands in Wales and Scotland. England has been running surveys at 3-4 selected sites a year since 2003 to assess the quality of visitor experience. There have been many locally initiated surveys each year.

Information about visitors to all types of woodland has been obtained by participating with other departments and agencies in commissioning the UK Day Visits Survey, which ran in alternate years up to 1998, the GB Day Visits survey in 2002/03, and a pilot of alternative methodologies in 2002. A separate long-term Scottish survey of outdoor recreation visits started in 2003, with Forestry Commission participation, so the GB consortium no longer exists. An England Day Visit Survey (including National Parks and open access) will run throughout 2005, also with Forestry Commission participation. Plans for a Day Visits Survey in Wales are under consideration.

Programme title: **Heritage and archaeology**

Location: Environment and Human Sciences Division, Forest Research and other institutes.

The Forestry Commission has for many years had a strong interest in conserving archaeological remains in forests, and in the historical and cultural value of woodlands themselves. The focus of this programme extends beyond artefacts and

monuments to include an understanding of the cultural heritage bequeathed by centuries of human activity in woodlands and the wider historic environment. The research aims are:

- to identify mechanisms by which the cultural heritage of woodland can be conserved;
- to raise awareness of archaeology and the wider historic environment in relation to forest management;
- to identify the contribution that an understanding of past woodland history can make to future forestry policy and practice.

The programme is small but has a number of key projects:

- The effects of trees and forest operations on archaeological features – research to understand the nature of the impacts and to identify methods of mitigation.
- Development of fieldwork methodologies for use in the archaeological assessment process. Ending 2005-6. Output includes assessment of remote sensing applications including LIDAR.
- Participation in the Scottish Environmental History programme
- The Forest of Dean and Northants Forest District heritage mapping and assessment projects. Outputs include review of PAWS restoration implications.
- An Oral History project examining the effects of a Scottish forest on the lives of people that lived and worked there.

Programme title ***Indicators of Sustainable Forestry***

Location: External providers

UK Indicators of Sustainable Forestry were published in October 2002, and are updated on the website <http://www.forestry.gov.uk/sfindicators> as new information becomes available. A number of relatively small pieces of external research have been commissioned to fill some of the gaps. These include:

- In 2004 we funded a project to review woodland butterfly data and contributed to funding a study of Environmental Justice in Scotland.
- In 2005-06 we plan to support work in Wales to compile information about the extent of community involvement in woodland management, following a study that reported on this topic for Scotland.
- We also provide an annual funding contribution for the IPD index of the financial return from commercial forestry.

Programme title ***Public Attitudes Surveys***

Location: External providers

A market research company has been commissioned to carry out a GB-wide Public Opinion of Forestry survey every second year since 1993. In 2003 the GB sample size was doubled to 4000, to give better results for individual English regions. During 2001, some questions from the GB survey were also asked in complementary

surveys in Scotland and Wales, each with 1000 respondents; there were similar complementary surveys in 2003, but asking more questions. In 2003, the GB survey was extended to run in Northern Ireland, with only minor differences, enabling us to compile UK-wide results. In 2005, the main survey covered 4000 respondents in GB, while complementary surveys of 1000 respondents were carried out in Scotland, Wales and, for the first time, Northern Ireland.

Since 2001 we have also collaborated with Scottish Executive on a Scottish Attitudes to the Environment survey, for which final results were published in January 2005.

Programme title: **Social Forestry**

Location: Environment and Human Sciences Division, Forest Research, University of Wales, Cardiff and other institutes.

The programme uses social science approaches to address organisational, institutional and societal questions across the whole forestry sector. The research includes work with individuals, social groups and communities and also organisations, institutions and processes such as Land-use Planning and EC funding programmes. The programme is closely linked to Forestry Commission's economic and statistical research.

The principal areas of investigation within Forest Research are:

- The development of methods for engaging with communities.
- An exploration of the part that recreation in Forestry Commission forests plays in sustaining businesses in the rural economy.
- The institutional context for forestry: managing change and maintaining good governance.
- Development of methods for evaluating forestry activities and social initiatives.
- Forestry and human health.
- Understanding how visitors to forests use woodlands, their information needs and their preferences for different spatial and aesthetic combinations.

Externally commissioned research draws on the skills of some of the UK's leading social research institutions and includes a number of PhD studentships co-funded with the Economic and Social Research council. The research is intended to identify ways in which the Forestry Commission's work can tie in to major Government policy themes:

- Inclusive access and use of forests,
- Forestry as a resource in maintaining sustainable communities,
- Forests as a resource for health and wellbeing,
- Governance of forestry at a time of rapid institutional change and,
- Consumerism as a driver of public attitudes towards the environment.

The underlying aims of the research are 1) to understand how forestry policy can align with wider social policy, and the activities and supporting conditions that this requires and 2) to understand the human factors that influence forestry. The programme therefore combines theoretical and practical approaches.

Products and resources

Programmes

Breeding & Production of Conifers
Improvement of Broadleaved Species
Selection & Testing of Conifers
Timber Properties
Wood Products

Programme title: *Breeding & Production of Conifers*

Location: Forest Management Division, Forest Research.

This programme takes the tested and improved resources from the *Selection & Testing* programme to provide a bank of material of known genetic quality. This stock is then used for advanced tree breeding work and to produce material for establishing seed orchards or supplies of improved seed for mass vegetative multiplication.

The tissue culture part of the programme is developing micropropagation techniques for use in the vegetative propagation of improved clonal material. Such techniques are valuable for the exploitation of the products of the tree-breeding programme because, when used with cryopreservation, they can circumvent physiological maturation and hence increase propagation potential. Some of the work is being undertaken through collaboration with cryopreservation specialists at the University of Abertay, Dundee.

Programme title: *Improvement of Broadleaved Species*

Location: Ecology Division in Forest Research, and in other institutes.

The Forest Research programme is primarily concerned with evaluating and testing provenances of the main commercial broadleaved species to secure the most appropriate sources of seed for timber production. The programme is co-ordinated with work in *Genetic Conservation* to ensure that the need to select seed for native woodlands from appropriate local sources can provide sufficient quantity and potential timber quality. Some low cost testing and breeding techniques are supported by the programme in Oak, Birch, Ash, Sycamore and Sweet Chestnut through Forestry Commission sponsorship for - and Forest Research collaboration with - the British and Irish Hardwoods Improvement Programme (a private sector led initiative). Forestry Commission is a funding partner with DEFRA in supporting breeding work at East Malling Research, which collaborates with Forest Research and BIHIP.

Programme title: *Selection & Testing of Conifers*

Location: Forest Management Division, Forest Research.

In the first part of this programme continues to evaluate established trials of a range of origins and provenances of the important commercial conifers and to make recommendations on the use of planting material from the most appropriate sources.

The second part of the programme involves the identification of superior phenotypes and their genetic evaluation in progeny and clonal tests for breeding work. A key output of the programme is the data on genetic gain achieved by improvement of particular characteristics, which can then be selected for the breeding and production programme. Effort is currently concentrated on improvements in volume yield, timber density, stem straightness and knot size and frequency in the major forestry species (Sitka spruce, Douglas fir, Scots and Corsican pine and hybrid larch). Grain angle is being added to the assessments. The work is linked to the *Timber Properties* programme, which seeks to improve timber quality potential in trees and performance as timber.

The programme is currently planting some large collections of Sitka Spruce clones as the test resource for future genetic improvement and testing using marker aided selection techniques (MAS). Initial laboratory work to identify suitable genetic markers is now taking place and involves international collaboration.

Programme title: *Timber Properties*

Location: Forest Management Division, Forest Research and Building Research Establishment

This programme is carried out in collaboration with Forest Research geneticists and the Centre for Timber Technology in Construction at the Building Research Establishment, with inputs from other programmes such as *Tree Stability and Climate*, and *Monitoring and Forecasting Forest Growth and Yield*. The programme is directed by a Steering Group composed of forest managers and timber industry specialists. Currently a major new project is the full tree and timber evaluation of a Sitka Spruce progeny trial planted in 1968 in collaboration with sawmills.

The objectives of the programme are:

- to quantify the qualities of timber to be expected from existing plantations, the knowledge of which needs to be improved to guide industrial development; and
- to establish quantitative relationships for major softwood species between silvicultural practice and changes in yield, timber density, knot size and frequency, grain angle and log straightness. These relationships are being incorporated in a modelling system to test and optimise different management regimes.

The current priority species is Sitka Spruce with some work on Scots Pine and initial consideration of the potential value of models for other UK grown species.

Programme title: *Wood products*

Location: A range of consultancies and research institutes, principally Building Research Establishment (BRE) and Timber Research and Development Association (TRADA).

The programme supports the processing and primary manufacturing end of the forest/wood chain. It is characterised by funding partnerships with other departments and the timber processing industries. The projects cover market and product development, the development of British Standards for wood and wood products, and the improvement of wood processing technologies particularly as regards conversion, kiln drying, strength-grading and engineered wood products. Major projects currently include the following.

- Supporting Sustainable Construction policy through Life Cycle Assessment of UK hardwood and softwood timber production. This has been incrementally developed from nursery and forest, through processing at sawmills and panelboard mills, and into production processes such as timber frame manufacture. Further development in collaboration with industry will support basic data for product labelling and proving product performance against the proposed Government Code for sustainable construction.
- Proving the performance of UK species in timber frame construction, and also in cladding applications (where the Centre for Timber Technology and Construction at BRE is also working in conjunction with an EU Northern Periphery funded research programme).
- Testing and improving the grading of British-grown species of hardwood and softwood timber particularly in preparation for the implementation of the new timber structures design requirements in Eurocode 5. The programme also supports the work of the UK Timber Grading Committee standards consultants and research.
- Improving the efficiency of commercially used kiln drying schedules, reducing the degree of distortion of timber in kiln and in service, assessing alternative kiln systems and exploring the potential for energy saving.
- Modelling wood characteristics to obtain a more fundamental understanding of the impacts of crop management and wood processing options (connects with Forest Research *Timber Properties* research programme and collaboration between Forest Research and BRE in the EU Mefyque modelling project and on compression wood).
- Investigation of new technologies with potential to promote added value for hardwoods and softwoods. This includes improved processing, engineered products, combination of timber with other materials and preservation technology.
- We are working with the timber frame industry on research to reduce construction cost through improved best-practice guidance and to generate information on flood resilience.
- Improving and better-targeting information on uses for UK timbers e.g. a recent TRADA project on round timber construction.

Environment, ecosystems and biodiversity

Programmes

Biodiversity evaluation and indicator development
Carbon dynamics in forests
Climate Change Impacts
Decision support for biodiversity
Diagnosis Investigation and Advice
Dieback of birch
Diseases of Native Broadleaves
Ecological Site Classification.
Ecology of Upland Native Woodlands
Entomology Advisory Service
Environmental monitoring and evaluation of forest ecosystems
Forest Hydrology
Genetic conservation
Impact of Herbivores on Woodland Ecosystems
Impacts of pests under changing management and environmental influences
Landscape Ecology
Lowland Native Woodlands
Management for Habitat Quality
<i>Phytophthora ramorum</i> and <i>P. kernoviae</i> ; including Site monitoring for <i>P. ramorum</i> and <i>P. kernoviae</i>
Plant Health (exotic pests)
Reclamation of Man-made sites for Forestry
Red band needle blight
Site monitoring for <i>P. ramorum</i> and <i>P. kernoviae</i> – see <i>Phytophthora ramorum</i> and <i>P. kernoviae</i>
Soil Sustainability
Species Action Plans

Programme title ***Biodiversity evaluation and indicator development***

Location Ecology Division, Forest Research.

A major field experiment devoted to assessing biological diversity in planted forests project ended in 2001 with results published in 2003. Further work has been undertaken to identify potential indicators of biodiversity and develop them through further fieldwork. The indicators under investigation include aspects of deadwood, vertical stand structure, birds and tree species diversity. The programme will last until 2004. The project is scheduled for review in the first part of 2004/2005. There is clear policy and practice rationale for continuing with work on biodiversity indicators, thus the project will be reconstituted to focus on this subject area. The assessment project data will be drawn on where appropriate, but a wider perspective including landscape-scale measures etc will be used.

Programme title ***Carbon dynamics in forests***

Location: Environment and Human Sciences Division and Biometrics Division, Forest Research

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. This programme builds on existing strengths within Environment and Human Sciences Division (growth processes especially under predicted scenarios of climate change and pollution and soil functioning) and Biometrics Division (yield modelling and life cycle analysis). Internet pages (<http://www.forestry.gov.uk/website/forestresearch.nsf/ByUnique/INFD-62HCJH>) provide an easily accessible and more detailed description of the programme and recent outputs.

Outputs will include an Information Note on carbon and wood products; software tools for the evaluation of Greenhouse Gas balance of bio-energy systems; and a software tool to estimate the carbon content in timber and wood products. The programme provides a major advisory function for the Forestry Commission and other parts of government.

Programme title: **Climate Change Impacts**

Location: Environment and Human Sciences Division, Forest Research

This programme addresses the complex issues of the direct effects of predicted global climate change with the principal objective of providing guidance on climate change adaptation. This objective will be achieved through three approaches, monitoring, impact studies and modelling. The monitoring element is largely being conducted through existing Forest Research networks including the National Inventory of Woodland and Trees (NIWT), the Forest Condition Survey and the EU/ICP-Forests Level I and II networks. The network of weather stations, largely associated with the Level II network also contribute to climate change monitoring while the recent establishment of an international Phenology Garden at Alice Holt is specifically aimed at climate change monitoring. Impact study research using the open top chamber facility at Headley is now concentrating on the effects of ozone pollution and contributing to the development of critical load assessment methodologies. Two approaches to modelling the effects of climate change are being followed; process modelling is being taken forward by close integration with the programme *Process modelling and data systems*, based on the UKCIP02 climate change scenarios. As a more immediate route to providing guidance on adaptation measures, ESC (Ecological Site Classification) has been modified to incorporate climate change scenarios and is being further developed to strengthen its knowledge base and incorporate additional functions relevant to climate change prediction. The final element of research is investigating the potential role of provenance selection for climate change adaptation through re-interpretation of existing provenance trials. New provenance trials for climate change research will be considered on the basis of these analyses. Information on all aspects of this research are available from the programme internet pages (<http://forestresearch.gov.uk/climatechange>).

Planned outputs are an Information Note on ozone and forest trees and peer reviewed publications to give scientific support to the strategic decisions that government may have to make on adaptation to climate change. This programme is

also developing guidance for the Forestry Commission based on reviews of climate change impacts on trees.

Strongly linked to this programme and to the *Ecological Site Classification* programme is the Forestry Commission contribution to the multi-agency MONARCH project – Modelling Natural Resource Responses to Climate Change – which is examining the potential impacts of environmental change on conservation of biodiversity. The research is led by the Environmental Change Institute of Oxford University and further details can be found on their website at www.eci.ox.ac.uk/biodiversity/monarch.html

The Forestry Commission contribution to the UK Environmental Change Network is included within this programme. Established in 1994, the aim of this network is to obtain long-term data sets, from a range of sites, to enable environmental change to be identified, and to assist in the improved understanding of the causes of such change. Measurements are made on atmospheric, soil and water chemistry, as well as a range of biological data to enable environmental effects on various aspects of the ecosystem, e.g. moths and climate, to be examined (see www.forestresearch.gov.uk/website/forestresearch.nsf/ByUnique/HCOU-4U4JA7 for further details).

Programme title **Decision Support for Biodiversity**

Location Ecology Division, Forest Research.

This programme is developing decision support tools to provide forest managers with biodiversity options for sites-types in terms of the habitats and species that may result from different management choices. Within the programme the HaRPPS (Habitats and Rare, Priority and Protected Species) decision support system is currently being developed to indicate the likely impacts of forest management on forest ecology and forest biodiversity. HaRPPS is designed to assist in forest planning; it is user friendly, offers quick and simple or detailed input modules, and is internet-based. HaRPPS provides operational and autecological information, and guidance, to forest managers. The application links to a specially developed Oracle database that is maintained by regular systematic review of new research findings. HaRPPS also uses information emerging from other Forest Research Programmes, in particular: *Species Action Plans*, *Biodiversity Evaluation* and *Management for Habitat Quality* and so provides a knowledge transfer system within Ecology Division. In addition, HaRPPS uses XML and HTML links to online information from the UK Biodiversity Action Plan, National Biodiversity Network and ESC Version 2 (using web services). In subsequent releases, HaRPPS will use ArcIMS technology to display and assess management options for key species and features. A beta version of HaRPPS will be delivered in March 2005.

The programme started in 1999 and is related to the *Ecological Site Classification* programme (ESC) (under “Forest Operations and Environment”). The main difference is that the ESC programme has developed and implemented a decision support system for matching tree species and NVC (National Vegetation Classification) woodland types to site type, and continues research to maintain and support the utility.

Some research from external providers is likely to be commissioned to develop scenario models for testing the interactions between biodiversity and other forestry objectives.

Programme title: **Diagnosis, Investigation and Advice**
Location: Tree Health Division, Forest Research.

Trees suffer from a wide array of damaging agents. These sometimes operate singly, sometimes in complex combinations. This is one of two programmes (the other being *Entomology Advisory Services*) aimed at identifying the causes of tree problems and providing advice on them to the Forestry Commission and the forest industry. The teams of advisers occasionally encounter problems that are worthy of in-depth investigation and therefore generate separate *ad hoc* projects.

The work of advisers in this programme provides valuable information on the general health of trees in Britain and is a valuable monitoring function. In addition to advice and guidance given to individuals, outputs from the programme include advisory notes and leaflets. The programme also supports a number of seminars and “forest health days” each year.

Support for the statutory functions of Forestry Commission with regard to non-indigenous pathogens is provided as part of this programme. The outputs involved are advice to the Forestry Commission, UK government and devolved administrations on forest diseases of quarantine significance.

Programme title **Dieback of Birch**
Location Tree Health Division, Forest Research.

An investigation in 2001-2003 of problems in establishing “new native woodlands” in Scotland revealed a widespread incidence of shoot dieback in birch associated with a range of fungi. This programme was created in 2003 to carry forward the investigation of the importance of these fungi and to advise forestry practitioners and the Forestry Commission on whether they are a serious, primary factor in dieback of birch and, if so, how they may be managed.

Programme title: **Diseases of Native Broadleaves**
Location: Tree Health Division, Forest Research.

This programme cover a range of small projects resulting from the major re-organisation of resources required in 2003 and 2004 to cope with the outbreak of *Phytophthora ramorum*. The principal research is into:

Phytophthora disease of alder. This is a relatively new disease, which has arisen as a result of hybridisation between two species of *Phytophthora*, and is now present in many European countries. The prevalence of the disease is regularly surveyed and other research directed at the epidemiology and control of the disease.

Alder dieback. This is a significant problem in northern Britain and unrelated to the *Phytophthora* disease. Research is aimed at elucidating the cause and investigating whether there are realistic options for managing it.

Oak dieback. This is a widespread problem in Britain and has been known for many years. Because its cause, or causes, are unknown, the advice that can be given to managers is limited. Research aims to investigate possible causes and to study the distribution and progress of the disorder to improve advice on risk management.

The programme has a high scientific content and will generate scientific papers alongside practical advice to managers.

Programme title: ***Ecological Site Classification***

Location: Ecology Division, Forest Research

This programme involves the development of a GIS-based ecological site classification (ESC) system. The research has achieved the integration of ecological data on plant–site interactions with geographic data sets to produce a decision support system to guide species choice and other aspects of forest management. The methodology has been published based on extensive testing in northeast Scotland (*Technical Paper 20*); another major case study from the New Forest has been published recently.

Work in the programme focuses on supporting the electronic ESC decision support system and improving its performance, especially in relation to nutritionally poor sites and the potential effect of climate change. Development of a GIS-based version and its availability via the internet will continue. ESC is being linked to other Forestry Commission modelling programmes (such as *Process Modelling & Data Systems* and *Decision Support for Biodiversity*) and with systems used by other organisations.

Outputs will include release of a GIS version of ESC available through FORESTER-GIS, and peer reviewed publications on the accuracy of ESC to estimate yield of Sitka spruce and predict soil type. The programme also provides advice supporting ESC and training courses.

Programme title ***Ecology of Upland Native Woodlands***

Location Ecology Division, Forest Research.

This programme is concerned with the ecology of native woodland types in upland areas of Britain - upland oakwoods, upland mixed ashwoods pinewoods, birchwoods, and upland wet woods. The main aims are:

- to investigate the natural succession of trees and broader habitats
- to explore ecological effects of management for habitat improvement, including removal of inappropriate species and consideration of use of appropriate grazing regimes.
- explore the ecological consequences of past woodland management on habitats
- to understand and monitor the ecological processes and long-term dynamics of native woodlands.

Involvement with grazing regimes will involve working closely with the *Impacts of Herbivore* Programme and monitoring of ecological processes will require strong linkage with the *Landscape Ecology* Programme.

Long-term monitoring will be undertaken in co-operation with other key interests as part of a strategy. Other partners will also be sought for research into ecological processes and into the relationship between native woodland characteristics and priority species under the UK Biodiversity Action Plan. (See also *Species Action Plans*.)

Programme title: **Entomology Advisory Services**
Location: Tree Health Division, Forest Research.

This is one of two programmes (the other being *Diagnosis, Investigation and Advice*) aimed at identifying the causes of problems and providing advice on them to Forestry Commission and industry. The teams of advisors occasionally encounter problems that are worthy of in-depth investigation and therefore generate *ad hoc* projects.

The work of advisors in this programme provides valuable information on the general health of trees in Britain and is a valuable monitoring function. In addition to advice and guidance given to individuals, outputs from the programme include advisory notes and leaflets. The programme also supports a number of seminars and “forest health days” each year.

Programme title: **Environmental monitoring and evaluation of forest ecosystems**

Location: Environment and Human Sciences Division, Forest Research

This long-standing forest monitoring programme arose from international concern about the potential effects of air pollutants on woodlands. It is complementary to the *Tree Health Monitoring* programme in “Forest Protection”, but differs in that environmental variables are monitored intensively alongside assessments of tree health. Recent and ongoing work has focussed on standardising monitoring techniques of tree health and environmental parameters across Europe. The monitoring work carried out within this programme is mandatory in member states of the EU and is carried out to agreed international protocols. This monitoring programme comprises 20 intensively monitored survey plots situated in either managed beech, oak, Norway spruce, Sitka spruce, or Scots pine woodland. Environmental variables monitored within the 20 plots include atmospheric chemistry, soil chemistry and tree health and growth. In addition to responding to specific research questions, the data contribute to the development of our national atmospheric pollution critical load maps. Critical loads reflect the sensitivity of an ecosystem to nitrogen, sulphur and ozone pollution and these maps are fundamental in the formulation of international protocols for the mitigation of pollution. There is now increasing emphasis on evaluating data from the 20 intensively monitored plots to identify trends over time and also relationships between ecosystem function and site-specific environmental conditions. The 20 woodland plots are also used as part

of a wider assessment of net carbon sequestration by European forests and to improve our assessment of the global carbon balance.

The programme will produce a revised manual for Crown Condition assessment and will report on the link between deposition chemistry, climatic conditions and tree health. The scientists working within the programme also have substantial responsibilities for UK input to European expert committees and panels.

Programme title: **Forest Hydrology**

Location: Environmental and Human Sciences Division, Forest Research

A key criterion of the Government's policy on sustainable forest management is safeguarding the quality and quantity of water.

Forests and forestry management practices can have profound effects on the freshwater environment. The main water quality issues are recognised as being: increased turbidity and siltation resulting from the soil disturbance accompanying cultivation, drainage, road building and harvesting operations; the impact of aerial fertiliser applications, in particular of phosphate and urea, on the nutrient status of receiving waters; and the enhanced capture of acid deposition by forest canopies leading to further surface water acidification. The effect of lowland pine forests on nitrate concentrations within groundwaters is an emerging issue in parts of lowland England. Water quantity issues include the threat posed by the expansion of conifer forests and to a lesser extent broadleaved forests to future groundwater supplies in drought prone regions and the impact of forestry on both winter floods and summer low flows. The effect of riparian forest management on the freshwater environment and the potential for the riparian clearance of upland conifers to aid the recovery of acidified waters are also receiving increasing attention. Finally, the recent flooding in England and Wales has renewed interest in the role of floodplain forests in controlling flood flows and mitigating the effects of floods.

This programme addresses the effect of lowland forestry on the quality and quantity of groundwater recharge, the impact of forests and silvicultural practices on winter floods and summer low flows, the effect of riparian forest management on the freshwater environment, the impact of forestry on surface water acidification, the demonstration of sustainable forestry to protect water quality and aquatic biodiversity, and the role of floodplain forests in flood defence and sediment control. Uncertainty over future rainfall patterns and quantities as well as the influence of climate change on tree growth make long term assessments a major challenge. The Water Framework Directive has increased emphasis on understanding these relationships at a catchment scale and in relation to other land uses. Consequently partnership working remains an important approach. Regular liaison with the water regulatory authorities and other interest groups will ensure that new problems are rapidly identified and addressed by further work and improvements in guidance. Expert advice is provided to national and international groups on the effects of forestry on water quality and quantity.

Following the publication of the 4th edition of *Forests and Water Guidelines*, particular issues will be explored in more detail in Information Notes, including one on water use of trees. The scientific evidence underpinning advice and guidance will be ensured through regular papers in peer-reviewed journals. A notable output will be contributions to a special issue of the journal *Hydrology and Earth System Sciences* entitled 'The Sustainability of UK forestry: contemporary issues for the protection of freshwaters'. A report has recently been produced on the hydraulic impact of floodplain woodland. The programme supports a substantial advisory function to Forestry Commission staff, the forestry industry and government.

Programme title **Genetic Conservation**

Location Ecology Division, Forest Research and external partners.

Biodiversity is the product of variation at the level of the population, species and ecosystem and policy aimed at conservation of biodiversity must address variation at each of these levels. This programme largely deals with variation at the sub-species level and concentrates on the assessment of variation within and between populations of a given tree or shrub species. The aim of this programme is to advance scientific understanding of the current patterns of genetic variation amongst native tree and shrub species in Great Britain, and to assess the influence of past, current and future management practices upon genetic variation. As a result, management recommendations for conserving genetic diversity and future adaptability will be produced.

There will be a strong focus on determining whether the origins of planting stock in native woodlands affect their ability to adapt to local conditions in future. Linkage to the *Landscape Ecology* Programme will be important. There will also be close linkage to tree breeding work for native species under "Forest Resources and Industry", so that the implications for genetic conservation of the use of improved and selected stock can be evaluated together.

The establishment and assessment of nursery and field provenance experiments make up the core of the programme and these examine adaptive traits of several native trees starting with birch, ash and rowan. This is being complemented by allied work carried out collaboratively by East Malling Research (formerly Horticultural Research Institute) and Forest Research, which is co-funded by Defra and the Forestry Commission. Alongside the provenance research is a programme of work based on molecular markers, which will tell us more about population history (including post-glacial migration routes), population structure, mating characteristics, and gene flow between populations. This information is being used to advise on management strategies for native tree species.

An early step has been to survey, identify and establish a database of autochthonous (self-seeded of local origin) native tree populations in England to add to those already completed for Scotland and Wales.

Technical advice on the effect of the Forest Reproductive Material Regulations on all aspects of genetic conservation policy is covered under this programme.

Programme title ***Impact of Herbivores on Woodland Ecosystems***

Location Ecology Division, Forest Research.

This research on large herbivores covered in this programme was formerly spread over 2 programmes *Deer Population Ecology* and *Forest Habitat Management*. The amalgamation recognises the similarity of impacts and of approach to understanding them: it also reflects the increased importance awarded to impacts on biodiversity. The research has 2 major foci.

Cattle grazing in native woods

Cattle are thought to provide biodiversity benefits in woodlands when grazed at low density. Because of these perceived benefits there is increasing interest in the use of cattle as a tool for nature conservation management in woodlands. Little information is available, however, with which the impacts of a given cattle-grazing regime on a particular woodland can be predicted. Additionally, there is little information available on the current use of woodlands for cattle grazing in Britain. The major focus of this programme is, therefore, to:

- gain an overview of the number, distribution, size and type of sites where cattle are currently being grazed in woodlands in mainland Britain.
- collate information on the reason for stocking with cattle, the cattle stocking regime, breed of cattle and the presence of other grazing animals at each site.
- collate observational information from site managers on cattle behaviour in woodlands.
- collate observational information on tree regeneration in the presence of cattle.
- if possible, draw conclusions about the impacts of cattle on woodlands and draw out generalisations about the effect of different stocking regimes.
- recommend further work to improve our ability to predict the impacts of different grazing regimes of cattle on different woodland types

Deer population ecology

It is vital for the protection and expansion of woodland that practitioners understand both the impacts of deer on woodland and the means by which deer can be managed to reduce impacts. In addition to research, therefore, this programme has taken on the important task of translating the results of research (by Forest Research and other organisations) into practical advice for woodland managers. Current work is aimed at increasing our understanding of population dynamics and behaviour, improving our ability to estimate population density and relating density to impact on crops and habitats. An external study, linked to this programme, on methods to estimate density started in 2002/03

Outputs from the programme are advice for land managers, scientific papers and policy advice to the Forestry Commission. The programme also supports Forestry Commission input to the Deer Initiatives in England and Wales and to the Deer Commission for Scotland. This is a long-term study that will be reviewed in 2005/06

Programme title: ***Impacts of pests under changing management and environmental influences***

Location: Tree Health Division, Forest Research.

This programme addresses the ways in which insects damage trees and the effects - economic and otherwise - of such damage. For several years investigation has been focused on green spruce aphid (*Elatobium abietinum*), the major insect pest of Sitka spruce, with smaller projects on insects that attack bio-fuel crops (short rotation coppice) and on pine looper moth, *Bupalus piniaria*. Research on *Elatobium* is linked to the potential impacts of climate change on commercial conifer crops in Britain because global warming is likely to have a major effect on the prevalence of the pest. This has been a strategic programme of particular relevance to Wales where the major experiments on green spruce aphid are located. Experimental work will come to an end during 2005/06 though analysis of data and publication of results will continue for some time; the latter will include guidance to managers and policy makers on impacts of pests on the main commercial timber species. As the project on *Elatobium* winds down, the programme will examine a range of other pest interactions that may be influenced by change – in climate or in silviculture. Of particular interest will be potential impacts from changing from clearfelling to “continuous cover” management systems.

Programme title ***Landscape Ecology***

Location Ecology Division, Forest Research and other institutes.

The Landscape Ecology Programme started in 1998/99 with the aim of *improving our understanding of how biodiversity responds to forest management at the landscape scale, and to translate this into practical management guidance*. The Programme spans both planted and native woodlands and other associated habitats.

The techniques for understanding and assessing landscape scale ecological attributes have been developed and tested through a number of case study sites, autecological studies, external landscape ecology related contracts, and recent developments in landscape ecology and geographical information systems (GIS).

Research initially focussed towards the evaluation of *landscape structure*, through the use of landscape metrics. This approach is now complemented by the development of Biological and Environmental Evaluation Tools for Landscape Ecology (*Beetle*), which encompasses simple species-based tools to examine and evaluate the underlying *landscape function*. Various evaluation tools have been applied at the forest, catchment, region and country scale.

This research and associated evaluation tools are intended to be equally applicable to large woodlands within a primarily forested landscape and small woodlands within an open matrix. The research is designed to assist the operational and strategic management of woodland landscapes; making it possible for forest/land managers to assess the ecological consequences of their plans, and make informed choices, in both space and time, along with other economic and social factors necessary to provide multiple-benefit sustainable forests.

This programme has links to all other programmes in "Forests and Biodiversity", especially *Lowland Native Woodlands*, *Ecology of Upland Native Woodlands*, *Management for Habitat Quality*, *Species Action Plans* and *Decision Support Systems for Biodiversity*.

Programme title **Lowland Native Woodlands**

Location Ecology Division, Forest Research.

The silviculture and ecology of broadleaved trees and woodlands are being studied using a combination of detailed scientific experiments, and practical forestry studies, to improve our understanding of the processes involved in the successful creation, restoration and management of lowland broadleaved woodlands. The information gathered will be used to improve the quality of advice available and the practical management of woodlands. Current projects focus on understanding the ecology and predicting the effectiveness of natural regeneration in relation to stand treatment, site and vegetation types and deer impact. A series of experiments to test methods of restoring native woodlands has been established.

This programme complements the *Ecology of Upland Native Woodlands* programme and has similar objectives and linkages to other programmes. The emphasis on achieving biodiversity together with good quality timber or coppice is stronger in the lowland programme because of the high proportion of lowland broadleaved woodlands that are native woods or are on ancient woodland sites. The link to *Alternative silvicultural systems for the lowlands* in "Forest Operations and Environment" is therefore strong. More detailed information is available on the Forest Research website:

<http://www.forestresearch.gov.uk/website/forestresearch.nsf/ByUnique/INFD-5Z5GES>

Programme title **Management for Habitat Quality**

Location Ecology Division, Forest Research.

A diverse programme focussed on planted forest habitats with the overall aim of providing guidance on the management of forest habitats at the stand or habitat scale. The approach is to identify management practices that will promote biodiversity. Practices will be based on the manipulation of natural processes and targeted towards specific ecosystem components where most benefits are likely to be gained. The priority themes selected are: managing open habitats, managing forest stands to develop mature habitat, including 'old growth' conditions.

The programme has links to several others including: *Landscape Ecology*, *Species Action Plans*, *Biodiversity Evaluation*, *Decision Support for Biodiversity*, and *Impacts of Herbivores*.

a temperature diffusion model to predict the rate of heat penetration to wood in compliance with the new international regulation requiring all packaging wood to be heat-treated. A new EU co-funded programme of research on Plant Health Risk and Management Evaluation (PHRAME), using pinewood nematode (*Bursaphelenchus xylophilus*) as a model system commenced in January 2003.

The principal output of the programme is advice to the Forestry Commission, UK government, devolved administrations, and other countries on forest pests of quarantine significance. The programme has a high scientific content and will continue to generate scientific papers. It also accommodates internationally recognised UK expertise in Pest Risk Analysis. Work in the programme is reviewed annually.

Programme title: **Reclamation of Man-made Sites for Forestry**

Location: Environment and Human Sciences Division, Forest Research

Use of land degraded by former industrial and urban activity makes an increasingly important contribution to the expansion of woodland. Trees planted on such sites offer immense social benefits in addition to the possibility of economic activity on formerly unproductive land. Research in this programme has already enabled techniques to be developed to overcome the physically hostile rooting environments and poor nutritional status of degraded land. Work is now concentrated on the use of bio-indicators to quickly judge site suitability; cost effective techniques to ensure tree establishment and growth; and the effects of trees on the dynamics of potentially toxic materials in so-called "contaminated land". Our objective is to enable afforestation to be carried out effectively and without releasing toxic substances into the surrounding land or water. The programme also supports a large consultancy requirement from Forestry Commission partners in fulfilment of objectives in the English Forestry Strategy, as well as across Great Britain generally. Internet pages (<http://www.forestresearch.gov.uk/fr/infd-5suk5s>) provide an easily accessible and more detailed description of the programme and recent outputs but are also summarised advice for practitioners.

The programme has an important advisory function for Forestry Commission staff and the forestry industry; this includes provision of advisory pages on the Land Regeneration Unit's website. Peer-reviewed papers on the potential for biological indications of possible forest end-use, and a summary of protocols for the early assessment of reclamation sites are planned.

Programme title **Red Band Needle Blight**

Location Tree Health Division, Forest Research.

Red band needle blight is an economically important disease with a world-wide distribution and affecting a number of coniferous species, in particular pines. The primary aims of this project are to determine the extent, severity and rate of spread of the disease in UK with particular reference to East Anglia Forest District, the impacts that this could have on tree mortality and timber yields and the suitability of

the different control measures within the UK. This will partly be achieved by surveys and by gaining a better understanding of the fungal biology in relation to the infection process and variation in the pathogen.

Programme title: **Soil Sustainability**

Location: Environment and Human Sciences Division and Forest Management Division, Forest Research

Since the Ice Age the soils in the UK have gradually evolved into a resource that functions as an integral link in the cycling of nutrients in forest ecosystems; a resource which is thus valuable and irreplaceable. The principal aims of this programme are firstly to identify and evaluate the potential impacts of forest management on soil status and dynamics (both physical and chemical), and secondly to develop and advise upon sustainable practices. Research, past and present, has particularly focused on harvesting, but pesticide usage, planting strategy and brash management are examples of topics which also fall under our remit.

Air pollution is a global issue that threatens the soil resource and yet is beyond the control of the forest manager. This programme therefore has strong links with the *Environmental Monitoring and Evaluation of Forest Ecosystems* programme. We are actively involved in the development of methods for estimating soil sensitivity to enhanced nitrogen and sulphur deposition.

The programme has a significant advisory function for the Forestry Commission and forestry industry and has recently provided input to the Wales Soil Strategy. It will generate a number of web pages. Information Notes are planned on the importance and management of brash and the use of sewage sludge and composts. Other publications on soil quality indicators and the environmental effects of wood ash will also be produced. Internet pages provide an easily accessible and more detailed description of the programme and recent outputs.

Programme title **Species Action Plans**

Location Ecology Division, Forest Research.

This programme supports the Forestry Commission's contribution to the implementation of the UK Species Action Plans (SAPs). A review of the SAPs relevant to forestry and their research needs was carried out in 1999 as a basis for planning this programme. Of 385 UK species action plans, 133 were identified as relevant in some way to woodlands but many of these are very local or rare. The review identified priorities for Forestry Commission research effort, based partly on how far the species status is likely to be affected by forest management and design.

Current priorities are for 15 species; red squirrel, capercaillie, Scottish crossbill, dormouse, twinflower, juniper, small cow-wheat, waved carpet moth, argent and sable moth, Scottish wood ant, Bechstein's bat, lesser horseshoe bat, pearl bordered fritillary butterfly, chequered skipper butterfly, lime bark beetle and a group of 'tooth

fungi' (stipitate hydroid fungi) associated mainly with the Caledonian pine forests of Scotland.

Research is focused mainly at understanding woodland habitat needs and the effects of forest management practices and will be integrated with other programmes such as *Decision Support Systems*, *Ecology of Upland Native Woodlands* and *Management for Habitat Quality*.

Sustainable management and protection

Programmes

Alternative silvicultural systems for conifers
Integrated establishment systems
Integrated Forest Management (<i>Hylobius</i>)
Integrated forest vegetation management
Management of Grey Squirrels
Management of Upland Native Woodlands
Non-chemical Protection
Operational safety and efficiency in the forest-wood chain
Protection of woodland ecosystems against mammals
Seed & seedling biology
Silvicultural Systems in the lowlands
Tree stability and climate

Programme title **Alternative Silvicultural Systems for Conifers**

Location: Forest Management Division, Forest Research

There is increasing interest in the potential use of alternative silvicultural systems to patch clear felling in conifer forests in Britain, particularly in those locations where non-market benefits (e.g. landscape, conservation) may be adversely affected by felling. This interest is generally classed under the terms "Alternatives to Clearfelling" (ATC) or 'Continuous Cover Forestry' (CCF). CCF is best considered as an approach to forest management based upon a number of guiding principles. These include management of the forest ecosystem rather than the trees, working with natural processes such as natural regeneration, respecting site limitations, creation of diverse stands with a range of species, and a presumption against clearfelling. This approach is favoured by a number of policy statements including the Welsh and Scottish forestry strategies.

However, there is a lack of knowledge of the silvicultural systems appropriate to CCF in British forestry, including how best to manipulate regular stands to promote natural regeneration and develop stable irregular stand structures. The research undertaken in this programme aims to elucidate the factors that will determine the potential for CCF on different sites in Britain and to transfer such knowledge to forest managers and other interested parties. Aspects studied include the development of natural regeneration in relation to site, stand structure and microclimate, the development of growth and yield models for irregular stands, and the role of mixed species silviculture in British conifer forests. A particular emphasis has been given to understanding the links between stand structure, light regime within the stand in relation to regeneration success, and stand stability against wind damage. The latter is particularly important given the serious risk of wind damage to conifer forests in many parts of upland Britain.

Planned outputs are 2 new Information Notes 'Establishment and interim results from the FE ATC demonstration sites in Britain' and 'Potential and management of mixed conifer/broadleaved stands in northern Britain.' Peer reviewed papers will continue to

ensure a sound scientific basis for advice. The researchers involved in this programme also support training courses and advise on pilot areas for ATC in public forests.

One other area covered by this programme is the management of long-term replicated forest experiments whose data can be used to validate predictions from models and short-term studies carried out in other areas of forest science. These experiments include cultivation, fertiliser, species and mixture trials. More details can be obtained from the research contact given above. The outcome of this work will be identification and cataloguing of key long-term experiments.

Programme title ***Integrated Establishment System***

Location: Forest Management Division, Forest Research

The overall objective is to research and advise the forest industry on procedures to improve establishment success and cost effectiveness whilst promoting sustainable forestry practices. The programme aims to provide management tools and advice encompassing all aspects of tree establishment through increased knowledge and understanding of physiological processes.

Within the programme, areas of research expertise include:

- planting stock quality
- establishment techniques
- stocking density assessment procedures
- nutritional sustainability
- fertiliser application to young crops
- root architecture modelling
- tree ecophysiology and molecular ecology

Current and agreed future work areas are:

1. Reduction of chemical inputs during establishment
 - Use of nutritional mixtures
 - Nutrition of restock sites
 - Targeting fertiliser applications through foliar analysis
2. Modelling of establishment and early growth
 - Predictive computer model for establishment success and growth
 - Development of decision support tool – the Establishment Management Information System [EMIS] - for delivery and analysis of silvicultural establishment techniques
 - Predicting long term effects of early growth benefits
3. Plant quality
 - Development and release of dormancy and cold tolerance
 - Successful establishment, with particular reference to new native woodlands
 - Evaluating new technology (e.g. planting machines)

4. Root architecture

- Cultivation and root behaviour
- Modelling of root architecture development

Research Information Notes are planned on the use of conifer mixtures, nursery and establishment best practice for larch, afforestation using planting machines, the development and persistence of multiple stems, and the use of direct seeding. Researchers involved in the programme will also produce a number of papers in peer-reviewed scientific journals on topics including the establishment and growth of trees planted into peat mounds on brush mats, the vegetative propagation of hybrid larch', the ecotypic preferences of Oak' and the ecophysiology of natural regeneration under continuous cover forestry.

Programme title ***Integrated Forest Management of Hylobius***
Location Tree Health Division, Forest Research.

This programme started in 1999 with the objectives of promoting and co-ordinating research into methods of “integrated crop management” in forestry as “integrated forest management” (IFM). The general objectives are to enable

- adoption of forest management methods that achieve acceptable levels of protection against pests and weeds with lower levels of chemical usage than at present;
- a reduction in the use of synthetic chemicals in British forests;

Within this general remit, the programme has rapidly focussed on the potential for IFM methods to minimise the current emphasis on insecticide applications to reduce damage to transplants from feeding by *Hylobius abietis* the principal forestry restocking pest. In an extension to the well-established Integrated Pest Management approach, research is aimed at improving our understanding of the behaviour and population dynamics of the weevil. Using this knowledge and its expected outcomes managers will eventually be able to monitor populations to determine risks, so that appropriate action – silvicultural, chemical or biological – can be taken to minimise damage. With these objectives in mind a series of major experiments started in 2003 to develop a Management Support System (MSS) to test the validity of existing information and to refine its application. The ultimate aim is to reduce populations below the economic threshold for a given site but initially the work will allow Forest Managers to make more informed decisions to improve restocking practices. Part of the IFM approach is to explore the potential for utilising natural variation in resistance of Sitka spruce to *Hylobius* to improve the quality of transplants in relation to their ability to withstand feeding damage.

A further major element to the programme is to develop a biological control method using nematode worms to kill *Hylobius* breeding in the bark of stumps. Although they are applied specifically to conifer stumps, nematode worms are the same species that occur naturally in soil and are widely used in horticultural systems to control a range of soil-living pests. The technique is proven in small-scale trials and has given good levels of weevil population reduction in forest-scale trials. The emphasis will now gradually move away from research experiments to larger forest

scale trials linked to management support. Recognising that chemical protection is likely to remain a part of the strategy for managing *Hylobius*, research is also maintained (though at a declining level) on proving the efficacy of insecticides.

Scientists in the programme team keep a watching brief for opportunities to develop IFM methods for other pests and diseases and to integrate with forest management initiatives such as Continuous Cover Forestry. Close links will be maintained with researchers in other programmes where pesticide reduction and IFM methods are under investigation

The main outputs from this programme are advice to forest managers on control of *Hylobius* and advice to the Forestry Commission on control policies for forest pests. The Management Support System for *Hylobius* will be a major development and the programme will be reviewed in 2005/06 after 3 years operation of the system.

Programme title ***Integrated forest vegetation management***

Location: Forest Management Division, Forest Research

This programme grew out of the realisation of the crucial importance of vegetation management to sustainable establishment of new woodland and successful regeneration of existing woodland.

Weeds compete for resources with newly planted trees and are probably the single most important factor preventing successful establishment, particularly on lowland fertile sites. There is a continuing demand for an authoritative source of advice to the Forestry Commission and private sector on specific weed problems throughout the UK. In response, comprehensive guidance on the use of herbicides in different situations has been produced and will continue to be updated and improved. A technology demonstrator of a web-based decision support tool advising on herbicide selection has also been developed, and a series of linked resource pages for pesticide users produced (<http://www.forestry.gov.uk/pesticides>). In general the programme serves as the source of expertise for forestry pesticide use and advises government and the forestry sector on the impacts of changes in legislation, commercial withdrawal of products and new problems (such as herbicide resistance and new weeds).

Forest Research has in the past put substantial research effort into investigating alternatives to the use of herbicides, and a new series of experiments was set up within the vegetation management programme in 1994. However, given the widespread adoption of the UK Woodland Assurance Scheme, calling for a reduction in, and eventual elimination of, synthetic pesticide use, there has been renewed effort in this field. For most weeding situations, alternatives to the use of herbicides exist, but they are nearly always substantially more expensive and often less effective than the use of herbicides. Opportunities exist both for investigation into novel forms of direct substitution with non-chemical weeding methods (such as biological control, cover crops and) and for investigation into manipulating silvicultural practices to enable an overall reduction in weeding intensities - and hence a reduction in herbicide use. Alternative silvicultural systems to clearfelling may also result in reductions in herbicide use. With correct management, it may be

possible to use natural regeneration to establish dense stands of trees, and control weed growth through canopy manipulation. However, in many cases, particularly on more fertile brown earths in the lowlands, profuse weed invasions take. As in other parts of the programme, continuing research is required to refine and improve the advice available to managers.

Programme title: ***Management of Grey Squirrels***

Location: Ecology Division, Forest Research and other institutes.

Grey squirrels are extremely destructive in woodlands and control methodology has been researched by the Forestry Commission for many years. However re-evaluation of control measures designed to protect trees is necessary to address the threat posed by grey squirrels to the native red squirrel and other wildlife. Consequently this programme cross-links to the *Species* programme in "Forests and Biodiversity". Research in *Management of Grey Squirrels* has the long-term aim of providing decision-support to woodland managers. Currently the most important project is a joint one with Forest Enterprise to develop "index trapping" methods to allow better targeting of control efforts. The programme manager also has a remit for "technology watch" on novel methods of mammal control. The closure in 2002 of the project to investigate the technique of immuno-contraception does not mean that interest in this and similar methods has evaporated. Thus programme leader remains in close contact with researchers in the UK and other countries where immuno-contraceptive techniques are being investigated on a variety of mammals.

The provision of practical advice to owners and managers has been an important element of this programme for several years. It is likely that the emphasis on "technology transfer" will increase and that the programme will become linked to complementary projects with external providers. As well as direct advice to individual owners and managers, the programme supports numerous seminars and workshops on grey squirrel control; it also provides expert input on behalf of the Forestry Commission to the "Squirrel Fora" in England, Scotland and Wales. The programme will be reviewed in 2005/06 when the main project on Index Trapping is coming towards closure

Programme title ***Management of Upland Native Woodlands***

Location Forest Management Division, Forest Research.

This programme is concerned with the management of native woodland types in upland areas of Britain - pinewoods, birchwoods, upland oakwoods, upland mixed ashwoods and upland wet woods. The main aim is to research alternative silvicultural options with the objective of improving management practice.

A series of long term monitoring plots have been established in five native pinewoods representing a range of site and climatic types in upland Scotland. Information has been collected on the age structure, spatial structure and recruitment of natural regeneration over time at each of these sites. This information is then being used as a model for the stand dynamics of pinewoods, and is helping inform management decisions on the recruitment of natural regeneration and

naturalisation (i.e. alteration of plantations of native origin seed source to more natural stand structures) of existing plantations. Further plots are likely to be established for other native woodland types.

'Managing the Pinewoods of Scotland' is a major recent publication. Planned outputs are a Practice Note on the control of *Rhododendron ponticum* in the British Isles and journal papers on the silviculture of native Scots pinewoods.

Programme title: **Non-chemical Protection**

Location: Tree Health Division, Forest Research and other institutes.

This programme has housed a number of diverse projects united by the need to address growing concern over chemical control methods. From 2003, research has been curtailed because of the reallocation of resources to cover the outbreak of *Phytophthora ramorum*. However work continues to identify exploitable resistance mechanisms to major forest pathogens such as *Heterobasidion annosum*. Research also continues into bio-control methods against *H. annosum*, especially into enabling wider use of the antagonistic decay fungus *Phlebiopsis gigantea*.

Non-chemical protection includes research carried out at the University of Abertay Dundee into the genetic manipulation of trees to confer protective mechanisms against threats from living or non-living agents.

Despite current reductions in resourcing, the aim is to retain this as a strategic programme generating scientific data and providing a "horizon scanning" functions. It provides advice on long term possibilities for innovative control measures and takes some through to direct advice to managers – as will be the case with *Phlebiopsis gigantea* as a biocontrol for *H. annosum*.

Programme title **Operational safety and efficiency in the forest-wood chain**

Location: Forest Management Division, Forest Research

Operational safety and efficiency in the forest-wood chain provides practical research and development to investigate the performance, in terms of quality of output, safety, environmental protection and cost-effectiveness of a wide range of forestry operations. One crucial objective is to ensure that the development and deployment of new equipment and operating techniques do not compromise the safety and comfort of operators.

Much of the work being undertaken now includes studies to maintain and improve operator health. Wherever possible we undertake collaborative research to provide practical solutions prior to the implementation of legislation. Topics on health safety currently being studied include:

- whole body vibration exposure
- operator protection from chainshot

- roll over protection in excavator based harvesters
- health management of machine operators

Research on operational efficiency has traditionally used work measurement and method study approaches to evaluate new equipment and systems. Increasingly, however, the projects in this programme will be aligned with other Forestry Commission research programmes to provide them with a practical and operational focus. The research represents the practical delivery of sustainable forest management and government policies relating to environmental protection, safe use of pesticides and management of invasive alien species.

Programme title ***Protection of woodland ecosystems against mammals***

Location Ecology Division, Forest Research.

This programme provides the operational support for mammal control and complements the more fundamental research in *Management of Grey Squirrels* and *Herbivore Impacts*. For the last several years, the programme has concentrated on practical research into improving the cost-effectiveness of physical barriers (fencing and tree-guards for example) against rabbits, voles and deer. It has also made a major contribution to reducing the death rates of woodland grouse species from strikes against deer fences.

A number of projects have recently ended and the future direction and emphasis of the programme has been reviewed. It is proposed to continue the programme for a further 3 years (i.e. until 2005/06) retaining its major technology transfer function, particularly with regard to fencing and control of mammals such as voles and rabbits. However it will also have an important role in “horizon scanning” for potential new mammalian pests or changes in range and distribution of familiar ones.

Programme title ***Seed and Seedling Biology***

Location: Forest Management Division, Forest Research

Until recently, British forestry has been based on raising seedlings in the hospitable environment of a nursery, and transferring the best ones to the forest planting site. Today there are many woodland managers who would prefer to use more natural processes in the creation and maintenance of uneven-aged and continuous-cover forests. Two methods are being increasingly employed, 'natural regeneration' (or more accurately 'human-assisted natural regeneration') and 'direct seeding', but are both proving to be much less predictable at establishing trees than traditional techniques. One major cause is an insufficient understanding of the factors that affect seed production, predation, germination, and early growth. A second problem is that techniques to store and handle tree seed, especially of many broadleaved species, lag at least 50 years behind that of agricultural, horticultural, vegetable and flower seeds.

An improved knowledge of tree seed characteristics will enable better human assistance to be given to 'natural regeneration'. And improvements to tree seed

quality and performance will increase the reliability of direct sowing and the efficiency of nursery production.

Outputs will include a guide to the identification of recently germinated seedlings in the field; it is being designed so that an electronic version can be used on a palmtop. Other publications include a Practice Note on raising trees and shrubs from seeds and journal publications on the efficacy of seed repellents, seed testing techniques, direct seedling of ash and sycamore, and the predation preferences for seeds of different trees and shrubs.

Further information is available at:

<http://www.forestresearch.gov.uk/website/forestresearch.nsf/ByUnique/INFD-63BCWL>

Programme title **Silvicultural Systems in the lowlands**

Location: Forest Management Division, Forest Research

The main objective of the programme is to provide guidance to the forest industry on the use of silvicultural systems in lowland woodlands. This is achieved by (a) increasing understanding of stand dynamic processes and publishing results in peer reviewed scientific papers, and (b) communicating the results of research to target audiences. The main areas of interest at present are:

1. To work with the Forest Enterprise “Alternatives to Clearfelling” (ATC) Group to produce a series of Information Notes on continuous cover forestry (CCF) and transformation.
2. To investigate the use of uneven-aged silvicultural systems in broadleaved woodlands (mainly types W8/WIO/W16).
3. Examine the potential for alternative silvicultural systems for management of lowland conifer forests, mainly Scots pine, Corsican pine, Douglas fir and Norway spruce.

Planned outputs include a major publication on the management of broadleaved woodlands. The programme also has a substantial advisory content.

Programme title: **Tree Stability and Climate**

Location: Forest Management Division, Forest Research.

Wind damage to upland forests in Britain is a major abiotic threat with important economic consequences. Silvicultural options such as thinning are severely restricted in the most vulnerable areas and production forecasts are calculated on the basis of assumed losses due to the wind. Current research is focused on the ForestGales decision support systems for predicting the risk of wind damage. The system operates at the stand level and a spatial version is being produced to integrate forest geographic information systems (GIS). ForestGales enables users to account for the changing risk of wind damage through the life of the crop when

making investment appraisals, considering silvicultural options or designing the forest landscape. New work is linked to *Timber Properties* research programme and will also develop model to be applicable to managing crops managed in systems other than large scale clear felling. The model will provide a significant support to policy studies of the potential impact of climate change and the research is also proving to be of interest to other sectors such as wind farms and insurance.

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Biometrics, monitoring and data management

Programmes

Countryside Survey
Forest measurement, monitoring and forecasting
Process modelling and data systems
Remote sensing
Tree Health Monitoring
Woodland Assessment Surveys

Programme title **Countryside Survey**

Location: External providers

We have contributed a small part of the funding for the Countryside Survey (CS), to add to funding for the Centre for Ecology and Hydrology from the Natural Environment Research Council, Defra and other departments and agencies. Our contributions include:

- in 2002-03, part funding for the FOCUS follow-up to CS 2000, which included comparisons between woodland data in CS and other data sources,
- in 2004 and 2005, contributions to funding and helping to organise a woodland topic group in a scoping study for CS 2006 (now CS 2007)
- spread over the period up to 2008, potential further contributions to CS 2007 development, data collection and analysis.

Programme title: **Forest measurement, monitoring and forecasting**

Location: Biometrics Division, Forest Research.

This programme provides the tools and models for forecasting timber production and forest development at forest and national level under a variety of silvicultural options. The outputs are fundamental to timber production forecasting required to lead investment in wood processing as well as being a key component of research-orientated models developed by Forest Research. However, the programme extends to quantifying and modelling the impacts on the physical environment of forests and of the impacts on the properties of timber as a material. It is highly relevant to 'life cycle analysis' of forest products, to studies of carbon sequestration by forests under different management regimes and to biomass forecasts (for renewable energy development). This aspect of the research is closely linked to the modelling studies in the *Climate Change* programme. It also contributes to market development through providing *Woodland Assessment Surveys* programme with the modelling system for the national forecasts of production. Key outputs are the procedures, tables and growth models used by the UK forestry industry.

The Forestry Commission sample plot databank provides the largest series of individual tree growth data for forest tree species in Great Britain with records dating back to 1910. The *Forest measurement, monitoring and forecasting* programme manages this national network of permanent and temporary sample plots representing a wide range of species, sites, yield classes and silvicultural treatments.

The sample plots provide the basic information (data and analysis) necessary for the development of yield models used for planning, inventory and production forecasting purposes. New priorities are the data needed to support silvicultural practice in mixtures and continuous cover management of the main commercial species affected. A new strategy has recently been developed for the future of the plot holding to better support policy needs (including climate change work). Critical data gaps are being assessed to see how they can be supported from a wide range of other experimental plots and records, as well as by new/replacement plots and tree ring analysis.

Development and promotion of new and improved methods of estimation and measurement are also included in this programme. The primary focus is on measuring the volume and quality of standing and felled timber. A current priority is to improve the standards of timber volume estimation and measurement by revised guidance, and also to extend this to electronic methods of measurement now used in the forest and at wood processing facilities so that they can be used with confidence by the trade. It also involves input to standards, and the provision of advice to regulators and industry practitioners faced with measurement problems.

The programme also covers the development and production of the National Private Sector Timber availability Forecasts for Scotland, England and Wales. The latest forecast was published in April 2001, but there are many other calls for bespoke forecasts. Working in collaboration with the *Timber Properties* and other Biometrics programmes the aim is to enhance these forecasts by the inclusion of information on the timber quality to be expected. The Private Sector Forecast System is currently being enhanced in order to provide whole tree biomass estimates in addition to timber.

Programme title: **Process Modelling & Data Systems**

Location: Biometrics Division, Forest Research

This is a multi-disciplinary programme led from Biometrics Division. It aims to integrate, develop and co-ordinate modelling initiatives, models and databases within Forest Research to improve forecasting of the response of forest systems to changes in the environment and in management practices. To date a number of modules have been harmonised into an integrated modelling framework, including a weather generator, a soil water balance model, an integrated evapo-transpiration model, a photosynthesis-stomatal conductance model, a bud-burst model, a light and rainfall interception model and single tree growth model. A selection of modules have been used as the constituent components of two models, *ForestFlux*, a model simulating the carbon and water fluxes between the forest canopy and the atmosphere, and *ForestGrowth*, a process based model of tree growth accounting for site conditions. *ForestGales*, an existing model forecasting tree windthrow, has been integrated in modular form and in turn more refined weather data are used by *ForestGales*. These models operate across a range of scales from individual trees, through stand and to landscape levels. A data warehouse (*FRED - the Forest Research Ecosystem Database*), bringing together a range of numerical and meta-data collected by Forest Research on forest ecosystems, has also been developed. *FRED* is an ORACLE database front-ended by Microsoft Access held on a central

server and accessed by PCs over the network. Prototype systems have been developed for interactive access of models and the database over the Forestry Commission Intranet. The programme of work is supervised by a steering group that includes staff from Forestry Commission, Forest Enterprise and external experts from UK and European research institutes.

Outputs from the programme will be

- website pages to enable access to a library of modelling routines and summary databases;
- peer reviewed papers to provide a sound scientific basis for model outputs and developments
- a strategy for identifying priority modelling modules, form of delivery and means for delivery to the Forestry Commission and other relevant organisations.

Programme title ***Remote Sensing***

Location: Biometrics, Forest Research

Earth observation from satellites, planes or remote controlled drones has advanced dramatically over the past 5 years and now offers a wide range of methods and technologies. We are investigating the capability of existing remote sensing systems to provide information to the forestry sector. Potential uses include extent of forest cover, forest inventory, health monitoring, and identification of nutrient deficiencies. This programme is being expanded to provide expertise specifically for the forestry sector.

An Information Note on the use of remote sensing techniques in operational forest management is planned. The programme will also generate peer-reviewed papers on the scientific background to the use of remote sensing in land management.

Programme title: ***Tree Health Monitoring***

Location: Tree Health Division, Forest Research.

Tree health is a matter of great public interest and concern. Through this programme, Britain participates in a pan-European annual survey of forest condition. The survey monitors crown density in some 370 plots distributed throughout Britain. Five species are surveyed - Sitka spruce, Norway spruce, Scots pine oak and beech. Assessments were started in 1987 and the run of data has allowed valuable year-to-year comparisons, which have been published annually for several years as Information Notes.

The monitoring has identified very weak downward trends in the crown density – and, by implication, health – of Norway spruce and oak since 1987. However, the interpretation of these, and other results, in terms of possible causes of damage is problematic.

The programme was reviewed in 2001/02 and retained on the grounds that it would be required as a major input to the UK programme for monitoring criteria and indicators of sustainable forest management.

Programme title: **Woodland Assessment Surveys**

Location: Biometrics Division, Forest Research.

This programme involves the collection, analysis and spatial modelling of woodland data at forest, regional and national levels for a variety of purposes. The main task is the National Inventory of Woodland and Trees, but other, one-off, surveys may be carried out. This is currently the principal means of measuring whether the Forestry Commission's mission to ensure sustainable forest management and expand Britain's forest and woodland cover is being achieved. The NIWT survey goes far beyond recording woodland size, species, area and age. It includes many factors related to forest management, timber potential, tree damage and vegetation structure. The survey is GIS based and can be used in conjunction with data from other land datasets. Work for the now completed 1995-2002 cycle of NIWT is described in *Forestry Commission Information Note 8*. The results are published in a digital map of woodland in Britain and a series of local and country statistical reports. Forest Research is currently consulting about their detailed proposals for the next cycle.

Development of survey methodology is an important part of the programme, for example incorporating new techniques in remote sensing, and testing new survey and data capture technology.