

FORESTRY COMMISSION

Description of the Research Project or Services

1.	Research Purchasing Manager (C&FS)	Stewart Snape
	Relevant PAG	Monitoring and Biosecurity

2.	Name of FR Programme Manager (PgM) or Project Manager (PM) and staff	Andy Moffat (PgM); Sue Benham (PM, WP1) Rona Pitman (PM, WP1) Anna Brown (PM, (WP2) Juan Suarez (PM, WP3) Bill Mason (PM, WP4)
	Name of Institution/company	FR
	Official address	Alice Holt Lodge, Wrecclesham Farnham Surrey, GU10 4LH
	Telephone No.	
	e-mail address	andy.moffat@forestry.gsi.gov.uk
	Programme Life (years)	4 Years
	Start Date	1st April 2011
	Completion Date	31st March 2015
	Revision Dates	31st March 2012/2013/2014

3. **Title of Research Project or Service**

Integrated Forest Monitoring

4. **Abstract of proposed research (Summary to be used on website/FRCC etc) (200 words)**

This programme provides and maintains a set of enabling frameworks for forestry data acquisition, storage, processing and use by a range of scientific and non scientific stakeholders. It comprises four main projects: (a) Research Forests, (b) Tree Health Surveillance, (c) Remote Sensing, and (d) Long-term Experimentation.

The Alice Holt Research Forest in England will be maintained and the network will be extended into Wales (at the Dyfi catchment near Aberystwyth) and Scotland (Queen Elizabeth Forest Park, Cowal & Trossachs FD). Significant partnership science will be sought, especially within Research Forests, to support the exploration of 'adaptive forest management' in the face of climate change. To support the Forest Biosecurity Strategy, a new forest health surveillance system will be developed in conjunction with Forestry Commission 'plant health specialists' and other forestry stakeholders. It will offer an 'early warning system' for pests and diseases, as well as quantifying distribution and impact on the forest. The remote sensing project will focus on (i) identification of Interpreted Forest Types, (ii) monitoring of changes and (iii) estimation of stand

parameters. The long-term experimental reserve provides a well maintained network of carefully designed and properly recorded field trials that can be used for research, reference and monitoring, demonstration and educational purposes.

5. Aims and objectives (word limit 500)

5.1 Aim of the research

The integrated forest monitoring programme:

- supports cross-cutting (repeat) data acquisition, of strategic use in monitoring and modelling, and supporting a range of CFS-funded research programmes;
- provides the ethos and opportunity for greater multi and interdisciplinary research, focussing on an understanding of cause-effect and process at selected important 'type' locations, and thus of importance to modelling and prediction systems;
- provides the infrastructure for continued development, integration and curation of FR's data assets;
- using remote sensing, increases certainty about Britain's forest resource in a cost-effective way;
- provides the infrastructure for closer working and integration of monitoring and evaluation activities within forestry sector management; facilitates the exploration of adaptive forest management as an adaptive strategy for climate change;
- complements other FC monitoring projects such as the National Forest Inventory;
- supports national and international reporting obligations and opportunities; provides a conduit and common protocol for interaction with European forest scientists;
- provides the opportunity and leadership for the further development of 'citizen science' projects;
- maintains a comprehensive suite of long-term forest experiments and trials (i.e. life span of >20 years) that can be used for research, reference and monitoring, demonstration and educational purposes including questions that are currently unforeseen.

In four years time, the IFM programme will deliver:

- a functional national forest health surveillance system; involvement of a range of national forest sector plant health champions; UK leadership to develop a pan-European system of a similar kind;
- at least three nationally significant Research Forests to support the research needs of the devolved countries; a large number of research projects will be undertaken at these locations, involving a range of internal and external scientists and generating non FC research income (real/in kind) of £0.5 million per annum;
- a consolidation of FR research data, including that from the extensive network of long-term experiments; appropriate systems to interrogate metadatabases and retrieve relevant data, and to publish summary information on the internet;
- important data and information in support of country reporting needs and UKFS;
- Successful proof-of-concept applications to classify forest types and monitor woodland changes using remote sensing technology;
- respect for the Forestry Commission as a professional 'actor' in environmental monitoring, achieved by adherence to and support for data sharing protocols at home (e.g. LWEC's UKEOF) and abroad (e.g. Forest Europe, UNECE);
- conspicuous support and partnership working in a range of important cross cutting

- research programmes involving use of environmental data;
- a significant number of scientific publications, book chapters, popular articles, conference papers and website pages;
- a major conference on forest monitoring, preferably in conjunction with IFOS.

Links with other programmes

The IFM programme is designed to support a wide range of other FR programmes, notably in the creation and support for Research Forests and in the provision or facilitation of scientific data and information from the various monitoring platforms run under the programme. Tangible current links include:

- data and scientific infrastructure to support the ManForC, Forest Hydrology and Soils and Knowledge management for Ecosystem services and Biodiversity programmes;
- research forest infrastructure to support the Forest Climate Change adaptation strategies programme;
- tree health surveillance to support the Advice and Scientific Support for Tree Health programme.

5.2 Work Areas

Please list your work Areas as shown in the table below and show how they further sub-divide Work Areas should be individually costed and be time bound – see 13. below. Please state key desired outcomes from each work area. First two years should be detailed, the next two in outline. See also Note for this Section below.

Work Area 1	<p>Maintenance and development of the GB Research Forest network (CFS funding profile: £197k p.a.) Staff: Sue Benham, Rona Pitman, Matt Wilkinson, Data Manager, TSU, Chemical Laboratory</p>
Work package 1.1	<p><u>Identification of new network; developing management agreements and relevant protocols; installation of monitoring equipment and collection systems</u> The aim is to develop a new network of Research Forests (RFs) to replace intensive monitoring plots set up under EU Regulation in the 1990s. The WP will involve considerable liaison with forest managers to establish the main research drivers for the RFs, and the ToR and protocols under which they will operate. Existing monitoring data will be collated for each site, whilst appropriate field monitoring equipment will be installed. Work will be put in to launch and publicise the RFs, and begin to attract the research community to them. RFs will be registered with selected national and international monitoring frameworks, e.g. ECN, LTER, ALTER-NET, SIGEO and ICP Forests. WP1.1 activities will take place mainly in years 1 and 2.</p>
Work package 1.2	<p><u>Data acquisition, QA, storage and transmission</u> Standardised data collection will begin once the RFs are commissioned, through field observation and measurement, and analysis of plant, water, soil and air samples. Data will be collated through the Forest Research Ecosystem Database (FRED), employing appropriate QA procedures. Summaries of these data will be published on appropriate pages of the FR website. Data will be shared with partners, e.g. via ECN and ICP Forests. WP1.2 activities will take place across the four year programme.</p>
Work package 1.3	<p><u>Development of special projects in Research Forests</u> This WP will be used to catalyse the use of RFs for research projects and</p>

Proposal for funding Agreement Number CFS 8-2011-15

	<p>programmes that would benefit from the research environment that RFs offer and that are appropriately carried out at catchment scale. For example, it is anticipated that RFs will be increasingly used by both research and management to test, monitor and evaluate different options under adaptive forest management. Other immediate uses for RFs include using as pilots to develop an ecosystems framework, and to explore fire risk. WP1.3 activities are more unpredictable than those above and can take place anytime throughout the programme's lifespan.</p>
Work Area 2	<p>Development and management of a GB forest health surveillance system (CFS funding profile: £40k p.a.) Staff: Anna Brown, Data Manager, FR Comms, possible FR programmers</p>
Work package 2.1	<p><u>ToR, identification of staff and common methodologies</u> This WP will be used to draw up the ToR for a new tree health surveillance system with appropriate partners in the FC countries, FC GB (notably IFOS), plus FERA and other PHSI's to identify how information is to be shared and to put in place the mechanisms to ensure that it does. QA issues will be addressed and SOPs drawn up. The format in which surveillance information and data are prepared will need to be agreed by FR and its customers. It may include input to a revised OGB2, and certainly to the publication of appropriate guidance and publicity for the new system. Strong liaison with head of FR's tree health team, or a nominee, will be required to support this project. . WP2.1 activities will take place mainly in year 1.</p>
Work package 2.2	<p><u>Testing of system and reporting in two directions – evaluation and refinement</u> Once a system is agreed and set up, it will be necessary to test it and refine as necessary. Success criteria and indicators will be identified and the system tested against them. Summaries of surveillance outputs will be published in appropriate media, including the FR (and FC?) websites. The surveillance system will be under continual evaluation, but most activity in this WP will take place in year 1 and 2.</p>
Work package 2.3	<p><u>Extension of system beyond FC – opportunities for wider sector involvement and citizen science</u> This WP will be used to explore how the FC surveillance system can be broadened to include inputs from other sources, including forestry professionals in the private sector, volunteering organisations and the lay public. Liaison with a range of organisations such as Sylva, RHS, Tree Council, AAIS and others will take place to extend the system and demonstrate a more inclusive approach to surveillance data gathering. The WP will also be used to further explore how this approach might be taken forward in Europe, supported by EU funding as appropriate. Work for this WP will begin in year 2.</p>
Work Area 3	<p>Remote sensing aims to increase certainty about Britain's forest resource. (CFS funding profile: core £79k plus £6k, 12k, 12k, 6k p.a. from external budget) Staff: Juan Suarez, PhD student to be appointed, Stephen Bathgate, Barry Gardiner, some TSU, Helen McKay</p>
Work package 3.1	<p><u>Identification of Interpreted Forest Types</u> The aim is to implement a successful application of machine learning to</p>

classify forest types as an alternative, or complement, to current methods for the creation of IFT maps.

Three techniques have been used to discriminate conifers and broadleaves: rule-based classifications in Definiens, Decision Trees and kNN. However, this type of analysis is affected by seasonal, phenological and geographical factors which are likely to introduce variations in the observed patterns of reflectance. Therefore, for instance, some species like larch can present similar reflectance than birch or oak. Machine learning techniques (e.g. kNN, Decision Trees, Random Forest, Artificial Neural Networks or Support Vector Machines) that have been tested in other countries to monitor and the classify forest types offer a significant improvement and will be investigated further.

Work package 3.2 Monitoring changes

The aim is to quantify phenological, geographical and sensor effects on the spectral response of the vegetation to produce fully automated methods for monitoring changes using time-series of medium resolution optical data.

The National Forest Inventory not only needs to be accurate and precise but also up-to-date. IFOS has identified a requirement for the continuous update of Britain's woodland map. As a result there is a need to monitor woodland loss due to clearfelling, windthrow or created by the effect of infestations and also the establishment of new plantings or the processes of natural regeneration.

The actual methodology implemented in the NFI relies on photo-interpretation analysis of digital aerial photographs, which is perceived as cost and labour intensive and highly dependant on the availability of national AP surveys which is captured in a 5-year cycle. Satellite images may be available once a year, indeed more frequent temporal coverage is theoretically possible, due to the growing number of sensors in space with similar technical characteristics, offering the ability for repeated monitoring over time They can be analysed through a range of techniques for the objective measurement of earth surface properties. The vegetation spectral signature allows for the development of quantitative relationships between remotely-sensed reflectance and vegetation parameters. Compared to both ground-based sampling methods and photo-interpretation analysis, the techniques are both synoptic and cost-effective.

The NDVI method is very simple and it has already being used to map forest changes in between NFI surveys. Other indices like Enhanced Vegetation Index (EVI) or Leaf Area Index (LAI) will be explored. A number of factors affect vegetation signatures: season; climate, in particular effect of rainfall or temperature variations over a growing season; terrain; geographical location; vegetation structure; variations of sun angle during the year and the characteristics of each sensor on the reflectance; the effect of shadows. A better understanding of these processes will translate into more automated classifications of changes enabling users to undertake analysis faster and more reliably.

Much of the work package will be addressed by a PhD jointly funded by the programme and the University of Edinburgh. It will establish links to tree physiology research programmes at FR looking for a better understanding between patterns of changes in reflectance and climatic

	variables.
Work package 3.3	<p><u>Estimation of stand parameters</u></p> <p>Until such time as country-wide Lidar is affordable, we will keep a watching brief on developments relevant to GB strategic issues. FR will maintain its lead in this area but as externally funded contracts for site-specific operational questions rather than using core funding.</p>
Work Area 4	<p>Long-term Experimental Reserve (CFS funding profile £40k p.a.) Staff: Bill Mason, Alan Harrison, Richard Jinks, Tom Connolly, Madge Holmes, TSU</p>
Work package 4.1	<p><u>Maintain sites and databases</u></p> <p>Desired outcomes: A selection of the best long-term experiments is secured to provide an invaluable resource that can be re-examined in the light of future questions especially about sustainable forest management.</p> <p>a) Experiments already selected will be maintained and periodic assessments made.</p> <p>b) Any remaining long-term experiments will be evaluated to decide future actions (close, moth-ball or include in the reserve). Experiment closure reports and other follow-on administrative actions will be completed.</p> <p>c) Databases will be maintained. The workload may increase significantly to ensure security of experiments on FC land in England if the ownership changes.</p>
Work package 4.2	<p><u>Collate the information from and publicise the existence of these experiments</u></p> <p>Desired outcome: reserve experiments are used for planned and unforeseen research needs in support of sustainable forest management and monitoring</p> <p>a) Contribute to the European Noltfox database of long-term experiments.</p> <p>b) Produce peer reviewed papers based on selected long-term experiments.</p> <p>c) Support the use of the reserve experiments for monitoring.</p>

6. Please indicate which of the FC's 6 Climate change priority actions this work fits into

Protect what we already have	<input checked="" type="checkbox"/>	Reduce deforestation	<input checked="" type="checkbox"/>
Restore the world's forest cover	<input checked="" type="checkbox"/>	Use wood for energy	<input type="checkbox"/>
Replace other materials with wood	<input type="checkbox"/>	Plan to adapt to our changing climate	<input checked="" type="checkbox"/>

7. Comment on how this research will address Country Strategy needs/targets (175 words)

<p>This Programme delivers a coherent, integrated set of data and knowledge that can be used to understand how our forests:</p> <p>1) are responding, in the long-term, to specific management decisions, an issue of direct relevance to all country strategies which are founded on sustainable forest management, and</p> <p>2) are affected by broad-scale external influences (e.g. incidence of pests and</p>

pathogens, climate change and pollution) over which managers have little control. Understanding these relationships will help countries develop policies and practical recommendations on the appropriate choice of species and volume of timber that can be sustained in a given area under given (and predicted) conditions. This information is in direct support of climate change mitigation commitments through carbon sequestration. The programme also offers an improved understanding of how forests and different forest species (at the local level) modify the effects of atmospheric pollution on their soils and water and the water draining from these systems. All of the country strategies highlight the need for assessments of forest health and condition with various indicators cited to determine forest status.

8. Identify and comment on any associated business risk of undertaking/not undertaking the research and how that will be managed

Undertaking:

Overall. At onset, the programme consists of four discrete projects which could operate in isolation of one another. To promote synergy and maximise potential integrative benefits, regular meetings of Programme PMs will be scheduled, together with CFS and country reps.

WP1. The main risk in setting up and running Research Forests is that no specific deadlines can be given for delivery of specific outputs because of the inherent variability and long response times of forests. However, the strengths of the programme reside in 1) its ability to analyse multiple, related data sets, and 2) the longevity of many of them. Together these enhance the ability to detect and explain change, so that important information can emerge.

WP2. The take up and execution of a surveillance system is dependent upon the dedication of a suitable resource in the Forestry Commission, by no means certain at the present time. The concept has been already tested with country FMOs and will be developed in close liaison with both senior policy and operational staff in the countries, in order to build a system that is fit-for-purpose AND executable.

WP3. Staff will need to be trained in the use of new methodologies. Most forestry staff engaged in inventory tasks will be using methods based on ground surveys. There will be an element of distrust with new technologies and change, which is natural, but must be overcome through effective outreach and demonstrations.

WP4. The resources allocated for this project are comparatively small, and they will need to be allocated carefully to maximise potential benefits.

Not Undertaking:

Overall. Without an IFM programme, the forestry sector would have to rely almost exclusively on monitoring data provided by successive national forest inventories, judged to be inadequate to be able to give answers on cause-effect relationships, and an unproven platform for forestry research in general.

WP1. The main risk of not supporting research forests is that irreplaceable information on trends in forest ecosystems will be lost, leaving the FC less able to defend its position on external drivers such as climate change and air pollution.

WP2. There is currently no fail-safe system in GB to support the identification of forest pests and pathogens – a real gap in Britain's forest biosecurity strategy. Without such a system in place, the forestry sector is dependent upon speculative reporting of occurrence by interested or concerned parties, and large areas of forest may go

unreported. Lack of early identification will lead to risk of pest/pathogen spread with consequent challenges to eradication, containment or management. Impact on forests will also increase.

WP3. The recent progress in using remote sensing to detect woodland loss within the mapped woodland will not be extended, e.g. automatic identification of areas achieving 'forest' status, thus limiting potential gains. The ability to detect areas of forest cover change which are not part of managed change will be seriously degraded or non-existent.

WP4. The considerable value gained in the long-term experimental dataset could be lost.

9. Research impact (economic, social, or biodiversity)

Who will benefit from this research?

Acquisition, management and utilisation of strategic forest data is vital to support both policy and operational staff who manage forests in the UK. Such data may be used directly by these stakeholders, but it is more likely that it will be taken and interpreted through a range of relevant research programmes, including those funded by CFS and by other research funders. Data will also be valuable for a range of science programmes supported but not controlled by the FC, both within and outside the forestry sector, e.g. UK-EOF, UNECE ICP Forests. The creation of a forest health surveillance system will service needs identified by the Defra/FC-led 'Tree Health Expert Meetings', i.e. a range of biosecurity stakeholders.

How will they benefit from this research?

WP1. Research Forests and the opportunities they provide will benefit the Territorial areas and Forest Districts in which they are located – through the ability to use data accrued/acquired to answer to specific issues – and through this to support broader country policies and forestry sector needs. Researchers will benefit from the provision of high quality scientific data, and the ability to test ideas supported by the knowledge about the forests that the IFM programme provides. The FC will thus benefit from the reputational advantage of supporting a unique and key resource for forestry, land-use and environmental science.

WP2. The forestry sector will benefit from the tree health surveillance system in the early and more precise reporting of potentially damaging agents, and through this be better able to respond before irreversible and more widespread forest damage takes place. Tree health researchers will benefit from gaining a better understanding of pest and pathogen distribution, in relation to environmental and management drivers.

WP3. IFOS, C&FS. Provision of more accurate information – in terms of temporal or geographical precision - complementing or replacing existing methods which will underpin the FC's aim of being the principal source of authoritative information on woodland in Britain.

Countries. Provided imagery is available it is possible to address country-specific questions on a wide range of key policy concerns. FC's switch to Next Perspective's mapping products, which includes Infra-red and lidar, offers the possibility of better species recognition, height and terrain assessments.

Industry. Depending on the cost of imagery, it may be feasible within the term of the Programme to provide sufficiently accurate estimates of standing volume and timber quality.

Other parts of FR. Strong linkages to stability and timber quality and strengthening links

<p>to mensurational science.</p> <p>WP4. The main impacts of the current suite of experiments will be economic and environmental - these are the management interventions they were designed to address. For example the selected experiments cover species, provenance and in some cases clonal choice; site preparation (cultivation, drainage, herbicide application), establishment (fertilisation, spacing, plant type); thinning practice; and residue harvesting.</p>
<p>What will be done to ensure that they have the opportunity to benefit from this research?</p> <p>Effective data sharing and communications is at the heart of this programme, and a communications strategy will be an early output. The FR meta-database, built during the last phase of the IFM programme, will be maintained and further developed in order to identify to FC and non FC staff the data available for use in research, policy and operational support. Focussing new data acquisition at a few selected sites (Research Forests) will facilitate closer research-forest interaction, and the genesis of jointly conceived and executed programmes which utilise the data (e.g. in testing adaptive forest management or in exploring the utility of the ecosystem services framework). The development of the tree health surveillance system is aimed directly at supporting front-line forestry staff who have the responsibility to manage disease and pest outbreaks, and it will be evolved in close co-operation with representatives from the countries and from FR's tree health team who will have a vital role in liaising with and informing the sector. FR's understanding of processes gained from the long-term experiments and/or fine resolution monitoring could be applied to help in the interpretation of NFI data.</p>
<p>Potential for innovation and new markets?</p> <p>The IFM programme is designed to maximise such opportunities. Future monitoring MUST be better integrated into policy and operational management decision making, and embedded in the most appropriate sector support, innovative opportunities will be maximised. Data capture should be very attractive to other research providers if effectively publicised – the Research Forest concept is designed to do this. Development of the health surveillance system is designed to explore opportunities, in this and other areas, for citizen science inputs, themselves often attracting funding streams. Remote sensing is at the sharp end of technological advance and there should be moderate opportunities to harness them here.</p>

10. Communication Strategy (please also see Box 14, item IFM2)

<p>Publications: See Section 14. FC publications likely to focus on guidance in use of monitoring and surveillance systems under development.</p>
<p>Reports: To be finalised in Section 14. Reports mainly to inform CFS and countries on progress in IFM – short and fit for purpose</p>
<p>Seminars/conferences: co-organising a major conference on forest monitoring and evaluation during the four year programme; participation and presentation in other forums as appropriate</p>
<p>Decision support systems: No stand-alone systems envisaged, but tree ill-health phenomena supported via on-line facilities</p>
<p>Website: FR website to be developed to accommodate and publicise IFM plans and deliverables, including provision of a portal to support the tree health surveillance system, and information on FR's Research Forests and main datasets.</p>
<p>Peer review papers See Section 14. Important in support of principal IFM activities and</p>

Proposal for funding Agreement Number CFS 8-2011-15

14. Deliverables and associated costs to Forestry Commission (KE = Knowledge exchange)

Work Area number	Output	Year 1				Year 2				Year 3				Year 4				Output	Total Cost
		Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4		
1,2,3,4	Four year programme (revised annually)		X				X				X				X			IFM1	
1,2,3,4	Joint communication strategy (detailed) (ditto)			X			X				X				X			IFM2	
1,2,3,4	Provide a report on advisory work to CFS				X			X				X				X		IFM3	
Maintenance and development of the GB Research Forest network																			
1	Research Forest plan for Great Britain			X														IFM4	
1	Research Forest publicity launched (mixed media)				X													IFM5	
1	Research Forest progress and delivery report to CFS (year 1)				X													IFM6	
1	Research Forest progress and delivery report to CFS (year 2)							X										IFM7	
1	Research Forest progress and delivery report to CFS (year 3)											X						IFM8	
1	Research Forest progress and delivery report to CFS (year 4)														X			IFM9	
1	Research Forest registration with monitoring systems (national/international)						X											IFM10	
1	Research Forest data collection, delivery and reporting (various recipients) (KE)																		
1	Chapters for Forest Monitoring book completed (Elsevier) (KE)					X													
1	Completion of data portal (FR website) (KE)							X											
1	Collaborative peer reviewed paper on quantification of ecosystem services through ECN monitoring (KE)				X														
1	Initiation of RF special projects (nominal timespan)									X									
1	Organise international conference on forest													X					



Proposal for funding Agreement Number CFS 8-2011-15

Signed.....Research Provider/HOD Date.....

Signed.....C&FS Advisor Date.....

A handwritten signature in black ink, appearing to read 'Rogge' or similar, written over a horizontal line.

Proposal Approved

CFS

Date 31st August 2011

15. Agreed Changes

Description of change:		
<p>Signed.....Research Provider Date.....</p> <p>Signed.....C&FS Date.....</p>		
<p>Signed.....Research Provider Date.....</p> <p>Signed.....C&FS Date.....</p>		
<p>Signed.....Research Provider Date.....</p> <p>Signed.....C&FS Date.....</p>		

16. Detailed communications plan:
Year 1
Year 2
Year 3
Year 4