



Programme 6: Forest Resource Assessment & Modelling

Section 1. Overview

Research Programme Title	Forest resource assessment, GHG balance and modelling.
Research Programme Short Title	Forest resource assessment and modelling.
CFS programme number	6
Version	1.0
Date	30 March 2015
Author	Tom Jenkins (with support from Robert Matthews as primary SGL)
Programme Life (Years)	5
Start date	1 April 2015
Completion date	31 March 2020
Cost of programme (£K)	£2676 (4 years); £669/yr

1.1 Summary of proposed research

Programme 6 (*Forest Resource Assessment, GHG Balance and Modelling*) was developed in direct response to feedback from stakeholders across the forestry sector. It is designed to address Research Area 6 (*Innovative Science Models, Data and Tools to Help Develop and Deliver Forestry Policy and thereby Improve Management and Resilience across the Forest Sector*) within the research brief arising from the Forestry Commission's Science and Innovation Strategy for Forestry in Great Britain.

The Programme therefore addresses the five key "research challenges" that emerged during the consultation process:

- RC1. To develop and implement an appropriate Quality Assurance framework for modelling within FR
- RC2. To develop and implement more reliable and flexible models for the sector
- RC3. To ensure integration and coherent delivery of model systems
- RC4. To develop and deploy improved models for forest and stand assessment and management
- RC5. To undertake and utilise physical and remote data acquisitions for monitoring and modelling

In addressing these challenges, this Programme undertakes underpinning research for other programmes and external stakeholders, by developing methods for data acquisition as well as models and tools to enable the assessment of the status and development of forests, timber, biomass and carbon stocks. This work also allows the impacts of disturbances and interventions to be modelled. Programme 6 will contribute directly to the evaluation of forest policies and practice through the analysis of datasets and the application of appropriate models and tools.

The Programme includes remote sensing research and some Technical Development. Long-term work includes the Permanent Sample Plot network, and the long-term experiments resource. The Programme is intended to play a pivotal role in knowledge exchange with the forestry sector by providing the data and tools needed to inform and verify decisions about forest policy and practice, and in applying data and tools to support the formulation and implementation of policy and practice.

A key overarching aim of this Programme is to build partnerships and capability spanning all modelling initiatives forming elements of the FC Science and Innovation Strategy.

Section 2. Description of work

2.1 Background

The development and use of interdisciplinary tools and models should support decision making in forest, ecosystem and wider land management to achieve sustainable and beneficial outcomes and better understanding between foresters and other parts of society. This will ensure that forestry contributes to the low carbon economy, for example by using data from the National Forest Inventory linked to financial and yield appraisal through production forecasting. Carbon stocks and timber production will be assessed and modelled to allow scenario planning for different management options; including the development of renewable energy policy and supplying information to inform the UK's legally binding international carbon reporting obligations. This research programme is designed to support both policy-makers and the forest industry with research directly linked to the assessment of the forest resource including timber growth, recovery and utilisation. This will be delivered through the development of a quality-assured suite of integrated models and tools which are underpinned through robust time-series data obtained from a sustained network of permanent mensuration sample plots. The models and tools developed under this Programme will be directly applicable to the implementation of sustainable forest management approaches required to meet the individual policy requirements of the three devolved administrations (DA's), including the scope to model the potential for alternative silvicultural systems, regeneration and novel tree species.

A key aim of the Programme is to pursue integrated development of key models, systems and tools of cross-cutting relevance to the programmes of the FC Science and Innovation Strategy, as well as for development of policy and practice.

2.2 Programme-level response to the research challenges

As part of its consultation with stakeholders over the Science and Innovation Strategy, the FC's Service Board for Inventory, Forecasting and Operational Support (IFOS) convened a stakeholder group to review information needs for the sector and to assess key gaps in existing work. The Review Group included representatives from Forest Research (FR), FC IFOS, FC C&FS, FC (England), FC (Scotland), NRW, Welsh Government and the private sector. The Group made an assessment of the ability of existing forest modelling systems and operational tools to contribute to three key areas of sustainable and resilient forest management in Britain, namely:

1. Making correct policy and business decisions
2. Delivering policy and business objectives
3. Verifying policy and its delivery

Key existing systems and tools assessed included:

- The FC National Forest Inventory (NFI) which provides fundamental information and evidence to address Issues 1 and 3
- The FC Forecast System which is the principal tool for assessing options for policies and business decisions (*i.e.* Issue 1)
- Forest estate management systems (as used by some private sector forest management companies) and research-based forest sector scenario analysis models (*e.g.* the Forest Research CARBINE forest carbon accounting model) which also assess options for policies and business decisions (Issue 1)
- Operational procedures and systems that support practical decisions and assist with carrying out forest management (Issue 2)

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- The FC Permanent Sample Plot network which provides fundamental research data to support the development, checking and improvement of forest models (Issue 3).

Underlying these systems and tools are a set of forest models with varying degrees of reliability and flexibility, including models for predicting stand growth and yield, estimating standing volume, biomass and carbon, estimating the distributions of tree sizes in forest stands, predicting production from thinnings and impacts on growing stock, and predicting timber assortments.

The Group identified a variety of risks and impacts due to poor reliability of information and evidence for certain forest types, policy and business scenarios and forest management decisions. The Group concluded that the risks identified could have major ramifications including:

- Policy makers and forest sector vulnerable to lobbying
- Legally binding GHG emissions commitments missed
- Loss of jobs and investment
- UK environmental credentials fundamentally compromised.

These risks were assessed as being already realised, or likely to occur in the short or medium term (less than 25 years). In purely financial terms all these risks were assessed as involving potential impacts which could amount to thousands of millions of pounds. The Group also identified significant reputational risks to FC and others; particularly if the assumptions and limitations inherent in current processes are not transparent and understood. The Group concluded that priority should be given to communicating, reducing, and mitigating these risks.

The Review Group concluded that research required to address the identified risks would involve five main endeavours:

1. Monitoring and research data acquisition
2. More reliable and flexible models
3. Improved tools for scenario analysis
4. Improved tools for growing stock assessment and management
5. Accelerated knowledge transfer.

The Work Packages developed within this Programme are designed to reflect the conclusions of the Review Group, the S&IS wider consultation and Country needs (through the Programme 6 Steering Group – see WP7: Programme Governance and Management).

This has included addressing an immediate priority to ensure that the forestry component of the UK's and country national greenhouse gas inventories are quality assured and transparent.

The review group recognised the fundamental and underpinning importance of this work to many economic, environmental and social aspects of British forestry policy. It also highlighted the consequential cross-cutting requirement to maintain core skills and capability in relevant areas of research. This is addressed through a longer-term aim of the Programme to develop and strengthen linkages across the programmes forming the Science and Innovation Strategy to support and integrate modelling initiatives and associated knowledge exchange.

2.3 Business considerations

Delivering against country research needs

The following long-term vision for Programme 6 was agreed by the designated representatives from England, Scotland and Wales (the Programme 6 Steering Group).

The Forestry Commission will routinely generate and update quality assured strategic estimates of current forest capital and GHG exchange and how these might change in the future. These estimates will meet current and future legal commitments and inform strategic policy and business decisions.

Forest managers across the sector will have access to the tools they need to assess and manage forest capital at both forest and stand levels, enabling them to deliver both policy and business objectives.

The widespread and high impact use of Programme 6 outputs will be underpinned by up to date, high quality scientific research.

The structure of Programme 6 is based on the work undertaken by the "FMMF Review Group" in 2014-15, the members of which included representatives of the three devolved administrations (DA's) as well as industry representation. The detailed content of Programme 6 for 2015-16, has been discussed at length by the Programme 6 Steering Group (P6SG) and was agreed in a meeting held on 25th February 2015.

The Steering Group agreed the following Critical Success Factors for 2020:

- Scientific knowledge and application substantively advanced compared to 2015 baseline
- Permanent Sample Plot data and metadata are accessible, maintained and relevant.
- High impact models, including those underpinning the NFI and GHG reporting, are documented, quality assured, fit-for-purpose and published
- FC Forecast system is documented, quality assured, fit-for-purpose and maintained
- Satellite data and data products routinely utilised to develop and improve models and inventory updates
- FC is recognised as the guardian of forest and timber inventory standards (Blue Book etc.)
- Forest managers across the sector have access to fit for purpose guidance and tools for assessment and management of forests and forest stands

Impacts and constraints

This is an ambitious programme designed to maintain and develop high impact forest models on a challenging budget. Timetabling of work is highly constrained by staff capacity; a number of work areas are dependent on a number of "singleton experts". Nevertheless, in an attempt to deliver as many of the customers' desired outputs as possible, it is inevitable that a number of FR staff are being expected to take on work outside their areas of immediate skills and experience. In some cases, staff time is divided across a number of outputs within a given time period, although we have tried to minimise this wherever possible. It is also important to note that, because of the constraints of funding, supervisory input from senior staff has been curtailed.

In the Work Programmes outlined below, there are a number of Work Areas identified as essential by stakeholders that cannot be covered in the short to medium term.

Finally, it must be recognised that a significant proportion of the work specified by stakeholder depends on the availability of high quality data, such as can be obtained from a well-designed, viable and sustained permanent sample plot network (and as was highlighted by the Review Group, whose findings are summarised immediately above).

Innovation potential

By their nature, forest models often result from incremental development. The planning work specified in Programme 6 for the first 12 to 18 months of the Science and Innovation Strategy will act as a springboard for the development of an on-going, resilient and cross-cutting programme of research that will provide models and tools of direct relevance to the sector in the 21st Century.

It is envisaged that this programme will innovate through various major releases of high impact information into the public domain, directly addressing the Government's Open Data (National Information Infrastructure) agenda. Publication of key data sets, in particular of permanent sample plot data and metadata, and dissemination of equations and models will open up many new opportunities within and outwith Forest Research. Publication will inevitably attract review, testing, debate and innovation all of which should lead to better and more informed application of this unique knowledge base.

There is significant potential for innovation across the programme over the first five years of the S&IS which might include:

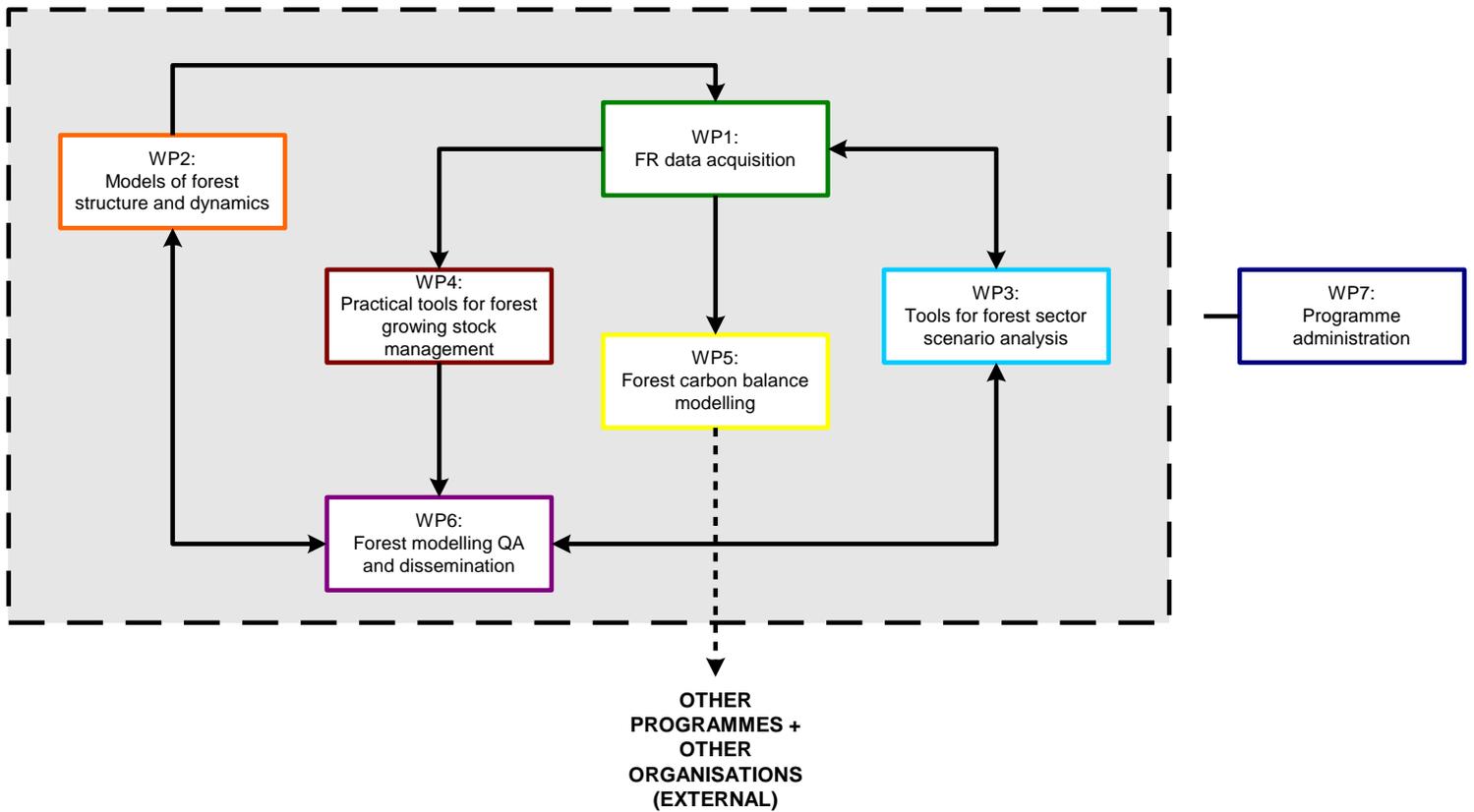
- A public release of the M1 growth and yield model
- Continued development of the individual tree growth model MOSES_GB, incorporating new sub-models of regeneration and early growth
- Use of LiDAR in developing improved allometric models for biomass estimation
- Novel and cost-effective use of remote sensing in forestry applications previously undertaken exclusively through ground-based surveys
- Regular recalibration of a developing suite of fit-for-purpose, QA'd and clearly documented models.
- Use of the permanent sample plot network in the statistical design of the NFI
- The integration of models developed across Programmes – *e.g.* ESC, CARBINE, stem straightness and timber quality models, and models of ecosystem services.

2.4 Work packages to address the research challenges

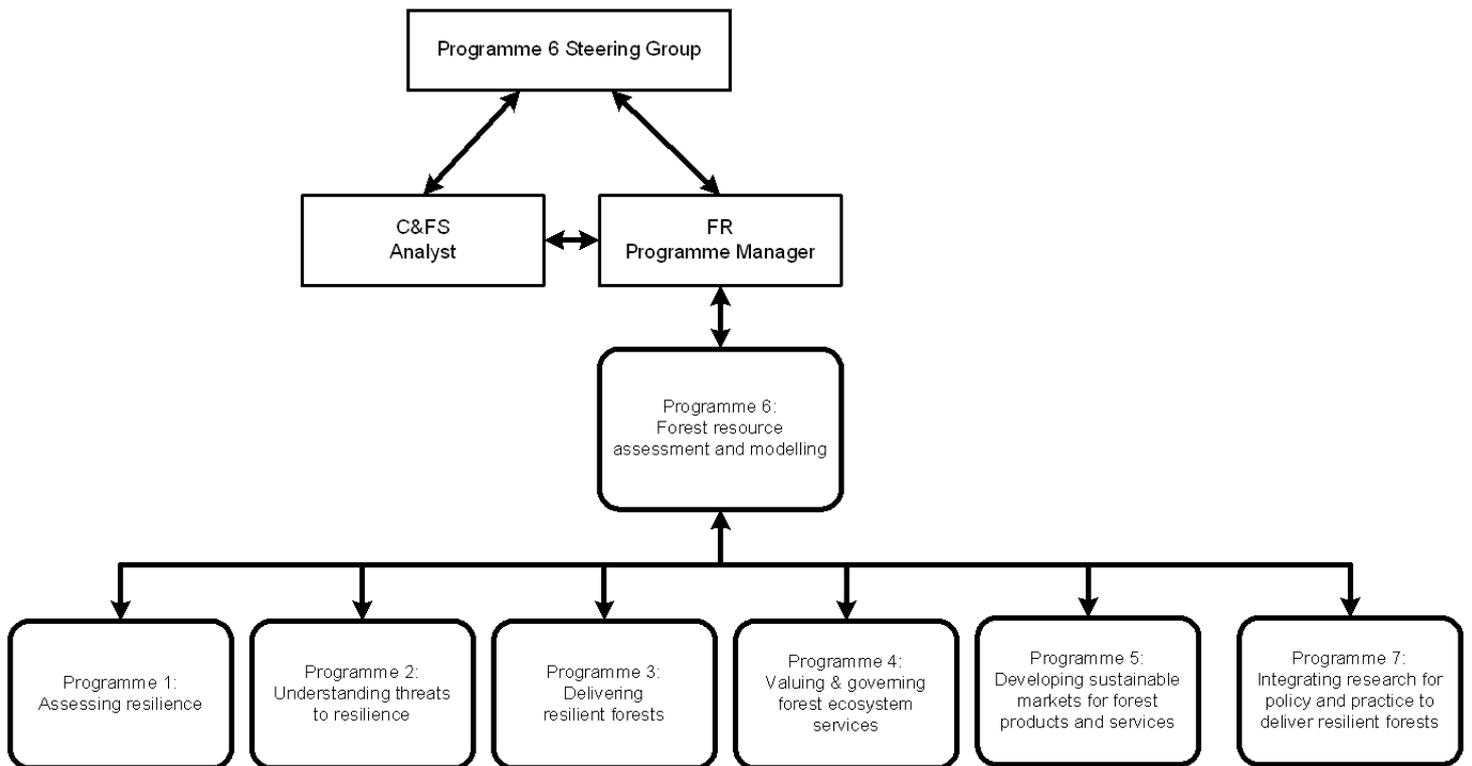
Work package titles

WP1	Research data acquisition to underpin modelling and verification of resilient forest management. (<i>Forest research data acquisition.</i>)
WP2	Models of forest structure and dynamics in pursuit of resilient forest management. (<i>Models of forest structure and dynamics.</i>)
WP3	Tools for scenario analysis to support development of a resilient forest sector. (<i>Tools for forest sector scenario analysis.</i>)
WP4	Tools for forest growing stock assessment and resilient forestry practice. (<i>Practical tools for forest growing stock management.</i>)
WP5	Modelling to underpin forest carbon balance reporting, management and policy. (<i>Forest carbon balance modelling.</i>)
WP6	Essential QA/QC and enhanced dissemination of forest models, tools and information. (<i>Forest modelling QA and dissemination.</i>)
WP7	Programme Governance and Management. (<i>Programme administration.</i>)

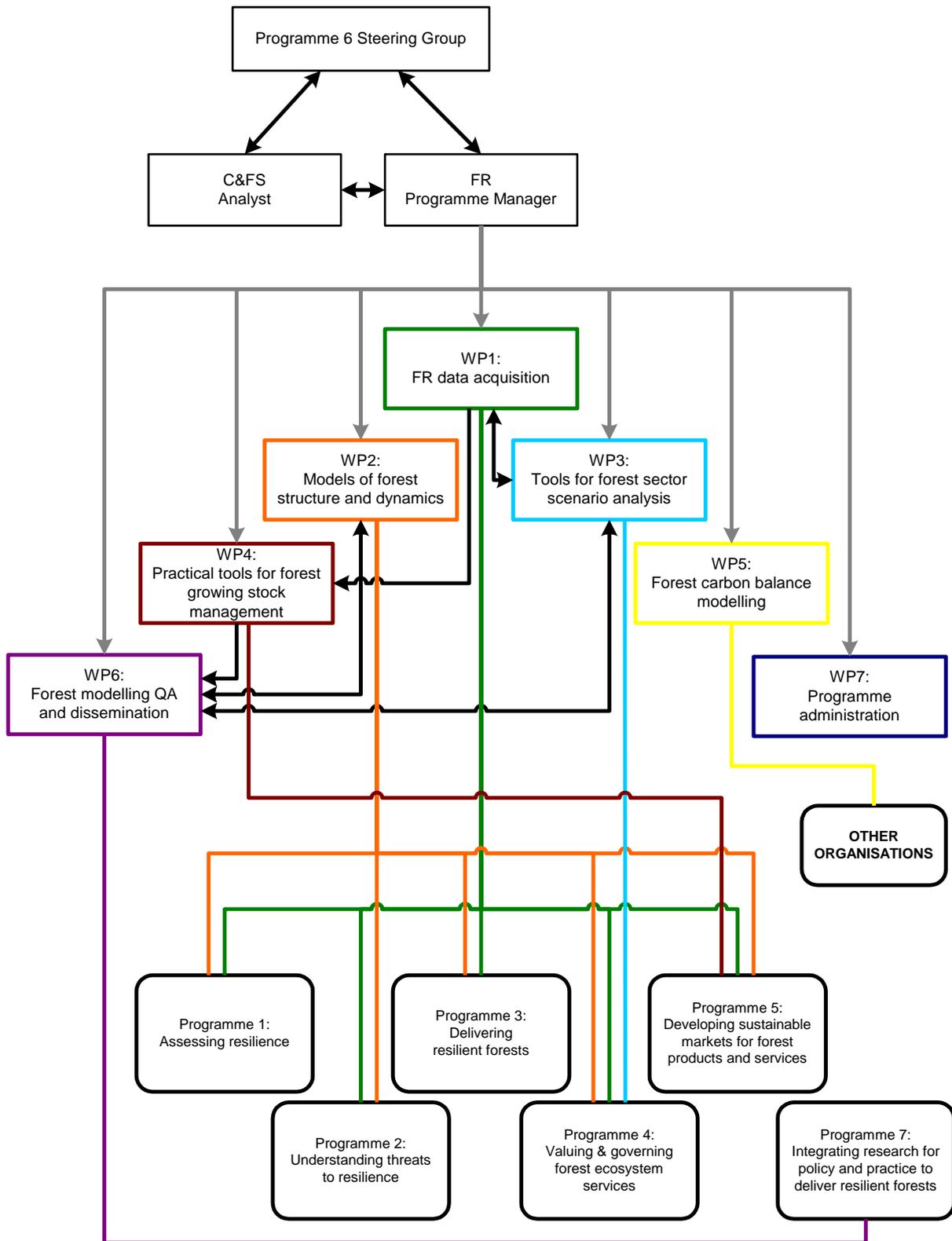
**FC SCIENCE AND INNOVATION STRATEGY 2015-2020:
PROGRAMME 6 LINKAGES BETWEEN WORK PACKAGES**



FC SCIENCE AND INNOVATION STRATEGY 2015-2020:
PROGRAMME 6 LINKS TO OTHER PROGRAMMES



**FC SCIENCE AND INNOVATION STRATEGY 2015-2020:
PROGRAMME 6**



WP Title: WP1. Research data acquisition to underpin modelling and verification of resilient forest management (*Forest research data acquisition.*)

Indicative costs (£k):	2015-16	2016-17	2017-18	2018-19
	204.40	107.34*		

Work package details:

WP1 directly addresses RC5 (*To undertake and utilise physical and remote data acquisitions for monitoring and modelling*) and is essential for meeting RC1 (*To develop and implement an appropriate Quality Assurance framework for modelling within FR*), RC2 (*To develop and implement more reliable and flexible models for the sector*) and RC4 (*To develop and deploy improved models for forest and stand assessment and management*).

Efforts will be sustained to ensure the provision and maintenance of fundamental data sets on forests that form the essential evidence base for the effective management of forest capital and the development, calibration and verification of key underlying forest models and tools.

The work package involves the development and implementation, in parallel to a procedural/modelling framework maintained and developed in WP3, of a carefully targeted programme of forest monitoring for verification and improvement of the main components of procedures and models, and of principal monitoring and forecast results.

Work area 1.1

Acquire essential data through 2015-16 sample plot measurement programme.

The purpose of WA1.1 is to undertake the minimum data collection in 2015-16 required to avoid permanently compromising the integrity of the FC's PSP network. Plots enumerated will be limited to those where forest management activities put the continued existence of specific plots at risk (in which case a final measure will be undertaken) or where to miss a measurement would compromise on-going research work (*e.g.* under WA2.3).

Specific outputs from WA1.1 are:

- A report on 2015-16 measurement programme
- Any additional records will be incorporated into the sample plot data bank and database.

It is important to note that to continue this approach is seen as a stopgap measure for 2015-16 only and to ignore the output of WA1.5 (below) could put the on-going Programme at risk.

Work area 1.2

Improve storage of sample plot data.

Sample plot data are currently processed and initially stored on an unreliable, obsolete and effectively unsupported Unix server ("Saturn").

Sample plot data are gathered in the field as tree-level assessments on "Husky" field computers (see WA1.3). These measurements are transferred to Saturn via a series of steps and are processed into an initial databank by bespoke software, compiled to run on Saturn (or any Unix computer with similar architecture).

FR has recently purchased a Windows-based server, on which a backup of the latest versions of the sample plot data are kept (processed and unprocessed). This server is routinely backed-up by FC IS.

The continued reliance on databank software and a tree-level database hosted and running only on Saturn poses a risk. It is therefore imperative that the databank software on Saturn is translated and re-written in a modern, supported programming language in order that all actions related to the secure storage of sample plot data can ultimately be carried out on the replacement Windows-based server.

The specific output for WA1.2 is to undertake the necessary programming and database design work to ensure that there are reliable and maintainable IT systems for importing, processing and securely archiving existing and future tree-level sample plot data. There are obvious links to WA1.3, WA1.4 and WA1.5.

Work area 1.3

Improve acquisition of sample plot data.

Sample plot data are routinely gathered by field teams on unsupported/out-dated "Husky" computers (which are now only available second-hand from sources such as eBay). The continued reliance on these devices poses a risk.

The outputs for WA1.3 are to develop improved ("future-proofed") protocols for sample plot data collection, to identify a reliable data capture device (but not to procure units, other than as a "test bed" at this stage) and to develop and implement improved ("future-proofed") data capture software. There are obvious links to WA1.2, WA1.4 and WA1.5. The potential suitability and cost of adapting NFI field survey software for integration in permanent sample plot data collection will be evaluated as part of this Work Area.

To accommodate the work within the resources available for the programme, this work area is planned to start in 2016-17.

Work area 1.4

Improve processing and analysis of sample plot data.

Tree-level data collected from the permanent sample plot network are currently processed and stored on an unreliable, obsolete and effectively unsupported Unix server ("Saturn"); see WA 1.2. These data are processed into plot-level records by bespoke software ("SPLOT"), compiled to run on Saturn. This software takes the databank measurements, checks for anomalies (e.g. "shrinking" trees) and converts them to plot-level estimates, which are ported to the database(s) on Saturn.

FR has recently purchased a Windows-based server, on which a backup of the latest versions of the sample plot data are kept (processed and unprocessed). This server is routinely backed-up by FC IS.

The continued reliance on the sample plot software running only on Saturn poses a risk. It is therefore imperative that the software on Saturn is translated and re-written in a modern, supported programming language in order that all actions related to the secure storage of sample plot data can be carried out on the replacement Windows-based server.

The specific output for WA1.4 is to undertake the necessary programming and database design work to future-proof and migrate SPLOT to the Windows server already purchased for this purpose (and being used as an interim archive and backup for data already processed on Saturn). There are obvious links to WA1.2, WA1.3 and WA1.5.

To accommodate the work within the resources available for the programme, this work area is planned to start in 2016-17.

Work area 1.5

Establish long-term purpose and prioritised plan for permanent sample plot network.

Since the end of 2012-13, data collection from (and routine maintenance of) the Forestry Commission's permanent sample plot (PSP) network has been critically impacted by a reduction in funding received from FC C&FS/IFOS. Emergency one-off funding from FC Scotland allowed the minimum data collection in 2014-15 to avoid permanently compromising the integrity of the FC's PSP network – effectively keeping it ticking-over. The level of available funds in 2015-16 again preclude all sample plot assessment except in situations where there is only one opportunity to collect data (e.g. from plots which have been wind-damaged or where management operations threaten the integrity of a plot) – *i.e.* any measurements in 2015-16 will, in most cases, be restricted to a "final measure" before plot abandonment (see WP1.1). If this situation continues in future years, it could put at risk much of the future intended work within this research programme.

There are, therefore, a number of imperatives for re-visiting, in consultation with key stakeholders, the long-term purpose and composition of the FC's permanent sample plot network. These include:

- Changes to modelling approaches and the purposes to which PSP data are routinely put.
- A need to specify cost and clearly justify the minimum network that will still allow meaningful data to be collected in support of the work undertaken within this and other Programmes (see the links to other Programmes and Work Packages schematically illustrated on pages 8 to 10). Factors to be considered here will include which species to short-list for inclusion (e.g. driven by perceived importance/impact) and the minimum sustainable number of plots required per species (e.g. driven by modelling/statistical requirements).
- A need to take account of the likely future character of forest stands across GB including type of management, species composition (e.g. to achieve/maintain resilience in the face of pests/diseases such as *Chalara*, *Dothistroma*, *Phytophthora*, AOD, etc.).
- A need to identify, specify and cost the minimum set of mensurational and other data that must be routinely collected on each measurement occasion.
- The opportunity to identify, specify and cost additional "nice to have" (e.g. tree health or climate change indicator) data that might be simultaneously collected in support of other research Programmes. (Once "on-site" and providing T&E costs aren't consequentially increased, the additional cost of some additional data collection may not be prohibitive.)
- Opportunities for including PSP's in the statistical design of the NFI.

The specific output for WA1.5 is to produce, in consultation with key stakeholders, an argued, targeted and costed plan for development of the FC's permanent sample plot database. There are obvious links to WA1.2, WA1.3 and WA1.4 as well as to other Work Packages and Programmes (schematically illustrated on pages 8 to 10).

The contents of this report will serve to inform the structure of this Programme in 2016-17 and beyond.

Work area 1.6

Demonstrate proof of concept for the application of terrestrial laser scanners (TLS) for above-ground tree volume and biomass estimation.

Work Area 1.6 will test the following four hypotheses:

- Tree volume, and hence above-ground biomass (AGB), can be measured robustly independent of empirical allometric relationships.
- TLS-derived estimates of AGB are consistent with allometric estimates across contrasting UK tree species.
- The impact of assuming constant within-tree and within-species wood density can be quantified using TLS-derived estimates of tree volume.
- Uncertainty in forest AGB is reduced by including samples of tree AGB that are unbiased in diameter and height.

Expected Outputs

- Point-cloud data and tools: plot-level tree structure data to augment existing forest inventory data, including tools and models for analysis. *N.B. Tools and models will be subject to IP rights owned by members of the existing research consortium (mainly with Tampere University of Technology, TUT, Finland).*
- Publications: wide-readership papers would include: improved forest C stock and fluxes estimates with uncertainty, quantify the impact of within- and between-site variations of wood density to address current controversies over AGB estimates. Subject-area papers may include: development of TLS methods to forestry; improved 3D reconstruction from TLS; vertical canopy profile information as a determinant of forest type; quantifying uncertainty in remote sensing estimates of AGB from LiDAR and RADAR.

Steering Group agreement for this Work Area is based on the presumption that the pre-existing IP arrangements do not substantively compromise the value of this work to the Forestry Commission.

Work area 1.7

Evaluate the potential of LiDAR to assess tree height, refine the SCBD, and improve the PF.

This Work Area will explore the potential of airborne LiDAR and other remote sensing technologies data to provide data for a new generation of models, to verify existing ground-based data sources and to augment “traditional” sources of mensurational data. There will be a proportion of time set aside for remote sensing advice to other research programmes and to field external enquiries.

The specific output from WA1.7 will be a report recommending options for integration of RS data to support development and application of state-of-the-art forest models, signed off by key stakeholders

WP Title: WP2. Models of forest structure and dynamics in pursuit of resilient forest management (*Models of forest structure and dynamics.*)

Indicative costs (£k):

2015-16	2016-17	2017-18	2018-19
120.31	22.03*		

Work package details:

WP2 directly addresses RC2 (*To develop and implement more reliable and flexible models for the sector*), RC3 (*To ensure integration and coherent delivery of model systems*) and RC4 (*To develop and deploy improved models for forest and stand assessment and management*). It is dependent on WP1 (*Forest research data acquisition*) and outputs from WP6 (*Forest modelling QA and dissemination*).

Improved forest models will be developed so that they can be quickly calibrated and re-calibrated as new data become available. The models will also be designed so that they can be readily adapted to represent new situations e.g. novel forest management options, genetically improved stock, pest and disease impacts, and climate change impacts. An immediate priority is to clarify the nature and scale of any limitations and biases in existing growth and yield models as an interim measure, whilst more reliable and flexible forest models are being developed.

Longer-term scientific objectives are:

- To develop a comprehensive understanding of tree and stand growth patterns over time in response to a range of site, environmental and management conditions.
- To identify and define a range of analytical models of tree and stand growth patterns over time, capable of predicting the development of principal growth and yield variables in response to a range of site, environmental and management conditions.
- To develop a consistent and harmonised methodology for the construction, calibration, implementation and validation of mathematical models of tree and stand growth.
- To develop a consistent and unified framework for delivery of forest growth and yield models across a range of media.
- To develop and implement a strategy for dissemination of results and support to users of forest growth and yield models including other researchers (through linkages with WP6).

Future work areas could include contributions to the required QA work on existing high impact growth and yield models, the development and implementation of an FR modelling strategy, the continued development and implementation of MOSES_GB, Urban forest biometrics, etc.

Work area 2.1

Strategically review existing available forest models.

Since around the time of the 2005 Production Forecast, the development of forest models within FR (with the notable exception of MOSES_GB) has been primarily directed towards the delivery of the 2011 Production Forecast and maintaining the forecast system (delivering additional functionality). Most existing FC models are stand-level and are designed for use in single species, even-aged forest components.

Although considerably more flexible than "YieldLookup" (the electronic version of the Forestry Commission's Booklet 48 that underpinned the 2005 production forecast), the development of the FC's primary growth and yield model (M1) has been constrained to ensure that the output is entirely consistent with Booklet 48 yield tables when modelled from year zero under standard (Booklet 48) management scenarios.

Recent experience with the development of MOSES_GB, and the fact that a number of FR's existing models are now being pushed beyond their intended design envelope, suggests that we now need to critically evaluate the modelling approaches that may be required to deliver the outputs that will be needed by stakeholders in the future.

The output from WA2.1 will therefore be a strategic review of existing available forest models (from Ireland, mainland Europe and beyond) which will serve to inform the subsequent development of a strategic prioritised plan for the cost-effective development of models of forest structure and dynamics for 2016-20 (*i.e.* WA2.2).

Work area 2.2

Develop strategy and prioritised plan for development of models of forest structure and dynamics for 2016-20.

Since around the time of the 2005 Production Forecast, the development of models of forest structure and dynamics undertaken within FR (with the notable exceptions of M1 and MOSES_GB) has effectively been carried-out on a responsive basis primarily to support delivery of the 2011 Production Forecast and also to supply information for the forestry component of GB's international GHG and carbon reporting obligations. Recent modelling work has included the development of improved single-tree volume functions and improved stand volume functions (both required for NFI reporting), improved biomass functions, revised thinning functions and the development of additional functionality within forest sector carbon accounting models. Although all of this work has been required to answer specific questions or to address known shortcomings/biases in the outputs of existing models, there is a clear need for a coordinated and more efficient Agency-wide approach to the development of models of forest structure and dynamics.

WA2.2 will take the review of existing models of forest structure and dynamics undertaken in WA 2.1, in conjunction with earlier work undertaken within FR on identifying the "elemental models" that would be required as building blocks, and will develop a coherent, coordinated and prioritised plan for the development of models of forest structure and dynamics in subsequent years of this Programme. Given the acknowledged impact of models of forest structure and dynamics on the work being undertaken in other FR Programmes, this work will be undertaken in consultation with other modelling stakeholders within FR.

The specific output from WA 2.2 will be an argued, targeted and costed plan for development of improved models of forest structure and dynamics, signed off by key stakeholders. This key report will serve to inform the future direction and priorities for modelling work undertaken within this Programme.

Work area 2.3

Further evaluate and develop MOSES-GB model in pursuit of resilient forest management.

The aim of this work area is to continue development of a flexible model of individual tree and stand growth for use in British forestry.

Existing growth and yield models in GB were explicitly developed for use in even-aged stands of a single species and cannot realistically be used to accurately predict the growth, yield and development of forest stands of mixed species and/or mixed ages. More flexible models are therefore needed to evaluate the impacts on stand growth and development of a wide range of silvicultural options that may be used as part of the 'Changing Silviculture' agenda within Britain. Work on models of this type has direct relevance in supporting research on "resilience" being undertaken elsewhere within FR.

Although currently parameterised only for British-grown Sitka spruce, MOSES_GB has the scope to be applied to mixed-age and mixed-species stands growing under British conditions (particularly if suitable data can continue to be gathered according to the latest amendments to the permanent sample plot data collection protocol). To feed into this project, coordinated parallel work is on modelling regeneration and early growth is being undertaken by a PhD student at Bangor University, funded jointly by the Scottish Forestry Trust, C&FS and Bangor University.

The specific outputs from WA2.3 will be a report on the validation and evaluation of MOSES-GB, a report on the progress being made by the PhD student at Bangor University, and an updated version of MOSES_GB for the existing user base (FC, FR and NRW).

Work area 2.4

Further evaluate and characterise robust application of M1 model.

M1 currently underpins the outputs from the GB Forecast. As indicated under WA2.1, although considerably more flexible than "YieldLookup", M1 has been constrained to ensure that the output is entirely consistent with Booklet 48 yield tables when modelled from year zero under standard (Booklet 48) management scenarios. M1 is, however, being used to model a range of management scenarios both within the Forecast System and for other research and policy purposes (most notably applications to do with the FC's Woodland Carbon Code and for other carbon accounting purposes). Some of these management scenarios (for example modelling the growth and yield of continuous cover stands) go well beyond the original design envelope of M1. The purpose of this work area, which will feed into work areas 2.5 and 6.1, is to validate various stand growth functions against permanent sample plot and/or other quality assured datasets. This will serve to highlight for which applications, and under what and circumstances, M1 can be assumed to perform robustly. This is essential information to have for such a high impact model and will be used as the basis for subsequent model documentation.

The evaluation of M1 will concentrate initially on high-impact scenarios, e.g. use of the model on "typical" component types derived from the sub-compartment database (such as unthinned Sitka spruce at the most commonly encountered combinations of initial planting spacing and assumed general yield class).

The outputs from this work area will be a report on the sufficiency of available data to validate key growth relationships in M1 model and a report on the validation of key growth relationships in M1 model (where data are sufficient), highlighting biases and uncertainties.

Work area 2.5

Scope options to address issues raised by evaluation of M1 model.

The aim of this work area is to produce a report describing and assessing options to address issues raised by the evaluation of the M1 growth model undertaken in WA 2.4. These options will include:

- “Macro-calibration” of the outputs of the M1 mode
- Recalibration of growth relationships in the existing M1 model
- Fundamental re-design of growth relationships and adding of functionality to M1
- Adoption of a new modelling framework as a replacement M1.

The assessment will include the identification and risks and impacts associated with not addressing issues raised by the evaluation of the M1 model, and indicative costs for any improvements, enhancements or replacement models.

The work area will be taken forward in close liaison with stakeholders and the Programme Steering Group, and there are important linkages with WA 2.2 and WP6.

Note: the funding currently allocated to this potentially high-impact Work Area has been highlighted as possibly being optimistic.

WP Title: WP3. Tools for scenario analysis to support development of a resilient forest sector (*Tools for forest sector scenario analysis.*)

Indicative costs (£k):	2015-16	2016-17	2017-18	2018-19
	68.40			

Work package details:

WP3 directly addresses RC2 (*To develop and implement more reliable and flexible models for the sector*) and RC3 (*To ensure integration and coherent delivery of model systems*). It is dependent on WP1 (*Forest research data acquisition*) and WP2 (*Models of forest structure and dynamics*).

The purpose of this work package is to support the reliable application and further development of reliable forest sector scenario analysis systems. Prominent examples are the FC Forecast System and the CARBINE forest sector forest carbon accounting model.

Forecast systems that work at the estate, regional and national (sometimes international) scales are needed to predict long-term trends in production and development of the growing stock. In a strategic context, the results of these forecast systems are used to ensure that planned levels of tree harvesting are consistent with the long-term viability of the forest estate. In a tactical context, they also support planning and operations in public woodlands and private estates. The application of a consistent forecasting methodology for both strategic and tactical analysis is an important way of achieving transparency in the relationships between actual forest management and delivery against policy targets.

In conjunction with more reliable and flexible underpinning forest models, the functionality of existing systems and models for assessing scenarios can be further developed and extended to allow the robust assessment of a wider range of forest policy options and business decisions that are of increasing relevance and importance.

Scenario analysis systems need to be based on a methodologically consistent framework of modelling procedures, so that they can be used to monitor and forecast the impacts of evolving management and widely varying policy options on the development of the UK forest resource, notably:

- The extent, composition and structure of the growing stock.
- The availability, potential and actual utilisation of timber and wood fibre, and implications for national energy/resource security.
- Trade-offs and synergies between wood production, wood utilisation and other key environmental, economic and social impacts.

The procedural/modelling framework needs to be applied in direct support to planning and operations in both state-owned woodlands and privately owned woodlands. The key elements of this framework need to be:

- Flexible so that they can be adapted easily to address new policy and management topics as they emerge. Consequently it is important that, as far as practicable, the overall system is designed to link easily with wider sources of data and relevant forest ecosystem, forest management and wood sector models, both currently available and putative.
- Capable of generating a range of relevant outputs in the form of reports, charts and tables that can be used readily as part of policy and management analyses and statements.
- Capable of generating inventory, monitoring and forecast results across a range of spatial scales, notably tree stands, estates, regions and countries comprising the UK (sometimes other international regions).

In the medium to long term, work areas could continue to develop linkages to spatial DSS development, and other models relevant to the estimation of resilient forest systems and the ecosystem services they deliver.

Work area 3.1

Enhance and maintain FC Forecast System to ensure robust application to key forest sector issues and questions.

The aim of this work area is to ensure that a key FC scenario analysis system, the FC Forecast System, is properly maintained and if necessary developed, to ensure its reliable application to forest policy and practice questions at GB and sub-GB scales.

The maintenance of, and development of enhancements to the Forecast System (N.B. the CARBINE forest sector carbon accounting model is covered under Work Package 5, to which there are linkages).

The maintenance and development work will be directed by the IFOS Inventory and Forecasting team and managed through a formal process of change management and version control.

The key output(s) from WP3.1 will be release(s) of refined/new version(s) of the FC Forecast System.

Work area 3.2

Specify enhancements to FC Forecast System to ensure robust application to key forest sector issues and questions.

The aim of this work area is to further develop, maintain and enhance the documentation and other technical material needed to ensure that the FC Forecast System is applied transparently and there is a clear understanding of the methodological basis for any results produced by the Forecast System.

The work area forms part of a commitment to formal documentation, QA and dissemination of key models, systems and tools and there are linkages to Work Package 6 of this Programme.

As with the maintenance and development work undertaken in Work Area 5.1, the process of specification and documentation will be managed through a formal process of change management and version control.

The output from WP3.2 will be the publication on the FC website of updated user requirements documents for the Forecast System.

Work area 3.3

Develop strategy and prioritised plan for development of forest sector scenario analysis tools for 2016-20.

The aim of this work area is to undertake a strategic review of the key forest sector scenario analysis systems currently available to support practical forest assessment and management, and to establish a prioritised plan for their improvement and innovative development.

The initial focus is on the FC Forecast System and the CARBINE forest sector carbon accounting model, as the principal systems relevant to the assessment and management of forest growing stock, its structure and carbon balance, particularly in support of resilient forest management and the delivery of key ecosystem services.

The strategic review will consider the possibilities for both incremental improvement of these systems and the development of innovative approaches. This will involve technical and theoretical evaluation of the systems to identify limitations, weaknesses and gaps in their potential application, as well as identification and consideration of the potential for novel linkages to key large-scale datasets, e.g. the National Forest Inventory, the Ecological Site Classification System and matrices describing scenarios for future land use.

The strategic review will require consultation with forestry practitioners and other stakeholders who make use of such systems, and with researchers across a wide range of disciplines involved in the development scenario analysis systems. The review will aim to identify and pursue linkages with relevant activities across the Science and Innovation Strategy, notably in Programmes 3, 4 and 5.

The output from WA3.3 will be a costed plan for development of improved scenario analysis tools relevant to the forest sector.

To accommodate the work within the resources available for the programme, the review is planned to start in 2016-17.

**WP Title: WP4. Tools for forest growing stock assessment and resilient forestry practice
(Practical tools for forest growing stock management.)**

Indicative costs (£k):	2015-16	2016-17	2017-18	2018-19
	0.00	14.18*		

Work package details:

WP4 directly addresses RC4 (*To develop and deploy improved models for forest and stand assessment and management*) and RC2 (*To develop and implement more reliable and flexible models for the sector*). It is dependent on WP1 (*Forest research data acquisition*).

There are many different approaches that can be applied in the assessment and management of the structure and growing stock of forest stands. In practical forest management, the choice of approach influenced by the scale and complexity of the forest areas to be assessed, the perceived value of the forest areas and by the local conditions and facilities available. Traditionally, such assessments have met commercial imperatives, principally the sale of timber and the control of thinning. However, there is an expanding requirement to provide measurement methods to address modern forest objectives, including the need to demonstrate compliance with the many criteria involved in meeting forest environmental standards. Measurement is expensive and, as pressures on forest owners and managers increase, the need for more efficient measurement methods becomes more important. There is scope to improve the precision and/or efficiency of existing assessment methods, and to expand their scope of application, and also to introduce innovative methods of forest assessment, based on rapid survey techniques and/or remote sensing. It is therefore essential that opportunities are exploited to improve forest measurement, assessment and management methodologies, and to apply new instrumentation. These improvements need to be translated into practical tools that forest managers can use in daily practice. Lack of support for this area of research and knowledge exchange can lead to inconsistent standards and to a loss of confidence in methods and destroy trust between forestry practitioners and wider stakeholders.

It follows that an important component of Programme 6 involves seizing opportunities to improve and develop innovative procedures and underlying models that support the day to day management of growing stock and wood production, to improve their accuracy, their cost-efficiency, and their relevance to wider modern forestry practice.

A longer-term aim of this work package is to engender cross-cutting activities with other relevant research initiatives supported by the Science and Innovation Strategy, notably research on techniques for measuring and modelling timber properties (from Programme 5), and the assessment of adaptability and resilience of forests under a changing environment (Programme 3).

Work area 4.1

Develop outline strategy and prioritised plan for development of practical forest assessment/management tools for 2016-20.

The aim of this work area is to undertake a strategic review of the key tools currently available to support practical forest assessment and management, and to establish a prioritised plan for their improvement and innovative development.

The initial focus is on tools relevant to the assessment and management of forest growing stock and its structure, particularly in support of sustainable yield forest management and complying with forestry environmental standards. Existing examples include the full and abbreviated tariffing systems, stand inventory and valuation tools and systems for the management and control of thinning and felling operations.

The strategic review will consider the possibilities for both incremental improvement of tools and the development of innovative approaches. This will involve technical and theoretical evaluation of the existing available tools to identify limitations, weaknesses and gaps in their potential application, as well as identification and consideration of the potential of novel stand assessment techniques including rapid survey methods and a range of remote sensing technologies.

The strategic review will require consultation with forestry practitioners and other stakeholders who make use of such tools, and with researchers across a wide range of disciplines involved in the development of stand assessment methods. The review should take account of any other existing relevant work streams, such as an existing initiative under discussion amongst the country forest services for the development of replacement forest survey tools. The review will aim to identify and pursue linkages with relevant activities across the Science and Innovation Strategy, notably in Programmes 3, 4 and 5.

To accommodate the work within the resources available for the programme, the review is planned to start in 2016-17, but some initial development may be possible in 2015-16, depending on whether work proceeds on the development of replacement survey tools for country forest services.

WP Title: WP5. Modelling to underpin forest carbon balance reporting, management and policy (*Forest carbon balance modelling.*)

Indicative costs (£k):	2015-16	2016-17	2017-18	2018-19
	134.845			

Work package details:

WP5 directly addresses RC2 (*To develop and implement more reliable and flexible models for the sector*), RC3 (*To ensure integration and coherent delivery of model systems*) and RC4 (*To develop and deploy improved models for forest and stand assessment and management*). It is dependent on WP1 (*Forest research data acquisition*) and outputs from WP6 (*Forest modelling QA and dissemination*).

The purpose of this work package is intended to address what has been recognised by the Programme Steering Group as the principal strategic priority goal for Programme 6 in 2015-16, which is to ensure that the forestry component of the GHG inventory is Quality Assured and transparent. Scope includes:

- Input data
- Scientific models (with linkages to WP2 and WP6)
- Systems (with linkages to WP3 and WP6)

The achievement of this goal is articulated through 4 closely-integrated work areas, which are intended to address the immediate priorities set by the Steering Group. Longer-term work areas could include further enhancements to the forestry component of the GHG inventory, the Woodland Carbon Code, modelling of carbon dynamics of harvested wood, Life Cycle Assessment, etc.

The definition of the work areas of the work package also recognises the key role played by timely dissemination and responsive knowledge exchange regarding the implications of emerging scientific understanding of forest GHG balances for policy and practice.

The work package explicitly includes integrated work between two FR Science Groups; Forest Mensuration, Modelling and Forecasting, and Climate Change.

Work area 5.1

Develop robust, transparent and quality-assured methodology for forest land component of UK GHG inventory

The aim of this work area is to develop a robust, transparent and quality-assured methodology for the forest land component of national greenhouse gas inventories for the UK and Devolved Administrations.

The representation of forest land in the 1990-2012 and 1990-2013 GHG inventories involved a number of important innovations including:

- Reference to a completely new National Forest Inventory
- Inclusion of older forest areas (in existence before 1920), which previously could not be easily incorporated into greenhouse gas inventories
- More refined representation of forest composition (species, growth rate, age)
- Detailed representation of forest management practices, linked to reported levels of wood production
- Representation of carbon dynamics in harvested wood products.

The introduction of these refinements and improvements constituted a major step forward in the robustness and defensibility of the forest land component of greenhouse gas inventories. The linkages to acknowledged published data sources also supported transparency. However, these improvements also led to large changes in the estimated emissions and removals associated with forest land. As a consequence, there is a need to build confidence amongst stakeholders in the reliability of the revised reported estimates. This involves engagement with stakeholders to make sure that the evidence base underpinning the improvements in methodology is fully available to them in an understandable form. There is also a requirement to provide rapid advice in response to queries and concerns raised by stakeholders regarding the robustness of inventory estimates and potential implications for forest policy and practice.

The recent developments in methodologies for the forest land component of greenhouse gas inventories have also highlighted a number of areas of uncertainty and as yet unresolved challenges, notably:

- Representing small forest areas (less than 0.1 hectare in size)
- Handling of forest areas classified in National Forest Inventories as “felled”
- Developing robust estimates of deforestation
- Reconciling the management of forest areas with reported levels of wood production over long time series
- Ensuring a robust scientific basis for the representation of the greenhouse gas dynamics associated with non-tree forest components (essentially litter and soil).

The work area involves two complementary activities:

1. Engagement and communication with policy makers and other stakeholders to ensure reliable knowledge exchange
2. Development, documentation and quality-assurance of the methodologies applied for the forest land component of greenhouse gas inventories, to ensure their robustness and transparency and to demonstrate their reliability.

The principal strategic aim is to have completed the essential implementation and documentation of key aspects of methodology in time for them to be applied and reported as part of inventory calculations scheduled for autumn 2015.

Because of the important policy implications of this work (and potential high costs to Government of incorrect GHG inventory projections), formal governance for this Work Area will be introduced through the involvement of a time-limited Project Board comprising members of the GB-wide ‘Carbon Data Group’ and a DECC representative.

The methodological developments under this work area are supported by further scientific assessments and analyses and essential developments to forest sector carbon accounting models, as specified in work areas 5.2, 5.3 and 5.4.

Work area 5.2

Establish robust scientific basis for modelling carbon dynamics of non-tree forest carbon pools.

The aim of this work area is to review the state of the art of scientific understanding of the carbon dynamics of non-tree forest carbon pools, and to develop a specification for improvements to the modelling of relevant processes to ensure their robustness.

Recent technical reviews (2013 and 2014) of national greenhouse gas inventories for the UK and Devolved Administrations have identified that estimates of emissions and removals associated with non-tree forest carbon pools, notably forest soils, require stronger justification and possibly improvement. The development of a defensible scientific basis for the modelling of non-tree forest carbon dynamics is also a high priority, in order to build confidence amongst wider stakeholders in the estimates reported in greenhouse gas inventories.

The work will involve compiling and synthesising the available scientific evidence that can inform the design, development and parameterisation of models for non-tree forest components including deadwood, litter and soil. The principal output will be a set of technical specifications for the improvement and/or fundamental development of relevant sub-models for inclusion into forest sector carbon accounting models, such as the CARBINE model, which is applied in estimating the forest component of national greenhouse gas inventories. The technical specifications will form the essential starting point for work area 5.4.

Work area 5.3

Modelling and analysis of changing stand C and GHG balances and their soil, litter and tree components.

Work area leader: James Morison

Indicative cost (2015-16): £54.38k

The aim of this work area is to undertake fundamental modelling and analysis of field assessments and monitoring of CO₂ and GHG fluxes associated with forests. The magnitudes of fluxes will be established and the contributions due to trees, litter and soils will be identified and quantified.

The work area is intended to provide fundamental data and evidence to inform the assessment undertaken in work area 5.2. Particular emphasis will be placed on making the best possible interpretation of scientific evidence and understanding related to soil GHG fluxes under forests, distinguishing key soil types, notably mineral, organic and organo-mineral soils. The evidence and its interpretation will be presented in a scientific report explicitly in support of work area 5.2.

Work area 5.4

Improve models of carbon dynamics of non-tree forest carbon pools.

The aim of this work area is to improve the implementation of sub-models of the carbon dynamics of non-tree forest components for inclusion in forest sector carbon accounting models, such as CARBINE, which is applied in estimating the forest component of national greenhouse gas inventories. This will provide a more robust and defensible basis for the estimates of GHG emissions and removals associated with forest land as reported in greenhouse gas inventories. The development and implementation of relevant sub-models will be informed by the scientific assessments and analyses undertaken in work areas 5.2 and 5.3. The aim is to have completed the essential implementation of key sub-models in time for them to be applied as part of inventory calculations scheduled for autumn 2015 (within work area 5.1).

WP Title: WP6. Essential QA/QC and enhanced dissemination of forest models, tools and information (*Forest modelling QA and dissemination.*)

Indicative costs (£k):	2015-16	2016-17	2017-18	2018-19
	44.37	121.68*		

Work package details:

WP6 directly addresses RC5 (*To undertake and utilise physical and remote data acquisitions for monitoring and modelling* It is dependent on WP1 (*Forest research data acquisition*).

The FC Science and Innovation Strategy recognises that Quality Assurance (QA) and Quality Control (QC) need to be integrally embedded processes in the design, development and deployment of models, systems and tools that support forest policy and practice.

Fundamentally, the adoption of formal QA plans for significant research initiatives should be viewed as an essential element of best practice, particularly for major modelling and systems development exercises.

In order to define and deliver a Quality Assured research and evidence programme:

1. Both researchers and those commissioning research need to understand what information is being sought and how it will be used so that
 - (a) those undertaking the research fully understand the nature of the issues that their work is intended to inform; and
 - (b) those using research outputs to make or advise on decisions understand the broad nature of the evidence (principally data and models) provided to them and in particular its strength and limitations
2. The overarching aim is to convey to decision-makers the strengths, risks and limitations in the way that the research has been conducted and the associated uncertainty around the outputs. This gives decision makers visibility of the strength of the analysis and how much confidence and weight they can place on it in the final decision making process.

More generally and practically, compliance with QA/QC standards should build confidence amongst stakeholders in the application of the forest sector models, systems and tools.

Outputs from a small number of business critical-models are used to inform many decisions across the forestry sector. Application may be through policy directives, best practice guidance, financial appraisals *etc.*, and the decisions affected include silvicultural practice (species choice, rotation lengths, thinning type and intensity), carbon-related targets/commitments, processing and other investment. Widespread use of model outputs in this way is the overarching driver of outcome-based, applied research; it is the principal justification for research work under the new Science and Innovation Strategy for Forestry.

Further investment in data collection, model development and technology transfer should be driven by a clear understanding of how that information/capability will be used and by implication its value. Factors that affect the value of such work include:

- The proportion of current and future growing stock in scope (species, silviculture *etc.*)
- The extent to which uncertainty and/or bias in models can be reduced
- The costs of data collection (for model development, validation and use)
- Model 'adaptability': Ease of re-calibration or re-configuration
- Usage: Must be trusted and accessible: Must be Quality Assured and published (*e.g.* via online access).

The above factors directly influence the application of models and tools in:

- Meeting legal, principally GHG reporting, commitments
- Monitoring of and managing forest capital
- Forestry related 'investment' e.g. processing
- Securing leverage and synergies with other research work streams.

Full, readily accessible and clearly written documentation provides the essential evidence base for demonstrating reliability of models and methodologies. Such an approach also helps the users of models and methodologies (and their results) clearly understand any associated underlying assumptions, limitations and potential risks involved in decisions that have been informed by them.

From a research perspective, the focussed improvement of existing models and methodologies, and key opportunities for innovation, can first be identified by understanding the restrictions and weaknesses in what currently exists and represents the current state of the art.

In addition to underpinning the essential QA and QC of key forest sector models, systems and tools, the work package recognises an important and intimate linkage to their effective deployment and dissemination.

Opportunities can be seized to push through and accelerate the deployment and dissemination of existing and new models, systems and tools that support policy and business decisions and day to day forest management, for example by packaging tools and models in computer software or applications, or through deployment over the web.

The work package recognises that successful knowledge exchange in terms of model deployment and dissemination involves first building confidence and credibility through appropriate documentation and supporting QA and QC.

A medium-term objective of this work package is to engender and support a strong QA and QC culture in modelling activities across all programmes of the Science and Innovation Strategy, and to increase the availability of key models and systems to the forest research community.

Work area 6.1

Maintain and enhance robustness of QA documentation of key FC/FR models of forest structure and dynamics.

The aim of this work area is to develop and maintain the essential foundation of QA documentation of key FC/FR models and systems of forest structure and dynamics. The work area will compile and enhance existing documentation to ensure compliance with government AQUA guidelines. This will be supported by more accessible summary documentation providing clear statements of the assumptions, strengths, limitations, uncertainties and risks associated with key FC/FR models and systems, including the intended scope of their reliable application. The intention is to ensure that the QA documentation satisfies the expectations of a range of stakeholders, from those with technical interests, to practitioners who are concerned primarily with the scenarios over which models can be assumed to be reliable and those which may involve high uncertainties or risks. The documentation produced by the work area will also inform the analysis of priorities for the improvement or innovative development of models and systems, and the acquisition of essential supporting data, through the strategic reviews in work areas 1.5, 2.2, 3.4 and 4.1.

Work area 6.2

Scope potential feasibility and cost of validating key FC/FR models of forest structure and dynamics against sample plot data.

The aim of this work area is to establish the technical feasibility and cost of developing a formal methodology for validating key FC/FR models of forest structure and dynamics against sample plot data. For each model within scope, this will involve:

- Identifying the assumptions, graphical and mathematical relationships and associated parameter estimates that need to be validated
- Establishing criteria for determining a sufficient level of validation
- Assessing the suitability of available data for undertaking validation to a sufficient standard
- Identifying potential opportunities for innovatively applying emerging data sources (such as available via remote sensing technologies) to strengthen validation
- Making an initial estimation of the costs likely to be involved to achieve validation with available and emerging data sources.
- Where data are insufficient for robust validation, an assessment of the requirements for acquisition of additional data, including the approaches and technologies that need to be deployed.

The scope of FC/FR models, systems and tools covered by the assessment will be specified by the Programme Steering Group.

To accommodate the work within the resources available for the programme, this work area is planned to start in 2016-17.

Work area 6.3

Scope approaches and implement the selected approach to formal QA plan for key FC/FR forest models, systems and tools.

This work area aims to develop and implement an appropriate QA plan for key FC/FR models, systems and tools. Defra requires all significant research projects to include a formal QA plan. Such a level of QA is clearly appropriate for key FC/FR research initiatives such as the data acquisition, modelling and systems development undertaken within this Programme.

The development of the QA plan will draw on existing examples from other research exercises but will ensure that the design adopted within the Programme is appropriate for the specific research and development being undertaken.

The scope of FC/FR models, systems and tools covered by formal QA plans will be specified by the Programme Steering Group.

Work area 6.4

Develop a digital resource providing access to sample plot meta-data.

The aim of this work area is to make progress towards the development of a digital resource providing access to data collected from FC permanent mensuration sample plots. In 2015-16, the work area will develop a digital facility that provides access to meta-data on sample plots (i.e. locations, species, etc., management, types of assessment taken). Initially this will be trialled internally within the FC. By making meta-data more readily available, this will enable potential users to more quickly identify the specific data that is of relevance to their research or policy needs, and to make targeted requests for access to data. The work area is limited to this scope in 2015-16 to allow for resources available, and also to provide an opportunity to identify and address any issues related Data Protection that may be highlighted by this initial exercise.

This planned release of high impact information into the public domain, directly addresses the Government's Open Data (National Information Infrastructure) agenda. Subject to the future levels of funding, and taking account of the competition for resources for other high priority work areas as Programme 6 develops, work on this digital resource could be further extended in years 2-5 of the Science and Innovation Strategy.

To accommodate the work within the resources available for the programme, this work area is planned to start in 2016-17.

Work area 6.5

Scope potential feasibility and cost of publishing M1 model as a software tool in 16-17.

The aim of this work area is to scope and assess the feasibility and cost of publishing the M1 forest growth model as an easy-to-use software tool.

M1 is regarded by the FC as the core dynamic stand level growth and yield model. However, its use is limited to internal applications by FR researchers and within the FC Forecast System. This is largely because currently the M1 model only exists as a research tool with a technically challenging user interface. Releasing M1 as a package as part of an easy-to-use software tool potentially represents an obvious 'quick win', in terms of improving the availability of forest models to wider forest sector stakeholders.

This scoping study will assess:

- The technical challenges involved in packaging M1 as an easy-to-use software tool
- Implied requirements for supporting documentation (e.g. user manual)
- Any requirements for supporting QA that may not be met by documentation and processes developed under WA 6.1 and WA 6.3.
- An initial estimate of costs involved in packaging and publishing M1

To accommodate the work within the resources available for the programme, this work area is planned to start in 2016-17.

Work area 6.6

Develop outline strategy and prioritised plan for enhanced Knowledge Exchange for 2016-20.

The aim of this work area is to undertake a strategic review of the key approaches currently available to support knowledge exchange with regard to the application of key forest models, systems and tools, and the interpretation of their outputs, and to establish a prioritised plan for their improvement and innovative development.

The strategic review will consider the possibilities for both incremental improvement in knowledge exchange and the development of innovative approaches. This will involve technical and theoretical evaluation of the existing approaches to knowledge exchange to identify limitations, weaknesses and gaps in their potential application, as well as identification and consideration of the potential of enhanced knowledge exchange approaches, including the accelerated dissemination of models and systems in the form of software-based tools, and the deployment of applications on hand-held electronic devices and web-based portals.

The strategic review will require consultation with forestry practitioners and other stakeholders, including other forest researchers, who rely on effective knowledge exchange. A key aim of the review will aim to identify and pursue linkages with relevant activities across the Science and Innovation Strategy, notably in Programmes 3, 4 and 5.

To accommodate the work within the resources available for the programme, the review is planned to start in 2016-17.

Work area 6.7

Revise OGB 32.

The aim of this work area is to support the development and publication of a revised and enhanced edition of Operational Guidance Booklet 32 (OGB32), Production Forecasting. This forms part of the essential operational guidance referred to by forest planners and managers in the forest management organisations of England, Scotland and Wales, when applying the FC Forecast System. As such, OGB32 constitutes a major plank in existing frameworks for knowledge exchange regarding the application of business-critical forest models and scenario analysis systems.

A revised and enhanced edition of OGB32 is needed to reflect the many changes and improvements that have been made to the functionality and application of the FC Forecast System.

The work area will be undertaken in close collaboration with Forestry Commission technical staff, who will lead the actual development and publication of OGB32.

To accommodate the work within the resources available for the programme, this work area is planned to start in 2016-17.

WP Title: WP7. Programme Governance and Management. (*Programme administration.*)

Indicative costs (£k):	2015-16	2016-17	2017-18	2018-19
	67.475			

Work package details:

Ensuring delivery and the continued development of Programme 6.

Work area 7.1

Programme Governance.

Continued liaison with Country representatives (the Programme steering group) and the development of Programme 6 in 2016/17 to 2019/20.

Work area 7.2

Programme Management.

Regular liaison with WP and WA leaders to ensure that outputs are delivered to schedule and to budget. Troubleshooting, where required.

Section 3. Communication Strategy

Covered in WA6. Members of the P6SG will also act as conduits and ambassadors for certain outputs from Programme 6.

There is considerable scope for work on internal- and external-facing communication to be undertaken collaboratively with Programme 7.

Section 4. Collaboration and networking

The Work Packages within Programme 6 cross over into a number of other Programmes within the research structure informed by the FC's Science and Innovation Strategy. Specifically:

WP1 – *Research data acquisition to underpin modelling and verification of resilient forest management* should link directly with work being undertaken in Programmes 1 to 5.

WP2 – *Models of forest structure and dynamics in pursuit of resilient forest management* should link directly with work being undertaken in Programmes 1 to 5.

WP3 – *Tools for scenario analysis to support development of a resilient forest sector* is of direct relevance to Programme 4.

WP4 – *Tools for forest growing stock assessment and resilient forestry practice* has obvious links to Programme 5, not least timber properties research.

WP5 – *Modelling to underpin forest carbon balance reporting, management and policy* is potentially cross-cutting, and will inevitably involve collaboration with CEH, DECC and others.

WP6 – *Essential QA/QC and enhanced dissemination of forest models, tools and information* is of relevance to all Programmes, but will necessitate bi-directional collaboration with Programme 7.

WP7 – *Programme Governance and Management* will ensure continued liaison with, and relevance to, external Programme stakeholders as well as facilitating cultural change within the wider FR modelling fraternity.

Section 5. Ethical and other considerations

5.1 Ethical considerations

There are no significant ethical considerations in 2015-16. In subsequent years, the release of data sets and some software tools may need to address issues regarding privacy of information and intellectual property.

5.2 Government survey control procedures

Ministerial approval must be sought before statistical surveys of businesses or local authorities can proceed so please describe briefly any relevant planned surveys.

None planned.