SCIENCE AND INNOVATION STRATEGY FOR FORESTRY IN GREAT BRITAIN

RESEARCH PLAN BRIEF

FOR

FOREST RESEARCH

CONTENTS

1. SPECIFICATION

1.1 Background

The publication of the *Science and Innovation Strategy for Forestry in Great Britain (SIS)* in March 2014 was suitably timed to reflect the need for forestry science to adapt to the many changes in the way in which forestry is governed and managed in Great Britain.

The SIS seeks to achieve four strategic outcomes:

1. Provide the evidence base for the delivery of healthy and resilient forest and wider ecosystems to provide benefits for society.

2. Provide the knowledge to deliver woodland management and expansion, as a component of sustainable land-use change.

3. Provide the evidence base to allow the forestry sector to deliver a wide range of benefits from trees and woodlands to support sustainable economic growth in Britain.

4. Result in changes to policy and practice through implementation by informed and engaged stakeholders, provide access to a high quality skill base of forest researchers, and be effectively leveraged to provide additional resources to increase the evidence base.

Each of the Research areas contained within this Research Plan Brief relates to one or more of the strategic outcomes, and this relationship is covered in the Research area descriptions.

The Forestry Commission expects the research which it commissions to complement relevant aspects of the European Union's co-ordinated research programme, in particular under Horizon 2020, the COST programme, ERA-NET and INTERREG programmes. Partnership working with European and global research programmes is encouraged and co-ordination is often through the European Forest Institute, its associated Regional Centres and the International Union of Forest research Organisations (IUFRO).

Partnership working also features at UK level, with the major funders of environmental research (i.e. Research Councils and Government Departments) having made commitments to align their Strategies through co-ordinated programmes of research with a strong focus on impact. The two co-ordinated programmes of relevance to our research are: 'Living with Environmental Change' [1]and the Defra Evidence Investment Strategy[2]. Impact is a high priority for the SIS, and research proposals should indicate how this will be achieved. Forest Research will be delivering work under Defra's 'Future Proofing Plant Health' programme. There are strong links between this programme and many areas within the research brief, which will need to be carefully articulated to ensure close collaboration and complementarity.

[1] http://www.lwec.org.uk/
[2] https://www.gov.uk/government/publications/evidence-strategy-for-defra-and-its-network

The role of CFS, as well as managing the research commissioning, is to identify new opportunities for collaboration, and facilitate their development. As an example, CFS will use its external research funding to provide opportunities within the Living with Environmental Change partnership to allow Public Sector Research Establishments, such as Forest Research, and other research providers to competitively bid for funding to deliver research priorities for the partnership. The Tree Health and Plant Biosecurity Initiative is a current example of this. CFS will use its extensive networks to identify and realise opportunities for leverage to benefit forestry research in general. CFS also wishes FR to seek opportunities for external partnership and collaboration to leverage the CFS research funds through EU projects, and other collaborative work with UK research institutions, government departments, and the private sector. FR programme and work package proposals should demonstrate clearly how they will build upon and complement other research elsewhere.

The structure of the Research Plan Brief is designed to facilitate interdisciplinary research and to involve several research FR programme groups in each high level Research area. The aim of this approach is to produce outputs that are more relevant to the complexity of the problems that this research plan seeks to address. FR programme proposals should be able to demonstrate explicit mechanisms which will create effective links between and within different FR programmes and work packages.

Following extensive consultation with stakeholders, a series of five high level issues were identified. These generated six Research Areas, which are set out in Section 3.

High level issues

Issue 1. We don't know what resilience is, how diversity contributes to it, what it looks like, and how it might be implemented. *Relates to SIS outcome 1.*

Issue 2. We need to know more about how to value all of the benefits that forestry provides to enable us to compare benefits provided by forests to those provided by other land uses. *Relates to SIS outcome 2.*

Issue 3. We recognise society's desire for more woodland, yet there are significant barriers to achieving it. *Relates to SIS outcome 1.*

Issue 4. We need to do more to support the continued expansion and development of sustainable market products from forests and woodlands. *Relates to SIS outcome 3.*

Issue 5. We need to stimulate innovation in inter-disciplinary modelling, data acquisition and the provision of tools to support better protection and management of our forests, woodlands and trees. *Relates to SIS outcome 3*

1.2 Commissioning from Forest Research

The nature of the programmes described in this document has been informed by a range of consultations with policy colleagues and stakeholders and by the discussions and workshops held jointly with other research funders. It takes account

of research issues, which have been identified as critical by the devolved administrations. In addition, the brief has been peer reviewed by members of the Expert Committee of Forest Science, and endorsed by the Forestry Commission Research Strategy Management Board.

This Research Plan Brief refers solely to Forest Research. Non-FR research will be covered by a separate brief. It will follow similar principles to address the same Issues.

The Research Plan Brief details six Research Areas, each with a series of Research Challenges to address. For each Research Challenge, a summary of the policy context and research context is provided that identifies the key research questions that Forest Research should address, followed by the research deliverables that the Forestry Commission is seeking. This structure is not prescriptive, and Forest Research will work together with CFS to identify the most effective programme structure for delivering the brief. The detailed research programmes will be developed by FR research teams in discussion with the CFS Analysts There is also a separate section on knowledge exchange.

The research deliverables detailed in each of the programmes are the top priorities required to meet the needs of that programme. Research teams may include additional deliverables if they are of the opinion that they will add value to the overall objectives of the programme. However, these must be realistic and deliverable within the timescale.

Forest Research is responsible for the management of the resources to undertake the scientific programmes of work and the deliverables contained within them.

1.3 Financial Framework

Four year proposals for research through FR programmes and work packages should be based on the financial framework outlined below.

The CFS budget for the element of the SIS to be delivered by Forest Research in the current year is £7.236m. This includes the £350k spend via IFOS on the Forest Mensuration, Modelling and Forecasting programme. These figures were agreed in the Cross Border and Forest Research Corporate Plans. Discussions are ongoing about the baseline for the next spending review, and the allocations for subsequent years. Until these are completed and the actual figures are known, Forest Research should plan the new programmes on the basis of flat lining the current budget.

During the recent series of workshops to identify the research issues and key questions, participants were asked to identify their priorities for research to help inform budget allocations. These views have been taken into account alongside corporate requirements for the Forestry Commission and wider government to provide indicative programme budget figures within a range. All of the programmes have a high priority for the FC; otherwise they would not be funded. However the funding ranges reflect the scale of research required, rather than the importance of it.

The indicative ranges of funding will allow Forest Research to develop a series of programmes, which have a degree of flexibility and allow for the inter-disciplinary approach to research to be achieved. However, the ranges operate within the overall

budget of £7.236m, and the final total for all of the programmes, including overheads, must not exceed this.

It is acknowledged that the demand for research may be greater than the budget allows. Programmes should focus on the highest priorities, while reflecting the needs of longer term research over the next four years. Forest Research should be clear about where it has the expert capability to deliver, and where it would be better to use external sources of science.

The budget for Knowledge Exchange primarily supports dissemination of research produced as a result of this brief. Each Research area will develop a plan for the manner in which it intends to communicate its outputs (see section 10). The funding for these activities is provided by the Knowledge Exchange fund, amounting to 25% of the total budget, shared amongst the Research areas.

Research area 6 is also cross-cutting and will support work done across Research areas 1-5. However, individual programmes will still need to make budgetary provision for operating their own models, e.g. climate change and GHG models.

Table 1 Indicative budget ranges for each programme[3]

Research area	**Short title**	**Lower (£M)**	**Upper (£M)**
Crosscutting	Knowledge exchange	1.811	1.811
Research area 1	Understanding ecosystem health and resilience	1.699	2.077
Research area 2	Managing forests for resilience	1.630	1.993
Research area 3	Valuing forestry benefits	0.305	0.373
Research area 4	Woodland expansion	0.297	0.407
Research area 5	Sustainable markets for forest products	0.446	0.545
Crosscutting Research area 6	Innovative science, models, data, and tools	0.470	0.575

1.4 Schedule

Near final research programmes should be prepared by FR in conjunction with CFS Analysts for delivery to CFS by March 2 2015.

Peer Review of research proposals will take place in the period from March 9 to March 23, 2015 with any follow up discussions with programme managers taking place by March 30, 2015 to allow final proposals to be agreed by the Research Strategy Management Board (RSMB) for an April 6 2015 start date.

1.5 Scientific quality and feasibility

Individual programmes should set out the research context in sufficient detail to demonstrate the contribution proposed to UK and international science, the opportunities for scientific innovation and the extent to which the research builds on existing strengths or develops new capabilities.

[3] These are indicative at this stage, and will need to be refined as the research programmes are developed. They have been based on the levels of expenditure of the current programmes relating to these Research Areas. See Annex A for this initial breakdown.

Programmes should include sufficient detail in their proposal to ensure that reviewers can assess the tractability of the research proposed; including the aims, objectives and hypotheses and the suitability of the approaches, techniques and methods to be employed.

Programmes should pay attention to the contributions and value of multi- and interdisciplinary approaches, the use and integration of social sciences and the use of appropriate statistics and biomathematics to ensure robust scientific design and outputs. Where appropriate, programmes should identify and provide proposals for the management of ethical issues as committed to by Forest Research[4].

Each programme will need to identify the significant risks to successful delivery of the research deliverables. Examples might include the interdependency on other research outputs or external dependencies out with the control of the researchers. FR should also consider how to identify critical paths within programmes to ensure that emerging events requiring research inputs (e.g. Asian Longhorn beetle) do not derail major programme outputs. Forest Research should be able to indicate how the risks will be managed.

The applied nature of forestry research and Forest Research's role in providing support to policy makers requires a degree of flexibility within the FR programmes to allow it to respond rapidly to emerging issues. When developing their programmes of research, FR should build in an appropriate level of contingency time to allow for this. The process for managing changes within the programme is set out in Annex B, and this should be followed to ensure that changes to FR programmes are agreed and transparent.

Programme managers should be realistic about the deliverables they are committing to provide under the research, not only in terms of delivering the science, but also delivering it on time. Whilst the CFS management of programmes will allow a degree of flexibility to ensure that emerging needs can be addressed, consistently under or late delivery is not acceptable. Whilst CFS does not wish to suppress scientific creativity, it needs to meet its customer expectations on delivery, and the credibility of the science and the reputation of the Forestry Commission will suffer, if this is not achievable (See section 2.3.1).

1.6 Peer Review

This commissioning brief has been peer reviewed by the Expert Committee on Forest Science (ECFS), and endorsed by the Forestry Commission RSMB. All research programme proposals will be subject to peer review by the ECFS. Review Criteria will include:

- Scientific quality, innovation and feasibility
- Collaboration, Co-ordination and Networking
- Knowledge Exchange

Peer review may highlight areas for change in the programmes, and Forest Research should have plans in place to allow this to be addressed within the timeframe given by 1.4.

[4] www.dius.gov.uk/policies/science/science-andsociety/

Programme outputs will be subject to peer review to ensure science quality. Forest research will publish and maintain a peer review programme, which is proportionate to the research deliverables being produced, and includes both internal and external review mechanisms. This must be sufficient to enable the Forestry Commission to meet its Open Access obligations.

2. Research Plan Management

Robust management arrangements are crucial to ensure that the programmes commissioned under the Science and Innovation Strategy for Forestry in Great Britain (SIS) deliver the desired outcomes. Governance arrangements will aim to balance a light touch in administration with ensuring clear communication and effective project management throughout the programme.

2.1 Research Strategy Management Board

The highest level of governance will be the RSMB, which is responsible to the FC Executive Board for delivery of the Science and Innovation Strategy. The principal tasks of the Board are to oversee and direct:

- the production of a Science and Innovation Strategy for British Forestry;
- resourcing of strategic programmes of research and research services to implement the Strategy, particularly those delivered by Forest Research;
- monitoring and evaluation of the programmes in the Strategy and the annual reporting on that progress to the EB and Commissioners;
- monitoring the Strategy to ensure that it is fit for purpose and delivering stakeholder expectations.

The RSMB will therefore have responsibility for overseeing the programme management and research budget allocation arrangements.

Membership will comprise:

Chair – Director Corporate and Forestry Support
Head of Analysts in CFS
FC Chief Scientific Advisor
FC Scotland Head of Policy
FC England Head of Policy
NRW policy lead
Defra Representative
Scottish Government representative
Welsh Government representative
CEO Northern Ireland Forest Service
Secretary (CFS)

2.2 FC Corporate and Forestry Support (CFS)

CFS is responsible for the delivery of the activities in the Cross Border Corporate Plan. Ensuring a robust evidence base for forestry authorities across the UK in order to underpin their policies, decisions and advice is a key priority which is delivered through the commissioning, funding, and delivery/client interface management of the programmes on behalf of the Research Strategy Management Board. CFS funds a

set of inter-disciplinary research programmes in Forest Research (FR) and purchases research from external providers to broaden the research base and bring in additional expertise. Research priorities are determined in partnership with country colleagues, FR, and other stakeholders. CFS supplies the delivery resource and secretariat for the RSMB which oversees the Science and Innovation Strategy for Forestry in Great Britain, and works with cross-Governmental research initiatives and Research Councils to track and influence future research opportunities and to promote and lever the FC's research capacity. It also provides the funding and secretariat for the Expert Committee on Forest Science, which provides expert independent advice and quality assurance on science. CFS chairs the Strategic Publishing Group, which schedules production of publications to ensure they reach the right audience at the right time, and deliver the greatest impact.

The aim of these governance arrangements for the 2015-2020 programmes is to:

- Build on the integration of research evidence achieved in the current Strategy; to provide more holistic evidence to policy and operational colleagues during the life of the 2015-2020 SIS;
- provide co-ordination across the FR programmes, work packages, and projects;
- enable flexibility within the broad objectives of the research plan; and to
- work collectively to deliver the research plan outcomes.

2.3 Programme management

CFS Analysts will be responsible for agreeing key outputs and timescales with policy customers and managing the relationship with FR to ensure that programme outputs are delivered on time. To support this, the analysts will meet regularly with FR programme managers and policy customers to ensure good communication about the progress of the science, and delivery of the outputs. Annex B provides a flow chart to outline how this process will work.

Proposed deliverables under the CFS research programmes will be collated into an outputs spreadsheet. This should include all types of published outputs, including guidance and research produced as peer-reviewed science journal publications, books, apps, e-pubs, decision support systems. This will allow the Strategic Publishing Group to identify outputs due to be produced in the next 6-12 months, and plan for disseminating them in the most effective way to achieve the greatest impact. The spreadsheet is updated on a quarterly basis by the CFS Analysts to reflect delays in production, or changes to the schedules. This is an internal document which is available to FR scientists and country policy leads.

2.3.1 Dispute resolution

In the event of a dispute between CFS and Forest Research relating to the failure to deliver work within agreed timescales, a dispute resolution protocol will come into play. The protocol can be seen at Annex C[5]. We do not envisage that this will be required on a regular basis, but it will provide a supportive framework to resolve issues which the normal programme management process cannot.

[5] This is still under development, so not attached.

2.3.2 Deliverables

Forest Research will respond to this brief by working closely with CFS Analysts to develop a series of research programme proposals, which address the requirements set out in the Research areas identified below. The detailed research programme proposals should be set out using the pro-forma at Annex D[6].

Each research programme proposal should set out:

- An abstract of the proposed research;
- The aims and objectives of the research and a statement of impact from the research and its contribution to supporting country strategies;
- A description of the key work packages and resultant deliverables including a knowledge exchange plan, identifying the format and methods to be chosen for communicating and disseminating research, based on the target audiences (see also 10.3 section on knowledge exchange);
- A detailed schedule of deliverables for the next 24 months (or longer, where appropriate) of the programme, which will be reviewed annually, and which should include materials for the use of both laymen and scientists;
- The structure of the work packages within the programmes and those responsible for delivering them;
- The linkages with the work packages within the programme and between programmes where this is appropriate to explain how the work will deliver the integrated outputs that are needed;
- A statement of funding requirements, including leverage from partnership, EU, or other funding sources;
- An analysis of threats to programme delivery and risk management options.

2.3.3 Reporting

At the end of each financial year each programme will be required to prepare and submit a report detailing progress against deliverables, the format of which will be agreed at a later date.

At the end of each financial year, CFS Analysts will prepare an evaluation report on each of the programmes under their management, which will be forwarded to Forest Research for discussion at the FR Executive Board. A joint report will be prepared for RSMB.

[6] This is still under development, so not attached.

3. FORESTRY COMMISSION RESEARCH PLAN 2015-2020

3.1.1 Research area 1: Understanding resilience in forest ecosystems in relation to biosecurity and climate change
Short title: Understanding ecosystem health and resilience

Research Challenges:
RC 1.1 How to define 'resilience' of different types of woodland with different objectives to different types of risk at different spatial/temporal scales
RC 1.2 Understanding influences on resilience and adoption of measures to increase resilience
RC 1.3 What are the pressures to which forests must be resilient over the next century?
RC 1.4 Maintaining ecosystem services and biodiversity whilst achieving resilience

3.1.2 Research area 2: Resilient forests, woodlands and urban trees which are able to adapt to global and local change
Short title: Managing forests for resilience

Research Challenges:
RC 2.1 What are the properties of trees which we are likely to grow for increased resilience; what is the likely impact on sector productivity of a switch to trees with these properties?
RC 2.2 How do we design, cultivate and manage adaptive, resilient woodlands?
RC 2.3 Forestry contribution to wider landscape resilience including mitigation of climate change
RC 2.4 What tools (and K.E.) are required to assess risk and resilience and support adaptive management?
RC 2.5 Increasing focus on protecting existing woodland and better management of undermanaged woodlands

3.1.3 Research area 3: The natural capital and ecosystem services provided by forests woodlands and trees are quantified and valued to inform decision making
Short title: Valuing forestry benefits

Research Challenges:
RC 3.1 How should forestry and woodland benefits be valued?
RC 3.2 What are the costs and benefits of forest management options to improve resilience and expand our woodland resource?

3.1.4 Research area 4: Understanding the drivers and barriers to woodland expansion, and identifying ways to deliver it in a sustainable land use context
Short title: Woodland expansion

Research Challenges:

RC 4.1 Assessing the behavioural barriers to woodland expansion – is there potential to apply social research to the barriers that exist to land use change?

RC 4.2 What are the financial and policy interventions required to overcome barriers and exploit expansion opportunities?

RC 4.3 Facilitating expansion of woodlands through targeting and provision of evidence

RC 4.4 Impacts of pests and diseases on the retention and creation of woodlands and forests

3.1.5 Research area 5: Developing efficient and sustainable supply chains for forest products and ecosystem services

Short title: Sustainable markets for forest products

Research Challenges:

RC 5.1 Supporting the development of new and innovative sustainable markets for forestry products and services

RC 5.2 How can we improve our understanding of non-timber products and services delivered by forests and woodlands?

RC 5.3 How do we ensure supply-chain investment, diversification and effective management?

3.1.6 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

Short title: Innovative science, models, data, and tools

Research Challenges:

RC 6.1 QA Framework for Modelling

RC 6.2 More reliable and flexible models

RC 6.3 Integration and coherent delivery of model systems

RC 6.4 Improved tools for forest and stand assessment and management

RC 6.5 Physical and remote data acquisition for monitoring and modelling

3.1.7 Research area 7: Knowledge exchange

RC 7.1 How do we ensure stakeholders and end users of research are engaged at the appropriate stage of the research process, rather than at the end?

4. RESEARCH AREA 1. UNDERSTANDING RESILIENCE IN FOREST ECOSYSTEMS IN RELATION TO BIOSECURITY AND CLIMATE CHANGE

4.1 Purpose

This Research area will support the delivery of Outcome 1 in the Science and Innovation Strategy for Forestry in Great Britain (SIS), namely 'Provide the evidence base for the delivery of healthy and resilient forest and wider ecosystems to provide benefits for society.' However it is a crosscutting Research area and will also help to deliver the other three outcomes in the strategy.

The work in this theme aims to improve our understanding of ecosystem services and how to ensure they remain resilient to change. The ecosystem approach has demonstrated its value in initiatives such as the Millennium Assessment; however, substantial research needs have been identified. These include methods of assessing ecosystem status (health and resilience), delivery of ecosystem services and their value to society, and a need for improved understanding of the relationships between different ecosystem services (provisioning, regulating and cultural) and underlying biophysical processes (supporting services). In addition, this theme should develop the Ecosystem Approach as an aid to decision and policy making; it has not yet been widely used, although progress is being made in forestry.

Research in this Theme takes place within the context of the UK National Ecosystem Assessment (NEA). The NEA was initiated by LWEC, for which the Forestry Commission, Defra and the devolved administrations are partners. The research will use the conceptual framework adopted by the NEA and aims to build on their work in areas that will be particularly relevant to forestry in the context of sustainable land use. Priorities include the development of improved approaches to the assessment of ecosystem services at a range of scales, with the aims of identifying environmental assets and related services that are at risk, and of developing the utility of the approach in management. Cost-effective application of the Ecosystem Approach in planning and management will be further explored and assessed through case studies at a range of geographical scales and governance levels.

4.2 Linkages

UK sustainable growth and environmental policies are strongly directed towards obtaining multiple environmental benefits: achieving a balance between human well-being and other outcomes, dealing with the potential impact of change, including climate change, biotic threats and making use of the ability of environmental resources to mitigate and adapt to such change. The complexity of the underlying issues requires an interdisciplinary research framework within which the interactions between different factors and drivers can be considered.

The research in this theme will link closely to work in Research areas 2 and 3 on resilient forests and valuation of monetary and non-monetary ecosystem services and benefits, work in Research area 5 on sustainable markets for forest products, and research in Research area 6 on innovative modelling and tools. The National Ecosystem Assessment (NEA) will provide a conceptual framework and a crucial baseline for identification of key issues and gaps which need to be addressed. Work is closely aligned with NERC Biodiversity and Ecosystem Service Sustainability (BESS). Research on tree health should complement the Defra 'Future Proofing Plant Health' programme.

Increased understanding of the requirements of resilience, and how these can be achieved, will help to sustain investor confidence in forests and woodlands; help to identify new options for forest management to address biotic and environmental threats; and will support the delivery of healthy, multifunctional, and resilient forests that deliver the widest possible range of societal benefits.

4.3 Research focus

The focus for research should take a broad interdisciplinary approach to the question and this will include:

- Evaluating approaches to adaptation and increasing resilience in forestry, focusing on the composition (species, origin, diversity, and stability of ecological communities) and management systems (silviculture and regeneration systems) that effectively address climate change concerns, biotic and abiotic threats;
- Understanding the impact of invasive pest species at the ecosystem level and finding technically and financially effective ways of anticipating new threats, rapid detection and identification, monitoring, and improving response strategies, modelling, biosecurity controls and practical measures for addressing them through;
- Horizon scanning to detect and prepare for new pest and disease threats before they arrive;
- Maintaining or improving the biodiversity of woodlands, halting decline in species where possible but recognising limitations and seeking sustainability of long term interventions. Considering the value of ‘new’ natives and ensuring both species choice and management build resilience in native forest ecosystems now and in the future.

4.4 RC 1.1 How to define 'resilience' of different types of woodland with different objectives to different types of risk at different spatial/temporal scales

Policy Context

Resilience is often quoted as being a key aim of policy, yet there is no agreed definition of what resilience means in a forest or woodland context. There is no common understanding across the broader land use sector, thus policies focussed on resilience for one sector can impact the resilience of another. Is a single species, single age conifer plantation more or less resilient than continuous cover woodland with a mixture of species? Is resilience about being able to withstand attack from pests or diseases, or is it about being able to adapt to changing climatic conditions?

An improved understanding of how resilience applies to different forest types, at a range of scales, and to different ecosystems and their services is critical for policy makers and land managers. By addressing resilience at the forest management unit, ecosystem, and landscape scales research needs to consider multiple resources, a wide range of factors and interactions.

Research Context

- Research will need to consider how 'resilience' can manifest in different ecological, silvicultural and economic contexts.
- What indicators can be used to determine trends, quantify and predict the resilience and biophysical limitations of delivery of ecosystem services? Predicting tipping points and ecosystem collapse will also be relevant. In fact, it may be more useful to identify characteristics of vulnerability or system instability. Research should assess and, where appropriate, further develop suitable indicators for use at different scales.
- What models are required to anticipate, or scenario plan for, threats to resilience? How can existing models be used to support this? Is the approach adopted by ESC suitable for addressing resilience issues?
- How can this approach be used to explore resilience, adaptive capacity and limits of change of ecosystems and their goods and services in plausible future scenarios? Research might consider climate change, pests and diseases, and other impacts, issues relating to system redundancy (e.g. which components of biodiversity underpin ecosystem function and which do not) and inter-relationships in ecosystem service provision. Where relevant, the research should draw on existing scenarios or on those in use elsewhere.

Research Deliverables

- A clear definition of resilience and how it can be applied to the varied and diverse nature of British woodland and forestry practices, in response to a variety of threats and changes.
- Increased understanding of the linkages between the primary ecological and evolutionary processes, ecosystem function and ecosystem services, to inform assessment of the consequences of loss of resilience across a wide range of forest and woodland types.
- An integrated framework for testing scenarios at different spatial scales, for use as an aid in decision making. In particular to improve understanding of the

effects of reduced resilience on ecosystem service and product provision and to identify points of instability and collapse.

- To improve understanding of the adaptive capacity of forests, woodlands and trees to deliver ecosystem services and products under a range of pressures and drivers of change (including changes to land use).

4.5 RC 1.2 Understanding influences on resilience and adoption of measures to increase resilience

Policy Context

We need to understand what factors reduce or increase resilience. Scale (temporal and spatial), composition and wider landscape context will all influence the level of resilience achieved. We need to assess whether the current silvicultural practices employed in modern British forestry are supportive of or detrimental to resilience, and what changes may be required to ensure they fully support future resilience. The influence of diversity on resilience is also required; we must ask whether a diverse forest is more resilient, in an ecological and economic sense, and at what scale this diversity should be cultivated. This will lead to a refining of silvicultural techniques aimed at fostering resilience (links to RA 2).

To ensure on-going resilience we need to consider the role of new species, their provenance and biodiversity impacts. Resilience could be achieved at different levels, in response to the likelihood of different risk scenarios. We need to understand at what level managers, policy makers and society are prepared to accept vulnerability and change in forests. Trade-offs may be required to maintain a portfolio of future forest types.

The process of adaptation can be perceived as costly, so there is a behavioural and communications aspect to this question. In some cases, known solutions to threats are not implemented for a variety of technical, economic, social or political reasons. Understanding and overcoming these barriers and resistance to change is essential for ensuring that research is converted into implemented solutions and threats to the industry can be effectively tackled.

Research context

- The research response will require identification of influences on resilience (both positive and negative) and then a refinement of these into knowns, known unknowns etc., using horizon-scanning and other techniques. Influences will also be identified in section RC1.1. This section is very closely linked to RC 1.4.
- Forests managed using current techniques, alternative systems and proposed ‘new’ species mixes could be ‘challenged’ using risk modelling techniques to assess outcomes for production, ecosystem service provision and society over time.
- Objections of land owners/managers to adopting measures aimed at the long-term survival and productivity of forests and woodlands may require work in tandem with RC 7.1 into understanding and influencing stakeholder behaviour.

- Development of ‘resilience risk assessments’ and their application to forest management systems, landscape/biogeographic and temporal contexts and species choice.

Research Deliverables

- A comprehensive understanding of the influences on resilience in different woodlands and forests, at different scales.
- An understanding of the technical, economic, social, communication and political barriers that stymie implementation of known solutions for resilience.
- Understanding of how woodland resilience fits into a broader resilient landscape and ecosystem.
    - Prof J Memmott - PhD Contribution 'Pollination services and Forestry - spatial patterns and sources. 2015/16 - £5,000
- An understanding of the factors that influence decisions by different land manger types, and an understanding of whether landowners can assist in answering questions of how and when to adapt woodlands for resilience.
    - Dyfi riparian PhD 2015/16 - £17,000

4.6 RC 1.3 What are the pressures to which forests must be resilient over the next century?

Policy Context

Decisions made now, in order to create effective resilience in woodlands and forests, will likely come to fruition several decades from now. In that time, forests and woodlands will face challenges from climate change, pests and diseases, environmental change and market change. Some of these will challenges will be familiar or easily anticipated; others may create rapid and unexpected change.

Research commissioned now must be able to provide long-term direction and stability to our forests, as well as respond to urgent threats or knowledge gaps. Horizon scanning to identify potential or high risk threats is an important step in ensuring rapid responses to threats and preventing maladaptation. This work area is very closely linked to RC1.2, and there are external links to CERF horizon scanning, CAMERAS in Scotland and the NEA.

Research Context

- The forestry industry maintains a relatively limited portfolio of productive species, with a particular emphasis on Sitka spruce. The emergence of disease in these key species could have a devastating impact both on our forest ecosystems and the forestry industry. Horizon scanning should identify threats to species, with follow-on research of biology and control mechanisms.
- Pests and diseases which are currently known but are likely to continue causing damage should also be identified. These may require on-going research into effective control mechanisms and surrounding communication.
    - Funding for £9.1m Tree health and plant biosecurity initiative - 2015/16 - £150,000: 2016/17 - £200,000

- Economic scanning may also identify future fiscal or market challenges for our forests, such as the impact of changes in grant systems or supply-chain costs.

Research Deliverables

- Identification of future likely or high risk threats to our woodlands and forests, including as applicable to key productive species.
- Preparation of control management strategies in advance of outbreaks – this allows sufficient time to ensure they are technically and organisationally sound and resources required for implementation can be anticipated in advance.
- Identify threats from non-biological sources, e.g. EU directives or markets.

4.7 RC 1.4. Maintaining ecosystem services and biodiversity whilst achieving resilience

Policy context

Resilience is concerned primarily with ecological stability; however, it also contributes to the continued ability of forests and woodlands to provide and sustain ecosystem services. This includes services such as carbon sequestration and substitution, flood amelioration and recreational and amenity services. The underpinning role of service provision by biodiversity is unclear; if forestry is to change to ensure resilient forests we must understand implications for biodiversity, ecosystem service provision.

Research context

- By linking with the focus in Research Area 3 relating to ecosystem services valuation (RC 3.1; 3.2), changes required to cultivate resilience should be evaluated for their impact on ecosystem services provision and valuation and biodiversity. Different economic and ecosystem services may be affected differently, in which case, the question of whether they can be substituted or ordered to maintain an overall balance of ecosystem services may be relevant.
- Understanding the carbon and greenhouse gas impacts of different policies and forest management decisions has developed in recent years but considerable gaps in the evidence base remain. Understanding these impacts is important in for reporting obligations for the LULUCF GHG Inventory and for helping forest managers to assess the impacts of different measures to develop adaptive and resilient woodlands. This work is closely linked to RA6, modelling work.
- Changes made to forests in order to achieve resilience and diversity will also likely alter the existing biodiversity of some areas. Efforts must be made to understand areas in which biodiversity can be preserved, or others in which it will be maintained in an altered form. This must refer also to our obligations under international agreements on conservation of biodiversity and commitments to EU and domestic legislation. We must understand what management is most appropriate to facilitate both biodiversity and forests capable of withstanding changing conditions. This can be informed by long term monitoring, pressure-state indicators and understanding of fundamental ecological processes.

Research Deliverables

- A system of evaluating ecosystem services must include provision for how these values will be altered on one hand by climate change and threats from pests and diseases, and on the other by efforts to create diversification and resilience.
- Research under this RC needs to include the impacts of changes to forest species or management on the ecosystem services of soils and water.
    - Bird Monitoring in Pangbourne 2015/16 – 2016/17 - £1350/yr

5. RESEARCH AREA 2: RESILIENT FORESTS, WOODLANDS AND TREES WHICH ARE ABLE TO ADAPT TO GLOBAL AND LOCAL CHANGE

5.1 Purpose

This research area is focussed on the practical solutions that will be required to deliver more resilient forests and woodlands in the future. It will need to examine environmental changes which might impact our forests and how we can adapt to these changes. It will need to consider the risks, costs and timing of adaption as well as social acceptability of proposed changes. The evidence base from this area will support Outcome 1 of the SIS, along with Outcome 2. This Research area should include ongoing commitments such as the Tree Health Advisory Service and catchment monitoring.

5.2 Linkages

This area will need to be linked to the more fundamental work undertaken in Research area 1, but will also inform Research area 4; Woodland Expansion. Any solutions will need to be sustainable and therefore the economic research and commercial aspects of Research areas 3 and 5 are also important. The research should also complement the work being undertaken in Defra's 'Future Proofing Plant Health' programme.

5.3 Research Focus

- Using the NFI[7] to gain a better understanding of the nature, condition, and distribution of forest types and species within British woodlands including their silviculture, ecology, growth and yield;
- Maintenance of a network of permanent sample plots to investigate the potential for alternative silvicultural systems, regeneration, and novel tree species;
- Understanding how and when to intervene to adapt woodlands and trees to environmental changes including climate change or pests and disease, as well as the risks & costs associated with adapting or failing to adapt;
- Learning how to manage forests at multiple scales to ensure that they are more resilient to climate change or pests & diseases including through management practices and tree breeding approaches to identify a wider variety of "future proofed" species and understand their silviculture including establishment requirements, production cycle and timber qualities;
- Horizon scanning to detect and prepare for new pest and disease threats before they arrive;
- Understanding the impact upon ecosystem services (such as timber yield & quality, improving water quality, soil conservation, and flood prevention/alleviation and carbon storage) of different adaptation strategies;
- Understanding the barriers to forest managers adapting and improving resilience of their woodlands;
- Developing multi-disciplinary tools to help managers identify and evaluate adaptation strategies with the best potential to deliver ecosystem services.

[7] Funding for the National Forest Inventory is in addition to the research funding outlined in Section 1.3 above, and is not, at this time, governed by the RSMB.

5.4 RC 2.1 What are the properties of trees which we are likely to grow for increased resilience; what is the likely impact on sector productivity of a switch to alternative species?

Policy context

The current portfolio of trees within Britain may be less suitable in the long term, as species are threatened by climate change and disease. In the case of our current narrow range of productive species, varying degrees of diversification will be required as a risk management strategy. In response to RC 1.3, which identifies threats to forests and woodlands, alternative species should be considered, which may confer greater resilience.

As the portfolio of species commonly planted broadens we require a greater understanding of these species in the fields of genetics, silviculture, pathology and entomology. A clearer understanding of a variety of potential new species will allow us to select species which are best suited to future conditions and to begin to prepare for the changes in forest management they will require. For urban trees, understanding the tolerance of species to the changing urban environment is key.

Understanding the carbon and greenhouse gas balance of alternative species or management choices (including for bioenergy, and in urban areas) is key to ensuring effective climate change mitigation in a resilient forest or woodland.

Research context

- In relation to new species of both conifers and broadleaves, trials are required to generate more information on seed origins and characteristics, site requirements, propagation, nursery regimes, establishment practice, herbicides, growth and yield, stand silviculture, timber properties, ability to provide related ecosystem services and market potential (linking to RA 5). Candidate species will need to be assessed for their potential to become invasive in British conditions, both now and for climate change scenarios. Risk analyses on invasiveness must be included to address the requirements of new EU directives and should link with similar work being undertaken at Fera.
- Consideration of a wide range of species as alternative productive species.
- This will take time and some of the results of this work will not be obtained within the time scale of the SIS, nevertheless investment in this area is needed now to provide potentially vital advice in the future. This a critical area where FR must collaborate internationally, as resources are unlikely to be available to fund all of the trials required.
- Consider within-species genetic diversity; testing of different provenances may contain information about adaptive responses to future threats.
    - Measuring adaptive potential for birch ash and Rowan - provenance trials 2015/16 - £17056
- Existing species should also be evaluated for their likely response to changing conditions, and their ability to withstand emerging pest and disease threats.

Research deliverables

- More detailed information about the provenance and properties of alternative productive species, as well as urban trees.
    - Engagement with EUFORGEN – 2015/16 on - £19,510
    - Support for Future Trees Trust for improvement and breeding of hardwood species 2015/16 on - £25000
- A risk assessment for the use of candidate species, including assessment of their invasiveness and potential pests and diseases (developed with RC1.2).
- A better understanding of the adaptive potential of our native tree species.
    - Contribution to Scots pine genetics PHD 2015/16 - £3,500
- Maintenance of a network of permanent sample plots to investigate the potential for alternative silvicultural systems, regeneration, and novel tree species;
- Development of growth and yield models for new species that show promise for productive forestry. Also development of growth models for urban trees. This has strong links with RA 6.

5.5 RC 2.2 How do we design, cultivate and manage adaptive, resilient and productive woodlands?

Policy context

If we are to plant a wider range of unfamiliar species in order to create more resilient forests, we need to understand the ramifications these changes will have on forest and woodland management. This includes understanding the impact which switching to mixed stands and woodland will have on silvicultural arrangements. The continuing transitions away from clear felling will also affect the nature of forests and woodlands in the future.

The implications for biodiversity of different combinations of management systems at a range of scales should also be assessed. In order to best respond to ensure resilient biodiversity, we also need to understand the role of landscape ecology and connectivity, and whether landscape ecology and site-based conservation working together or separately may offer the best solutions for different areas.

Increasing diversification, new species and changes in silvicultural techniques to create resilience will impact on productivity. Growth and yield models must be updated to reflect changes in species and management, both for forest and urban trees. Furthermore, understanding the properties of these new resilient species will allow us to consider their potential in terms of marketable products for the future.

Research context

Conservation priorities must also be determined to allow decisions to be made about when it is appropriate to protect and restore sites, versus creation of new habitat. The negative aspects of this approach must be examined, such as the possibility that habitat networks will open up pathways for the spread of pests and diseases.

We need to understand which silvicultural and management systems work best with new and mixed species for resilience. At what scale should mixed species and/or mixed aged systems be used and what would their impact be socially and

environmentally if used at a landscape scale? This links to RA 1, in determining the 'resilience' outcomes we seek to achieve in terms of biodiversity and ecosystems.

Research deliverables

- Guidance on which species mixtures should be used and which avoided and how they should be planted and managed to reduce landscape scale risks.
    - UK Butterfly Monitoring Scheme 2015/16 – 2016/17 - £5000/yr
- A better understanding of the social and commercial acceptability of the wide spread use of mixtures in British forestry.
- In tandem with RA6, growth and yield models for intimate mixtures and for mixed ages crops which show the effect which changes in planting and felling practices, in order to cultivate resilience, will have on productivity.

5.6 RC 2.3 Forestry contribution to wider landscape resilience

Policy context

When discussing the relative merits of forestry as a land use, it is helpful to discuss the services it provides not just within forests, but also as one part of a larger sustainable ecosystem. This includes its contribution to closely related environments, such as agriculture and hydrological systems, but also urban environments. This research challenge considers the benefits of more closely integrating forestry and other land uses. It is important to consider the carbon and greenhouse gas balance of forestry integrated with other land uses, including renewables, to ensure effective climate change mitigation.

Research context

- This work programme provides for collaboration with other fields and partnerships who are involved in evaluating ecosystem resilience on a broader scale.

Research Deliverables

- Understand the contributions of resilient forests to helping other land uses, environments and society withstand the challenges of a changing climate.
- How do other land uses (eg agriculture and urban) impact on woodland biodiversity and resilience?
- How to most effectively integrate forestry and other land uses.
- Consider the potential for trees and woodland to mitigate the effect of climate change in an urban environment and subsequent impact on human health.

5.7 RC 2.4 Which tools (and K.E.) are required to assess risk and resilience and support adaptive management?

Policy Context

The adoption of new species, silvicultural methods and forest management systems required to create resilience will also likely hasten the need for adapted operational practices, equipment and methods. Policy support is also required to ensure practitioners are facilitated in continuing to meet their legal obligations as regulations adapt in response to challenges including climate change and biodiversity.

Research Context

- Tools already exist to help managers, including Forest Gales, to deal with wind throw, and ESC to help match species to site (Right Tree Right Place for Urban species/site matching). With an increasing suite of management techniques and species the existing suite of risk management tools needs to continue to be reviewed to adapt to the new situations (strongly linked to RA 6). Some linkage will also be required with the financial evaluation of risk of crop failure to see if any potential added costs are off-set against lower risks.
- Tools which also assess the carbon and greenhouse gas balance of various species and management options (such as the tools developed for the Woodland Carbon Code) will also need continual review to incorporate changing management and new species considered under RC 2.1.
- Itree, which helps to assess and understand the ecosystem services provided by urban trees and greenspace, requires some further refinements in the UK context.

Research Deliverables

- Comprehensive and consistent method for evaluating risk/resilience across a range of woodland and forest setting. This should have a close link to other work in this area, such as the PURE project.
- Development of practical advice and support for changes in operational practices, including species selection, management and legal adherence.
    - How do silvicultural practices influence dormice populations in commercial plantations? 2015/16 - £10,000
- Ongoing support, guidance and research into new products or techniques which may enhance adaptive capacity.
    - Support for CCFG National Conference 2015/16 - £1500
- Ongoing development and support of existing tools

5.8 RC 2.5 Increasing focus on protecting existing woodland and better management of undermanaged woodlands

Policy Context

A huge proportion of British woodlands, particularly in small private ownership, are undermanaged. In addition to potential loss of biodiversity and increased pests and diseases, this woodland fails to contribute its full potential to a range of targets for environmental sustainability. In order to encourage adequate management, commercial incentives must be considered in tandem with Research area 5. There is room for consideration of governance in relation to regulation and incentives for management. Increasing the natural capital associated with existing stocks should also be emphasised, e.g. through avoiding deforestation and restocking effectively. This would also help to reduce the possible conflicts of land use change due to the creation of new woodlands and is linked to Research Area 4.

Research context

- Evaluation of different land management strategies which might suit currently undermanaged woods.

- Lifecycle assessment of the carbon and greenhouse gas balance of bringing these woodlands back into management is important in understanding the overall impact to mitigating climate change.

Research Deliverables

- Adequately quantify the improvements to ecosystem services (including carbon and biodiversity) which could be gained with more effective management.
- Identify undermanaged woodlands and effective incentives suited towards their owners.

6. RESEARCH AREA 3: THE ENVIRONMENTAL ASSETS, BIODIVERSITY AND ECOSYSTEM SERVICES PROVIDED BY FORESTS WOODLANDS AND TREES ARE IDENTIFIED AND VALUED TO INFORM DECISION MAKING

6.1 Purpose

This research area aims to strengthen understanding of the economic values of forestry in supporting natural capital and delivering ecosystem services. It relates closely to the SIS Outcome 3, developing an evidence base to enable the forest sector to deliver benefits to support sustainable economic growth. It also supports other objectives in the Strategy on underpinning healthy and resilient forest ecosystems and delivering sustainable land-use change. Work undertaken by Forest Research should complement externally commissioned work by independent research providers to deliver robust outputs, which may be subject to considerable external scrutiny.

6.2 Linkages

Economic analysis has a role in supporting scientific endeavour in wide-ranging areas of research on forestry. This research area is intended to build upon inter-disciplinary analysis across the research programmes delivered by Forest Research. It will also support decision-making and policy instruments that seek to enable forestry to play a greater role in delivering benefits to society.

The research area has strong links to Research area 4, Woodland expansion, Research area 2, Resilience (risk), and Research area 5, Forest product markets.

6.3 Research Focus

- Quantifying the location, scale of delivery, and physical benefits of woodland for ecosystem services (such as improving water quality, soil conservation, and flood prevention/alleviation and carbon storage) and comparing different woodland types with different types of existing land use. Devising appropriate metrics is expected to be a major challenge in this work.
- The development of market-based approaches to maintaining natural capital and delivering forest ecosystem services to support sustainable economic growth and to help avert risks from ecosystem degradation.
- The increasing importance of the need to consider the “basket” of ecosystem services when evaluating the benefits provided by woodland to society at both landscape and ecosystem scales, such as flood/climate change mitigation;
- Understanding the value of rural and urban ecosystem services (cultural, social, environmental or economic) and devising mechanisms for evaluation and payment, and to develop systems for natural capital accounting;
- The development and use of interdisciplinary tools and models to support decision making in forestry and wider land management to achieve sustainable outcomes and better understanding between foresters and other parts of society. It is important to understand the impacts of woodlands at both a stand and wider catchment landscape scale and to understand risks to woodlands in order to devise adaptive actions. This will support longer-term decision-making that accounts for the “basket” of forest ecosystem services in a wider land-use context, using the best data available (e.g. the NFI).

6.4 RC 3.1 How should forestry and woodland benefits be valued?

Policy context

Forests and woodlands provide a wide variety of services, which in turn provide economic, environmental and social benefits, in both market and non-market contexts. Efforts must be made to ensure that benefits are accurately captured and, where appropriate, translated into common monetary values, which is essential to enable effective advocacy of forestry as a land use and to enable a commonly agreed system for evaluating land use benefits. This includes accounting for the full range of benefits (including from urban forestry, see RC 2.3) and for the changes in values over time (e.g. due to climate change, new technologies or as woodlands mature). Measurement systems must be capable of accounting for benefits delivered at different spatial and time scales.

Woodlands deliver benefits in a wider land-use setting. Comprehensive assessments of the benefits and disbenefits of various land scenarios (e.g. clean water, pollution absorption, biodiversity, flood amelioration, carbon sequestration) should help to indicate optimal land-use decisions and assist expansion efforts under RA 4.

Research context

While considerable research has been carried out in the past to value forest ecosystem services, important gaps in our understanding remain. Such gaps relate both to dose-response functions (for example, impacts of new woodland on water quality) and to estimating associated economic values. A number of factors are pertinent in determining future research needs on valuation:

- Values vary spatially and further empirical and modelling work is required to estimate these effects.
- Values for some benefits vary significantly over time (carbon values, for example, due to new technologies and the impacts of climate change). This can lead to perverse outcomes from economic appraisals.
- Improved valuation is needed of the contribution of woodlands in a wider land-use context; for example, in understanding agricultural opportunity costs and forestry values in integrated land-use settings.
- Consistency and rigour are important in enabling analysis of values across different land-uses and sectors. In addition, further integration of forestry into cross-sectoral research initiatives is desirable.
- A further dimension concerns shared (rather than individual) values and the use of a wider set of evaluation methods, incorporating social as well as economic expertise.

All of these factors support a need for further valuation research as well as more flexible and sophisticated techniques to facilitate more accurate and comprehensive evaluations, including across different scenarios. They also point to a need for collaboration and partnership with other research bodies to enable mutually beneficial exchange of expertise and resources. The ability to integrate forestry research on the topic into standard approaches across sectors will increase the usefulness of values in comparing different land uses.

The opportunity cost of retaining existing land uses for whole parcels or sections of land rather than switching to other uses should be considered. This point may create a useful synergy with work on expansion of woodlands (RA 4 and RC 2.5), by accurately comparing the costs of converting marginal areas of agricultural land.

Research deliverables

- Improved methods for quantification and valuation of the impacts of forestry.
- A more complete evidence base of forest values, using common monetary metrics where appropriate.
    - Woods for health seedcorn 2015/16 - £5000
- Better decision support tools to support analysis over different spatial and temporal scales and to integrate forestry into cross-sectoral analyses.
- Social research to understand the barriers to developing new markets, such as carbon, and how to overcome them.

6.5 RC 3.2 What are the costs and benefits of forest management options to improve resilience and expand our woodland resource?

Policy context

Silvicultural practice will need to change in the coming decades to respond to wide-ranging pressures and opportunities facing our trees and woodlands. For example, changes in forest design and management will be needed to create adaptive and resilience woodlands (see RC 2.1 and 2.2). It will be important to understand the costs and benefits of these changes, and how they will affect the industry as a whole. Appraisals and evaluations of pilot and demonstration projects will help to inform future strategies and policy decisions.

Research context

- Economic analysis helps to identify actions which can minimise costs and maximise revenues. Research in this area is particularly important at a time when significant changes to the structure and management of our woodland resource may be needed.
- Further research is needed to refine economic models so that a more comprehensive range of costs and benefits of different forestry practices can be analysed. Such analysis will help our understanding of potential trade-offs and synergies between different forest ecosystem services.

Research deliverables

- Understanding of the costs and benefits of adapting our woodland resource over the coming decades, including impacts on the forest industry and wider ecosystem services.
    - The Economics of Forestry Based Inventions for Health. PhD Studentship 2015/16 - £12,000
- Creating an evidence base to inform future strategies to build a resilient woodland resource (linking to work in RA 2 on creating those resilient woodlands and forests).

7. RESEARCH AREA 4: UNDERSTANDING THE DRIVERS AND BARRIERS TO WOODLAND EXPANSION, AND IDENTIFYING WAYS TO DELIVER IT IN A SUSTAINABLE LAND USE CONTEXT.

7.1 Purpose

The expansion of the wooded area within GB is a policy aspiration for all three countries, which recognised the benefits that increased woodland cover can bring. These include carbon storage, biodiversity benefits, a thriving forest industry, mental and physical benefits to visitors and many other ecosystem benefits services. However, in each country the area planted is falling behind the policy aspiration. This is not a technical challenge, but often a social one since, beyond the obvious constraints imposed by CAP support for agriculture, landowners need to be persuaded of the benefits of woodland to them and their land holding before they will change land use. This research area seeks to examine the constraints and barriers that are preventing the planting of woodlands and forests and provide solutions.

7.2 Linkages

This research area directly links to the second research outcome in the Science and Innovation Strategy (deliver woodland management and expansion as a component of sustainable land-use change). However, information coming from Research areas 1 and 2 that also link to resilience (Outcome 1 in the SIS) will be required to ensure that the models for planting and for management that are being proposed to landowners match with current thinking and research. For some owners, a financial case is often the strongest and hence links will also be required to Research Area 3.

7.3 Research Focus

- Identifying methods[8] to successfully increase Britain's woodland cover and the percentage of woodlands under recognised management plans[9];
- Integrated and interdisciplinary social research across the rural and environmental sectors to learn what motivates farmers, landowners and managers to take up incentives and adopt other delivery mechanisms for land use change through sustainable long term management;
- Quantifying the location, scale of delivery, and physical benefits of woodland creation and management on ecosystem services (such as improving water quality, soil conservation, and flood prevention/alleviation and carbon sequestration and storage) and comparing different woodland types with different types of existing land use;
- Further understanding is needed of the carbon storage and greenhouse gas implications of the creation of different types of woodlands, including small-scale forestry in farms and in urban areas. This will enable a better comparison with other land-uses and support the evidence base on integrated approaches to land management.

[8] This includes understanding land owner behaviour, sensitive silvicultural techniques, and improved regeneration techniques.
[9] i.e. consistent with the UK Forestry Standard.

7.4 RC 4.1 Assessing the behavioural barriers to woodland expansion – is there potential to apply social research to the barriers that exist to land use change?

Policy context

Public attachment and support for expansion of woodlands varies across Britain, both across countries and between rural and urban communities. In many cases, good evidence in support of woodland creation and management is available but fails to result in practical change.

In the urban setting forestry has a significant potential to contribute to the health and well-being of residents (see 2.3 and 3.1), who may however have little ownership or connection to trees. Urban forestry presents an opportunity to create a woodland culture and generate connections between individuals and the communities.

Research context

- How does the public perception of forestry and woodland, and the desire for its expansion differ across regions and user groups?
- Do urban forests have a significant effect on public support for forestry in the wider landscape?
- Do alternative ownership/management models, such as community woods, increase woodland culture within GB, and how do we encourage them?
- What are the main emotional and psychological barriers, (as opposed to fiscal barriers) to the uptake of forestry for rural users and landowners, in particular farming communities who have no traditional involvement with woodland?
- What are the most effective ways of getting access to the audiences to facilitate behavioural change? This may include non-traditional methods such as citizen science, interactive and crowd-sourced dispersion of information and community management. Does research done in other sectors, including behavioural economics, have applications for increasing support for forestry?

Research Deliverables

- What existing external knowledge is there in other fields that can be applied to increase the support for forestry? What are the peculiarities that relate to the specific issue of forestry expansion?
- What are the barriers to change in favour of forestry amongst those who own, manage, or aspire to own land? Could alternative methods of support; (i.e. other that increasing forestry grants and reducing agricultural grants) be deployed to help encourage woodland creation?
- Measurement of support for existing and expanded woodlands across regions and user groups.
- Innovative methods for growing the woodland culture within GB.

7.5 RC 4.2 What are the financial and policy interventions required to overcome barriers and exploit expansion opportunities?

Policy context

Currently there is insufficient new planting, in terms of commercial conifers and broadleaves, to meet future demand for wood products and to meet aspirations for woodland expansion set out in country policies. In order to encourage sufficient planting, there must be viable commercial opportunities (see RA 5) and access to incentives for landowners, including under UK and EU grants, structural and rural development funds. Increasingly farmers and landowners are also looking for biomass for both heat and RHI payments. New broadleaf planting for this purpose needs to be considered against the grant structure available for agricultural land.

The principal barrier to forestry expansion is the current CAP regime of support for farming. However other potential disincentives include, the time it takes to realise any return, modest returns compared to subsidised agriculture, high transaction costs, the prolonged timescales involved in the consultations to get forestry approval, complicated certification of environmental obligations, and the lack of knowledge and forestry expertise amongst farmers. Reduction of unnecessary 'red tape' is in line with government priorities across all departments. Similarly, competition for land use, political lobbying in favour of agricultural subsidies and opposition from some in the agricultural community reduce the likelihood of woodland expansion on farmland. There are strong links between this area and outputs on valuation from RA 3.

Research context

- The assessment of various land use models and options to achieve significant woodland expansion, particularly of productive conifer forests in the uplands, with reference to constraints mapping exercises such as Indicative Forestry Strategies in Scotland.
- A comparative economic analysis between upland farming compared with forestry and the level of sensitivity to farming subsidy.
- The effect that subsidies for wind-farms are having on the area of upland forest and the total amount lost to wind-farms as a land use.
- An assessment of models for upland land use involving both forestry and agriculture, taking account of farm viability and how the two land-uses could most effectively be integrated without negative societal and environmental impacts.
- The potential impacts of new markets for wood-fuel and how this could influence land use decisions and silvicultural options at both a small scale (for domestic use) and at a larger scale for the generation of electricity.

Research Deliverables

- A sensitivity analysis of the economic viability of forestry land use to level of direct grants and to the levels of competing farm subsidies.
- A summary of the principle deterrents and hurdles to land use change.
- The impacts of issues such as transport costs and remoteness on forestry.

7.6 RC 4.3 Facilitating the expansion of the woodland area through targeting and provision of evidence

Policy context

Expansion targets and increasing returns for forestry can encourage landowners to consider planting new areas. However, other options which may incrementally increase the area of forestry include planting marginal land, setting up demonstrations of best practice, considering planting on a “whole farm” basis, (rather than in blocks), and promote integrated land management. New tools and models in RA 6 will increase understanding of where to locate and manage new woodlands.

In some areas, restrictions imposed by local government planning policies or other objections restrict the scope to expand the forest area. However, sometimes such restrictions are based on the misguided interpretation of factors regarded as constraints. To combat this, effective communication, knowledge exchange and early engagement with communities is an objective of forestry policies. Community knowledge in relation to benefits such as rural employment and development, or urban health and regeneration, can increase community interest, foster support, and develop a sense of “ownership” of woodlands. This in turn allows for potential community involvement and management, but also a better understanding of where restrictions are necessary, e.g. for timber operations or because of plant disease.

Research context

- Identify options for land use, including for marginal land. Consideration should be given to developing land-use models for integrated land management and what combinations of land use can easily co-habit on various land types. Utilise targeting to identify what type of woodland to plant, based on land type and outcome desired. The consideration of scale should also be included, e.g. where urban trees or micro-scale plantations are viable options.
- In some areas of Europe, forestry cooperatives work effectively. These can be supported under the EU Rural Development Programmes and may offer a way of increasing wooded areas, including land of marginal agricultural use.
- An assessment of how communal ownership or management of woodlands (community woods) may alter the perception of woodland help to deliver both increased management activity and woodland expansion.
- There is an opportunity to use existing and future FR research to inform planning evaluations. Evidence which is easily accessed and adapted through knowledge exchange could impact positively on the creation of new woodland.
- Opportunities to demonstrate best practice such as through breeding programmes or the public forest estate should be considered. Due consideration should be given however to the economic valuation of practices.

Research Deliverables

- Understanding integrated land use options and impact on economic viability.
    - Modelling and assessment of upland afforestation in Cumbria, UK. 2015/16 - £ 9850: 2016/17 - £11250 (Also strong link with Innovative science, models, data and tools to help develop and deliver forestry

policy and thereby improve management and resilience across the forest sector)

- A clear picture of what gaps in evidence or communication are creating barriers to planning evaluations and how FR evidence and knowledge exchange can respond to these. Developing a clear picture of local planners' information needs and how best to service them.
- A statement on the principal constraints to woodland expansion.
- An exploration of what mechanisms, (e.g. grants, demonstration projects, tax incentives, projects at local level) may serve to increase the area of woodland.
- Identify barriers to sustainable forest management – eg where UKFS is not being adequately implemented.

7.7 RC 4.4 Impacts of pests and diseases on the retention and creation of woodlands and forests

Policy context

Diseases, as well as the presence of mammalian pests are a deterrent to woodland expansion (interact also with RA 1 and 2). As well as damaging living trees, they create uncertainty in selecting resilient species for replanting and new woodland. In relation to mammalian pests in particular, there is an issue of public perception, as the damage done by deer and grey squirrels is not recognised and there is insufficient resolve to address the threat. Moreover, a lack of public awareness of diseases affecting trees can facilitate the spread of tree diseases. This theme aims to maintain our expertise in pesticide use and mammal control methods, essential if woodland expansion (and the restocking of affected woods), is to be successful.

Research outcomes

- Methods of control are made available and the various options are explained clearly so that they are used by landowners and other relevant practitioners.
- For key pesticides and control methods for serious pests which have been withdrawn, alternatives must be developed and tested.
- A range of alternative treatments are researched and their practical deployment developed in anticipation to the withdrawal of existing controls, such as cypermethrins, so that forests are not rendered vulnerable to pests.
- Species that have the potential to replace those susceptible to pests and diseases are investigated, their silviculture is understood and their use is adopted to increase resilience in the future (with reference to RA 2).
- For species that are susceptible, (such as ash) more resistant strains or cultivars are researched and developed sufficient to enable them to be planted with confidence.
- Species can be used and grown in a way that minimises their vulnerability, such as in mixtures, using shorter rotations or grown as coppice

Research Deliverables

- Options for the control of existing and potential threats and diseases, including replacements for withdrawn pesticides.
    - Moth Monitoring in Pangbourne – 2015/16 – 2016/17 - £5846/yr
- Recommendations for how best to communicate the threats and solutions in relation to pests and diseases to the forestry sector and other interested parties.
- Recommendations for how to make woods more resilient, in terms of species, strains, and silviculture to draw upon to replant affected woods and continue the expansion for both conifer and broadleaf woodland.

8. RESEARCH AREA 5: EFFICIENT AND SUSTAINABLE SUPPLY CHAINS FOR FOREST PRODUCTS AND ECOSYSTEM SERVICES

8.1 Purpose

The purpose of this programme is to support Outcome 3 of the SIS, allowing the forestry sector to support sustainable economic growth in Britain, by adding value to a forest product supply chain that is effective, efficient and economically sustainable.

8.2 Linkages

In order to create full impact from the activities and outputs from this programme, close linkages will be required to work packages from other programmes, particularly activities associated with Research area 2, tree breeding for improved quality and timber properties of resilient species, Research area 4, woodland expansion., and Research area 6, yield modelling.

Linkages are relevant also to Research area 3, on valuing forestry benefits, which will continue the development of forest ecosystem service markets to support economic growth and contribute to averting risks from ecosystem degradation.

There are existing research partnerships that could help deliver some of this programme, including Strategic Integrated Research in Timber programme, Wood Knowledge Wales and additional European partnerships.

8.3 Research Focus

- Supporting the forest industry with research to optimise timber growth, recovery and utilisation. Utilising a network of permanent sample plots which can demonstrate the potential for alternative silvicultural systems, regeneration, and novel tree species, and environmentally and financially sustainable multi-benefit forest management approaches. This work will contribute to better understanding of the life cycle impacts of different scenarios for forest management and timber utilisation;
- Improving knowledge of the wood and timber marketable properties of tree species identified for resilience;
- Continuing to investigate ways to improve the efficiency of the timber value chain. This includes a focus on genetic improvement in relation to wood and timber properties, to develop methods and technologies that deliver market requirements and added value forest products;
- Recognising the new markets provided by wood-fuel, and examining how woods can be managed and created to serve these markets, and the skills needed to do so whilst achieving longer term gains in carbon storage and other benefits;
- Investigate the potential to create markets for ecosystem services, and non-timber products.

8.4 RC 5.1 Supporting the development of new and innovative sustainable markets for forestry products and services

Policy context

In order to ensure investment and management in woodlands and forests, sufficient market returns are required to incentivise it. As species, quantity and quality of wood produced by forests shifts in response to climactic and disease pressures (see RA 2), the market at which they are directed may also need to be altered. This could be due to disruption of supply to current markets or due to the opening up of new, higher-value markets. Horizon scanning to identify potential market opportunities for various wood species could allow required investment and support to be anticipated.

Research context

- Low-end markets such as for commodities, raw materials or biomass can provide steady markets for forest outputs. Furthermore, through engineered timber, low value markets can utilise much of the produce unsuitable for niche markets, particularly if weakened by climate change or pests and diseases.
- This research area will need to work closely with RC 2.1 on the wood and timber properties of new tree species with potential in British forestry.
- Opportunities should be sought to target products at a variety of scales, by producing goods which range from nanofibre to large feedstocks.
- This research area should also consider innovation in forestry practice, which may have the potential to lead to efficiencies and cost savings for the sector.

Research Deliverables

- Using horizon scanning, identify future market and technology opportunities.
    - ERA-NET+ project WoodWisdom-Net+ . Membership of the partnership allows us to leverage our resource many time. The partnership supports four current transnational projects with UK partners, which will run until 2017/18 - £50,000 per year
        - VARMA - Methods for improved wood raw material efficiency and value added products (€926k)
        - ReWoBioRef – Developing wood refinery technology for waste wood streams (€1,308k)
        - Wood2New - (1) Identification of opportunities and limitations for the use of wood in interiors; (2) to assess and enhance the beneficial effects of wood on human well-being. (€1,260k)
        - COSEPA – To develop a selective, resource scarce, techno-economically feasible separation and conversion concept for separating hemicelluloses and producing new, value added products from bio-based raw material. (€931k)
    -
- Identify potential levels of returns in current and emerging markets.
- Take into account both industry supply volumes and the quality of various species likely to be grown for resilience purposes.
- Identify market support required in the development of new product markets.

8.5 RC 5.2 How can we improve our understanding of non-timber products and other services delivered by forests and woodlands?

Policy context

Forests and woodlands provide valuable products and services in addition to wood-based products, including carbon sequestration, flood amelioration and amenity resources. Research area 3's concerns itself with valuing these services, but under Research area 5 we should seek out ways of capturing these services in market form. This may include adoption and improvement of ecosystem services markets in operation elsewhere, or the development of new models.

Research context

- Investigate the non-timber services and products which have marketable potential, with reference particularly to best practice examples elsewhere.
- How can non-timber goods and services co-exist with timber production and with each other?

Research deliverables

- Proposals for market models which may create or improve realised value from non-timber products.

8.6 RC 5.3 How do we ensure supply-chain investment, diversification and effective management?

Policy context

Sufficient supply of raw materials will be required to satisfy demand in the above discussed market. At present, supply is forecast to peak by 2030 and decline thereafter. This is likely to lead to increasing proportions of market demand being filled by imported wood, representing a lost opportunity for the domestic sector.

In order to prevent this, both current investment and increased management is required. Greater certainty about the nature of future market demand and emerging markets would increase investment incentives. Innovative approaches to diversify and develop the supply chain should also be encouraged. Supply chain diversification is essential to ensure a robust industrial capacity, sufficient to withstand impending market and ecological challenges.

Returns must be adequately captured to ensure management. Small broadleaved woodlands in particular lack adequate incentives for proper management.

Research context

- Investigate tree breeding technologies and silviculture to improve quality from yields per hectare.
- Use demonstration plots and modelling to test hypotheses.
- Investigation and development of innovative products and systems for value chain improvement.

Research deliverables

- Innovative approaches to incentivising improved supply chain management are required.
- Analysis of appropriateness of grants v. market based approaches.

9. 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.

9.1 Purpose

This Research area will principally support the delivery of Outcome 3 in the SIS, namely 'An evidence base to allow the forestry sector to deliver a wide range of benefits from forests and woodlands to support sustainable economic growth in Britain.' It is a cross-cutting Research area and is essential to providing the underpinning models and tools the forestry sector requires to deliver the strategy. Research areas 1-5 of this strategy aim to directly address key issues and challenges affecting the forestry sector in Great Britain; successful achievement of the required outcomes and delivery of evidence across these areas will depend critically on access to cross-cutting models and tools that are fit for purpose. Initial funding for Research area 6 includes some allocation for modelling support to Research areas 1-5 (See Annex B). This will need to be refined according to requirements.

Models developed need to be loosely integrated, so that they can be applied flexibly and consistently when exploring research questions for complex forest systems at various scales (e.g. stand, forest, landscape; up to the forest gate, up to the point of delivery, use or disposal of harvested wood products). Models need to be made available to researchers and other analysts as readily accessible systems and tools.

Model outputs will always have associated limitations and uncertainties, it is essential that these are characterised and clearly understood by model users. The models and systems and tools developed from them need to be robustly designed, calibrated and verified based on supporting theory, data and observations. Failure to observe these fundamental Quality Assurance requirements will undermine delivery of the SIS and leave the sector vulnerable to lobbying.

Research area 6 is an expression of the need for suitable models, tools and underpinning data, to facilitate Research areas 1-5. However, taking an overarching policy objective of sustainable forest management as *axiomatic*, innovation in models, data and tools is needed to directly address three cross-cutting challenges:

1: Getting policy and business decisions right: In order to ensure resilience of forestry systems and to practice sustainable forest management, we need to maintain and make best use of forest capital[10]. Making the best use of forest capital is central to achieving wider objectives. In order to understand how policy changes and/or business decisions might affect forest capital and its use, we need the capacity to quantify the impacts of different policies and business decisions.

2: Delivery of policy and business objectives: We need to ensure that practice is consistent with policy and/or business objectives on forest capital and makes best use of forest capital. Therefore, we need tools, in the form of guidance, procedures, systems or software, to help forest policy analysts and forest managers test options and manage forest capital to meet policy and business objectives. Operational

[10] Forest capital can be defined narrowly as the growing stock of forests (e.g. standing trees, timber volume, biomass or carbon stocks), or more widely as the natural capital and ecosystem services associated with forests. The wider definition is pertinent when considering cross-cutting support by this programme to the other programmes forming this strategy.

support, guidance and advice plays a supportive role in helping woodland owners and managers to deliver policy and business objectives; such work should also be linked to economic analysis. Furthermore, as and when models are revised or introduced it is essential that these 'policy-to-practice' components are similarly revised or put in place. It is essential that decision support tool development proposals account for likely costs of capturing the data necessary to operate such systems (see FC Policy on Commissioning of Decision Support Systems 2010).

3: Verifying policy and its delivery: We need to monitor forest growing stock and harvesting in order to check that core objectives, such as a commitment to sustainable forest management, are being met. We also need to check that any information, systems, processes and underlying models involved in the assessment of policy options and business decisions are 'fit for purpose'. We need to ensure that data are acquired from forest monitoring and experimental research networks that can be analysed and interpreted for such purposes.

Innovation in data, models and tools is central to addressing these sectoral challenges, improving forest policy, economic decisions and forest management and increasing resilience in an uncertain world. In response to these challenges, the FC utilises and depends upon the outputs from a small number of 'business critical' models. HMG will publish definitive guidance on Analytical Quality Assurance (AQuA) in the summer of 2014 and this will be a key reference going forward.

Some of the key models and tools in current use are decades old and the degree to which they remain 'fit for purpose' in an evolving environment is open to question. The FC needs to ensure that the assumptions, limitations and uncertainties associated with business critical models are both understood and communicated to end users (Macpherson, 2013). Furthermore, an innovative approach to mitigating high risk assumptions, limitations and uncertainties is needed. Changes to the scenarios that business critical models need to represent include:

- Silvicultural practice:
    - The relative values of provisioning and non-provisioning services
    - The risks to forest capital from biotic and abiotic events
- Advances in analytical and statistical modelling techniques;
- Availability of data from key experimental sources (e.g. Permanent Sample Plots or long running experiments) for model calibration and validation;
- New data sources including remote sensing and the NFI.

The majority of models and decision support tools in use by FC and the wider sector do not, of themselves, meet the Government's definition of 'business critical'. Although the principles of good Quality Assurance still apply to these models and tools (particularly transparency over assumptions and limitations) the level of resources applied to QA should be proportionate to the associated risks.

There is an ongoing need to address current and emergent issues and responsive modelling is a key component of this. The opportunity costs of not so doing are difficult to evaluate but it is recognised that the risks associated with this are in the order of £100s millions per annum (FMMF Review Group, June 2014). There is, in particular, a need to capitalise on the data and experimental networks we already have in conjunction with new modelling techniques and with new data (e.g. from

Copernicus satellite-derived and NFI programmes) to both improve the 'evidence base' and to secure efficiencies in ongoing programmes.

9.2 Linkages

Research areas 1-5 are predicated on having a robust knowledge of the current forest resource and of how that resource might change under a range of different scenarios. If the fundamental models and decision support tools that underpin such understanding are poor, outputs from Research areas 1-5 would be heavily qualified.

Individual research proposals will need to establish additional links to other stakeholders and expertise. Maximising public benefit through the application of open data principles and by ensuring that models are in the public domain, and can be both tested and built on by others, are key success criteria. FR programme and work package proposals should demonstrate leverage opportunities being created.

9.3 Research Focus

- The focus for research is on models, data and decision support tools that inform or underpin high impact decisions. These include strategic/policy decisions (e.g. increasing the proportion of low impact silvicultural systems, or setting a target for forest carbon stocks) and the cumulative impact of forest managers using model-driven guidance to secure specific or multiple aims.
- Supporting the forest industry with research to optimise timber growth, recovery and utilisation, in conifers and broadleaves. This will be delivered through the maintenance of a network of permanent sample plots, and by adopting an environmentally and financially sustainable multi-benefit forest management approach, which will investigate the potential for alternative silvicultural systems, regeneration, and novel tree species;
- Developing multi-disciplinary tools to help managers identify and evaluate new woodland sites offering the best potential to deliver the most ecologically efficient basket of ecosystem services;
- The development and use of sophisticated interdisciplinary tools and models to 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 by using National Forest Inventory data, linked to financial and yield appraisal through production forecasting. Carbon and timber production will be assessed, to allow scenario planning for different management options including the development of renewable energy policy. Model design and scope should evolve to reflect emerging and changing priorities in woodland creation, location and management; for example, the further development of the iTree model to evaluate urban trees and woodlands, and the development of carbon models to evaluate the GHG impacts of small-scale and farm forestry.

9.4 RC 6.1 QA Framework for Modelling

Policy Context

Errors, biases and uncertainties in business critical models are by definition high risk in reputational and financial terms. Research in this research challenge is intended to ensure that these substantive risks are addressed by embedding a QA culture into model commissioning, development and application.

Research Context

Business Critical Models in scope include (non-exclusive list):

- Equations for estimating stem volume, applied in the NFI and in day-to-day forestry practise.
- The Forest Yield software tool and the forest yield tables it contains.
- The M1 analytical model of forest growth and yield, widely applied in the Forecast System and other FC systems.
- Models for predicting tree size distributions in forest stands.
- The BSORT model for predicting forest biomass.
- The Ecological Site Classification expert system for understanding site-suitability for tree species, including the version implemented for exploring climate change scenarios.
- The Forest Gales model for understanding and managing wind risk to forests.
- The CSORT stand-level forest carbon accounting model.
- CARBINE large-scale scenario forest carbon accounting model framework.

Other important high impact but not business critical models that should be proportionately reviewed include (non-exclusive list):

- Hylobius Management Support System.
- Habitat Condition (?)
- Beetle (?)

Research Deliverables

- Identify and QA (as per AQuA, section 9.1) FC's existing suite of high impact models. Work has started on this process but will need to continue in 2015-16.
- Publish models and underpinning data in a form that can be understood, tested and built on by others (both scientists and end users). Work has started on this process but will need to continue in 2015-16.
- As part of the QA framework, develop and implement approaches for quantifying and reporting uncertainties in key models.
- Develop and implement a strategy for model improvement and innovative development, informed by the outcomes of QA analyses.

9.5 RC 6.2 More reliable and flexible models

Policy Context

RC 6.1 will undoubtedly highlight that better forest models are needed: models that are more demonstrably representative of modern silvicultural practise, that can be quickly calibrated and re-calibrated as new data become available, and which can be readily adapted to represent new situations e.g. novel forest management options or pest outbreaks. RC 6.2 ensures that fundamental models are delivered, which are fit for purpose, facilitate the work of Research areas 1-5, and support policy and practice aimed at securing the future of British forests and the wider forestry sector.

Research Context

The principal focus is to address high impact limitations associated with the validated scope of models in RC 6.1. In this context, it should be noted that these models are designed to address fundamental and enduring questions facing British forestry but are being increasingly applied beyond their true scope, often to help address, at short notice, evolving and emerging issues and challenges in the forest sector. The research must deliver modelling approaches capable of timeously tackling the contemporary and emerging problems and questions being raised in British forestry.

Research Deliverables

- Define, prioritise (impact basis – criteria to be agreed) and implement a programme of model improvement. This could range from re-calibration and verification of current models to innovative development of completely new models. The modelling approaches must be designed to deliver robust results based on currently available data, to the extent that this is feasible.
- Publish resultant models and underpinning data in a form that can be understood, tested and built on by others, subject to commercial sensitivities.
- Define and prioritise requirements for new data collection that would address any outstanding ‘high risk’ assumptions and limitations of the refreshed high impact modelling suite (see also RC 6.5).

9.6 RC 6.3 Integration and coherent delivery of model systems

Policy Context

Complex systems and tools are needed to deliver to build the evidence needed to deliver this brief. The provision of such systems and tools frequently involves joining individual models up to form bigger and more complex systems, to enable complex forestry systems and problems to be analysed. Examples include the FC Forecast System and the CARBINE large-scale scenario forest carbon accounting model. Model systems and tools must be designed and delivered so that they can give transparent and timely answers to the questions posed by policy makers, researchers and other stakeholders.

Research Context

- The integration of models into complex but easy-to-use systems and tools needs a plan for sharing, use, re-use and flexible adaptation of component models. Consistency will be required in the adoption and development of model paradigms and approaches, including the use and input of data and

output of results. Protocols will be required to ensure consistency in model architecture and reliable data exchange, and in the design and delivery of modelling platforms. The joining up of component models to form more complex systems has implications for the application of the resultant system, its limitations, and associated uncertainties in results.

- Complex model systems also require the continuation of capacity to enable their maintenance and updating, and also call-off resource to provide ad-hoc advice and support to users of the systems and other stakeholders.

Research Deliverables

- Define, prioritise (criteria to be agreed) and implement a programme for the development, delivery and maintenance of complex model systems and tools needed to achieve the cross-cutting RA outputs and outcomes of the strategy.
- Define and implement protocols for the design architecture of complex model systems and for sharing of information between components.
- Define and implement protocols for the design and delivery of complex modelling systems which present a consistent interface to users.
- Define, prioritise and implement a plan, with associated capacity, for support to the maintenance and updating of identified model systems (to include Forecast System Version extant as at 31.03.15).
- Allocate X hours per annum (subdivide by system?) for ad-hoc advisory support to the application of identified model systems.

9.7 RC 6.4 Improved tools for forest and stand assessment and management

Policy Context

Along with modernising the suite of forest models themselves, there is a concomitant requirement to modernise the procedures, methodologies, guidance and systems that support the day-to-day management of stands and forests. This includes improving accuracy and relevance to contemporary and emerging forestry practices. This should be done in conjunction with RC 2.4.

Research Context

Advances in analytical and statistical methods present an opportunity to provide forestry practitioners with modern methods and tools for the day-to-day management of stands and forests. These may take many forms, including computer software and applications; however the culture of the forest sector dictate a requirement for multiple delivery options, e.g. including paper documents and online forms to ensure that they are both useful and used. Part of the focus is to update and modernise existing tools affected by innovations in RC 6.1, RC 6.2 and RC 6.3. Specific examples include guidance on forest mensuration procedures, silvicultural practice, guidance on matching tree species to sites and on tree establishment, support to the management of risks (e.g. windthrow, diseases) and support to the management of harvesting and extraction of wood including the ‘chain of custody’ within forestry.

In conjunction, RC 6.1, RC 6.2, RC 6.3 and RC 6.4 will deliver a suite of robust, transparent, defendable and informative models, and an associated ‘toolbox’ of

guidance, procedures and systems that enable both policy advisors and practitioners to make informed decisions (to secure specific desired policy/business goals) on, for example:

Tree establishment and restocking (including species choice)
Tree establishment policy and practices
Silvicultural policy and practice (including nature and timing of thinning interventions and appropriate rotation lengths to meet defined goals)
Management of key risks to the security of forests
Management of effective wood production and use.

And to (in conjunction with the National Forest Inventory):

Monitor and report progress towards achievement of desired goals

Research Deliverables

- Define, prioritise (criteria to be agreed, with stakeholder involvement) and implement a programme for the development, delivery and maintenance of methodologies, guidance and tools needed to facilitate day-to-day forestry practice relevant to contemporary and emerging needs.
- Define and implement protocols for the design and delivery of tools which present a consistent interface to users, but allow for variations in the needs and culture of forestry practitioners.
- Define, prioritise and implement a plan, with associated capacity, for support to the maintenance of and ad-hoc advisory support to identified tools.
- Allocate sufficient time for ad hoc advisory support to the application of identified model systems.

9.8 RC 6.5 Physical and remote data acquisition for monitoring and modelling

Policy Context

Development of reliable and robust forest models with quantified uncertainties can only be undertaken if model development, calibration and verification are founded on suitable data. There is, therefore, a continuous policy requirement to demonstrate (preferably through publication) that the models used in determining policies and applied in day-to-day forestry practice have an ‘audit trail’ to relevant supporting data and observations about forests.

The FC has supported the collection of long-term research data sets to meet multiple objectives (e.g. direct comparison of experimental treatments, demonstration of practice). Key efforts have included long-term silvicultural and environmental experiments and a network of permanent mensuration sample plots. More recently, the focus of these experimental networks has been narrowed and reduced significantly to emphasise the support to development and QA of forest models. Nevertheless, the cost of ongoing experimental forest monitoring is significant and it is important that the data and evidence provided by them delivers substantive improvements in the models, systems and tools identified in this Research area, and adequately underpins their QA.

Remote sensing (RS) has, for many years, offered considerable potential to transform a range of land management and forestry business processes. Historically

many limitations have existed including data resolution, data storage and data analysis capacity; however the key barriers to 'operationalisation' of current potential are commonly understood to be data continuity, data currency, data access (particularly cost) and definitional and interpretational issues (e.g. 'land cover' is not the same as 'land use').

The Copernicus program goes a long way to removing some of these barriers and opens up opportunities for efficiency and effectiveness gains in, for example:

Continuous (not sample based) land use/habitat inventory and monitoring;
Monitoring of disturbances (man-made and natural) and 'forest health';
Calibration/Validation of, for example, windthrow models.

Research Context

- The research required to secure relevant and fit-for-purpose data for development and QA of forest models needs to demonstrate precisely how substantive improvements will be delivered; in terms of the applicability, flexibility and reliability of forest models and tools, and/or the reduction/quantification of uncertainties in predictions. Opportunities to link with modern and emerging survey methods including RS should be pursued to ensure data is collected robustly and cost effectively.
- The required research on RS should be undertaken in collaboration with strategic partners and have a clear focus on routine delivery of quality assured products that meet defined business needs. There are obvious links that should be made to Natural Capital Accounting, Tree Health and the National Forest Inventory.

Research Deliverables

- Define, prioritise and implement (impact basis – criteria to be agreed) requirements for short-term and long-term experimental monitoring of forests, explicitly to deliver defined improvements and underpin QA of key identified forest models.
- Ensure the resultant data is QA'd, fit for purpose and accessible (eg through publication)
- Produce an inventory of low/nil cost RS data currently available (or scheduled to become available before 2017)
- Define and prioritise (impact basis – criteria to be agreed) potential applications for RS. This needs to, where appropriate, include reference to current monitoring procedures (e.g. afforestation, deforestation, tree health, habitats and disturbances).
- Establish and formalise strategic partnerships to take forward and 'operationalise' lead options –including provision for data storage, analysis and dissemination.

10. KNOWLEDGE EXCHANGE

10.1 Purpose

Section 6 of the SIS sets out our aspirations for ensuring that the results of research are effectively communicated. The outcomes of research are not an end in themselves but rather should inform forestry policy and guide forestry practice. This requires a strengthened knowledge base, to allow future decisions to be based on robust, reliable and up-to-date evidence, which is also open and accessible, in order to create an environment that stimulates innovation. The continuing commitment to policy advice is a key aspect of knowledge exchange. Forest Research is responsible for KE delivery, and will provide regular progress updates through FC CSA reports to the RSMB.

Communication will be more than an activity carried out at the end of research programmes; the ongoing exchange of knowledge between those who carry out the research and its end users are key issues for this Strategy. The most effective way to strengthen communication is through the direct involvement of the user communities in both the conduct of research and the formulation of research programmes – and knowledge exchange mechanisms, as indicated in the SIS, will be established to achieve this. Direct participation will not only promote shared understanding and collaboration, it will increase the resources available for disseminating it to as wide an audience as possible and provide feedback for changes to the strategy.

Knowledge exchange supports researchers by ensuring they have access to relevant experience and opportunities to develop knowledge and expertise. Young researchers should receive continued access to experience and qualifications through mentoring and expert supervision. Holding annual seminars to bring together students, supervisors, policymakers and practitioners to provide an opportunity to learn more about post-graduate environmental research being funded by the Forestry Commission provides opportunities for knowledge exchange that will shape future research. It is import to continue to promote more forestry qualification opportunities/skill sets (for example silviculture practices and woodfuel systems) before and at degree level to assist the development of a skilled forestry workforce. Research may be required to better understand demographics of the forestry workforce to predict future requirements in the coming decades. It is vital to ensure an adequate workforce profile, both in numbers and skills sets, is available to meet future projected timber forecasts and ambitions to expand the forestry sector.

Academic credibility and career progression are enhanced by specifying in the development of research projects and programmes the outputs in the scientific literature and at conferences and science workshops. KE provides support for researchers funded by the Forestry Commission to attend international conferences to communicate regularly with colleagues abroad and to keep forestry research in touch with foreign opinion relevant to sustainable forest management in the UK.

10.2 Linkages

The Forestry Commission has made a commitment in the SIS to ensuring that 25% of research funding is used for KE. This should be achieved across the whole of the research plan, and may be greater in some programmes than others. Research programmes should identify where KE activities are best delivered, and bid into this allocation. Furthermore, given government commitments to open access of research,

provision should be made within research area KE budgets for the costs of publishing research as open access.

Innovation in forestry research can be encouraged by facilitating researchers to work with experts in other sectors, such as finance and animal genomics, or collaboration with visiting scientists. Participation in a variety of research opportunities can bring new perspectives, share knowledge and skills and highlight the contributions forestry can make to broader land use research. There should also be consideration given to developing business partnerships with stakeholders and experts from beyond the forestry sector, in order to develop a network of knowledge and expertise that will foster inter-dependence between business and research.

10.3 Research Focus

Vehicles and media for supporting knowledge exchange are set out in section 6 of the SIS, and programmes should indicate how they will use these in the communications plan for each programme.

As part of the expected deliverables (see 2.3.2) Forest Research will develop a Knowledge Exchange strategy which should identify:

- key target audiences;
- the approaches, communication and engagement methods to be adopted;
- measuring the success of priority outcomes sought for each audience;
- the methods and metrics by which the impact of these activities and progress towards achievement of priority outcomes will be assessed and measured;
- deliverables to be produced for each research area, which should include both a scientific and a layman's version of research produced under each area.

10.4 RC 7.1 How do we ensure stakeholders and end users of research are engaged at the appropriate stage of the research process, rather than at the end?

Policy context

Increasingly and throughout the process of developing the Science and Innovation Strategy, transparency and engagement with a range of stakeholders has been emphasised. However, some stakeholders, particularly those without a tradition of involvement may continue to feel excluded from the research and information process, if they are exposed only to the results of the developed research. Efforts therefore should be made to continue to identify the variety of audiences and end users and consider how groups differ in their willingness to engage at various points in the process. This RC links also to RC 2.1 and RC 4.1, which consider behavioural aspects.

There can be drawbacks to extensive stakeholder involvement which should be identified. Because of the increased emphasis on open government, some stakeholders are repeatedly called upon to contribute, resulting in 'stakeholder fatigue'. Similarly, involvement is problematic if it leads to short-termism, at odds with the long-term research requirements of forests. Stakeholders can differ in regards to how involved they are, with a temptation to listen to parties which are more vocal.

Research context

- Active engagement with stakeholders in specifying the research programmes and their outputs to deliver the strategic outcomes, and understanding the barriers to behaviour change are key to ensure research results are adopted and become part of mainstream activity.
- We must understand how we assess and categorise the various stakeholders and users who use or benefits from forests.
- What are the most effective methods to inform, enable and engage the public on issues such as biosecurity, resilience and climate change? This may include non-traditional methods such as citizen science, interactive and crowd-sourced dispersion of information and community management.
- What are the most effective methods to inform enable and engage a wide range of industry end users (e.g. landowners, practitioners, decision makers and operational staff)?

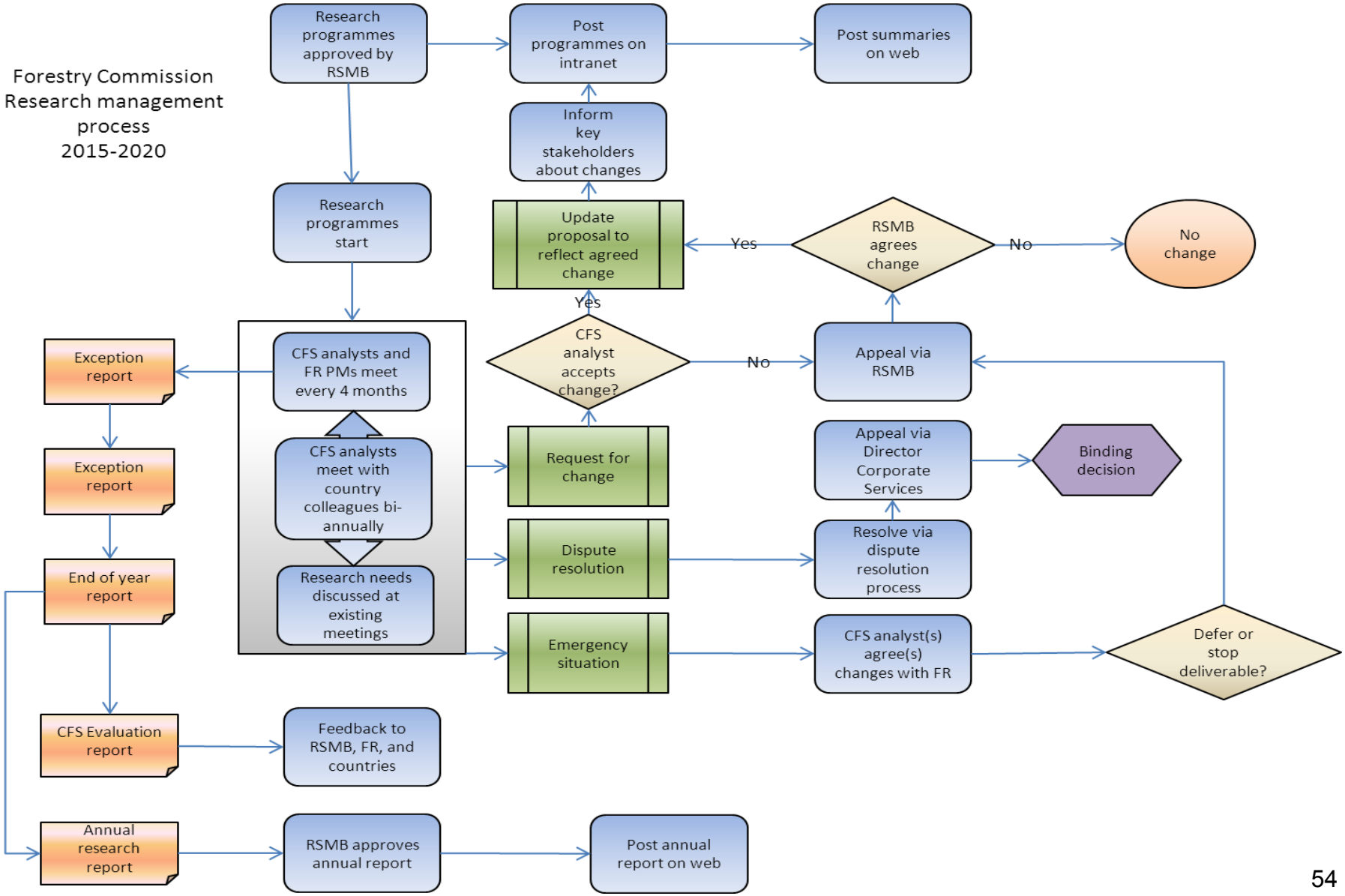
Deliverables

- A complete picture of categories of stakeholders and users.
- An understanding of effective communication methods, dependent on the target group.

11. ANNEX A - Outline showing derivation of initial allocation of funding to new high level programmes

		New high level programmes						
Current FR Programmes	Budget 2014/15	Understanding resilience	Resilient forests	Valuing forestry benefits	Woodland expansion	Sustainable markets for forest products	Innovation in models, data, and tools	Total
Knowledge management for Ecosystem services and Biodiversity	500	250	150	50			50	500
Forest hydrology and soils	451	200	200		51			451
Economic research for sustainable forest management	170			170				170
Managing Forest Carbon and GHG Balances	775	300	300	50	50		75	775
Forest Climate Change adaptation strategies	525	75	400				50	525
Urban Trees and Greenspace in a changing climate	344	200	100	44				344
Integrated Forest monitoring	356	125	125	56			50	356
Advice and scientific support for tree health	1757	800	700	50	157		50	1757
Species and gene conservation	410	300	50				60	410
Alternative Management Approaches	525	125	300		100			525
Wood and timber properties	250					250		250
Tree Selection and Breeding	400					400		400
Social Research for Forestry in Sustainable Society	300	100	50	25	125			300
Forest mensuration and modelling forests	350						350	350
Overheads	123	42	40	8	10	11	12	123
Total	7236	2517	2415	453	493	661	697	7236

12. ANNEX B – Research management process



13. Annex C – Initial draft of dispute resolution protocol

Research Dispute Resolution[11]

Introduction

Contractual disputes are time-consuming, expensive and unpleasant. They can damage relationships and can impact on the supply of research outputs. They can add substantially to the cost of a research programme, as well as nullifying some or all of its benefits or advantages. They can also impact on the achievement of value for money. It is in everyone's interest to work at avoiding disputes in the first place and the emphasis should be on effective relationships between FR and CFS through teamwork and partnering. Inevitably, however, disputes do occur and when they do a fast, efficient and cost-effective dispute resolution procedure is needed.

In general terms, the Forestry Commission's objective is to ensure that relationships between Corporate and Forestry Support and Forest Research are non-adversarial, that the research brief contains provision for the resolution of disputes which are appropriate having regard to their nature and substance and that such provision should, so far as possible, ensure that relationships are maintained.

Dispute Avoidance

Once the SLA is in place good research commissioning management is key. This should include monitoring, by both parties to the agreement, for the early detection of any problems. Both CFS and FR agree to give the earliest possible warning of any potential dispute and regular discussions between the CFS Analysts and the FR Programme Manager should include reviews of possible areas of conflict.

Dispute Management

If a dispute arises, both parties agree to manage it actively and positively and at the right level in order to encourage early and effective settlement. This will avoid any escalation of costs, damage to organisational reputation through delayed delivery, and further damage to the CFS/FR relationship.

Dispute Resolution

If any dispute arises out of or in connection with this Agreement, either Party may give notice to the other Party in writing that a dispute has arisen. The Parties shall first attempt to settle the dispute, in good faith, through negotiation between the CFS Analyst and the relevant FR manager.

If the dispute cannot be resolved by the CFS analyst and the relevant FR manager within five business days of the issue of the dispute notice, each party shall refer the dispute to their Head of Centre/Head of Analysts for resolution.

If the Head of Centre/Head of Analysts are unable, or fail, to resolve the dispute within 15 business days of the date of issue of the dispute notice, the parties shall refer the dispute to FR CEO/Director CFS.

If the FR CEO/Director CFS are unable, or fail, to resolve the dispute within 25 business days of the date of issue of the dispute notice, the parties shall refer the

[11] This is subject to discussion and agreement with FR

dispute to the Research Strategy Management Board, who will decide the course of action to be taken.

The final route of appeal against any ruling by the RSMB will be to the Director of Central Services, who decision shall be final and binding.

14. ANNEX D – Pro-forma for research programme proposals

The exact format is under development to ensure it is compatible with the CFS research document management system. However it will provide provision for the deliverables indicated in section 2.3.2 above