FORESTRY COMMISSION
Description of the Research Project or Services

1.	Research Purchasing Manager (C&FS)	Roger Coppock
	Relevant PAG	Forest Products

2.	Name of FR Programme Manager (PgM) or Project Manager (PM) and staff	Elspeth Macdonald (PgM) John Fonweban (PM) Stefania Pizzirania (PM) Andy Price (PM)
	Name of Institution/company	FR
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	Programme Life (years)	4 Years
	Start Date	1st April 2011
	Completion Date	31st March 2015
	Revision Dates	31st March 2012/2013/2014

3.   Title of Research Project or Service

Wood and Timber Properties Programme

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

The focus of this research programme is to assess and quantify the effects of silvicultural practice, genetic choice, site factors and climate upon the wood properties of the key timber species growing in Britain and the performance of wood products from these species. The programme works on issues at three time scales:

1. Short-term (1-10 years). Assessment of the spatial distribution of the current forest resource and the suitability of this resource for different end-products.
2. Medium-term (10-50 years). The impact of site, genetic choice and silviculture on the quality of the forest resource for stands being or recently established.
3. Long-term (>30 years). The long term impact on the future British timber resource of the changing climate and opportunities for improvement and long-term resilience through genetic selection.

The programme involves field measurements, evaluation of the latest forest and timber measurement techniques, statistical modelling and software simulation. This requires wide ranging collaboration with a range of partners in universities and other research

organisations together with close collaboration with the Tree Selection and Breeding, the Integrated Forest Monitoring, Forest Climate Change Adaptation Strategies, Economic Research for Sustainable Forest Management and Alternative Management Approaches programmes within Forest Research.

5.   Aims and objectives (word limit 500)

5.1 Aim of the research
The research programme can be broken into 4 linked themes:

1. Resource Assessment: Development of methodologies for assessing the forest and wood product resource
2. Characterisation: Detailed measurement of the key wood and wood product properties that are identified in 1 in order to understand the factors controlling these properties.
3. Modelling: Development of statistical models to allow prediction of the properties characterised in 2.
4. Prediction: Using simulation software to link the models developed in 3 with growth models, climate models, ecological site classification and field measurements (ground-based or airborne) to forecast the quality of future forest resource and its suitability for a range of products.

The purpose is to provide the forestry and processing sector in Great Britain with as comprehensive an assessment as possible of the current and future resource in order that informed decisions on forest management, species selection, wood processing, investment and policy can be made. The focus is on the major timber species (Sitka spruce, Scots pine, Douglas fir, larch and oak) and close liaison with the forestry and processing sector is fundamental to ensuring the relevancy of the work. The scope of the work is ambitious and covers many disciplines and therefore very close collaboration with a range of universities and other research groups in the UK and abroad has been and will continue to be a feature of the programme.

5.2 Work Areas

The programme is broken into 8 work areas and these are listed below:

Work Area 1: Timber Resource Assessment (Project Leader: Barry Gardiner. Other participants: Elspeth Macdonald, Shaun Mochan, John Fonweban, Stefania Pizzirani, Carina Convery, Stephen Bathgate, Juan Suarez, Andy Kennedy, Andrew Price, James Ramsey, Greg Searles, Tom Drewett, Steven Adams)

This work area is focussed on developing methods for measuring and predicting the timber properties of the existing forest resource in Great Britain and specifically Sitka spruce, Scots pine, Douglas fir and larch. Work encompasses evaluating a range of field based assessment methods including visual assessments, acoustic tools and terrestrial and airborne LiDAR and developing protocols and recommendations for their use. Such methods are used in surveys of timber quality and the development of empirical statistical models to allow mapping of the key properties across Britain. In addition models of the internal wood properties of all 4 species are being developed that allow prediction based on

stand growth and site conditions. The majority of work to date has been on Sitka spruce and Scots pine and increasing focus is now being given to Douglas fir and larch. Work is in collaboration with Edinburgh Napier and Glasgow Universities and is closely linked to the Integrated Forest Monitoring programme in FR.

Work Area 2: Impact of Climate Change on Tree Growth and Wood Properties (Project Leader: Barry Gardiner Other participants: John Fonweban, Carina Convery, Steven Adams)

The models described above are based on data from trees growing over the last 10-100 years and will in general not be able to account for the impact of a changing climate. In order to develop models that can account for climate change it is first necessary to understand the impact on tree growth and wood properties of climatic variables known to be important, such as temperature and soil moisture. This work is predominately experimental with detailed measurements (on order of 10s of minutes) of tree growth and within ring wood properties together with meteorological factors (air and soil temperature, soil moisture, solar radiation, etc.) taking place at sites on Griffin Forest (near Aberfeldy) and Harwood Forest (near Otterburn). This work is being carried out in collaboration with Glasgow University and the Forest Climate Change Adaptation Strategies programme in FR.

Work Area 3: Impact of Alternative Silviculture (Project Leader: Elspeth Macdonald. Other participants Barry Gardiner, John Fonweban, Stefania Pizzirani, Carina Convery)

With the increasing use of alternative silvicultural systems to clearfell and replant it is important to understand the impact of these alternatives on log and wood properties of importance for timber processing. There has been very little work on the subject even in continental Europe and therefore it has been necessary to conduct our own measurements. These have taken any opportunities to measure the same wood properties as in Work Area 1 for stands managed with alternative systems, which unfortunately are rare in Britain. At the same time we are developing joint proposals with colleagues in continental Europe in order to benefit from their longer experience of such silvicultural systems and access to a wider variety of forests with a broad range of silviculture. This work is in collaboration with the Alternative Management Approaches programme in FR.

Work Area 4: Moisture in Wood and Impact on Drying and Distortion (Project Leader: Barry Gardiner. Other participants: Carina Convery, Marc Jones, Jaz Canavan, Mike Yerbury)

Industry has identified drying distortion as one of its primary concerns leading to substantial downgrade and rejection of sawn timber. The difficulty is that distortion can be a result of a complex interaction between wood characteristics such as grain angle and Microfibril Angle with water movement in the wood. Experiments are being conducted using NMR x-ray scanners and Raman microscopy to measure water movement in wood and the properties of the wood controlling distortion as water is removed. In addition to the role water has in distortion it is the major factor in the cost of processing wood for a variety of uses such as sawn timber, panel products and biomass. The energy required to dry wet wood is considerable and yet there has been little quantification of the variation in moisture content of wood within and between trees and stands and during different times of the year. This will form the basis of an industrial PhD with Egger Forestry Ltd. This work is in collaboration with

Surrey and Glasgow Universities.

Work Area 5: Economics of Management for Timber Quality (Project Leader: John Fonweban. Other participants: Barry Gardiner, Gregory Valatin, Vadims Sarajevs, Stephen Bathgate)

The emphasis in commercial forestry has generally been on maximising volume. Therefore, felling ages have been linked to the timing of maximum annual increment. Little effort has been placed on calculating when trees are accumulating their maximum value. At the same time forest owners and managers have been receiving an increasing body of information recommending the best silvicultural practice for growing quality timber but with no analysis of the cost versus the perceived benefit. This work area will develop economic yield models and build economics, including the costs of each management action, into the timber property models developed in Work Areas 1, 2 and 3. This will allow an assessment of the impact of actions on the value of end products. In collaboration with the Economic research for sustainable forest management programme in FR.

Work Area 6: Mechanical Properties as an Aid to Selection (Project Leader: Elspeth Macdonald. Other participants: Barry Gardiner, Carina Convery, Steve Lee, Rob Sykes)

The focus of tree breeding has been primarily on improving the growth rate and form but taking care to minimise wood density. However, recent work suggests that wood stiffness may have inadvertently decreased with the improved progeny of Sitka spruce. Therefore, it has become important to identify traits that are informative of wood stiffness and that can be used in breeding selection. Initial efforts will be directed at reassessing the wood stiffness of the Sitka spruce General Production Population in order to determine the scale of any potential change in selection if wood stiffness was added as a criterion. This will be followed by a more comprehensive assessment of the heritability of important traits controlling wood stiffness and strength in Sitka spruce. This work will form the major part of a PhD by Elspeth Macdonald and will be carried out in collaboration with the Tree Selection and Breeding programme.

Work Area 7: Assessing Quality of Broadleaves (Project Leader: Andrew Price. Other participants: Barry Gardiner, Carina Convery)
A recent survey conducted by Forest Research of broadleaf owners and managers and broadleaf timber processors identified shake as their major concern. Some preliminary studies have indicated that acoustic velocity and/or stem lean may be used to identify those standing trees with a propensity to develop shake when felled. The next stage is to validate the proposed methodology on new sites and if this proves successful to write up the work as a field book.

Work Area 8: NPP NorToSIA Project (Project Leader: Stefania Pizzirani. Other participants: Barry Gardiner, John Fonweban)

This project is a follow-up to the major EU project called EFORWOOD and will be completed by September 2011. The project has developed methods for the assessment of the sustainability (economic/environmental/social) of the forestry wood chain by calculating the total value of key indicators along the chain. It allows for changes to any of the processes along the change (e.g. change in management approach, harvesting operations, transport,

etc.). The data obtained to calculate economic sustainability will be of value in the development of the methodologies in Work Area 5.

Work Area 1	**Timber Resource Assessment**
Work package 1.1 Models of wood properties for Sitka spruce/Scots pine/Douglas fir/Larch	
Work package 1.2 Link with production forecast to add quality to future volume estimates	
Work package 1.3 Mapping of wood properties of key species across GB	
Work package 1.4 Develop methodologies for incorporating the use of TLS and LiDAR in timber resource measurement	
Work package 1.5 Knowledge transfer	
Work Area 2	**Impact of Climate Change on Tree Growth and Wood Properties**
Work package 2.1 Review of existing knowledge on impact of climate change on tree growth and wood properties of key species	
Work package 2.2 Impact of climatological factors on Sitka spruce growth and wood properties	
Work package 2.3 Knowledge transfer	
Work Area 3	**Impact of Alternative Silviculture**
Work package 3.1 Measurement of the impact of spacing on wood properties	
Work package 3.2 Measurement of the impact of varying competition on wood properties	
Work package 3.3 Knowledge transfer	
Work Area 4	**Moisture in Wood and Impact on Drying and Distortion**
Work package 4.1 Water movement in wood and effect of drying on distortion.	
Work package 4.2 Variation in moisture content within and between trees and sites and seasonable variability	
Work package 4.3 Knowledge transfer	
Work Area 5	**Economics of Management for Timber Quality**
Work package 5.1 Incorporation of economic calculations in stand yield models for Sitka spruce and Scots pine	
Work package 5.2 Incorporation of economic calculations in current timber property models for Sitka spruce and Scots pine	
Work package 5.3 Knowledge transfer	
Work Area 6	**Mechanical Properties as an Aid to Selection**
Work package 6.1 Assessment of use of mechanical property measurements in tree breeding	
Work package 6.2 Incorporation of key wood mechanical properties in tree breeding programme	
Work package 6.3 Knowledge transfer	
Work Area 7	**Assessing Quality of Broadleaves**
Work package 7.1 Development of methods for identifying standing oak prone to shake	
Work package 7.2 Knowledge transfer	
Work Area 8	**NPP NorToSIA Project**
Work package 8.1 Development of method for assessing the sustainability of the forestry wood chain	
Work package 8.2 Knowledge transfer	

* Add new work areas and packages as required

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

Protect what we already have ☐	Reduce deforestation	☐
Restore the world's forest cover ☐	Use wood for energy	☐
Replace other materials with wood ☒	Plan to adapt to our changing climate	☒

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

The long term sustainability of the forests in all countries in the United Kingdom is dependent on forests being economically sustainable. This requires a long-term commitment by government, forest owners and wood processors to the investment in the sector. Such investment can only happen if there is confidence in the resource availability over the next 25-30 years, which is why such importance is quite rightly placed on the production forecast. However, to maximise the economic benefit from our forests we need to understand exactly what resource is available, where the resource is, over what time-scale it is available and what end products the resource is suitable for.

Although the emphasis in the forest strategies of England, Scotland and Wales is different, all recognise the key role of forests in the rural economy by creating jobs and wealth. All the strategies point to the requirement of maximise the economic potential of the forests and to ensure continued investment in the sector. The role of this programme is to provide the sector with the most comprehensive information possible on the current resource, how this resource will change in the future and what are the impacts of tree breeding, silviculture and climate. Therefore, the programme helps underpin strategic decisions on how best to manage our forests, what use to make of the timber from our forests, where to focus timber production and what type of processing capacity is required.

At a time when forests are being required to deliver a wider range of services and the area of forest with a primary aim of timber production being reduced it is imperative to maximise the effectiveness of these areas to ensure a future for our wood based industries. How best to do this requires detailed research on the best plants to use, how to manage the forest with proper consideration for site and climate and the most appropriate uses for the wood from different sites and forest types. This programme along with the Tree Selection and Breeding, the Integrated Forest Monitoring, the Forest Climate Change Adaptation Strategies, the Economic Research for Sustainable Forest Management and Alternative Management Approaches programmes is focussed on helping to provide that information and to support the strategies of the Forestry Commission in each country.

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

The major risk in not conducting this research is a decline in the knowledge of our forest resource and a concomitant reduction in the economic sustainability of the forestry sector. Timber is an internationally traded commodity and in order to compete in that market place we need to thoroughly understand our own timber supply and how to utilise it. Only by such knowledge can we increase the added-value of our forests, ensure continued investment and make forestry in the UK more economically viable. Without continued research we are in danger of slowly losing our forest-based wood processing industry with severe consequences for the sustainability of the sector. For example, the the closure of the St Regis hardwood paper mill had a big impact on the subsequent management of English and Welsh broadleaf woodland with a decline in thinning.

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

The main impact of this research is economic with the focus on providing information to help the sector to maintain its profitability and to hopefully enhance the value of our forests. Currently prices are reduced in order to deal with the huge uncertainty when sands or timber are purchased. In other words buyers have to take a precautionary approach to their purchases. By improving knowledge of the exact volumes available and the properties of the wood available from a stand or a log load it becomes possible for processors to be more confident of the value they can realise and to offer higher prices to the grower. If it was possible to increase the stumpage value of our forests then less government spending is required to support the sector through planting and establishment grants. At the same time through work such as NorToSIA we are able to compare the economic, social and environmental impacts of different management decisions so that planners and managers can weigh up the impacts of their decisions not just on timber production and profitability but biodiversity, recreation, etc. Such knowledge is of huge value to managers who are trying to provide multiple benefits from their forests and when the highest value for some forest areas may not be in timber production but, for example, as part of the local tourism industry..

Who will benefit from this research?
Forest managers, forest owners, wood processors, policy makers

How will they benefit from this research?
Better information on the existing timber resource and suitability for different products. Improved knowledge of the impacts of site, silviculture and climate on future timber supplies together with the economic, social and environmental impacts.

What will be done to ensure that they have the opportunity to benefit from this research?
The programme has a long history of providing information and knowledge to the sector in a range of different forms. These include:
1. Workshops and seminars including workshops in the forest and at processing facilities
2. Publications in trade magazines (e.g. Forestry Journal)
3. Publications using Forestry Commission series (e.g. Research Information Notes and Field Books)
4. Publications in scientific journals and presentations at conferences

5. On-line simulation software. These include linked growth and timber property models and management decision support systems

Potential for innovation and new markets?
There has already been a successful Joint Venture (TimberSONICS) developed from within this programme. The most likely prospects for innovation are in the commercialisation of measurement technologies in partnership with businesses wrking on forest measurement (e.g. TreeMetrics in Ireland or Microtech in Italy)

10. Communication Strategy

These are outlined in detail in section 14

Publications: A "Bulletin" for Scots pine in a similar format to the publication by John Moore for Sitka spruce. Hopefully, further publications can be planned for Douglas fir and larch.

Reports: There are a series of reports planned. Many of these are for internal use within the FC to act as discussion papers to allow decisions on the next stage (e.g report on adding economics into growth and timber property models). In addition reports are produced as part of the PhD process (annual reports on progress)

Seminars/conferences: In collaboration with the SIRT programme (Edinburgh Napier and Glasgow Universities) we plan a series of focussed workshops each year with processors to directly show the key people in the organisation the value of the latest research findings to their business. In addition presentations at ICF Research Update seminars, at the APF show, etc. to demonstrate to a wider audience the value of a better understanding of our timber resource.

Decision support systems: Continued development of the models available though the FR web portal. This will include addition of models for Douglas fir and larch and development of a DSS for managing Sitka spruce similar to the existing one for Scots pine. Continued development of the Prehas software for evaluating the quality of stands prior to harvesting. Exploration of the use of the ATLAS software from SCION in New Zealand as a framework for integrating growth models, mensuration measurements and wood property models and measurements

Website: Existing website to be maintained and enhanced with links to partners and collaborative research programme web sites.

Peer review papers: Strong focus on producing peer-reviewed over the next 4 years. Plan to have at least 6 papers a year from the programme. In addition I would expect approximately 4-6 presentations at scientific conferences each year, often as part of COST actions.

11. Under government survey control procedures, Ministerial approval must be sought before statistical surveys of businesses or local authorities can proceed. Please indicate any intention to carry out a survey.

Yes ☒ No ☐

• If yes please give brief details
There may be a need for questionnaires to growers and processors about key quality issues they have with specific species. Such a questionnaire was previously carried out

for Scots pine in Northern Scotland.

12.   Details of support agreed or to be sought from funding bodies for project
(*including in-kind support)*

13. Resources (times and fees) requested from the Forestry Commission

14. Deliverables and associated costs to Forestry Commission

Work Area number	Output	Year 1				Year 2				Year 3				Year 4				Output	Total Cost
	Key deliverables only	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Unique Identifier	
WA1 Total																			
1.	Forestry Commission Research Report on "Wood properties and Uses of Scots pine in Britain"																		
1.	Timber quality part of 2011 Production forecast																		
1.	ArcGIS maps of wood properties of key species for Great Britain																		
1.	PhD on "Wood Quality of Douglas Fir"																		
1.	PhD on "Timber Quality of Plantation Larch Growing in Scotland"																		
1.	PhD on "Improving the quality of Sitka spruce structural timber through raw material segregation and alternative sawmill cutting patterns"																		
1.	MSc on "Assessing the quality of Scottish-grown Douglas-fir timber"																		
1.	Internal report on methods for linking TLS and airborne LiDAR for mapping the forest resource																		
1.	Onlline models for predicting the timber properties of Douglas fir and larch																		
1.	DSS for managing Sitka spruce																		
1.	Research Information Note comparing different methods (visual, photographic, TLS) for assessing the form of standing trees																		
WA2 Total																			
2.	Internal Report on "Impact of climate																		

	change on tree growth and wood properties of key species"																		
2.	PhD on "The Impact of Changing Climate on Tree Growth and Wood Quality"																		
WA3 Total																			
3.	Scientific paper on the impacts of alternative silviculture on wood properties																		
WA4 Total																			
4.	PhD on "Mobile Magnetic Resonance Imaging of water distribution in wood"																		
4.	PhD on "Effects of Drying on the Dimensional Stability of Spruce Wood"																		
WA5 Total																			
5.	Internal report on "methods for incorporating economic calculations into yield and timber property models"																		
5.	Online models of timber properties of Sitka spruce and Scots pine linked to growth models and incorporating economic calculations																		
WA6 Total																			
6.	Internal report on the consequences of including measurements of wood mechanical properties as criteria in tree breeding of Sitka spruce																		
WA7 Total																			
7.	Research Information Note setting out measurement protocol for determining standing oak prone to shake after felling																		
WA8 Total																			
8.	Final report on NPP NorToSIA project																		
All Work Areas	Provide a report on advisory work to CFS			X			X			X			X						

Signed…………………………………….Research Provider/HOD

   Date………………………….

Signed……………………………………C&FS Advisor

   Date………………………….

Proposal Approved   CFS   Date 31st August 2011

15.   Agreed Changes

Description of change:
Signed………………………………….Research Provider   Date……………………………   Signed…………………………………….C&FS   Date……………………………
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16. Detailed communications plan:
Year 1
Year 2
Year 3
Year 4