

Forestry Commission

Adaptation Reporting Power: Second Round Report

December 2016

Executive Summary

Introduction to the review

The Forestry Commission (FC) is the non-ministerial Government department responsible for advising on and implementing forestry policy. The Commission manages the public forest estates in England and Scotland, administers grants for expanding and managing forests and regulates tree felling. It also provides advice to Ministers, undertakes and commissions research, sets standards for good forestry practice and protects Britain's forests from pests and diseases. In England the Public Forest Estate amounts to approximately 253,000 ha of which 215,000 hectares is woodland, equivalent to 16% of the country's woodland cover.

Forestry Commission England (FCE) is not a statutory undertaker but was invited to prepare a voluntary assessment of the risks that climate change presented to its activities and functions under the terms of the Climate Change Act (2008) which was published in 2012. This report reviews progress on actions set out in the first round report (ARP1) and presents a revised risk assessment and list of new actions that have arisen as a result of this review.

Understanding Climate Risk

Our understanding of the science of climate change and how it will affect forestry in England has not significantly changed since ARP1. However, we have identified five areas in which our ability to address these effects has become clearer. This has had an impact on either the urgency of addressing priority risks or the practical approaches to managing climate risk:

- The Ecological Site Classification decision support tool for tree species selection has been upgraded to (a) support decision-making for 57 tree species; (b) incorporate UKCP09 climate projections; (c) incorporate management prescriptions and; (d) provide improved representation of 'very poor' soils.
- A new version of the *ForestGALES* decision support tool for wind hazard management has been revised to provide (a) predictions of damage that better reflect observed damage; (b) updated species specific crown representation; and; (c) improved handling of cultivation and drainage.
- Understanding of the link between climate and pest and disease outbreaks has advanced, particularly the pivotal role of climate-induced stress increasing the propensity for serious outbreaks.
- Evidence from other countries, particularly France and North America has improved our knowledge of the likely impacts of climate change on forestry in Britain and provided examples of intervention that is deemed necessary to address the risks associated with climate change.

- Following the series of wet winters (2013/14 and 2015/16), evidence on the role of woodland creation and management in reducing flood risk has improved.

Review of priority risks

The priority risks identified in ARP1 have been reviewed and all are considered still to be relevant to FCE's three main areas of activity: (a) Impact on woodland and forest management on the Public Forest Estate (and wider woodland resource); (b) Impact on Forest Services' ability to facilitate adaptation in private sector woodlands; (c) Impact on business and corporate activities. A commentary is provided on how the priority risks identified in ARP1 affect these three principal activities.

Identification of key risks

Three key risks have been identified as a result of this review:

- Species diversification – a small seed trading industry, adherence to past policies and practice on broadleaf tree planting compounded by seed being sourced from inappropriate regions of Europe, and current nursery insecurities and business models are limiting progress on species diversification, heightening the risk created by limited species diversity in England's woodlands. Limited availability of UK planting stock also plays into the second risk, with limited availability of UK-grown 'adapted planting stock' leading to continuing importation of live plants.
- Tree health – there is limited understanding within the sector of biosecurity measures that can be implemented to avoid or limit the impact of pest and disease outbreaks – or practical action. The lack of species diversity within commercial woodlands continues to present a plant health risk. As a result of recent pest and disease outbreaks, tree health is now considered the highest priority risk to the forestry sector, in line with the findings of the 2012 UK Climate Change Risk Assessment.
- Woodland Management – 42% of English woodland remains unmanaged.

Addressing uncertainty

As a result of the long time-frame associated with the forest management cycle, uncertainty is a key barrier to the uptake of adaptation measures in the forestry sector. Key areas of uncertainty relating to uncertainty include: (a) projections of the future climate; (b) changes in wind risk; (d) biological response of trees to climate change; (e) interactions between climate change and the behaviour of forest pests and diseases, and; (f) wildlife behaviour.

A number of evidence gaps have been identified as 'critical research questions' that will be largely addressed through the research programmes associated with the Science and Innovation Strategy for Forestry in Great Britain. Six specific research gaps that relate to adaptation have been identified through this review:

- Performance of 'emerging species';

- Silviculture of mixed species and continuous cover forestry;
- Timber sector market projections;
- Chilling requirement for germination of native species in the context of the changing climate;
- Capacity and threshold for existing woodlands to adapt through phenotypic plasticity;
- Capacity and threshold for species' genetic variability to provide an adaptation measure through assisted migration;
- Monitoring of tree growth rates to inform response to climate change.

Uncertainty is addressed across both the Public Forest Estate and in FS guidance to the private sector through ensuring that all actions regarding woodland planting and management are consistent with current climate and weather conditions – and then to consider a range of questions relating to a range of climate change projections and their likely impacts. The same approach is applied to Public Forest Estate planners and private sector foresters through engagement and outreach.

Review of first round report *Outline Adaptation Plan*

Progress on actions outlined in the ARP1 'Outline Action Plan' has been reported:

- **Changes in Governance:** ongoing devolution of the functions of the Forestry Commission has resulted in a greater focus on the requirements of the forestry sector in England, including the introduction of a Corporate contingency planning process and the establishment of Incident Management Teams to respond to serious events.
- **Filling gaps in evidence and addressing uncertainty:** There is a strong focus on Climate Change in the seven research Programmes that have been developed from FC's Science and Innovation Strategy for Forestry in Great Britain, with 3 devoted to different aspects of resilience.
- **Outreach and Guidance:** Forest Services' dedicated outreach post has been effective in sector communication, leading to the publication of the forestry sector Climate Change Accord and the 2015 British Woodlands Resilience Survey followed by the establishment of the Forestry Climate Change Working Group.
- **Embedding adaptation in forestry regulations and grants:** No changes to forestry regulations have been instigated to address climate change adaptation, but resilience and adaptation principles were considered during the development of the Countryside Stewardship woodland grants, including the requirement to assess both current and future species suitability when selecting planting stock.
- **Implementing the Climate Change Action Plan for the Public Forest Estate (CCAP):** The CCAP has been effective in (a) increasing the diversity of species planted on the PFE; (b) encouraging the application of continuous cover systems of management; (c) ensuring that all new and revised infrastructure has capacity for

projected increases in precipitation; (d) increasing awareness of forest health issues, and; (e) introducing fire resilience mapping into forest planning.

- Adaptation indicator development: A number of Corporate Performance indicators have been identified as relevant to resilience and climate change adaptation, including: (a) Proportion of England's woodland area in management; (b) Number of tree pests and diseases established in England in the past 10 years; (c) Number of high priority forest pests in the UK Plant Health Risk Register; (d) Measure of woodland resilience to climate change based on the size and spatial configuration of woodland patches within the landscape. A number of other indicators have been developed since ARP, including a measure of the conservation condition of woodlands using information from the National Forest Inventory and Wildfire indicator on Public Forest Estate and other public and private woodlands.

New actions arising from the review

A number of new actions, in addition to those instigated in response to FCE's ARP1, have been agreed through this review:

- A revised Climate Change Action Plan for the PFE will be published in 2016;
- FCE will publish a position statement in 2017 on approaches to adaptation;
- FS will work with the Forestry Climate Change Working Group to facilitate the understanding and implementation of appropriate actions;
- FCE will draft a recovery plan for extensive wildfires as part of wildfire contingency planning, prepare a wildfire risk map, work with EE to embed Wildfire Management Plans into Forest Design Plans and support Natural England to develop wildfire resilience in Countryside Stewardship mandatory options;
- FCE will develop a contingency plan for drought, to cover impact, evaluation and recovery phases;
- FCE will work with Forest Research to develop 'climate change adaptation areas' to demonstrate adaptive practice in Alice Holt Forest;
- FS will work with Forest Research to develop an annual growth indicator based on 'sentinel sites'.

Evaluation of barriers and interdependencies

A number of barriers to adaptation have been identified, in part through the British Woodlands Resilience Survey 2015, and can be summarised as:

- Uncertainty – leading to resistance to adopting alternative approaches to woodland management.
- Timeframe – forest planning and management function over the time-frame of decades; as a consequence forestry advisers, woodland managers and woodland owners are reticent to make rapid and significant changes to forest management.

- Lack of confidence – to some extent, adaptation measures are ‘stepping into the dark’ requiring a high degree of confidence that the actions are appropriate.
- Policy conflicts – there is a perception that many of the adaptation measures being advocated, particularly over planting stock, run counter to other existing/past policies.
- Lack of ‘adapted planting stock’.
- Cost of implementing adaptation measures – largely related to expectations of timber market demand.

The review has concluded that better provision and explanation of guidance to the private sector is the priority to address the barriers that have been identified, alongside clearer articulation of FCE’s approach to adaptation providing granularity for different woodland types and management objectives.

Monitoring and evaluation

Climate change adaptation has been embedded across the organisation as business as usual, rather than as a bespoke, activity. Where adaptation is treated as a specific activity, evaluation mechanisms are outlined below:

- The Climate Change Action Plan for the Public Forest Estate: Progress and effectiveness of implementation will be considered at the five-yearly review due in late 2016 and, also, through the PFE’s biennial review against the UK Woodland Assurance Standard.
- Sector resilience outreach activity: The effectiveness of FS’s guidance and outreach programme will be assessed against a baseline set by the 2015 British Woodlands’ Resilience Survey.
- Rural Development Programme: The effectiveness of RDP-funded woodland grants in enhancing resilience will be evaluated as part of the Programme’s mid-term review in 2017.

Benefits and opportunities

Implementation of adaptation measures has had synergies with two other programmes of work:

- Species diversification in response to recent plant health concerns has been strengthened by initiatives to increase species diversity as an adaptation measure, both on and off the Public Forest Estate.
- Opportunities for woodland creation and in-forest measures in existing woodlands were identified in the ARP1 report as an adaptation measure. This has put FCE in a good position to respond positively to recent flooding events, for example through the Cumbria Floods Partnership, in early 2016.

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1 Introduction

1.1 Forestry Commission and the Adaptation Reporting Power

Forestry Commission England (FCE) was invited to prepare a Climate Change Risk Assessment under the Adaptation Reporting Powers of the Climate Change Act (2008), in the first round of reporting. The report was published in March 2012. Although FCE is not a priority reporting organisation or statutory undertaker, it was invited to report as:

'England's woodlands are important national assets which are both vulnerable to climate change and have a valuable role in helping people adapt to its effects'.

In common with other first round reporting organisations¹, FCE was invited to produce an update on its first round report (ARP1), setting out progress on actions and assessment of risk. This review responds to that invitation, with the formal process appraisal presented at Annex 1.

1.2 Forestry Commission England's role

1.2.1 The Forestry Commission

The Forestry Commission is the non-ministerial Government department responsible for advising on and implementing forestry policy in England. It is a cross-border public authority responsible separately to Ministers in England, Scotland and its role in Wales was amalgamated into Natural Resources Wales in April 2013. Forestry is a devolved matter and in England the Commission reports to the Secretary of State for Environment, Food and Rural Affairs. The Commission is headed by a Board of Commissioners, whose principal duties and powers are defined in the Forestry Acts 1967 and 1979.

The Commission manages the public forest estates in each country, administers grants for expanding and managing forests and regulates tree felling. It also provides advice to Ministers, undertakes and commissions research, sets standards for good forestry practice and protects Britain's forests from pests and diseases. In England the Public Forest Estate amounts to approximately 253,000 ha of which 215,000 hectares is woodland, equivalent to 16% of the country's woodland cover.

¹ Adapting to Climate Change: Ensuring Progress in Key Sectors 2013 Strategy for exercising the Adaptation Reporting Power and list of priority reporting authorities.

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/209875/pb13945-arp-climate-change-20130701.pdf

1.2.2 Forestry policy in England

Strategic forestry policy in England is the responsibility of Defra Ministers and is set out in the 2013 Forestry and Woodlands Policy Statement². Following Government's review forestry functions in England³, it was announced in 2014 that: *Having carefully considered the options and the views received on the review's conclusions, Ministers have decided that the Government's key Forestry Functions will continue to be delivered by the Forestry Commission; with enhanced working arrangements between Defra and the Commission at all levels to strengthen integration between policy and delivery.*

1.2.3 FCE's strategic objectives

As set out in FC England's Corporate Plan for 2016-17⁴ (FCE, 2016), FCE are tasked with working with a wide range of partners — other government bodies, private sector businesses, charities and civil society organisations — to deliver the functions and priorities set out in Defra's Single Departmental Plan⁵ and which reflect the role that England's trees, woods and forests have in delivering the priorities as set out. The work will focus on:

Protect – We will: Manage threats from pests and diseases of woodland trees so that the value of natural capital in woodland is maintained.

Use light touch regulation to create a level playing field on which sustainable businesses can thrive to protect the wider environment and prevent unnecessary loss of or damage to woodland.

Make England's woodland more resilient by increasing its ecological diversity and enabling landowners to manage populations of deer and grey squirrels, and minimise the negative effects caused by invasive species.;

Improve – We will: Support the forest economy to grow and bring more woodlands into sustainable management, benefiting people, nature and the economy.

Expand – Help the forestry sector create significantly more woodland in England to provide increased environmental, social and economic benefits.

² Forestry and Woodlands Policy Statement (2013).

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/221023/pb13871-forestry-policy-statement.pdf

³ Review of forestry functions and organisational arrangements for their delivery in England (2013).

https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/224841/pb13976-forestry-functions-review-130717.pdf

⁴ Forestry Commission England Corporate Plan 2016-17.

[http://www.forestry.gov.uk/pdf/Corporate_Plan_2016-17.pdf/\\$FILE/Corporate_Plan_2016-17.pdf](http://www.forestry.gov.uk/pdf/Corporate_Plan_2016-17.pdf/$FILE/Corporate_Plan_2016-17.pdf)

⁵ Defra Single Departmental plan 2015-20.

<https://www.gov.uk/government/publications/defra-single-departmental-plan-2015-to-2020/single-departmental-plan-2015-to-2020>

Key functions include carrying out statutory regulatory functions (for example in relation to tree felling, plant health and environmental impact assessment), managing the Public Forest Estate, administering grant schemes, and providing expert advice (both nationally and locally). Urban trees and woodland are covered by the UK Forestry Standard and within FCE's remit; the Urban Forestry and Woodlands Advisory Committee Network has recently published its 'Urban Vision'⁶.

1.2.4 Forest Services

The vision for forest services is to provide a service to society based on evidence-based standards, expert advice, communications, partnerships, grants and regulation. Through this service, Forest Services aims to empower and motivate Landowners and managers, businesses, civil society organisations and local communities to protect, improve and expand England's woodland resource. An indicator framework⁷ has been developed outlining the intended impact of delivery, focussing on the strategic objectives outlined in Section 1.2.3. Three of the Corporate Performance indicators have been selected from the wider palette of adaptation indicators described in Section 4.2.6, specifically:

- Measure of woodland resilience to climate change based on the size and spatial configuration of woodland patches within the landscape;
- Number of high priority forest pests in the UK Plant Health Risk Register (UKPHRR);
- Proportion of England's woodland area in management.

The indicators cover three principal aspects of adaptation in the forestry sector, but do not track the diversity or suitability of planting stock for which there is currently no appropriate data-set for the wider forestry sector.

Under the Grants and Regulation function of Forest Services, FCE issues 2,000 - 2,500 felling licences each year and has more than 10,000 active grant schemes. These grant schemes are funded by the Rural Development Programme for England, primarily through the English Woodland Grant Scheme (EWGS: now closed) and Countryside Stewardship Grant Scheme (CS). CS supports woodland planning, woodland creation and woodland improvement. FCE is also responsible for supporting economic activity in the forestry sector through co-delivery of RDPE Axis 1 grants (LEADER, Countryside Productivity) and supports the sector in realising EU Structural Investment funding opportunities by working with the 39 Local Enterprise Partnerships. Forest Services also provides policy support, including national-level engagement and empowerment, through its Policy Advice Team.

⁶ Our vision for a resilient urban forest (2016). [http://www.forestry.gov.uk/pdf/urban-forest-final-v4.pdf/\\$FILE/urban-forest-final-v4.pdf](http://www.forestry.gov.uk/pdf/urban-forest-final-v4.pdf/$FILE/urban-forest-final-v4.pdf)

⁷ FCE Corporate Plan Performance Indicators and Woodland Indicators 2015. [http://www.forestry.gov.uk/pdf/FC-England-Indicators-Report-20152.pdf/\\$FILE/FC-England-Indicators-Report-20152.pdf](http://www.forestry.gov.uk/pdf/FC-England-Indicators-Report-20152.pdf/$FILE/FC-England-Indicators-Report-20152.pdf)

1.2.5 The Public Forest Estate

The FC owns and manages a significant Public Forest Estate (PFE) in England on behalf of the Secretary of State. The PFE is the largest single land-holding owned by the State. It covers 253,000 ha of land, 2% of the total land area of England, and 16% of England's woodland. It comprises 215,000 ha of wooded habitat and 38,000 ha of non-wooded habitat and includes over 67,000 ha of SSSI (of which 99% are in favorable or recovering condition as at December 2010). The estate is sustainably managed and approximately 1.4 million m³ of timber is harvested each year, representing the largest single supplier in England. The PFE is also the single largest outdoor recreation provider in England. The Public Forest Estate is managed by Forest Enterprise, an Executive Agency of the Forestry Commission, which employs around 800 people.

1.3 Governance and organisational structure

1.3.1 Cross-border level Governance

At England/Scotland level, the work of the Forestry Commission is governed by a Board of Commissioners including both Executive (Director England, Head of Forestry Commission Scotland) and a number of non-executive Commissioners, representing the interests of the wider forestry sector. The Chair of the Board of Commissioners is appointed by the Secretary of State for Environment, Food and Rural Affairs. Operationally, work is managed through the Executive Board, which is chaired by Director England.

1.3.2 Organisational structure

FCE is organised as two separate bodies. Forest Enterprise England which manages the Public Forest Estate and Forest Services, the centre of expertise in forestry, delivering to the wider forestry sector in England on evidence-based standards, expert advice, communications, partnerships, grants and regulation. It also liaises with other bodies within the Defra Group (including Natural England and the Environment Agency) and provides advice on forestry policy development to Defra and other Government Departments. Each has its own management Board, reporting to the FCE Executive Board. Both are supported by Corporate Services, including Information Services and finance functions.

As a result of the devolution of GB shared services, ensuing from the devolution of forestry policy, FEE has taken on full responsibility and autonomy for HR, Finance, Information Services and Communications as well as a range of other forestry support services. The services previously supplied by IFOS (Inventory and Forestry Support) hosted by FC GB have been transferred to Forest Research and will continue to support FE England and FE Scotland under a Service Level Agreement. This includes Production Forecasting and maintenance of the Sub-Compartment Database, the main repository of forestry data for FEE.

1.3.3 Governance in England

The delivery of forestry policy in England is governed by the England National Committee, which is chaired by the Chair of the Forestry Commission and its membership includes Defra's Director, Natural Environment and representatives covering the interests of both the FC and wider forestry sector. Operationally, the work of FCE is managed through the FCE Executive Board, chaired by Director England, and includes Chief Executive Forest Enterprise, Head of Finance, Head of Communications and Director Forest Services.

Following the Government's response to the Independent Panel on Forestry's report in 2013 administrative arrangements, within the limits of current legislation, has seen the transitioning of FEE into a more distinct body in anticipation of legislative change that would create an independent organisation. FEE England is managed by the Forest Enterprise Strategy Board, comprising Chief Executive Forest Enterprise England (Chair), Head of Human Resources, Head of Marketing, Head of Finance & Business Support, Head of Corporate Affairs & Governance, Director of Operations, Head of Estates, Head of Strategy & Insight and two non-executive members of the England National Committee.

2 Understanding climate risk

2.1 Changes in science and projected impacts

Tree Species Selection and future performance

During the reporting period covered by this review, Forest Research has significantly enhanced the decision support tool for tree species selection, Ecological Site Classification (ESC)⁸. To address the objective of species diversification to enhance resilience, the model now has been extended to include of 57 tree species. The most significant addition has been the modelling of future climate scenarios. This allows the user to consider the potential change in productivity of each tree species resulting from climate projections to the middle and end of the century. Although 1:250,000 soils data under-pin the model, site specific outputs are dependent on the input of accurate soil data.

In 2015 further enhancements to the ESC model has seen the launch of ESC v4⁹ based on open source software. This has allowed the integration of GIS technologies and on-line map-based presentation of the information. To improve guidance on very poor wet sites, features have been added to allow users to examine the impact of typical management operations (drainage, fertiliser application, brash management) on species suitability. The climate projections have also been updated, with a mean future climate data-set developed from the eleven member ensemble provided as one of the products of the UKCP09 projections¹⁰.

Modelling wind hazard

A new version of the Decision Support System *ForestGALES*¹¹ (version 2.5) has been released which includes a number of important improvements. Users' experience indicated that the previous version tended to predict more damage than was observed, which has been supported by a structured comparison with actual storm damage, and ongoing research into the science of wind risk in forests. As a result, the estimated critical wind speeds for damage are higher, and stands are now predicted to be less at risk of damage. The way in which input data relating to cultivation and drainage are handled has been improved while crown size representation for some species has also been updated.

⁸ Ecological Site Classification. <http://www.forestry.gov.uk/esc>

⁹ ESC v4 on-line decision support system. <http://www.forestdss.org.uk/geoforestdss/esc4.jsp>

¹⁰ UKCP09 Climate Projections 11-member Regional Climate Model. <http://ukclimateprojections.metoffice.gov.uk/22541/>

¹¹ ForestGALES decision support tool. <http://www.forestry.gov.uk/forestgales>

Link between climate and pest and disease outbreaks

Understanding of the link between climate and pest and disease outbreaks has advanced, particularly the pivotal role of climate-induced stress increasing the propensity for serious outbreaks. The knowledge of climate limitations on specific forest pests, diseases and syndromes has also improved, including for *Phytophthora ramorum* on larch and Acute Oak Decline.

Evidence from other countries

Evidence from other countries, particularly France and North America has improved our knowledge of the likely impacts of climate change on forestry in Britain and provided examples of intervention that is deemed necessary to address the risks associated with climate change. Assisted migration (both of better adapted species and genetics) and improved stand management (thinning to reduce water use and the impacts of drought) are topics where scientific understanding has improved.

Role of forestry in flood risk management

Following the series of wet winters (2013/14 and 2015/16), evidence on the role of woodland creation and management in reducing flood risk has improved, particularly the analysis of the impact of forestry and non-forestry measures associated with the Pickering *Slowing the Flow* project¹². Understanding of where woodland can make the greatest contribution to reducing peak flows and protecting communities at risk has also been advanced, with 'opportunity mapping' for flood risk management used in targeting the Countryside Stewardship Woodland Creation Grant.

2.2 Review of risks assessed in the first round report

The priority risks assessed in ARP1 are set out below. A brief commentary is provided for each. Following review, all are assessed as still relevant. Further detail is provided in Section 2.3 for those that are seen as representing the priority risks that need to be addressed.

2.2.1 Impact on woodland and forest management on the Public Forest Estate (and wider woodland resource)

- Extremes of summer drought and temperature will be beyond conditions that some species in some locations are capable of withstanding.
 - Still considered a priority risk, but incorporation of UKCP09 projections and updated suitability models in ESC indicate that future species suitability may be less severely impacted than previously assessed.

¹² Slowing the Flow Partnership briefing: Boxing Day 2015 flood event.

[http://www.forestry.gov.uk/pdf/160329_PBeck_Boxing_Day_2015_Final.pdf/\\$FILE/160329_PBeck_Boxing_Day_2015_Final.pdf](http://www.forestry.gov.uk/pdf/160329_PBeck_Boxing_Day_2015_Final.pdf/$FILE/160329_PBeck_Boxing_Day_2015_Final.pdf)

- Insufficient genetic diversity and ‘conservative’ provenance selection provides limited resilience and capacity to adapt to climate change.
 - The lack of consensus across the sector and availability of planting stock has increased the importance of this issue, which is further explored in Section 2.3.
- Current silvicultural systems, predominantly based on single species, clear-fell, models have limited resilience to climate change and current biosecurity concerns.
 - Particularly in the context of tree health, addressing limited species diversity has emerged as critical and is further explored in Section 2.3.
- The distribution of timber species may be inappropriate to the changing climate, resulting in risk to future productivity and consequent maintenance of UK Woodland Assurance Standard (UKWAS) certification, in the absence of adaptation.
 - Remains a key concern and is one of the main drivers behind the vision for the Public Forest Estate set out at Annex 2.
- Changing climatic conditions will favour some non-native invasive species presenting risks to woodland biodiversity and increasing management costs if woodland Sites of Special Scientific Interest (SSSIs) are to be maintained in good condition.
 - Recent European legislation on non-native invasive species raises the relevance of this risk and the potential costs of addressing it.
- Trees under (climatic) stress at greater risk to insect pests and tree disease outbreaks, coupled to changing climatic conditions more favourable to some insects and pathogens.
 - Further evidence has emerged on the link between climatic stress and forest pest and disease outbreaks.
- Present risk of wildfire incidents and future increases in likelihood and severity, particularly with increasing areas of open habitat management.
 - Wildfire remains on the government’s National Risk Assessment and Register as well as wildfire assessment, planning and advice being included on many Local Resilience Forums’ Community Risk Registers and Fire and Rescue Services’ Integrated Risk Management Plans.
 - Wildfire has been defined as a priority risk in the Climate Change Action Plan for the Public Forest Estate and in Natural England’s and the Chief Fire Officers’ Association Adaptation Reporting Power reports.
- Inability of the National Arboreta to maintain current collections.
 - Little can be done to address the threat to current collections, but accessions policies consider the impact of climate change.
- In the absence of management, larger populations of deer and squirrels benefitting from milder winters.

- Unsustainable populations of deer and grey squirrels remain a major threat to regeneration and new planting and will continue to do so for the foreseeable future.
- Capacity of forest infrastructure (including reservoirs, roads and paths, culverts and steep slopes) to withstand higher winter rainfall and more intense rainfall events may be insufficient.
 - Most of the focus in this area since ARP1 has been on addressing the requirements of the Reservoir Act, but the failure of steep slopes has become more of an issue in recent years following heavy winter rainfall.
- Inability of nurseries to source appropriate seed (due to climate, biosecurity and trade restrictions) and supply changing requests (species and provenance) for planting material in the necessary timeframe.
 - Remains a key risk linked to species diversity and genetic adaptation and is explored in more detail in section 2.3.

2.2.2 Impact on Forest Services' ability to facilitate adaptation in private sector woodlands

The majority of the priority risks outlined in Section 2.2.1 also apply to England's wider woodland resource and will affect the ability of FCE to carry out some of its functions, particularly the ability to enhance the resilience of woodlands. Specific risks identified in ARP1 were:

- FCE's advice to woodland owners may not be appropriate to the future climate, with a consequent decline in woodland condition, productivity and economic resilience of the forestry sector, possible;
 - A key risk with FCE's interventionist approach coming under challenge from some quarters. The risk is being addressed through being clear that different actions are required to meet different management objectives and by using expert advice from Forest Research as the foundation for guidance.
- FCE's advice on planting mixtures may not be 'climate-proofed', leading to a lack of resilience in the woodland resource and poor return on public funding of woodland creation (through the English Woodland Grant Scheme);
 - A requirement to consider current and future performance using ESC is a requirement of the Countryside Stewardship woodland creation grant, but uncertainty in the future climate means that this remains a risk.
- The need to maintain/increase food production, in part as a result of global climate change, may limit the ability of FCE to facilitate a step change in the rate of new woodland planting. Land availability may be further restricted by the need to maintain water resources in areas of low (and declining) rainfall.
 - Increasing woodland creation rates in line with the aspirations set out in Government's 2013 Forestry and Woodlands Policy Statement remains

challenging. However, at the present time, other barriers (regulatory, economic and cultural) are more significant than competition for land with food production.

2.2.3 Impact on business and corporate activities

The main impacts of climate change on business and corporate activities are common to most organisations, and relate to working conditions, working patterns, energy use and the ability of FC's built estate to cope with the changing climate.

- Climate change policies increasing energy and water costs with the consequent economic impact on the organisation.
 - Long term risk that needs to be considered as part of business sustainability plans.
- Risk to buildings and staff where offices are located in flood plains.
 - This remains a risk, but business continuity planning has been shown to be effective, as demonstrated in the Foss House case study in Section 4.2.1.
- Rising fuel costs (in response to climate change policies) reducing net financial returns from timber harvesting and transport;
 - The decline in oil prices since ARP1 has resulted in the risk not being realised in the short term, but it remains a risk in the longer term.

2.3 Assessment of new priority risks

The lack of diversity in tree species and genetics within species had been identified as a priority risk in ARP1. However, the risk of limited diversity had been expressed in the context of climate change and, particularly, uncertainty in the way in which climate change will progress. The risk of the lack of diversity has been heightened by the series of pest and disease outbreaks that have affected British forestry in recent years, including Asian Longhorn Beetle, *Phytophthora ramorum* on larch (and other species, to a lesser extent), oak processionary moth, the syndrome known as Acute Oak Decline and *Chalara* dieback of ash. There are also concerns over the potential for *Xylella fastidiosa* to impact British woodlands, particularly because of its broad host range.

The potential for climate change to make pest and disease outbreaks more frequent and intense was also identified as a priority risk in ARP1. The protection of England's woodland resource is also the priority for woodland policy at the present time.

As such, risks from the lack of species/genetic diversity and from pest and disease outbreaks (tree health) are not new priority risks, but they have been identified as the key risks to address at the coming time. If these two risks are to be addressed, it will require intervention to enhance resilience, which highlights the third of the three key risks to the English woodland resource – the lack of management. Although the majority of conifer woodland is in active management, nearly 60% of the broadleaf resource is

unmanaged. Un-managed woodland provides few opportunities for regeneration of trees that are adapting to the changing environment or for species diversification.

These three key risks – together with emerging barriers to addressing them – are further explored in sections 2.3.1 to 2.3.3.

2.3.1 Species diversification

Since ARP1, four further risks have been identified within the nursery and seed supply area that may result in the use of inappropriate planting stock and impact on species diversification. These risks should be considered alongside the barriers set out in Section 5.

Monopoly in trading: The UK has only a few seed trading businesses. The recommendation to import native tree species seed from France has challenged their business models as access to seed is largely controlled by one company in France which already trades in the United Kingdom. This has meant there has been little incentive for them to advocate current Forestry Commission advice on the use of more southerly provenances of native species.

Legacy of past broadleaved tree planting policies: Prior to the need to adapt to climate change being articulated, accepted practice was to plant local origin material as this will have adapted to local soil and climate. Although it is acknowledged that more southerly origins will confer improved productive performance as the climate changes, there is continued debate as to whether this is an appropriate action within native woodlands and many conservation bodies continue to advocate and plant local origin material. While the market is still demanding local origin material of native tree species, many of the nurseries are not prepared to take the commercial risk of growing 'adapted planting stock' and sufficient quantities are not available for adaptation measures to be widely implemented.

Seed sourced from inappropriate origins: The industry imports seed of native species from Eastern Europe. This has largely been driven by the desire of the nursery sector to produce planting stock from seed in a single year; failure of mast years in the UK and preferred regions of western Europe, for oak in particular, has resulted in seed being imported from Eastern Europe where the mast is more reliable. This challenge has been addressed by FCE raising the issue with the sector and by providing help with research into the storage of vulnerable seed.

Importing of seedlings and trees: Since ARP1 was published, it is apparent that the practice of growing UK provenances in continental European nurseries is widespread. For a number of decades, the landscape industry has imported large mature plants from mainland Europe. Both practices run a high risk of importing pests and diseases to the UK. The desire to plant more southerly origins of native tree species has resulted in the import of planting stock directly from regions that have a similar climate to that

projected for the UK in the future. The UK nursery sector believes that it could satisfy the home market with material all grown within the United Kingdom. However, nurseries argue that uncertainty and discontinuities in the availability of incentives for planting means that they would be carrying too high a financial risk to do this.

Genetic adaptation: The rate at which climate change is progressing requires tree species to move up to 30 times faster than they recolonized the UK after the last ice-age. Assisted genetic migration (i.e. planting more southerly origins) represents an approach for maintaining the suitability of individual species and is being widely adopted for some exotic conifer species such as Douglas-fir. Many of the major forest nurseries are now stocking improved genetic material from more southerly origins for the main native forest species, but evidence from the 2015 British Woodlands Resilience Survey indicates that use of 'adapted planting stock' is not widespread: *"There is a low awareness of climate projections for their locality, together with a lack of knowledge of soils, which means that most woodland stewards are unaware of the potential impacts of environmental change. Most owners have not reviewed species suitability under projected climate conditions and are therefore unaware of the need to, and potential for improving the resilience of their woodland. Uncertainty around the concept of provenance/origin, improved planting stock and genetic diversity points to a requirement for improvements in education and the communication of scientific and practical evidence"*.

2.3.2 Tree health

Deterioration of tree health in existing woodlands remains the most significant risk currently faced by our woodlands.

Biosecurity: The number of pests and diseases having a negative impact on England's Woodlands has increased dramatically over the past 20 years. This is likely to be a result of a combination of climate change and global trade in plant commodities. The arrival of *Chalara* dieback disease of ash in the UK was a wake-up call for foresters to consider the sourcing of their planting stock and to reduce the risk of importing pest and diseases. The importation of live plant material continues to be the most significant pathway for pests and diseases to arrive in the UK.

Evidence from the British Woodlands Survey 2015 highlights this risk: there are low levels of awareness and action in relation to bio-security among woodland owners, which was only marginally better among forestry professionals, suggesting that there is a need to review whether current guidance on bio-security and risk assessment can be made more effective.

Lack of species diversity: *Dothistroma* needle blight on pine species and *Phytophthora ramorum* on larch species has injected urgency into tree species diversification in conifer woodlands and the nursery sector has responded by making an

increasing range of conifer tree species available in UK nurseries. However, in the uplands, Sitka spruce still dominates planting stock posing a significant future risk. Furthermore, there has been little change in the diversity of native species planted and concerns have been raised over the availability of good quality native tree species' seed in the UK. The Future Trees Trust (FTT) has reported on the conditions of UK native seed stands on the national register¹³ and has completed a review of tree species not represented on the register. Subsequently FTT, Forest Research and the Confederation of Forest Industries (Confor) have drafted a National Tree Improvement Strategy.

The findings of the British Woodland Survey 2015 show that the majority of respondents held the view that there was not enough species diversity within commercial woodlands while around half of the respondents were of the view that in non-commercial/native woodlands there was insufficient species diversity for the woodlands to be resilient.

2.3.3 Woodland management:

The changing climate will put our woodlands, particularly those on the drier and more southern parts of England more frequently into stressed conditions. This will almost certainly have a negative impact on these woodlands. Only 17% of conifer woodlands are unmanaged. However around 60% of our native woodlands are currently unmanaged. For woodlands to be healthy and resilient they need to be dynamic with a range of age classes represented to promote evolutionary adaptation and to enable assisted migration.

Regeneration only occurs when there is a silvicultural or natural intervention creating enough space and light to encourage the establishment (or planting) of a new generation of trees.

The British Woodland Survey 2015 finds that: *“Many of the actions for increasing resilience will flow from good management planning and levels of understanding of the issues, both of which appear to be insufficient. The high number of woodlands without a management plan will undermine attempts to improve resilience.”*

¹³ FRM registered 'Selected' seed stands audit. <http://www.futuretrees.org/files/uploads/FTT-seed-stand-audit-Stage-1-report-V2.pdf>

3 Addressing uncertainty

3.1 Uncertainty in climate impacts relevant to the forestry sector

As a result of the long time-frame associated with the forest management cycle, uncertainty is a key barrier to the uptake of adaptation measures in the forestry sector. Approaches to addressing uncertainty in the medium and long term have therefore been developed, to give foresters the confidence to act.

Climate projections: The precise way in which climate change progresses, particularly its timing, remains the largest uncertainty in the forestry sector. In particular, conflicting messages over whether summer droughts will increasingly impact on English forestry or whether the UK's maritime climate will result in an increase in summer rainfall. Adaptation actions, specifically the selection of planting stock, will also need to accommodate both current and future climates; this may involve the planting of more frost-sensitive species and or genotypes involving significant risk if occasional cold winters remain a feature of England's climate. These uncertainties associated with the future climate are currently (and probably permanently) intractable; however, they do provide context for the 'resilience approach' adopted by FS and FEE, focusing on diversity, better matching of species to local (and variable) site conditions, and a need to accommodate both current and future climates.

Wind risk: The impact of windstorms is highly dependent on direction and distribution of wind speeds within the mean. Current climate projections do not include projections of changes in the wind climate, enhancing uncertainty in a key area of forest planning and management that is already subject to a high degree of uncertainty. Although the decision support system, *ForestGALES*, has recently been updated (see Section 2.1), this did not extend to future climate projections.

Biological response: Although there is a reasonable knowledge of how common tree species respond to weather conditions (and the performance across climatic clines), there is no certainty as to how they will respond to the changing climate (including the potentially beneficial effects of rising atmospheric carbon dioxide levels). Climate matching¹⁴ provides an indication of how trees perform under similar climatic conditions to those that England will experience as climate change progresses, although it is unlikely that exact climate analogues exist, particularly given the UK's location on the Atlantic seaboard.

Interactions between climate change and forestry pests and diseases: CCRA2 identified disease and insect pest outbreaks as the most significant risk to the forestry

¹⁴ Trees4Future Climate matching resource. <http://193.185.149.21/maps/dev/cltool/clt.php>

sector in the UK. Although the Defra Group Plant Health Risk Register¹⁵ provides a list of more than 600 potential plant disease/insects that the UK is at risk from, including 279 'forest pests' (as at end September 2016), there is no indication as to how/when they are likely to be introduced nor how they will interact with the changing climate. Pest and disease outbreaks can only remain an issue of high uncertainty but, as explained elsewhere, stronger evidence is emerging of the interaction between trees under climatic stress and pest/disease outbreaks.

Wildfire behaviour: Larger, high impact and numerous wildfire incidents are likely to occur due to metrological factors. Although FCE has evidence from six years' worth of wildfire statistics across Great Britain, especially for forest fires, there is a need to define a baseline metric to establish the effectiveness of wildfire prevention measures. This will have a significant impact on how we plan for the future and adapt to a climate with increased wildfire impact, likelihood and severity.

3.2 Evidence gaps

A number of critical Research questions were drawn up by FCE as input to the development of the Science and Innovation Strategy (SIS) for Forestry in Great Britain, in 2014. Those relating to climate change adaptation and resilience are listed below and augmented by a series of more specific research gaps set out in section 3.2.2. All were incorporated into the seven research programmes of the 2015-19 SIS, primarily the three 'resilience programmes' (see Section 4.2.2 and Annex 3).

3.2.1 Critical research questions for England

Resilience and plant health

- How can the resilience of trees to pest or disease threats be evaluated at a range of scales?
- What tree species and silvicultural systems should we be encouraging to produce resilient woodlands and what are their requirements?
- How can tree breeding and selection for resistance to pests, disease and climate change improve long-term resilience?
- How are host susceptibility and pest behaviour influenced by changes such as climate change, changing silvicultural practice and changing age structure?
- What interaction is there between the impact of newly established and endemic pests?
- What impact can introduced pests have on native species occupying the same niche?

¹⁵ Defra Group Plant Health Risk Register. <https://secure.fera.defra.gov.uk/phiw/riskRegister/>

- What adaptive strategies and management techniques, including silvicultural systems such as coppicing and pollarding, can be developed to reduce the risk and effects of pests and diseases and what are their impacts?

Public engagement

- How can we better instigate behaviour change in owners to enable and encourage a more co-operative approach to the management of forests?
- How can we better build consensus with the public on controversial methods to manage pests and disease such as wildlife management, biological control, lack of intervention and use of pesticides?
- What are the most effective methods to inform, enable, engage and deliver useful results from the public on issues such as biosecurity, increasing woodland resilience and climate change (for example through citizen science programmes, community ownership and management)?
- How can the particular challenges facing the urban forest (e.g. ensuring species chosen are resilient to climate change, spread of pest and diseases, and impact of liability concerns) be better understood to ensure the full benefits of the urban forest are realised?

Silviculture

- What are the sensitivities of undisturbed forest soils to the impacts of climate change and how can the impacts best be mitigated?
- How do management interventions affect future growth and yields in light of projected climate change?

Timber markets

- What species and silvicultural systems will provide fibre with the properties needed to meet future market demands (for example timber properties for joinery, construction and biochemical purposes)? Collaborative work with timber engineers, architects and retailers may be needed in the future.
- What is the effect of continuous cover forestry and other establishment and management systems on timber quality?

Biodiversity and landscape

- How do practical measures & management interventions affect priority species in light of projected climate change?
- What is the role of landscape scale (i.e. more widely focussed than individual sites) adaptation in forestry? What evidence is there that landscape-scale approaches to climate change adaptation are effective?
- When will tree species such as oak and sweet chestnut that are currently considered to be resilient to wildfire need to be redefined as at risk from wildfire in the United Kingdom?

3.2.2 Specific research gaps

Performance of 'emerging species': While there is limited experience of the use of a number of 'emerging species' in UK forestry (see chapter 12 of the Read Report¹⁶ for list of species and 'experience categories') and many of these species are now assessed in the Ecological Site Classification Decision Support System, precise climatic, edaphic and management requirements and limitations are not well-described.

Silviculture of mixed species and continuous cover forestry: Within stand species diversification and the adoption of continuous cover systems of management are promoted as adaptation measures. However, because of the dominance of single species clear-fell forestry systems, the silviculture of mixed species and continuous cover stands is not well understood, nor are the economics of such management systems.

Timber sector market projections: Currently there is reticence within the commercial sector to plant 'emerging species' due to uncertainty over future demand for timber from species planted at small-scale when compared to current timber production (primarily for softwood). Information is available on the qualities and specifications of emerging species but scepticism still needs to be addressed.

Chilling requirement for germination and climate change: A small number of studies have considered whether chilling requirements for germination will no longer be met as the climate warms. For some species there are concerns that it could have a major impact on natural regeneration, although plasticity and evolutionary adaptation may counter the risk.

Capacity and threshold for existing woodlands to adapt through phenotypic plasticity: England's ancient woodlands have survived a series of climatic changes although none as significant as those projected for the next century. Resilience has therefore been demonstrated and is, in many cases, being assumed in the context of climate change. However, the plasticity of existing woodland ecosystems to adapt to climate change is uncertain. A programme of monitoring responses to significant 'weather events' is required to establish the ability of woodland ecosystems to adapt to climate change and design intervention strategies, including in SSSIs and ancient and semi-natural woodland, as climate change progresses.

Capacity and threshold for species' genetic variability to provide an adaptation measure through assisted migration: It is widely accepted that more southerly provenances (in the northern hemisphere) of tree species generally perform better than planting stock of local origin. Generic guidance has been published by Euforgen¹⁷, citing

¹⁶Read Report. <http://www.forestry.gov.uk/readreport>

¹⁷Use and transfer of forest reproductive material in Europe in the context of climate change.

the value of assisted migration in adaptation strategies. However, the potential of within species genetic variability to be deployed as an adaptation measure is poorly understood and further trials, including the translocation of genetic material to hotter drier conditions, is needed to demonstrate and quantify the value of the genetic resource associated with both native and exotic species common to forestry in England.

Monitoring of tree growth rates: Although the mensuration permanent sample plot network provides a comprehensive network (more than 500 plots) for providing data on increment as input to growth and yield modelling, data are collected at 5-yearly intervals, at best. Growth data are not collected at an annual time-step across a designed network. As a result, input data are not available for reporting on the impact of specific weather/climatic events on tree growth/increment, or to provide input data for the development of process-based predictive growth models.

3.3 Approach to addressing uncertainty

The approach adopted across both the Public Forest Estate and in FS guidance to the private sector is to ensure all actions regarding woodland planting and management are consistent with current climate and weather conditions, and then:

- Consider whether those actions would remain sustainable under conditions represented by a high climate change scenario in the middle of the century;
- In particular, asking the question: is planting stock at the southern extent of its range?
- Species diversification is being promoted, to provide resilience to both climate change and biosecurity threats;
- Alternative to clear-fell systems of management are being promoted as these are likely to be more resilient under a range of future climate scenarios;
- Management plans are being promoted to encourage woodland managers to think of the future;
- Woodland owners/managers are being encouraged to bring unmanaged woodlands into management to encourage evolutionary adaptation and provide the opportunity for more interventional approaches to adaptation to be implemented;
- Woodland owners/managers are being encouraged to reduce other pressures on woodland ecosystems (invasive species, populations of squirrel and deer).
- Woodland owners and managers are being encouraged to 'plan for the unexpected' (i.e. contingency planning) to minimise the impact and aid the recovery from extreme weather events (windstorm, flood, drought, wildfire).

<http://www.euforgen.org/publications/publication/use-and-transfer-of-forest-reproductive-material-in-europe-in-the-context-of-climate-change/>

3.3.1 Engagement with the private sector

The series of extreme weather events since 2010 (winter cold, drought, flood/extreme rainfall and windstorm) has resulted in a slightly different approach to communicating climate risks to the private sector; rather than a focus on changes to the mean climate, as depicted in climate change projections, sector engagement has communicated the need for woodlands to be able to cope with extreme weather events which, themselves, will become more extreme as the climate changes. In the context of impacts on the woodland resource, water availability is likely to be the limiting factor; extreme rainfall events are likely to have the greatest impact on forest infrastructure. In terms of encouraging the private sector to adapt species choice, FS has continued to advise that ESC suitability projections for the UKCIP02/UKCP09 2050s High emissions scenarios (for ESC v3 and ESC v4, respectively) remain appropriate since, although these represent two of the more extreme projections for the middle of the century, they are consistent with more central projections for the end of the century and, additionally, trees will need to survive the more extreme events (particularly drought).

Contingency planning and incident management has been a major area of activity since FCE's first round ARP report was published, representing a new approach to dealing with uncertainty associated with the stochastic nature of weather events that are linked to the changing climate. This approach has been embedded across the business and is set out in further detail in Section 4.2.1.

3.3.2 Addressing uncertainty on the Public Forest Estate

Forest Enterprise's approach to uncertainty and resilience balances its role in delivering environmental, economic and social objectives, as required to meet the requirements to comply with certification to the UK Woodland Assurance Standard (UKWAS). This requires that other pressures on woodland ecosystems are reduced (invasive species, tree pests and diseases, limits on regeneration) and that forest design plans are developed to provide resilience to extreme weather-related events, while considering the likely impacts as set out in climate change projections. Contingency planning is an integral part of this process.

However, the Public Forest Estate is a business, meaning that adaptation measures are considered against business objectives. This is demonstrated by the Thetford forest case study (see Section 4.2.5), where the under-planting programme responded to a need to improve the economics of the management of Corsican pine stands while also providing resilience against an uncertain future. This approach to adaptive management is further exemplified by the vision for the Public Forest Estate (see Annex 2), in which functional productive ecosystems from analogue climates will provide low cost regeneration and resilience, and are considered as 'the direction of travel' over the longer term.

4 Review of first round report 'Outline Adaptation Plan'

4.1 Summary of Actions

Actions from First round report			
Summary of actions	Time-scale	Summary of progress	Assessment of extent actions have mitigated risk
Changes to governance across FC	2012-2016	<p>Climate Change Strategy Group disbanded as a consequence of on-going devolution.</p> <p>Forest Services remains as single policy/expertise/regulatory/delivery entity.</p> <p>Climate change embedded in other policy and delivery risks on FC Risk Registers.</p> <p>Climate Change continues to be championed by Director Forest Services (most recently, 12/15).</p> <p>Contingency planning process introduced, including the establishment of Incident Management Teams to respond to serious events.</p> <p>Increased Plant Health team capacity, funded by enhanced funding allocation.</p>	<p>Renewed focus on adaptation measures appropriate to England; neutral impact.</p> <p>Better integration of policy and delivery will mitigate risk.</p> <p>Climate change being embedded as 'business as usual' will mitigate risk.</p> <p>The profile of adaptation/resilience has been maintained and will mitigate risk.</p> <p>Improved organisation and sector resilience to extreme weather events and other 'incidents' including pest/disease outbreaks.</p> <p>Woodland resilience enhanced through increased diagnostic capacity.</p>
Evidence	2014-2015	'Critical research questions' relating to adaptation/resilience have been integrated into three of the seven research programmes that support the revised Science and Innovation Strategy for Forestry in Great Britain.	Improved focus on research required to deliver the needs of forestry in England will mitigate risk.
Outreach and Guidance	2012-2015	<p>Dedicated outreach post on adaptation/resilience has been effective, including drawing together a sector response through the sector Climate Change Accord.</p> <p>The 2015 British Woodlands Resilience Survey (part-funded by FC).</p>	<p>Increased understanding and debate of adaptation and resilience across the sector will lead to implementation of adaptation measures and the mitigation of risk.</p> <p>Improved understanding of the level of adaptation in the sector, enabling design of interventions to mitigate risk.</p>
Regulations and grant-aid	2012-2015	Woodland for Water targeting of the EWGS & CS woodland creation grants support flood alleviation.	Enhanced contribution from forestry to landscape scale risk mitigation.

		<p>Programme to bring more woods into management, including through the EWGS Woodfuel Woodland Improvement Grant.</p> <p>Adaptation embedded in the CS Woodland Creation Grant, primarily through UKFS requirements.</p> <p>ESC analysis introduced as a requirement for the CS Woodland Creation Grant.</p> <p>Introduction of Woodland Management Plans as a requirement for grant aid, including a resilience section.</p>	<p>Management intervention required to implement adaptation measures and mitigate climate risk.</p> <p>Public funding supports adaptation, mitigating risks to English woodlands.</p> <p>Improved understanding of species selection (and soils) mitigates risk of inappropriate species choice.</p> <p>Better planning of existing and new woodland will raise profile of climate change and mitigate risk.</p>
<p>Climate Change Action Plan for the Public Forest Estate</p>	<p>2011-2015</p>	<p>Adaptive Forest Management concept embedded into forest management practice; 349 participants on Continuous Cover Forestry courses from 2011-15. As a proportion of the estate, clear-fell management has reduced from 51.6% to 46.0% whilst alternatives to clear-fell (including Continuous Cover Forestry methods) have increased from 26.6% to 30.1% percent since April 2011.</p> <p>Managing our woods sustainability, maintaining UKWAS certification and implementing the UKFS guidance on Climate Change. A number of commendations received in UKWAS audits, including trialling performance of alternative forestry species such as Macedonian pine along with partnership working with FR to respond to pests and disease outbreaks.</p> <p>In order to increase species diversity, a wide range of alternative species are being planted as part of the conventional restocking programme. 18 additional minor forestry species have been requested from nurseries since 2005, comprising 5.5% of the total conifers planted in 2015. In addition, increasing areas are being under-planted to allow successful establishment of more sensitive forest species. See Thetford case study.</p> <p>Increasing awareness of forest health issues. Approximately 2 forest health</p>	<p>Management of forests under CCF is more responsive to changing site conditions; this, combined with enhanced structural diversity, will mitigate the risk of impact of future changes.</p> <p>Maintaining UKWAS certification demonstrates breadth of activity to ensure sustainability of the estate and consideration of climate change impacts under UKFS will mitigate the risk of future impacts.</p> <p>A greater diversity of species reduces the likely impact of future climate changes such as drought or a resulting increase in pests and diseases thereby reducing the risk of future impacts.</p> <p>Raised awareness has led to greater understanding and</p>

	<p>days run per year since 2013 with roughly 30 attendees per event.</p> <p>Fire resilience mapping and adaptation work has been trialled in South England Forest District and recommendations for roll-out are being considered as part of the revision of forest plan guidance taking place in 2016.</p> <p>Contributing to sustainable water management and ensuring that all new or revised infrastructure is built following Centre for Hydrology's 'Flood Estimation Handbook' and associated software that takes into account latest information and climate change models on flood design. This helps ensure infrastructure has the capacity to accommodate increases in precipitation. Since 2011, 12 reservoirs have had maintenance worked carried out on them, 4 of which were substantially rebuilt with increased spillway capacities to accommodate greater flood events. Total spend amounting to £375k.</p> <p>Central Tyre Inflation systems are being applied to reduce impact on roads and reduce maintenance and resource impacts. CTI is part of the award criteria in tenders for haulage contracts. Increasingly, specialist timber lorries are being fitted with the equipment as they are replaced. The 2012 revision of the FISA document 'Haulage of Round Timber - code of practice' has included CTI as a non-mandatory element.</p>	<p>broader take-up of actions to reduce risks.</p> <p>Templates have been created for identifying sites and landscapes at high risk from wildfire, to define cost-effective locations for prevention/preparedness measures.</p> <p>Forest infrastructure is better able to accommodate future high volume water flow and therefore the risk of adverse impact is significantly reduced.</p> <p>The reduced impact on roads through CTI use has led to less material required for road maintenance and therefore less CO₂ produced as a result of reduced demand for extraction, delivery and repair of roads.</p>
<p>Indicator development</p>	<p>Resilience indicator for the woodland resource in England based on woodland habitat network metrics.</p> <p>Adaptation indicator for the PFE based on tree species diversity of planting stock.</p> <p>Impact indicator of 'woodland condition' through the NFI.</p> <p>Tree health resilience indicator based on Defra's plant health risk register.</p>	<p>Resilience/adaptation indicators allow progress to be monitored and new measures to be implemented or policies developed, as necessary.</p>

4.2 Details of implemented and new actions

Details of key actions, both those set out in FCE's outline adaptation plan and new actions that have been implemented since ARP1 was published, are set out in this section. Actions are only covered where further detail, beyond that given in the Table in Section 4.1, is available.

4.2.1 Changes in Governance

Governance arrangements have changed since FCE's ARP1 was published. The strong role of the FCGB Executive Board has diminished as a result of ongoing devolution and its activity is largely restricted to ensuring the transfer of the remaining shared and cross-border functions to the countries or to Forest Research, which retains a GB remit. In 2013, the functions of the Forestry Commission in Wales were transferred (along with those of the Countryside Commission for Wales and Environment Agency Wales) to a new body, Natural Resources Wales. The (GB) Climate Change Strategy Group ceased to exist as part of these governance changes, with climate change policy development and delivery being handled by the administrations in the three countries.

In England, FC Governance arrangements have been stable, with climate change adaptation the responsibility of the Planning and Environment team in Forest Enterprise and Forest services' Policy Advice team for the wider forestry sector. In turn, the Forest Services' Board and Forest Enterprise Management Board govern delivery in the respective parts of the organisation, while the England National Committee provides overall over-sight.

Delivery arrangements for forestry policy have been clarified, with FC and Defra working more closely together to improve the efficiency and effectiveness. A number of policy/delivery areas where joint working between Defra and FC is required comprise a 'Forestry Shared Programme', including climate change adaptation.

Although the changes in governance have resulted in climate change adaptation no longer being treated as a GB issue, devolution to country teams has resulted in a number of benefits:

- Adaptation is now treated as 'business as usual';
- Adaptation can focus on the key risks and barriers to adaptation as they affect forestry in England, rather than generic cross-border risks;
- Policy and delivery are more closely linked, leading to more effective policy design to address delivery barriers;
- FCE, Natural England and Environment Agency working more closely together to achieve adaptation objectives across the natural environment;
- Contingency planning and incident management have been embedded across the business as set out in the following section.

Contingency planning and incident management

Contingency planning has been a major area of activity since FCE's first round ARP1 report was published. Operational Guidance Booklet 17a – Contingency Planning Framework and 17b – Managing Incidents in the Forestry Commission were published in 2014, with a cross-FC target audience, including in dealing with the private sector during and following pest and disease incident and natural hazard events. Contingency planning for the response and recovery phases following a wildfire is also a central tenet of the Forestry Commission's wildfire Practice Guide¹⁸, now used as guidance for Countryside Stewardship grants and some Local Authorities' development planning.

Forest Services has also introduced a new approach to incident management that has been enacted for plant health (Oriental Chestnut Gall Wasp, Oak Processionary Moth), catastrophic wind-blow (St Jude's Day Storm; storms 'Desmond' and 'Imogen') and flood (Storm 'Desmond') events. Contingency planning for major incidents includes an annual incident management exercise (major-exercise Aspen 2015, mini-exercise Birch 2016 and major-exercise Chestnut 2016), the setting out of clear roles across the organisation, the allocation of duty officer responsibilities for a member of the FS Board at all times and close working with the contingency planning teams in Defra and the Environment Agency. Additionally Forest Enterprise England and Forest Services worked in partnership with six Fire and Rescue Services in exercise Scots Pine (2016) to improve response to wildfire incidents in Southern England.

The incident management process becomes operational when amber or red alerts are received from the Natural Hazards Partnership and the National Severe Weather Warning System (triggering the establishment of incident-specific requirements), or when a new pest or disease outbreak or infestation arises. Since the Incident Management Team (IMT) was established in 2014 (including occasions when the draft plan was used), it has been activated 9 times, as detailed in the table below:

Date	Duration	Nature of incident
27 October 2013	2 days	St Jude's Day Storm, Catastrophic wind-blow threat (National Incident Management Team).
4 December 2013	2 days	Catastrophic wind-blow threat, AMBER Wind Alert Northern and Midlands of England (National Incident Management Team).
24 December 2013	1 day	Catastrophic wind-blow threat, AMBER Wind Alert South and East of England (Local Incident Management Team).
12 February 2014	5 days	Catastrophic wind-blow threat, RED Wind Alert Cumbria (National Incident Management Team).
27 June 2014	4 days	Oak Processionary Moth, East Sheen, Richmond, London (Local Incident Management Team).
4 July 2014	7 days	Oak Processionary Moth, Olympic Park, Stratford, London (Local Incident Management Team).
11 June 2015	61 days	Oriental Chestnut Gall Wasp, Farningham, Kent (National Incident Management Team).

¹⁸ UKFS Practice Guide: Building wildfire resilience into forest management planning (2015).
http://alpacorn.forestry.gov.uk:7777/portal/page?_pageid=33,2235956&_dad=portal&_schema=PORTAL

5 February 2016	7 days	Catastrophic wind-blow threat, Storm Desmond, Cumbria (Local Incident Management Team).
8 February 2016	2 days	Catastrophic wind-blow threat, Storm Imogen, Southern England (Local Incident Management Team).

On Boxing Day 2015/16, a Local Incident Management Team (Yorkshire and Northeast and East and East Midlands Area Teams) was focused on the threat of catastrophic wind-blow. Business Continuity Planning was actioned when the office in Foss House, York was flooded in late 2015. This is presented in the case study in box 1.

Box 1. Foss House case study of Business Continuity Planning.

The Forestry Commission demonstrated its ability to respond effectively with Defra Estates and *Interserve* in responding to the Boxing Day flooding at Foss House in York.

Defra quickly established a Business Continuity team which we were able to support and we worked with Defra colleagues to assess the impact whilst seeking to protect information and FC assets.



The Business Continuity Plan involved establishing a new office on the 4th floor. This was achieved within the 1st week of the New Year including establishing a new IT network, transferring key equipment and helping pack and store non-essential information. The incident has highlighted the key benefit of being able to work remotely via laptops which enabled business continuity during the period of disruption.

Learning points from the incident included:

- Defra Estates require the Emergency Contact details of key staff to enable effective contact to be established following an incident.
- If personal Protective Equipment (PPE) is required in flood damaged areas it should be used by all.
- There is a need to consider the areas which were impacted and those which could have been damaged if the flooding was higher when assessing future risk, particularly for key assets such as the ground floor IT server room.

Box 2. Oriental Chestnut Gall Wasp case study of incident management.



Forestry Commission England demonstrated its ability to respond effectively to an outbreak of Oriental Chestnut Gall Wasp with private and public stakeholders in June / August 2015.

Forestry Commission England quickly established a National Incident Management Team to define the Incident Action Plans aim and objectives and co-ordinate colleagues and stakeholders including; Forest Enterprise England, Animal and Plant Health Agency, Natural England, Kent Fire and Rescue Service, Kent Police, Highways England, Sevenoaks District Council, Scout Association and private woodland owners.

Learning points included:

- Reducing the size of Incident Management Team meetings to just the core team.
- Posting a Site Incident Controller to develop the Operational Site Assessment, coordinate operations, manage Forest Works Managers and provide on-site communication liaison.
- Developing a tree health master plan to outline key linkages and join up supporting processes and functions.

Enhanced plant health team capability

As a result of concerns over the increased frequency and severity of forestry pest and disease outbreaks, particularly *Chalara* dieback of ash, an enhanced Plant Health budget has been allocated to FCE by Defra, supporting dedicated tree health officers and other FCE staff as designated. FS's Plant Health team works closely with Defra, the Animal and Plant Health Agency, Natural England, Environment Agency, major eNGOs and the wider forestry sector. The team has contributed to, and works towards, the objectives of the Plant Biosecurity Strategy for Great Britain and the Tree Health Management Plan. A National Plant Health Risk Register has been developed as a major reference tool to identify forestry pests and diseases of greatest risk. Pest Specific Contingency Plans (PSCPs) and Pest Specific Risk Assessments (PSRAs) are produced for those of greatest concern. The Tree Health Management Plan is being revised in 2016/17, including the development of a Resilience Plan. PSCPs & PSRAs will be developed or updated as required.

4.2.2 Filling gaps in evidence and addressing uncertainty: Climate Change in FC's Science and Innovation Strategy for Forestry in Britain.

The Science and Innovation Strategy for Forestry in Great Britain (SIS)¹⁹ was published in 2014, following stakeholder input and public consultation. Research on climate change impacts and adaptation was primarily addressed through '*an evidence base for the delivery of healthy and resilient forest and wider ecosystems to enhance benefits for society.*' In turn, the SIS was used as the basis for the development of seven Programmes through which FC's main research provider (and Agency), Forest Research, is managing its research over the period 2015-2019. Three of the seven programmes focus on the subject of resilience, as listed below, with further detail provided at Annex 3. Climate change impacts and adaptation represent only one element of woodland resilience, but all work areas of the three resilience programmes are listed at Annex 3 for completeness. All seven programmes are given below, with further detail available from the Forestry Commission website²⁰.

- Programme 1 - Assessing resilience
- Programme 2 - Understanding threats to resilience
- Programme 3 - Delivering resilient forests
- Programme 4 - Valuing and governing forest ecosystem services
- Programme 5 - Tree breeding
- Programme 6 - Modelling and mensuration
- Programme 7 - Integration

4.2.3 Outreach and Guidance

In FCE's ARP1 report, published in February 2012, it was recognised that a major challenge to implementing climate change adaptation strategies is the many uncertainties associated with climate change. The ARP1 report identified the barrier as: *"If field practitioners are not engaged with, and shown what needs to be done, they will not implement the adaptive strategies that are considered not to carry any risk. This means forests do not become more resilient to the changing climate leading to declining forest condition over time."* At the time of publication of FCE's ARP1 report there had been no evaluation of the views of the forestry sector to establish a benchmark to assess progress against. The following section sets out the actions resulting from the outline adaptation plan in FCE's ARP1 report.

¹⁹ Science and Innovation Strategy for Forestry in Great Britain (2014).
[http://www.forestry.gov.uk/pdf/FCFC002.pdf/\\$FILE/FCFC002.pdf](http://www.forestry.gov.uk/pdf/FCFC002.pdf/$FILE/FCFC002.pdf)

²⁰ Forestry Commission research homepage. <http://www.forestry.gov.uk/research>

Engaging the sector

A forestry sector Climate Change Working Group was established in 2013 in response to the commitment made in the 2013 National Adaptation Programme. Initially this was led by the England Woodland and Timber Partnership (EWTP) and, following the dissolution of EWTP, by a steering group of individuals represented among others, the Institute of Chartered Foresters (ICF), Confederation of Forest Industries (Confor), the Woodland Trust, the Country Landowners and Business Association (CLA), the Royal Forestry Society (RFS) and the Environment Agency's (EA) Climate Ready Service. The group developed an informal communications plan based on a 'message house' (see Figure 1) to promote adaptation across the sector. This has delivered numerous talks, seminars and conferences around the country.

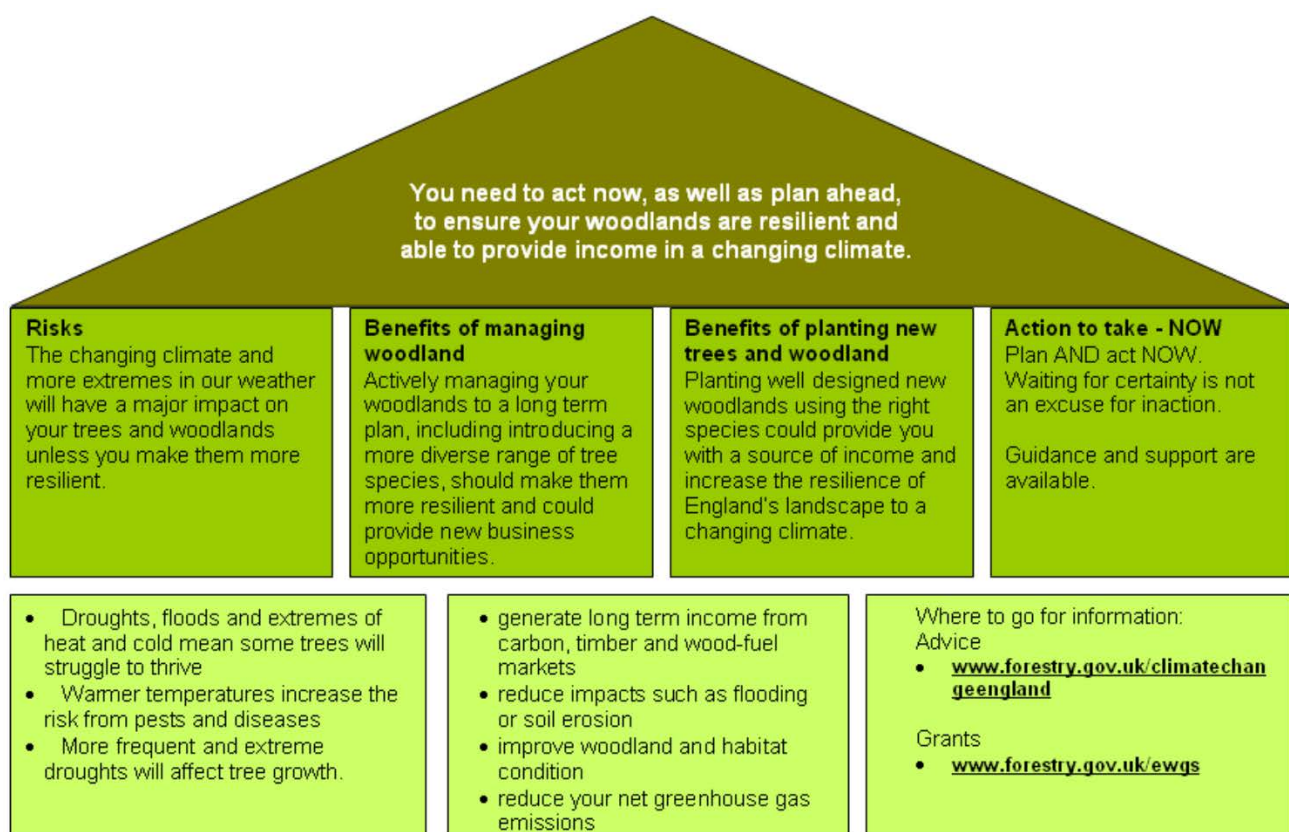


Figure 1. Climate change adaptation Message House for forestry, developed by the National Adaptation Programme forestry sector working group.

Forestry Commission England published its internet resource 'Managing England's Woodlands and Climate Change'²¹ in 2012. This resource was developed to make the

²¹ www.forestry.gov.uk/climatechangeengland

best available advice available in a single place. The resource draws heavily on the principles that were developed for the PFE's Climate Change Action Plan (2011).

The biggest single risk to forest resilience had been identified as the lack of species and genetic diversity. Following further development of the Ecological Site Classification (ESC) decision support system to accommodate a wider range of species (see section 2.1), FCE and the Institute of Chartered Foresters jointly hosted a series of workshops in 2013 to highlight climate change issues to the sector and introduce them to the new version of ESC (version 3). The event was successful, with more than 110 professional foresters gaining first-hand experience of the tool. This partnership has continued with further events to raise the professional standards of foresters in England, focusing on the need for holistic management plans to ensure resilient managed woodlands. These workshops have subsequently reached an audience of over 700 foresters.

As awareness grew within the English forest industry other organisations, including the Confederation of Forest industries (Confor) and the Royal Forestry Society (RFS), have run their own workshops for members to encourage awareness of the challenges woodlands face and the need to implement species diversification and other adaptation measures.

During 2015 ESC v3 was accessed nearly 5,000 times and its use is now integrated into forestry courses at Stirling, Inverness, Bangor, Newton Rigg as well as smaller learning institutions. Guidance for practitioners continues to be developed and refined to support the woodland options within the Countryside Stewardship grants scheme.

To give practitioners confidence in the performance of some of the lesser used tree species, FCE co-sponsored the Sylva Foundation to develop an internet site – Silvifuture²² – to host a database giving details of individual stands of minor species and a 'blog facility' to share knowledge and encourage debate.

To facilitate the sharing of knowledge and create an iterative learning platform, FCE has also developed a members-only LinkedIn site exploring issues around adaptation to climate change and resilience in silviculture. The ICF and the RFS have also initiated their own blogs to encourage members to have similar discussions.

All Forestry Commission Area teams have run tree health seminars and a significant effort has been made to train Forestry Commission staff on practical ways they can mitigate the risk of spreading disease around the country through their actions.

Sector activity

This work brought together a partnership of major forestry stakeholders to discuss resilience in its widest sense and how the industry could develop an action plan going forward. After several small meetings a major workshop, facilitated by the Environment

²² Silvifuture internet site. <http://www.silvifuture.org.uk/>

Agency's Climate Ready team, met in June 2014 to agree a way forward. The partnership agreed:

- A high level sector statement (incorporating previous work), reflecting one voice across the industry;
- 'Adaptation in Action' statements to allow each organisation to express its own objectives and approach to adaptation;
- A small team involving former members of the EWTP Climate Change working group to take forward the initial work.

As a result of this initiative, the Forestry Sector Climate Change Accord 2015²³ was launched at the CLA Game Fair on July 31st 2015. Speaking at its launch, Environment Minister Rory Stewart said:

"Building our resilience to climate change is important for everyone. That's why we developed the first National Adaptation Programme report setting out actions for government, businesses, local councils and communities. It's crucial we take the changing climate into account in all our decision making and I congratulate the forestry industry on these proposals. By ensuring we manage our woodlands carefully and plant more diverse species we can improve the resilience of our forests and safeguard them from the risks posed by climate change."

The Accord sets out common themes across a wide partnership of organisations that environmental change is impacting our woodlands, and that fundamental change in management is necessary. A series of 'Adaptation in Action' statements from a number of organisations accompanied the Accord, outlining their specific stance, activities and intended outcomes.

The partnership was conscious that there was no benchmark to assess the current stance of the sector on environmental change, and to measure progress against. The partnership used the Accord to launch the 2015 British Woodlands Resilience Survey²⁴. The results of the survey were published in late 2015 following a conference²⁵ on resilience organised by the Woodland Trust and Royal Forestry Society in October 2015.

Tree Health engagement

Our aims have been (1) to promote collaborative action by the tree, woodland and forestry community to maintain a healthy and resilient plant sector; by providing up-to-date guidance in dealing with specific pests and diseases and on planting resilient landscapes; and (2) increasing awareness and understanding of the importance of tree

²³ Forestry Sector Climate Change Accord. <http://sylva.org.uk/forestryhorizons/environmental-change>

²⁴ 2015 British Woodlands Resilience Survey. <https://sylva.org.uk/forestryhorizons/bws2015>

²⁵ Resilient Woodlands: Meeting the Challenges conference presentations. <http://www.rfs.org.uk/events/conferences-and-seminars/rfs-conference-2015-presentations/>

health within the 'engaged public', by working with NGOs and membership organisations across the sector and through proactively sharing information with the industry.

In terms of specific biosecurity engagement - The Forestry Commission Plant Health team in England has employed two Biosecurity Officers, each with a separate focus: arboriculture/urban and forestry. The main focus will be on the actions listed in the Raising Awareness and Involvement and Biosecurity Consortium sections of the UK Plant Biosecurity Strategy. Both posts have been working closely with the FCGB Plant Health team, FCE's Policy Advice team and DEFRA colleagues. Their main focus has been intelligence gathering and engagement with industry, providing technical advice on biosecurity issues, so providing stronger links to practitioners in arboricultural and forestry sectors. The Biosecurity Officers have also provided improved arboricultural capability in outbreak management situations.

Wildfire engagement

In October 2014, Forestry Commission England undertook a wildfire prevention workshop in partnership with Hampshire Fire and Rescue Service to address forestry and open habitat risks. The workshop engaged a wide range of delegates including land managers and Fire and Rescue Service staff. The workshop was based around the Forestry Commission's Practice Guide *Building Wildfire Resilience in Forestry Management Planning*. The workshop was strongly supported by delegates, highlighting the need for partnership working between Fire and Rescue Services and land managers.

Forestry Commission's Wildfire Practice Guidance is also the reference guide for Countryside Stewardship options for lowland and upland heathland management.

4.2.4 Embedding adaptation in forestry regulations and grants

Forestry regulations

No amendments have been made to forestry regulations since the publication of the first round ARP report. However, the way in which forestry regulations are applied are currently being assessed with a view to increasing the rate of woodland creation (Durham EIA pilot) and the proportion of England's woodlands in active management (Earned Recognition pilot). Although neither initiative is focussed on climate change adaptation, woodland creation will enhance the resilience of the overall woodland resource, while woodland management is required for adaptation measures to be implemented in existing woodlands.

The 'Durham EIA Pilot' (as set out in the 2013 Forestry and Woodlands Policy Statement) aims to: *Develop a strategic screening process, working within the existing regulatory framework and associated environmental standards, which will identify appropriate areas for woodland creation where there would be a presumption in favour of planting. The pilot will also consider whether there are other aspects of the current regulatory and consultation processes for woodland creation that are not needed to ensure*

environmental and social benefits but do deter landowners from bringing proposals forward.

This aim of the project has been translated into a more practical task: *to identify how communication, best practice in woodland design, the provision of a strategic view on woodland creation and information sharing can help clarify understanding of both why, and in what situations, an Environmental Impact Assessment (EIA) may be required – and where one is unlikely to be called in.*

The objective of the 'Earned Recognition' pilot undertaken in Southwest England was to develop a process through which forestry agents with a good track record in preparing woodland management plans could 'self-certify' the plans that they write, reducing the delay (and cost to Forest Services) associated with FS Woodland Officers having to sign off every management plan.

Wildfire EIA Operations Note

Building on from the risk of wildfire identified in the Open Habitats Policy, Forestry Commission England, in partnership with the Chief Fire Officers Association and Fire Brigades Union, drafted an Operations Note for FCE staff to ensure wildfire risk is clearly addressed in relevant stages (Screening, Scoping, Environmental Statement, Decision and Review) of an Environmental Impact Assessment where deforestation occurs to re-create Priority Open Habitat. The Operations Note builds on lessons learned and engagement with a wide range of stakeholders.

English Woodland Grant Scheme (EWGS)

Little further progress was possible in embedding adaptation in EWGS following publication of FCE's ARP1 report, as the scheme was due to close in 2014 (being replaced by Countryside Stewardship grants in the 2014-20 Rural Development Programme). However, in the final two years of the scheme, woodland creation grants were targeted to contribute to flood alleviation (alongside improvements in water quality). 1,200 ha of woodland was planted in areas targeted for flood alleviation, with the majority in Yorkshire and the Northeast, where Forest services worked in partnership with the Environment Agency funding a dedicated 'Woodlands for Water' post.

Countryside Stewardship Woodland Creation Grant (WCG)

Adaptation was embedded in Countryside Stewardship forestry grants developed as part of the EU co-financed Rural Development for England, 2014-2020. Specific adaptation measures for the Woodland Creation Grant are set out below:

- UKFS requirements for species choice (using Ecological Site Classification to predict productivity) apply;
- Targeting to contribute to flood alleviation;
- Additional 'points' for riparian woodland where EA shade mapping ('Keeping rivers cool') indicate lack of riparian tree cover;

- Targeting to increase the size (and resilience) of existing woodland priority habitat;
- Additional points for larger (and, therefore, more resilient) woodland.

Countryside Stewardship woodland grants

The contribution of each of the Rural Development Programme's forestry measures to adaptation and resilience was also evaluated as part of scheme development:

a) Provide incentives and advice to support the creation of new woodland

Requirements for species diversity and choice could be used to ensure that new woodlands are adapted to the future climate, increasing the overall resilience of the woodland resource (UKFS). Where new woodlands expand existing woodlands, they are likely to increase their overall resilience; the same outcome is likely where new woodlands increase landscape connectivity (Lawton Review and UKFS).

b) Provide advice, guidance and incentives to improve the management of woodlands, particularly to make them less susceptible to the impacts of climate change, natural disasters, disease etc.

Adaptation of existing woodlands can only proceed if they are in management (including the conscious decision of non-intervention). Management (including of deer and squirrel) will: enhance regeneration and evolutionary adaptation; potentially enable conversion to continuous cover systems of management; present opportunities for species diversification and choice through under-planting or at restocking; and allow upgrading of forest infrastructure (roads, bridges, culverts, dams) to account for projected changes in the climate (UKFS). The requirement for a UKFS-compliant management plan will also ensure that climate change projections are a consideration of planning and management.

c) Provide advice and support to enable the restoration of woodlands affected by natural disasters (including pest and disease outbreaks)

The first UK Climate Change Risk Assessment highlighted the combined risk from climate change and pest and disease outbreaks to the forestry sector. Restocking provides opportunities for species diversification and the choice of species that are likely to be better adapted to the future climate.

d) Provide advice and support to farmers and land managers to restore the historic environment

The restoration and expansion of traditional woodlands and systems of management (wood pasture, coppice, veteran trees) is likely to reduce other pressures on them and so promote adaptation (Defra Adaptation Principles), particularly where this leads to an increase in the area of woodland in active management.

e) Support and advice for forestry business development and business planning

Will promote adaptation if support leads to a larger area of woodland in management (see b, above).

f) Support and advice for setting up Forestry producer groups and co-operative activity between groups

Will promote adaptation if support leads to a larger area of woodland in management (see b, above).

g) Support for capital investment to increase uptake of innovative practices/ new technology in the Forestry Industry

Will promote adaptation if support leads to a larger area of woodland in management (see b, above), through funding harvesting and primary processing equipment.

h) Provide advice to increase uptake of innovative practices/ new technology in the Forestry Industry

Will promote adaptation if support leads to a larger area of woodland in management (see b, above).

i) Support the provision of advice and training to develop business, management and marketing skills in the Forestry Industry

A lack of skills (including basic silviculture) and understanding of climate change issues has been identified as a major barrier to the implementation of adaptation measures in the forestry sector (FCE first round ARP report). This measure will help to address the barrier.

j) Support investment in physical assets to improve forestry performance

Potentially provides support for upgrading forest infrastructure (roads, bridges, culverts, dams) to account for climate change projections (particularly increased winter rainfall).

k) Support training, advice and knowledge transfer activities aimed at improving supply chains in the forestry industry

Will promote adaptation if support leads to a larger area of woodland in management (see b, above).

4.2.5 Implementing the Climate Change Action Plan for the Public Forest Estate

One of the key successes of the Climate Change Action Plan for the Public Forest Estate 2011-16 was the level of awareness that it raised across the business. It served to promote thinking about the impacts of a changing climate and, in turn, to drive business activities to mitigate the impacts. The result is that consciousness for the need for change now permeates all aspects of the organisation and the revised Climate Change Action Plan for the future will seek to build on this understanding. This heightened awareness, alongside the pressure of increasing threats from pests and diseases, has driven significant change, particularly in the practice of adaptive forests management and increasing species diversity. In the future, much of this work is considered as part of a wider framework of forest resilience, considering the health of the whole ecosystem and ensuring its sustainability into the future.

Adaptive Forest Management

To ensure that the Public Forest Estate is resilient to future changes in climate and associated extreme events adaptive forest management is required. This has been pursued as part of the continuous cover forestry (CCF) approach which further increases resilience to change and reduces the potential for adverse environmental impacts associated with clear-fell (e.g. loss of soil, soil-carbon and soil biodiversity). Almost 350 staff have attended courses on CCF and, as a result of this greater awareness, the proportion of the Public Forest Estate managed as alternatives to clear-fell has increased from 26.6% to 30.1% between April 2011 and April 2015. The benefit of such an approach is that demand for restocking is reduced and instead natural regeneration is managed to become the future forest cover. This reduces the area of bare soil and associated impacts and, instead, *de facto* results in a species composition and canopy that is suited to the site.

Sustainability of the Public Forest Estate

UK Woodland Assurance Standard Certification enables the PFE to market timber products as *FSC and PEFC certified*. In order to meet the standard a number of broad-ranging requirements have to be met that include the UKFS and associated Climate Change. Since 1999 the Public Forest Estate has been independently certified and this has been maintained to the present. A number of commendations have been received during the independent audits against the UKWAS Standard. These include trialling the performance of alternative forestry species such as Macedonian pine along with increasing the level of partnership working with FR to respond to pest and disease outbreaks. FEE's continued certification to the UKWAS standard is demonstration of both the organisation's commitment to meeting sustainability requirements and confirmation of the execution of its duties.

Increasing species diversity

Increasing species diversity is fundamental to adapting the Public Forest Estate to a changing climate and also to mitigate the impacts of an increasing number of forest pests and diseases and the changing site conditions such as drought in the East of England. In order to increase species diversity, a wide range of alternative species are being planted as part of the conventional restocking programme. In total, 18 new minor forestry species were requested from nurseries since 2005 comprising 5.5% of the total area of conifers planted in 2015. In addition, increasing areas are being under-planted to allow successful establishment of more sensitive forest species that would not be possible to establish in open conditions. The award-winning work carried out in Thetford forest demonstrates the impact of the work on the estate and its role as an exemplar of best practice for the industry.

Forest health

One of the most significant risks to forest health is the impact of pests and diseases that may be inextricably linked to climate change. The prevalence of warmer and wetter conditions creates an environment suitable for many wind-based pathogens to spread rapidly and the more likely occurrence of drought conditions increases the stress for trees and increases the risk of infection. Some pests and diseases can be contained, others require particular forest management techniques to reduce their impact while a proportion simply cannot be controlled. A number of forest health days have been organised on the Public Forest Estate to highlight the risks associated with the current pests and diseases as well as raise awareness of potential future issues and the management techniques that can be applied to reduce their impact. A minimum of 2 days per district have been held since 2013 with at least 30 people attending at each event.

Fire resilience

Fire resilience mapping and adaptation work has been trialled in South Forest District and recommendations for roll-out are being considered as part of the revision of forest planning guidance taking place in 2016. The risk of extensive fire damage is most acute within the South and therefore work to date has concentrated in this area. However, the lessons learned are expected to be shared more widely in due course.

Sustainable Water Management

The management of water on the Public Forest Estate has come into sharp relief in recent years, both in terms of its role in retaining water as part of wider water catchment management and flood prevention downstream and also in terms of ensuring the existing infrastructure can accommodate future anticipated volumes. All new or revised infrastructure is built following the Centre for Hydrology's 'Flood Estimation Handbook' and associated software that takes into account latest information and climate change models on flood design. This helps ensure infrastructure has the capacity to accommodate increases in precipitation. Since 2011, 12 reservoirs have had maintenance worked carried out on them, 4 of which were substantially rebuilt with increased spillway capacities to accommodate greater floor events; the total spend amounts to £375k. In addition, the 'Slowing the Flow' project in Pickering see PFE case study 1 on next page) highlights the work that has taken place to retain water on the estate in order to manage peak flows and reduce the likelihood of flooding for communities downstream. The lessons learned from this project are presently being considered in other areas to enhance the role of the Public Forest Estate in the wider water catchment.

Case studies of adaptation in action on the Public Forest Estate

PFE CASE STUDY 1: SLOWING THE FLOW AT PICKERING

'Slowing the Flow' at Pickering is exploring a new approach to flood management. It is about working with nature to store more water in the landscape and slow its passage downstream. Whilst this will not prevent all flooding, it is expected to reduce the frequency of future floods in Pickering, as well as deliver a range of other benefits to the local environment and community. The project was developed through partnership working with agencies, land owners, communities and research organisations, including:

- Forest Research;
- Environment Agency
- Natural England
- North York Moors National Park Association
- Durham University
- Ministry of Defence
- Duchy of Lancaster
- North York Moors Railway



Flood alleviation has been achieved by working with natural processes on the Public Forest Estate. 167 small-scale 'leaky' woody dams were established across 44 ha of forest catchment, including recently clear-felled sites to reduce the peak discharge, thereby reducing flow through Pickering town. Two large timber bunds were also constructed within the forest, contributing to other measures within the catchment, including woodland creation, improved farmland, moorland and woodland management and the creation of a natural flood area above the town.

A detailed analysis of the Boxing Day 2015 flood event in relation to previous peak flows, concluded that the Slowing the Flow project measures prevented flooding that would otherwise have occurred to a small number of residential properties and the museum in the Beck Isle area of Pickering. The results suggest that the measures reduced the peak flow by 15-20%. It is difficult to separate the contributions from the different measures but based on the extent of inflows to the flood storage area, it is estimated that around half of the reduction was due to the upstream land management measures and half due to the flood storage area.

PUBLIC FOREST ESTATE CASE STUDY 2: UNDER-PLANTING OF THINNED CORSICAN PINE CROPS FOR *DOTHISTROMA* NEEDLE BLIGHT AND CLIMATE CHANGE ADAPTATION IN THETFORD FOREST**Managing *Dothistroma* Needle Blight in Corsican pine through thinning.**

There is increasing evidence that some 17–20 year old Corsican pine (CP) is suffering increased mortality on heavily infected *Dothistroma* Needle Blight (DNB) sites, mainly from secondary pathogens. Forest Research (FR) colleagues have advocated that increasing air flow through such crops, by heavy early thinning, may be able to prevent this premature death. Conventionally these CP crops were not thinned until at least 22 years old, using rack and matrix systems. However where there is abundant natural regeneration of Scots Pine within these crops the results of thinning are disappointing, costly and, due to the small diameter of the harvested logs, much unrecoverable material is left on site. East England Forest District (EEFD) has therefore been undertaking trials to assess whole tree harvesting methods and opportunities that such an approach may present for future management.

To date the amount of timber volume recovered is significantly better (c 100m³ per ha), income is increased and cost reduced. Although there is a moratorium on planting CP (since 2006) there is still a 12-year programme of first thinnings to be completed and the trial is currently delivering 100 hectares of thinning per annum. The sites are being under-planted using species tolerant of light and moisture deficits and resilience to climate change projections. Experience in the District has demonstrated that frost damage limits the range of species that can be planted. However the micro-climate under the canopy is significantly warmer and has enabled a greater range of species to be selected. This has resulted in new opportunities arising to increase species diversity and options for the future at a much lower cost than the scenario of forced premature clear-fell and subsequent establishment.

Aims and Objectives of the Trial

The main aim of this trial is to establish the right mix of tree species and silviculture required to efficiently and effectively produce an understory capable of succeeding the CP above, should it fail.

Specific Objectives: -

- Test performance of conifer species on a range of soil types under the canopy (Macedonian pine, Weymouth pine, Douglas-fir, Grand fir, European silver fir, western red cedar, Japanese cedar, coast redwood, Atlas cedar, Serbian spruce).
- Monitor impact of mammal pressure through using fenced and unfenced areas.
- Trial high and low stocking densities of under-planting to help understand the impact this has on tree survival.

Outcomes

Monitoring of the trails will be continued to establish which of the species are performing well under the canopy. At this early stage, what has become clear is that the manipulation of the over-storey is critical in controlling the ground vegetation and aiding establishment without recourse to herbicides. This trial marks an exciting piece of work for EEFD and early indications suggest that under-planting could be a cost effective way to manage the impact of DNB and impacts from climate change.

4.2.6 Adaptation indicator development

Although none of the indicators detailed below were developed in response to FCE's ARP1 report (and, indeed, some were pre-existing), they all provide either a baseline to monitor progress against or a time series giving an indication of woodland resilience or public/sector attitudes to resilience

Proportion of England's woodland area in management (FCE Corporate Indicator)

The percentage of woodland in active management has gradually increased since the April 2011 baseline of 52%, to 58% in September 2016. Some of this increase is due to a refinement of the methodology for this indicator to include previously under reported management plan areas. This indicator of woodland in management includes woodlands where management plans are in place and those that have received woodland grants or felling licences over the previous 5 to 10 years. However, it is recognised that other woodlands might also be considered as managed by their owners.

Number of tree pests and diseases established in England in the past 10 years (FCE Corporate Indicator)

Four tree pests and diseases have established since 2006 in England: oak processionary moth (OPM), alder rust, acute oak decline (AOD) and *Chalara* dieback of ash. The total is two less than in the 10 years preceding the April 2011 baseline date, as three earlier diseases have fallen out of the series and only *Chalara* dieback of ash has been added.

Number of high priority forest pests in the UK Plant Health Risk Register (UKPHRR²⁶)

In 2016, a new headline plant health indicator was added to FCE's Corporate Performance Indicators²⁷. The indicator reports trends in forest pests from the UK Plant Health Risk Register that records and rates risks to UK crops, trees, gardens and ecosystems from plant pests and pathogens. The individual ratings for Likelihood and Impact are each on a scale from 1 to 5. Likelihood times Impact ratings therefore can have values from a minimum of 1 to a maximum of 25. This indicator is used here to identify so called 'significant' forest pests, i.e. those with a threshold level of Likelihood x Impact Risk of 15 or more despite the mitigations in place to reduce their risk. The threshold of 15 was chosen to identify the 'higher risk' pests. The numbers of 'medium risk' pests with a mitigated likelihood times impact risk rating of 10 or more are also shown as context. Taking into account the economic, environmental and social importance of the host species, these risk scores are used to help prioritise additional actions to combat the threats posed by the pests. It should be noted that the data are for the UK. Nearly all forest pests present in the UK will also be present in England. those absent from the UK are very likely to pose a threat to England.

²⁶ UK Plant Health Risk Register – <https://secure.fera.defra.gov.uk/phiw/riskRegister/>

²⁷ FCE Corporate Performance Indicators. [http://www.forestry.gov.uk/pdf/FC-England-Indicators-Report-20163.pdf/\\$FILE/FC-England-Indicators-Report-20163.pdf](http://www.forestry.gov.uk/pdf/FC-England-Indicators-Report-20163.pdf/$FILE/FC-England-Indicators-Report-20163.pdf)

Measure of woodland resilience to climate change based on the size and spatial configuration of woodland patches within the landscape (FCE Corporate Indicator)

In this indicator, connectivity is a measure of the size and distribution of patches of forests and woodlands. Maintaining and improving connectivity is important in ensuring the long-term survival of biodiversity in a fragmented landscape, especially under a changing climate. This indicator of the resilience of English woodland to cope with climate change has gradually improved since March 2010 including an improvement in the most recent year. The indicator shows an increase in connectivity for forests and woodlands in England between 2010 and 2013. Over the same period there has been a corresponding increase in the area of forests and woodlands. The change in connectivity may be related to woodland size and changes in woodland pattern, or both.

Measure of the conservation condition of woodlands using information from the National Forest Inventory (NFI Official Statistic)

The indicator is based on sample square data from the National Forest Inventory and its development is being finalised. It is likely that woodland condition will be reported separately for native woodland (defined as a minimum of 80% native species for woodlands in England) and other woodlands, separately. First cycle results will be published in 2017 and, as with other NFI metrics, updated on a five-yearly basis. A decision is yet to be taken on whether interim results will be reported mid-way through the reporting cycle.

Wildfire indicator on Public Forest Estate and other public and private woodlands

This indicator reports the impact (area burnt, number of incidents and duration) of wildfire within forests and woodlands. It uses Department of Communities and Local Government supplied Incident Reporting System data provided by England's Fire and Rescue Services and the National Forest Inventory (NFI).

Diversity of tree species ordered from nurseries for planting on the Public Forest Estate

This indicator was first published in the Adaptation sub-Committee's 2013 progress report (*Managing land in a changing climate*). A time series has been constructed which pre-dates moratoria on the planting of ash and Corsican pine (resulting from *Chalara* and *Dothistroma* needle blight outbreaks, respectively). This indicator shows significant progress in species diversification across the Public Forest Estate.

Area of woodland created in areas targeted for flood risk management

This indicator reports the area of woodland created in areas that have been mapped as potentially benefitting from increased tree cover to contribute to flood risk management. The indicator therefore reports the contribution of woodland creation to societal resilience, rather than the resilience of the woodland or the forestry sector. The data-set is restricted to woodland creation funded through the Countryside Stewardship grant

scheme (Rural Development Programme) or its predecessor, the English Woodland Grant Scheme (from 2012, when spatial targeting for flood risk management was introduced).

British Woodland Survey 2015

Although the British Woodland Survey was not specifically developed as an indicator (see detail in Section 5.1), it provides a wealth of baseline information for constructing a future indicator of the attitudes towards climate change and uptake of adaptation measures. The Sector Partnership (see Section 4.3.1) will continue to evaluate the results of BWS2015 and identify the most appropriate information for developing a progress indicator.

Public Opinion Survey of Forestry (Forestry Statistics: Official Statistic)

This biennial survey reports public attitudes towards forestry and has included two sets of questions related to climate change since 2009, one set primarily relating to climate change mitigation and the other, on attitudes to adaptation and woodland management. Relevant questions and responses at the four survey points are given in Table 2.

Table 2. Selected climate change-related questions from the Public Opinion Survey of Forestry 2015 ([http://www.forestry.gov.uk/pdf/pof2015ukeng.pdf/\\$FILE/pof2015ukeng.pdf](http://www.forestry.gov.uk/pdf/pof2015ukeng.pdf/$FILE/pof2015ukeng.pdf)).

Statement	Percentage of English respondents in agreement			
	2009	2011	2013	2015
Planting more trees can help us cope with climate change by providing shade and reducing the effects of flooding	67	74	73	67
A lot more trees should be planted	92	90	85	78
More information should be provided about the ways in which wood can be used to lessen our impact on the environment	86	86	80	73
Different types of trees should be planted that will be more suited to future climates	70	74	71	67
Trees should not be felled in any circumstances, even if they are replaced	17	21	23	26
No action is needed, Let nature take its course	16	20	18	23
There is nothing that anyone could do that would make any difference	13	13	17	21

4.3 Details of new actions arising from this review

Table of actions: new actions		
Further or new actions planned	Risks addressed by action	Timescale for new actions
A revised Climate Change Action Plan for the Public Forest Estate will be published in 2016. The plan will both build on progress made in the previous CCAP and reflect the current vision of resilient forests of the future, as outlined previously (see Annex 2).	The updated CCAP will consider the developments made in the 2011-16 CCAP and will seek to build on the progress made. The risks to be addressed will cover the breadth of activities undertaken on the PFE from those affecting forest resilience to the PFE's role in sequestering carbon and the opportunities to reduce emissions in the functioning of the business.	To be drafted by end of 2016
FCE will publish a policy position statement in 2017 on the use of Forest Reproductive Material (both species and genetics) and its use to adapt to the changing climate.	Misunderstanding and consequent criticism of FCE's guidance on adaptation of the growing stock has led to confusion over appropriate actions on individual sites, in turn leading to limited implementation of actions to address the risks set out in section 2, as evidenced by the British Woodlands Survey 2015.	2017
FS will work with the Forestry Climate Change Working Group to facilitate the understanding and implementation of appropriate actions. Further details are provided in Section 4.3.1.	The lack of implementation of adaptation actions which has increased the vulnerability of English woodlands to the impacts of climate change.	2017-
FS's Contingency Planner will draft a recovery plan for extensive wildfires as part of wildfire contingency planning.	The plan will set out actions to ensure that the loss of woodland area is minimised, including through the development of a wildfire risk assessment which would be required for the deployment of Rural Development Programme funding. The plan will be based on Forestry Commission's Practice Guidance and link to Forest Services Major Wildfire Incident Contingency Plan. Wildfire risk will be monitored and disseminated using wildfire alerts and warnings from the Natural Hazards Partnership.	2017
Forest Services will create a Wildfire Risk Map.	While Forestry Commission has a database of wildfire incidents attended by Fire and Rescue Services. For regulation (EIA), forest management planning and future climate change modelling, we require a risk map of possible high threat sites and landscapes. Partnership work between University of Manchester, Forest Research and Forest Services has successfully demonstrated an approach used by Canada and New Zealand.	2017

FS will develop a contingency plan for drought, to cover impact, evaluation and recovery phases.	FS, working with Forest Research and the National Forest Inventory team, will develop a contingency plan for monitoring the impact of a future severe drought event and implementing necessary responses, to ensure that the sector as a whole can learn from such an event and enhance resilience.	2017
FS will work with Forest Research and Forest Enterprise England to develop 'climate change adaptation areas' to demonstrate several different types of adaptive practice in Alice Holt Forest. Initial work will select and include adaptation areas into the new AH Forest Design Plan.	Examples of climate change adaptation, for demonstration purposes, take time to come to fruition. The adaptation areas will demonstrate different measures and encourage the sector to incorporate adaptation to climate change into forest design and forestry best practice, thus operationalising the requirements of the UKFS Forests and Climate Change Guidelines.	2016- 18
FS will work with Forest Enterprise to embed Wildfire Management Plans into Forest Design Plans for woodlands and forests at most risk from severe wildfire in southern England.	Wildfire Management Plan drafted for Haldon Forest and Dartmoor FDP in partnership with FS Wildfire Subject Matter Adviser. Work is starting on New Forest's Open Habitats FDP.	2016 - 18
FS support Natural England to develop wildfire resilience in Countryside Stewardship mandatory options.	FS meeting with DEFRA and Natural England to define the requires for wildfire resilience within Countryside Stewardship (CS) options UP3 and 4 (Upland Management) using FC wildfire Practice Guide and case studies from FE Forest Design Plans. Work will start on using lessons learnt on CS Options LU1, 2 and 3 (Lowland Heath).	2016-17
FS will work with Forest Research to develop an annual growth indicator based on 'sentinel sites'.	At present, although there are networks of mensuration permanent sample plots and forest intensive monitoring sites together with the five-year field sampling programme associated with the National Forest Inventory, growth data are not collected at an annual time-step. The development of an annual growth indicator for 'sentinel sites' would enable the impacts of inter-annual weather variability to be analysed and the impact of climate change on the forest/tree growth to be evaluated.	By 2020
FS will ensure that climate change impacts and adaptation remains at the heart of the Science and Innovation Strategy for Forestry in Britain (SIS).	The SIS sets the direction for forestry research in Britain to 2020. Research commissioning and governance processes, together with the future status of Forest Research are currently under review through the cross-border Forestry Governance project. FS and FEE will ensure that adaptation remains at the heart of forestry research to address the risks identified in ARP1 and CCRA2, as set out in Section 2.	2016-20

FS will develop Tree health Incident Management Plans in line with the requirements of the National Plant Health Contingency Plan (being reviewed / developed by Defra).	FS Tree Health team working in collaboration with Defra and APHA, will develop a specification for implementing responses, to ensure that the sector as a whole can learn from pest and disease outbreak events and enhance future resilience.	By 2017
FS to develop a Tree Health strategic and operational assessment of response options to improve decision-making for Operations Commanders during incidents.	FS Contingency planner is working with the Tree Health team to define assessment of options based on framework contracts and experience of previous incidents.	2017
FS to work with DEFRA to finalise the DEFRA Generic Contingency Plan for Plant and Bee Health.	FS Contingency planner and Tree Health working with DEFRA to ensure inter-operability and clear reporting processing between various agencies and organisations.	2016-17
FS will work with FR to test susceptibility/resistance to pest and disease outbreaks.	Develop a rapid experimental approach to test the susceptibility of a range of tree species to novel pests and diseases.	By 2020

4.3.1 Sector partnership

The British Woodland Survey 2015 demonstrated that progress has been made in raising awareness with forestry professionals about the environmental challenges facing our woodlands face. This is only now starting to affect behaviour. However woodland owners have not made the connection between immediate environmental issues such as increasingly negative impacts from pest and disease outbreaks, and the need to build resilience into their woodlands. If this connection is not made then woodlands will be not be brought into management quickly enough maintain resilience to the environmental change.

The need for species diversification as insurance for resilient woodlands is now widely understood by foresters and starting to be implemented. However the use of more southerly genetics within forest reproductive material to make woodlands more resilient has not yet been mainstreamed. There is a risk that the forestry sector does not act promptly on emerging evidence through implementing adaptive management. By securing a cross sector partnership, built on the Climate Change Accord and the base-line from the BWS2015, a platform of communication and actions can be established.

The partnership (the Forestry Climate Change Working Group) will respond to the limited implementation of adaptation actions which has enhanced the vulnerability of the sector, through the following actions/activities:

- We will continue to work with the partners that created the 'Climate Change Accord', and have formalised the partnership during 2016 to develop a cross industry action plan to ensure adaption to climate change is based on sound evidence.

- We will foster an atmosphere which encourages open and honest discussion about the environmental challenges facing our sector by being quick to share intelligence, and offering freely accessible expertise;
- We will work with Forest Research and partners to improve the evidence base concerning understanding and motivations among private owners relating to climate change and resilience;
- We will work with our partners to raise the standards of management plans, ensuring that contingency planning for pest/disease, wildfire, floods, droughts and storms are developed
- We will work with contingency planning and emergency service stakeholders to ensure forestry and woodland is appropriately and well placed to build future resilience.
- We will work with the England and Wales Wildfire Forum and its members, as well as local Wildfire Groups to ensure forestry and woodlands are appropriately adapted for future wildfire threats.
- We will work with the DEFRA Contingency Planning Forum to ensure Forestry Commission England is well positioned to improve the resilience of forests and woodlands, including partnership working with the Animal and Plant Health Agency, Environment Agency and Natural England.
- We will work with the CLA, RICS, RFS Sylva and others with a strong connection to woodland owners to establish the best ways of reaching this audience, and jointly influencing their behaviours.
- We will assist the Future Trees Trust, nurseries and partners to develop a resilient native tree resource in the UK, and seek the globally most appropriate seed sources for exotic species.
- We will work with the PFE and the private sector to develop model demonstration resilient woodlands to influence actions across the forestry sector.

4.3.2 Update to Climate Change Action Plan for the Public Forest Estate

The current FEE Climate Change Action Plan expires in 2016 and the revision provides an opportunity to reflect on progress made on previous commitments and refresh future commitments in light of enhanced scientific understanding of climate change impacts for forestry. The revision of FEE's operational guidance, transitioning to a new guidance framework from April 2017, also provides the opportunity to revise the format of the Action Plan in line with new corporate structures. The format of revised Climate Change 'Policy, Procedures and Guidance' (PPG) in line with this new framework is proposed and outlined below, along with background to some of the possible content.

Review of previous CCAP

The progress made under the previous CCAP, running from 2011 to 2016, is summarised below, along with a review of strengths and weaknesses to inform development of the next plan:

- Increased understanding and awareness of climate change amongst staff was the most significant achievement of the last action plan – raising the profile of the issues resulting from climate change;
- The increase in alternative forestry species being planted on the estate is testament to the awareness raised by the previous plan as well as the increased use of continuous cover systems of management;
- Not all of the 18 activity streams have been delivered as set out in the summary at the end of the document nor has the annual monitoring taken place within districts as expected.
- The document itself is 20 pages long and if more concise could increase level of engagement with the desired activities.

Objectives for revised Climate Change PPG

Based on experiences and progress made over the past 5 years forthcoming climate change documentation will aim to meet the following objectives:

- Use the most up to date and relevant scientific evidence to inform action;
- Provide clear direction on a small number of nationally driven activities that are SMART (specific, measurable, achievable, realistic and time-bounded);
- Set a framework of principles to inform district specific climate change / forest resilience action plans based on enhanced thinking around 'future forests types';
- The two main drivers of the framework will be to inform adaptation activities through ISO14001 Environmental Management process and mitigation through forest management activities;
- The national climate change PPG document will be as brief as possible.

Format of revised climate change policy

FEE's future climate change approach will be set out within a 'Policy, Procedures and Guidance' document in line with the new guidance framework being put in place from April 2017 onwards. In order to meet the objectives set for the revised documentation and new format it will have the following structure:

1. Principle and Essentials for staff to follow;
2. Introduction: summary of progress and statement of future intent;
3. Legislation, UKFS, UKWAS and corporate expectations regarding Climate Change;
4. Climate Change forecasts and implications for forestry;
5. FEE national objectives and principles for district actions, both adaptation and mitigation, outlining a new framework for thinking about future forests;
6. Monitoring of progress.

5. Appraisal of barriers and inter-dependencies

The principal barriers and interdependencies relating to adaptation are addressed in Section 2.3 on new priority risks, which have emerged as a result of barriers to implementation of adaptation actions. The barriers are broadly covered under the headings:

- **Uncertainty** – leading to resistance to adopting alternative approaches to woodland management.
- **Timeframe** – forest planning and management function over the time-frame of decades; as a consequence forestry advisers, woodland managers and woodland owners are reticent to make rapid and significant changes to forest management.
- **Lack of confidence** – to some extent, adaptation measures are ‘stepping into the dark’ requiring a high degree of confidence that the actions are appropriate. This is a particular change for advisers, including FC Woodland Officers, when advocating change in management/planting stock for private sector owners, particularly if such actions are counter to ‘perceived wisdom’ or existing practice and policy.
- **Policy conflicts** – there is a perception that many of the adaptation measures being advocated, particularly over planting stock, run counter to existing/past policies. In some cases, this is a misreading of guidance, while in others, there is an urgent need to adapt planting stock to meet future challenges.
- **Lack of ‘adapted planting stock’** – this is a real barrier, as set out in Section 2.3, and will only be addressed if the sector places orders for adapted planting stock early, to give the nursery sector the time to raise the plants and confidence that there is demand for the trees; in effect, there is a miss-match of supply and demand.
- **Cost** – to date, cost appears to be a minor barrier, with the exception of the commercial forestry sector, where increased establishment costs and the likelihood of lower productivity are both deterring growers from species diversification. This is particularly the case in the uplands, where Sitka spruce continues to dominate both restocking and new planting.
- **Market uncertainty** – growers are reticent to diversify planting stock as they are uncertain of future market demand for ‘minor species’ and are concerned that small volumes of a range of minor species will not be marketable.

Many of the barriers outlined above are evidenced in the British Woodlands Resilience Survey, summarised in Section 5.1.

5.1 Evaluation of sector progress and barriers: British Woodlands Resilience Survey 2015

The British Woodlands Resilience Survey 2015 was launched in summer 2015 (see Section 4.2.3) providing a benchmark for the views of different components of the woodland and forestry sector on resilience and environmental change. The Survey highlights the barriers to progress in embracing adaptation across the sector and has been summarised below for this reason. Most of the barriers and actions to address them are explored elsewhere in this review.

5.1.1 Sector attitude towards climate change

The British woodlands survey 2015 reported that among all respondents, 52% believed that the climate is changing to such an extent that it will affect UK forests in the future. However, there was a high degree of uncertainty among 34% of respondents, while only 14% believe the climate change would not affect UK forests. There was more uncertainty among woodland owners than professionals: 45% of owners believed that climate change will affect forests and 55% of owners were uncertain or disagreed with the statement.

90% of respondents reported observing at least one form of environmental change in the last 10 years, with impacts from vertebrate pest such as deer and squirrels most cited by woodland owners, while pathogens and pests were most commonly reported by forest professionals. Among those reporting an increase in environmental impact over recent years, there was a clear relationship between the number of impacts observed and the proportion of those who believe that climate change will impact the UK's forests in the future.

5.1.2 Key Findings

1. Overall, accordance of actions with guidelines for adaptation within the UK Forestry Standard is currently low.
2. High awareness among woodland stewards of environmental change impacts may provide new opportunities to engage with woodland managers, particularly if focussed around issues of direct and local relevance.
3. Professionals and agents were generally more aware and active in implementing adaptation measures than owners, indicating that existing sources of information and outreach activities among these groups are effective.
4. Lack of information and advice available to woodland owners and managers to help them respond to existing and emerging threats surfaced as a key issue. A number of owners expressed a view that subjects covered by the survey were too technical. Existing assumptions concerning comprehension and knowledge of adaptation and resilience may be unrealistic.

5. A dearth of contingency plans among owners and managers to deal with major events such as fire, pest and disease outbreaks, and extreme weather, is of considerable concern.
6. Low awareness of climate projections for their locality, together with lack of knowledge of soils, means that most woodland stewards are unaware of the potential impacts of environmental change. Most owners have not reviewed future species suitability and are therefore unaware of the potential for creating more resilient forests.
7. Uncertainty around the concept of provenance, improved material and genetic diversity points to a requirement for improvements in education.
8. Low levels of awareness and action in relation to biosecurity among owners, which was only marginally better among professional foresters, could involve a review of the feasibility of recommended approaches, an assessment of risks and feed into predictive modelling.
9. Targeted funding to support actions which might benefit the resilience of woodlands, particularly pest management and control, would be highly beneficial.
10. Many of the actions for increasing resilience will flow from good management planning and levels of understanding of the issues, both of which appear to be insufficient.

5.1.3 Interpretation of BWS15 to inform FCE's actions for addressing barriers to adaptation

Most of the outreach and guidance work to date has been focused on forestry professionals and 70% of this group believe that the climate is changing to such an extent that it will affect UK forests in the future. The fact that professionals within the industry are recognising the need to adapt to climate change and make significant changes to current silvicultural practice is best demonstrated through the climate change Accord signed in the summer of 2015. However, it is of concern that only 45% of woodland owners have the belief that climate is changing to such an extent that will substantially affect forests. A further 37% were uncertain and it is possible that FCE's outreach and guidance may not have reached this group. The 18% who do not believe climate change will affect their woodlands may be individuals in denial of climate change and therefore outside of our influence to change behaviour.

A quote from the survey highlights where information provision can be improved: *"There is loads of info out there. The trouble can be finding it. The FC website has tons of really good info, but their website is appallingly difficult to use, and find the info you want"*. The outreach programme will address and improve information provision, working with key stakeholders.

Implications for outreach programme

- There still is a significant percentage, 25%, of forestry professionals who are still uncertain about the impacts of a changing climate. The current survey does not identify whether this audience is spread across the forest industry or possibly located within areas where climate change is not predicted to have a negative impact such as the West Coast of Scotland. There is therefore a need to continue working with forestry professionals.
- It is clear from the survey, however, that there is a very significant audience of woodland owners and agents who still can be influenced to change behaviours. This may well mean that our current efforts should be directed through channels currently under-exploited such as the Royal Institute of Chartered Surveyors and the Country Landowners and Business Association (CLA).
- Whilst significant effort has been made to compile a resource of advice on the Forestry Commission website it is clear that further work is required to make this easily available to forestry professionals, agents, woodland owners and all involved in the forestry sector. It is likely that this will involve closer working with sector organisations with an educational remit, including through the Forestry Climate Change Working Group.

5.2 Evaluation of progress and barriers on the Public Forest Estate

One of the most significant barriers to enhancing species diversity on the Public Forest Estate, to date, has been the suite of issues around nurseries meeting the demand for alternative forestry species desired by forest districts. In 2015 the nurseries were only able to supply half of the alternative forestry species plants requested. The sourcing of new seed, the techniques for germination and onward planting and success rates and associated high costs for each step have meant that supply has been unable to meet demand and therefore progress has been hindered. FEE's long-term forecasting of species demand has assisted in overcoming this barrier, demonstrating a long-term commitment to certain species and allowing the nurseries to develop the knowledge and infrastructure required for minor species with certainty, within the supply chain. However, more progress in the knowledge of nurseries in the production of such species is needed in order for the demand for to be met. The significant progress that has been made in the past 5 years, however, demonstrates what can be achieved. It is expected, therefore, that with an on-going commitment from the PFE the economics will continue to improve and what are presently deemed 'alternative species' will form part of the standard business model.

6. Appraisal of mechanisms to monitor and evaluate

Climate change adaptation has been embedded across the organisation as business as usual, rather than as a bespoke, activity. Where climate change adaptation is treated as a specific activity, evaluation mechanisms are outlined below:

The Climate Change Action Plan for the Public Forest Estate: Progress and effectiveness of implementation will be considered at the five-yearly review due in late 2016. The effectiveness of the actions set out in the Plan will also be considered against the principles of sustainable forest management at the biennial certification review against the UK Woodland Assurance Standard (UKWAS) by the Forest Stewardship Council.

Sector resilience outreach activity: The efficacy of the sector outreach Programme will be evaluated against the baseline British Woodland Resilience Survey in 2015, when it is repeated (date to be confirmed). For those aspects of the programme relevant to the general public, the biennial Survey of Public Opinion of Forestry provides a route to evaluating the effectiveness of the Programme.

Adaptation in the Rural Development Programme: The effectiveness of climate change measures in the Rural Development Programme (Countryside Stewardship) will be reviewed at the Programme's mid-term review in 2017, and the findings incorporated into any domestic successor scheme that is developed following the decision that the UK will leave the European Union.

At this stage, it is therefore not possible to review the effectiveness of evaluation or monitoring.

There is no further monitoring or evaluation of risks or measures to address those risks, outside the actions listed above and through the indicators that have been developed (Section 4.2.6) or are in development. Where relevant, the effectiveness of actions to address climate risks is evaluated in the review of progress in Section 3.

7. Opportunities and benefits

Given the long time-frame associated with forest planning and management, it is not possible to identify opportunities or benefits deriving from each of the actions in the outline adaptation programme presented in the ARP1 report. Interdependencies were covered in detail in FCE's ARP1 report; the analysis holds and is not repeated in this review.

However, there are two areas where the implementation of adaptation measures has had synergies with other programmes of work:

- 1) Species diversification in response to recent plant health concerns has been strengthened by initiatives to increase species diversity as an adaptation measure, both on and off the Public Forest Estate.
- 2) Opportunities for woodland creation and in-forest measures in existing woodlands (see Pickering Slowing the Flow case study in Section 4.2.5) were identified in the ARP1 report as an adaptation measure. This has put FCE in a good position to respond positively to recent flooding events, for example through the Cumbria Floods Partnership^{28,29} in early 2016.

²⁸ Opportunity mapping for flood alleviation: <http://www.forestry.gov.uk/fr/infd-7t9jrd>

²⁹ Briefing on woodlands and flood risk management: [http://www.forestry.gov.uk/pdf/FR_WoodlandsandFRM_briefing240216.pdf/\\$FILE/FR_WoodlandsandFRM_briefing240216.pdf](http://www.forestry.gov.uk/pdf/FR_WoodlandsandFRM_briefing240216.pdf/$FILE/FR_WoodlandsandFRM_briefing240216.pdf).

Annex 1: Process Appraisal

1. How have things changed within your sector/organisation?

Do you think the reporting process has influenced the way in which your sector/organisation has operated since submission of first round reports? If so how?

It is difficult to say whether the reporting process has been the main driver for the way in which climate change adaptation is approached within FC England, or whether the changes have been incremental, responding to a better understanding of climate change issues across the organisation.

The main change that we have seen is that adaptation is better integrated across the organisation's work with improved understanding by colleagues across the organisation. Our view is that this improved integration is a result of: (a) climate change being a component of all three of our delivery programmes rather than as a programme in its own right; (b) an outcome of having a post dedicated to adaptation/resilience communications/outreach; (c) the drive for 'resilience measures' being strengthened by the series of pest and disease outbreaks that have occurred since the first round report was published and (d) a function of time and exposure to climate change issues.

Do you consider that the Adaptation Reporting Power process has benefitted your sector/organisation? If so how?

It has benefitted the organisation to a limited extent, primarily though raising the profile of adaptation with the England National Committee through three presentations based on the actions and implications of the first round report.

Do you think the Adaptation Reporting Power process has led to any negative consequences? If so, what and how?

There may be a perception that the approach is overly process-driven, acting as a barrier to implementing the necessary and straightforward actions. However, evidence is limited as the report was not widely circulated to avoid 'process over-load'.

What new information has come to light since the submission of first round reports that has required an adaptation response? For example, new functions/roles within the organisation, new data filling information gaps, new methodologies / technology to deal with uncertainties.

The most significant change since the first round report was published has been the increased incidence of pest and disease outbreaks, highlighting the need for better bio-security, alternative forestry practices and greater diversity of species and genetics. The subtle shift in how climate change projections are communicated – moving from hotter drier summers and milder wetter winters to more extreme weather within those same general trends – has necessitated a slightly different approach to communicating the need to adapt; the new approach focuses on the need to adapt to extreme years rather

than a change in the mean climate. However, there has been consistency in the adaptation actions required.

Has the current risk appetite within your sector/organisation changed on account of the climate change risks and impacts identified?

There is a divergence within the sector on risk appetite as demonstrated by the results of the 2015 British Woodlands Resilience Survey. Forestry agents appear to be willing to take on the risk of planting alternative and less widely planted species to respond to the threats that climate change and pest and disease outbreaks present. Woodland owners appear to be less willing to move from the status quo, potentially as a result of the difficulty of engaging with ~60,000 owners as opposed to low hundreds of forestry agents and professionals. Within the Forestry Commission, the loss of native and commonly planted productive species has highlighted the need to diversify planting stock and to adopt alternative management practices, accepting that risk is attached to these measures.

Have you noticed any changes in switching from a mandatory to a voluntary approach?

None – largely because FC was a voluntary reporting organisation (not a statutory undertaker) within the mandatory reporting framework of first round ARP reporting.

2. Progress

Do you consider actions set out in your progress update have allowed your organisation to build adaptive capacity?

Yes – adaptation is now embedded more fully across the organisation, which, coupled with progress in research and the development of improved decision support systems, has put FCE in a better position to deploy resilience measures across all its functions.

Do you consider that your organisation is more aware and resilient for the impacts likely from a changing climate?

The organisation was aware of climate change and how it was likely to impact forestry in England prior to the first round report as a result of previous training and staff engagement initiatives. However, the development of contingency planning and the establishment of the national Incident Management Team has enhanced the resilience of the organisation and the wider forestry sector to extreme weather events (including wildfire), which are likely to become more frequent as climate change progresses.

Exemplars

Do you feel the actions listed in the update are exemplar? If so, how?

The actions do not appear to be stand-out exemplars, but they do demonstrate how adaptation has been embedded as business as usual activity, particularly through the Climate Change Action Plan for the Public Forest Estate. Our work on sector outreach is

also a reasonable example of an organisation identifying a problem (lack of implementation of adaptation measures) and establishing an initiative to address the problem.

Would you be willing to develop a case study to highlight best practice in conjunction with Defra / Climate Ready Support Service?

Yes – if Defra/CRSS felt that it would be helpful to do so.

Challenges

Where and why have challenges been experienced when making progress on actions?

The diverse objectives of woodland owners have presented a challenge in terms of enhancing the resilience of England's woodlands, generally; in some cases conservation-focussed organisations interpret the 'precautionary principle' as not changing practices (particularly planting stock) until we are more certain of the detail of climate change, believing that there is sufficient genetic diversity within England's semi-natural and native woodlands to allow them to adapt through natural processes. Those owners/managers with timber production as an important objective are more open to planting 'adapted planting stock'; their view of the precautionary principle is that the risks are greater in not adapting. Both approaches have merit for meeting the objectives of individual woodlands, but there has been a lack of understanding in some parts of the sector that we are promoting different actions for different woodland management objectives, rather than a 'one size fits all' approach.

Within the organisation, some Woodland Officers have struggled to find acceptance for current advice on adaptation, because they are dealing with individuals and organisations with established views on appropriate practice in the past (and present, if projected climate change is not accounted for).

Were these challenges expected or have they come to light as part of the process?

The challenge outlined above has come to light through our outreach programme. In part, this is a result of the long planning horizon for forestry and conservatism within the sector, which often leads to a delay in decision-making. This issue is highlighted in the British Woodland Resilience Survey, which indicated the willingness of woodland managers and agents to embrace adaptation, contrasting with reticence among woodland owners.

Interdependencies & Barriers

What challenges have been experienced working through the issues related to interdependencies and barriers?

In many cases – both in the private sector and on the Public Forest Estate – the availability of 'adapted planting stock' has been the biggest barrier to the uptake of adaptation measures. This is understandable, given that requests for planting stock over the past 20 years have been dominated by 'local provenance' and a limited range of

native species, in part driven by public procurement in many cases requiring local provenance and native species. The issue has also been compounded by biosecurity concerns, further limiting the availability of French origin planting stock of native species. The lack of Quality seed stands of most minor species has also been a factor limiting species diversification in native woodlands.

How effectively have barriers been tackled?

Addressing the lack of availability of adapted planting stock cannot be tackled over-night and requires supply and demand to work in tandem. Sector engagement has focussed on asking woodland owners considering new planting or restocking to order their plants in advance so that appropriate seed can be sourced. Some organisations have arranged contract growing of planting stock, to ensure that appropriate material is available to meet their management objectives, avoiding the need to import (with inherent biosecurity risks).

FCE funded a first phase review of seed stands of minor native species and this led to the sector taking the second phase forward, with new seed stands now identified. We have worked with partners to embed adaptation principles in procurement guidelines, and continue to do so.

What wider actions, outside your organisation, within trade bodies, or through Government, are necessary to address barriers?

As set out above, there is a need for Government and the forestry sector to work more closely with the nursery sector to better link supply and demand, both in terms of quantity and nature of the planting stock.

Annex 2: Vision for the Public Forest Estate

The impacts of Climate Change on the Public Forest Estate require a new framework of thinking about forest resilience. Hotter drier summers, milder wetter winters and the associated range of pests and diseases require us to think differently about not just species assemblages but the full forest ecosystem. A paradigm shift in thinking is required, and to inform a new framework there is much that can be learnt from the past as well as temperate forests, globally; especially those hosting species previously present in the UK's distant past. As part of this new framework a dialogue has been launched to consider the use of Pacific North West and Central European High Forest tree communities in the UK. They provide analogues of previous UK woodland prior to the Quaternary period as well as being functional naturalistic forests able to produce timber and well-suited to the UK climate of the future in both the wet oceanic conditions of the West and drier more continental conditions of the East, or lowlands and uplands, respectively.

A review of UK history provides some of the answers for how to consider forest resilience because the anticipated climate of the future is not so different to that experienced in the prehistories of our forests. Prior to the Quaternary Period, the UK hosted an array of forestry species including Sequoias, Cryptomerias, Liriodendron, Cedrus, Magnolias and others during the Tertiary Period. The ensuing glacial advances and interglacial retreats resulted in the successive obliteration of these and others species and, in most cases, their eventual disappearance from the continent. Those species that survived did so because they were suitably adapted to the conditions of the refugia that remained free of ice. Due to the barriers presented by the Pyrenees, the Alps, the Mediterranean and the Sahara, the European refugia of the UK's tree population lay, predominantly, within the Iberian Peninsula, Georgia, the Carpathians and the Balkans. These refugia supported only a narrow range of species; those that could exist at high altitude; or with the low temperatures and the dry continental conditions of south and south east Europe. This successive 'scraping off' of trees with each glacial advance resulted in the UK hosting only those species that were able to recolonise at speed – in effect, the 'weed species' of Europe, a pale shadow of the vibrant palette of species previously hosted across Europe and in the UK.

The tree species presently native to the UK are a small sub-set of the suite of pre-Quaternary NW European temperate forest species. However, it must be remembered that these are nevertheless demonstrably robust species; all have survived repeated spells in warm and dry, or cold and dry refugia. They are therefore of proven 'resilience'. The rationale for considering the Central European forest models for the lowlands, and particularly the East, of the UK is that these assemblages not only suit conditions of the present and likely future UK climate but could potentially have naturally migrated to the UK. However, it is recognised that a process of 'assisted migration' will be required to match the pace of current climate change.

The rationale for considering the North West of America as a future model rests on a rather different premise. A far greater range of species persisted in North America, a result of the mountainous land barrier for refugia running North-South rather than the European East-West direction. During the Quaternary period the resulting refugia in NW America were therefore of greater ecological amplitude than European refugia. As well as representing southern frost free locations (with the survival of tertiary species such as Sequoias, Liriodendron and Magnolias), and cold and dry conditions comparable with those in south eastern Europe, the refugia represented cold and wet oceanic climates. These latter more oceanic conditions are much like the present north and west of the UK, and hosted species that survive in the pacific NW and mountains of other Western states. Many of these are now the key timber species used in UK forestry; Sitka spruce, hemlocks, firs and American cedars.

Consideration of alternative models of forest ecosystems as part of the proposed silvicultural framework represents more than simply increasing species diversity; it represents a paradigm shift in thinking in forest resilience, encompassing not only genetic, species and structural diversity but an array of other aspects. These include genetic outcrossing and the free development of co-adapted gene complexes, phenotypic plasticity, natural and vegetative regeneration, shade tolerance, interaction with other non-tree species, soil integrity and structure and soil species diversity particularly mycorrhizal fungi. This is necessary because, for example, it is known that mixed species stands in temperate forests perform better in terms of basic productivity, in capturing light, water and nutrients. This will prove important in achieving a wider range of 'ecosystem service goals' such as timber production, carbon sequestration and water quality management into the future.

Species variation, soil fungal biodiversity and genetic variation are the keys to disease resistance and resilience against environmental change. Natural regeneration and regrowth, as opposed to restocking, further bolster resilience. Therefore, it is recommended that stands are appropriately mixed into functioning forest 'communities', regeneration and regrowth are utilised wherever possible and stands are enhanced with additional species wherever required. While remaining appropriate to the historical and policy context, this should occur whether in Ancient Woodlands or existing continuous cover forests. Understandably, the key characteristics of Ancient Woodland must continue to be protected. However, consideration of the forest models that will thrive must be based on our current understanding of the analogues of the past while moving more towards a more 'naturalistic' forestry model for the future.

In summary FEE is therefore considering two models to increase the resilience of the future Public Forest Estate; a lowland temperate native European forest model for lowland parts of England particularly in the south and east (including the conservation of past native forest fungi and tree species conserved within our Ancient Woodlands) and a NW American 'production' model, particularly for upland north and western areas of

England. In expression this may take the form of enhanced naturalistic characteristics in our established forests, a move towards CCF and other low impact silvicultural systems, and a more novel approach to afforestation, looking ahead to climatic conditions that might prevail in the 50 to 100 years that the trees we plant or establish now will face as they reach economic and ecological maturity.

In consideration of these models, forest resilience must take account of more than just species diversity, considering also species interaction, inter-dependence and the natural characteristics of the performance of trees within the wider forest ecosystem. The result is that a debate has been launched on the policy of reverting Plantations on Ancient Woodland Sites back to native species; of also considering alongside their restoration to native woodland the 'future natives' and past natives and the associated forest structure that could provide greater resilience, and mechanisms by which change and conservation can proceed into the future.

Policy should be developed to guide forests towards the conservation of key native woodlands features such as our legacy of soil fungal diversity and the genetic variation found within our native trees, alongside naturalistic NW American and central European productive forest models as appropriate to site conditions. The result of this should be that the Public Forest Estate will be more resilient to the anticipated changes and uncertainty in the climate of the future and able to continue to offer the breadth of ecosystem services for which it is so well regarded.

Annex 3: Work areas of SIS research Programmes 1-3

Programme 1 – Assessing resilience and sustainability of forests

WP1. Defining Resilience

- Exploring socio-ecological systems as a context for defining forest resilience.

WP2. What contributes to resilience?

- Genetic Conservation (Provenance and EUFORGEN).
- Genetic Conservation (Molecular).
- Influence of a diversification of forest stands on biodiversity and woodland ecosystem resilience.
- Assessing taxonomic and functional diversity and levels of functional redundancy in woodlands at different temporal and spatial scales.
- Evidence of site and landscape factors on woodland biodiversity and resilience.
- Spatial indicators of ecosystem services, biodiversity & resilience.

WP3. Risks and Resilience

- Climate change forest vulnerability and risk – from concepts to practical assessments.
- Wind risk - ForestGALES development and application.
- Wildfire risk – assessment and modelling.
- Flood risk – Quantifying the impacts of woodland planting.
- Protection forestry - forest landslide and erosion risks (work area to be developed).

WP3. Resilience at multiple scales

- Landscape scale forest ecosystem service simulation and Ecological Site Classification (ESC) development.
- Urban Forest Resilience.
- Afforested Peatland Restoration and Ecosystem Services.

WP5. Quantifying changes to resilience

- Integrated monitoring of ecosystem change.
- Quantifying forest stand C & GHG dynamics.
- Protecting soil C and function.
- Impact of forestry on acidification.

WP6. Knowledge Exchange

Programme 2 – Understanding biotic threats to resilience

WP1. Environmental effects on pest and disease impacts

- Pathogen epidemiology in relation to distribution and impact.
- Spruce pests under changing climate and management.
- Understanding the causal interactions in oak declines.
- Biology and ecology of introduced pests.
- Understanding causes of bark stripping in grey squirrels.

WP2. Understanding natural resistance

- Resistance in larch to *Phytophthora ramorum*.
- Understanding resilience in pine to *Dothistroma septosporum* and PtLM.
- Understanding resilience in juniper to *Phytophthora austrocedri*.
- Drought tolerance in Sitka spruce.
- Tolerance in horse chestnut to bleeding canker and *Cameraria ohridella*.
- Health assessments of novel species and provenance trials.

WP3. Future threats

- Climate modelling to understand pest and disease impacts at national and regional levels.
- Risks to UK forests from invasive bark beetles.
- Risks to UK forests from *Phytophthoras*.
- Identifying key future pest and pathogen threats.

WP4. Surveillance and detection

- Surveillance and monitoring for invasive insect pests.
- Surveillance and detection of invasive pathogens.
- Improving survey methods for grey squirrel damage.
- Feasibility of meta-barcoding as a generalist survey tool.
- Novel methods for detection and control of insect pests.
- Remote sensing for tree health surveillance.

Programme 3 – delivering resilient forests

WP1. Planning and management to deliver forest ecosystem resilience

- Simulating resilient future forests in management and planning – to deliver ecosystem services in different climate and socio-economic contexts.
- Managing impacts of energy forestry on soil and water – to inform possible future expansion of SRF.
- Impacts of conventional forestry on soil and water – advice for sustainable water and soil management.
- Resilient forests and protected – for resilient populations of protected woodland species.
- Ecological implications of biotic threats – understanding these threats and off-setting their impacts.

WP2. Silviculture and resilient forests

- Silvicultural systems – the scientific basis for alternative species and felling approaches to become part of mainstream forestry practice in Britain.
- Plant production – to predict the impact of climate change on natural regeneration, and to provide technical information on processing and pre-treating seeds of alternative species to diversify forests.
- Regeneration and stand tending – improved methods of regeneration that will be more resilient to biotic and abiotic threats.
- Long-term experiments – conserving the best silviculture and genetics field experiments as a vital strategic resource.
- Demonstrating adaptation – forest-scale demonstrations to show how adaptive management and planning can help improve resilience.
- Forest Reproductive Materials – scientific support and advice to customers and stakeholders on FRM implementation issues.
- Human dimensions of forest management practices – to understand how these help deliver, or constrain, resilience.
- Governance structures – to identify and describe different structures and processes that support resilient forest management.

WP3. Species and resilient forests

- Emerging Species – information from trials, tree collections, climate matching and literature to assess the silvicultural suitability of species that might be grown for increased resilience.
- Provenance of introduced species – reviewing historical and experimental information to provide practical guidance on provenance selection of alternative species.

- Resistance breeding – using field trials to identify genotypes in threatened species which show resistance to pathogens or insects of interest.

WP4. Integrated weed, pest and disease management

- Pesticides and forest vegetation management – to maintain the availability of pesticides for dealing with invasive pests, diseases and weeds, and to develop integrated methods of managing invasive vegetation.
- Fungicides and non-chemical disease management – options to control conifer and pine pathogens (DNB and *Heterobasidion* root and butt rot).
- Grey Squirrel Control – effective, practical and economic options for grey squirrel control (trapping, baiting, pine martens).
- Attitudes to Pest Management – to understand the range of stakeholder attitudes towards pest and disease management methods, in order to advise on the best approaches to adopt to improve woodland resilience.
- Integrated *Hylobius abietis* management – practical alternatives to insecticides for managing the large pine weevil.

WP5. Resilient urban forests

- Choosing tree species for a resilient urban forest – advice delivered through a DSS tool and publications.
- Urban forest creation – advice to tackle the barriers to creating sustainable and resilient new urban forests, and demonstrations of forestry's value in the landscape (including land regeneration and applying the i-Tree Eco model).

WP6. Managing biotic threats

- Phytosanitary pest management – to identify new pests and pathogens that pose a quarantine threat to Britain's forests and trees, and to evaluate the risk they pose.
- Advice and support for pest and disease management – investigating and diagnosing reports of tree disorders, advising on appropriate action, and operating the Tree Health Diagnostic and Advisory Service (THDAS).
- Surveillance and management of *Dothistroma* needle blight – encompassing long-term stand manipulation experiments.

