

Climate Change Risk Assessment

Forestry Commission
England

Invited Report under the
terms of the Reporting
Powers of the Climate
Change Act (2008)

Executive Summary

Introduction

Forestry Commission England (FCE) was invited to prepare this Climate Change Risk Assessment under the Adaptation Reporting Powers of the Climate Change Act (2008). 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'.

The Forestry Commission is a non-Ministerial Government Department that reports to the Secretary of State for Environment, Food and Rural Affairs. Forestry Commission England (FCE) is a separate part of the Forestry Commission with responsibility for advising on, implementing and delivering forestry policies in England. FCE is also responsible for the management of 258,000 ha of land (woodland and non-woodland habitat) that comprises the Public Forest Estate (PFE).

The scope of this report covers FCE's functions, including the management of the PFE and those that relate to the wider woodland resource of England delivered by FCE's Forest Services through application of evidence-based standards, provision of expert advice, effective communications, partnerships, grant-aid and forestry regulation. The report also considers FCE's role in influencing research and development, which is primarily the responsibility of Forestry Commission Great Britain as articulated in the Science and Innovation Strategy for British Forestry.

This report is based on current arrangements for forestry in England, which may change in response to devolution and Government's response to the reports of the Independent Panel on Forestry and the Forestry Regulation Task Force.

Approach

By its nature, forestry and climate are closely linked and forest management takes climate into account on a daily basis. An initial assessment of risk was undertaken through discussion with key experts across the Forestry Commission, based on an understanding of current climate-related impacts and an over-view of climate change projections. A conventional risk evaluation framework based on impact and likelihood modified by proximity and cost was adopted. This initial Risk Assessment was tested at a discussion workshop, including representatives from the private sector and civil society. The final risk evaluation identified a series of high priority risks, based on likelihood, potential impact on FCE's activities and an urgent need for action. The implications for the delivery of FCE's main functions were then considered.

Priority Risks

There is clear evidence that there will be, over coming decades, major impacts on the performance, survival and distribution of woodland species. This will impact on woodland biodiversity, timber production and the economic sustainability of the timber industry and the wider services that woodlands provide for society. Priority risks have been evaluated as those with high likelihood, high impact, and for which urgent action is needed to address those risks. A consequence of the long planning horizon for forestry is that many of the risks that require urgent action represent impacts that will occur long into the future.

Priority risks to woodland and sustainable forest management largely relate to the current distribution of tree species both on the PFE and in private sector¹ woodlands. Many species in their current locations may not prove viable for commercial forestry as a result of climate change. The risk of changing site suitability is a particularly important issue for the FC's arboreta and tree collections. Limited species diversity and an over-reliance on clear-fell systems of management similarly represent climate change risks. Limited species diversity also heightens the risk of future interactions between climate change and pest and disease outbreaks. Changing climatic conditions may favour some non-native invasive species presenting risks to woodland biodiversity, as will rising populations of deer and squirrels responding to milder winters. The capacity of forest infrastructure (including reservoirs, roads and paths, culverts and steep slopes) to withstand higher winter rainfall and more intense rainfall events is also an area of concern, as is the increasing risk of wildfires on woodland and non-woodland habitats.

The priority risks to FCE's Forest Services functions (grant administration, forestry regulation and private sector engagement) relate to these same risks to sustainable forest management. As a consequence, FCE's advice to woodland owners on forest management may not be appropriate to the future climate, with a consequent decline in woodland condition, productivity and economic resilience of the forestry sector possible. The risk is further heightened for advice on planting mixtures for new woodland which 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).

The near-term risks to corporate and operational activity are a lower priority than for the two other areas of work because of the shorter planning horizons. The most significant is the risk to buildings and staff where offices are located in flood plains. Indirect effects of climate change, through rising energy and fuel prices also represent a significant risk, particularly for timber transport.

¹ 'Private sector' woodland is used in this report to mean non FC-managed woodland and includes woodland owned by individuals, institutions, civil society organisations, Local Authorities and Government Agencies.

Opportunities

A number of opportunities are likely to arise for the delivery of FCE's functions as a result of climate change. These include opportunities to plant timber species that have previously been limited by temperature and increased productivity (and therefore timber production) where supply water is not limited. The drive for sustainable use of materials and replacement of fossil fuels may see wood increasingly being sought as a resource. The increase in demand, in part driven by renewable energy requirements (see below), is likely to result in rising timber prices and a more sustainable economic outlook for the PFE.

Wood as a renewable source of energy and heat is likely to be increasingly in demand, responding to the rise in fossil fuel prices, and policies promoting renewable energy. As a consequence, thinning operations may become financially viable, providing economic benefits and improvement in woodland habitat quality, both on the PFE and more widely in England's woodlands.

The shade provided by woodlands may draw rising visitor numbers to the PFE as the climate warms, providing new business opportunities. Climate change will also provide potential new opportunities for FC's arboreta in global genetic conservation, while their setting could attract rising numbers of visitors, again increasing recreational income.

Climate change may act as a driver for woodland creation to meet landscape adaptation objectives, including for flood alleviation and water catchment management. The public's view of trees and forestry as a positive environmental story could also promote public engagement and the ability to communicate the benefits of woodland management. The mutual benefits of climate change adaptation and woodfuel production that can be achieved through bringing woodlands into management provide real opportunities to facilitate the delivery of both objectives. Increased engagement with woodland owners would also help to communicate the need to reduce pressures from rising populations of deer and grey squirrel through the development and implementation of effective population control programmes.

Implications for the trees and woodland on the Public Forest Estate

By the middle of the century, under a High emissions scenario, there is a risk that slightly more than 24% of the PFE would be Unsuitable or Marginal (in terms of commercial timber production), should these more extreme climate scenarios be realised and in the absence of adaptation. Of this area, only 5% would be deemed Unsuitable. This compares with the 'baseline scenario' of 9% of PFE woodland in the Unsuitable/Marginal category (of which only 1% is Unsuitable). It should, however, be noted that the Marginal category assumes that attitudes of forest managers to acceptable levels of productivity adapt to changing conditions. For both conifers and broadleaves, more than 75% of the PFE would remain as either Suitable or Very Suitable under the relatively extreme climate change scenarios assessed here.

For conifer stands, the implications are that even in the absence of adaptation when restocking at the current time, there is a likelihood that those stands would remain Suitable through the majority of the current rotation (~40-60 years, depending on species). However, any delay in implementing adaptation measures with respect to species choice would increase the proportion of crops subject to risk for the latter half of the century (i.e. 2080s). For broadleaf species, a risk assessment for the middle of the century should not be considered in isolation as a significant proportion of its rotation (generally >100 years) would be beyond this time-frame.

The relatively benign risk assessment for the middle of the century (i.e. 2050s) is replaced by a much more serious picture towards the end of the century. Across the PFE, only 38% of stands would be considered Suitable or Very Suitable under current definitions. The situation for conifers is particularly worrying, with 32% of stands classified as Unsuitable in this analysis. In contrast, only 11% of broadleaf stands would be defined as Unsuitable, with the majority (58%) assessed as Marginal.

In terms of productivity, when these figures are aggregated across the whole of the PFE, there is a risk that productivity (or yield class) could decline by 7% by the 2050s and by 35% by the 2080s, in the absence of adaptation. The implications are more serious for broadleaf woodland for which there is a risk of a 49% decline in productivity by the 2080s (15% by the 2050s), reflecting, in part, the larger proportion of broadleaf woodland on the PFE in those regions where the climate projections indicate more serious summer droughts are likely. For the main productive conifer species, there is a risk that productivity could decline by 32% by the 2080s (5% by the 2050s).

Implications for the management of the Public Forest Estate

In the short term, it will be difficult to identify the direct effects of climate change from the general variability in weather conditions and implications for delivery are likely to be minimal over this timeframe. However, failure to implement the Climate Change Action Plan (CCAP) risks damaging the reputation of Forest Enterprise England (FEE) and the wider FCE, as the issues of limited species diversity, over-reliance on clear-fell management systems and species distribution based on past climate have been well documented. Reputational damage may also arise if actions on the PFE, including those in support of Ancient Woodland policy (Keepers of Time) and Open Habitat Restoration policy, deliver habitats that are seen as vulnerable to climate change as a result of their structure, species composition or genetic diversity.

In the medium to long term, failure to implement the CCAP would become increasingly serious, affecting timber income, recreational businesses on the Public Forest Estate and, therefore, its economic resilience. Failure to make necessary adjustments to the specifications of infrastructure on the PFE as part of routine maintenance/renewal programmes (at limited costs) could lead to greater impacts on

future forestry operations and larger costs if remedial action is required outside routine management cycles.

There will, inevitably, be costs associated with the implementation of adaptation measures. These will relate to both increases in management costs and reductions in timber income. However if adaptation, as outlined in the CCAP, becomes standard practice, costs should be minimised. There will also be significant opportunities for the PFE, particularly in the north and west where water limitations are less likely. Adaptation will allow further opportunities arising from climate change to be grasped.

Implications for corporate activity and functions

If risks to Corporate objectives are to be minimised and the opportunities for delivery are to be grasped, climate change should be considered in FCE's decision making processes as standard practice. Such an approach should include: planning for the future through building climate change into corporate risk models and horizon scanning; accommodating any increased costs of operating that result from climate change – or adaptation measures to address risks – in top level budget forecasts; changing the way FCE does business by incorporating climate change (both adaptation and mitigation) into corporate values, and; increasing the use of scientific and socio-economic experts to evidence and support activities, monitor success and adopt the approach of 'adaptive management'.

Implications for Forest Services' activities

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 enable and motivate landowners and managers, businesses, civil society organisations and local communities to protect, improve and expand England's woodland resource. Increasing resilience to climate change is central to these objectives and the approaches, tools, initiatives and frameworks that constitute this function provide opportunities to effect climate change adaptation – but there are also significant risks.

The need to ensure that PFE woodlands are resilient in the face of climate change will make FCE's role in providing high quality guidance on appropriate adaptation measures increasingly important. There is therefore a reputational risk to FCE if clear guidance to support the UK Forestry Standard (UKFS) Guideline on Forests and Climate Change is not available during the initial period of the Outline Adaptation Plan. An urgent requirement for monitoring and communication across the sector is therefore clear, facilitated by Forest Services, to enable iterative sharing of knowledge.

An increased focus on management plans is likely to facilitate the take-up of adaptation measures, as outlined in the UKFS Guideline on Forests and Climate Change. The development of management plans, which underpinned many of the

recommendations of the Forestry Regulation Task Force, will also deliver some of the wider objectives of forestry grants and regulation.

An assessment of the ability of the current grant and regulatory framework to address climate change issues concluded that it had sufficient flexibility to deliver both mitigation and adaptation objectives for forestry in England. However, clear guidance and direction will be required for the successful implementation of measures.

Given the current focus on pest and disease issues, there may be limited capacity for mainstreaming climate change adaptation, initially. However, because biosecurity and climate change are closely linked and, in some cases, require similar measures to address them (particularly species diversification, monitoring and adaptive management), opportunities should be taken for communication and co-delivery of adaptation and biosecurity initiatives.

Woodland creation and tree planting is a focus of Forest Service's activities and presents significant opportunities for climate change adaptation, both enhancing the resilience of England's tree and woodland resource through appropriate species selection and helping wildlife to adapt to climate change through the development of habitat networks.

Interdependencies

The Risks to FCE's functions and the likely effectiveness of the responses to them, will be dependent on a range of other factors, policies, processes and initiatives operating at local, national and international scales. Some of these interdependencies will be directly relevant to forestry and/or climate change; others will be totally independent.

Many of the interdependencies relate to influencing the level of woodland creation and management. In general, this assumes that increased levels of woodland creation and management represent positive adaptation outcomes.

Although the current and future impacts of pests and diseases are likely, at least in part, to be a result of climate change, biosecurity is a key interdependency that should be considered in its own right. Other pressures on woodland ecosystems include air pollutant deposition, the disposal of waste to forests and, critically, invasive plant and deer/squirrel populations that limit regeneration. In turn, these are dependent on a range of policies and interventions, many of which operate at landscape-scale and require engagement with, and the participation of, landowners.

While the woodfuel/biomass agenda is likely to increase the level of management in England's woodlands and therefore promote adaptation in the most part, there is also a risk that high woodfuel/timber prices coupled to limited supplies (domestically and, potentially, internationally) could lead to unsustainable exploitation of the woodland resource.

New woodland planting has the greatest potential for climate change adaptation. However, there are significant barriers to the creation of new woodland including the protection of landscape character, food security, the imbalance between agricultural and forestry subsidy, the process associated with gaining consent for woodland creation (particularly where of significant scale) and land values (including perceived land values). The success of carbon finance initiatives and the Woodland Carbon Code in achieving a step-change in woodland planting will be critical.

The response to climate change will be dependent, at least in part, on the availability and communication of clear, agreed, guidance that is consistent with national and international policy. Development of this guidance will, in turn, be dependent on the continued availability and effective administration of research funding.

The interactions between forestry and other policy areas have the potential to both promote and limit the implementation of adaptation measures. For example, national non-native invasive species policy and the EU Habitats Directive provide protection against inappropriate adaptation measures; however, if implemented in an inflexible way, they could restrict necessary adaptation for commercial forestry. This interaction between biodiversity objectives and commercial forestry will be key to the development and implementation of adaptation across the forestry sector as a whole.

The future of the PFE could influence the ability to enhance the resilience of the 202,000 ha of woodland (within a total estate of 258,000 ha) and its role as a pathfinder for adaptation measures. Coupled to the future of the PFE is the future role of the Forestry Commission. The views of the Independent Panel on Forestry and Government's response to its final report and to the report of the Forestry Regulation Task Force are therefore relevant.

Outline Adaptation Plan

The Outline Adaptation Plan builds on commitments made in Defra's Departmental Adaptation Plan. Although the majority of actions are already being progressed, all are subject to Government's response to the reports of the Independent Panel on Forestry and the Forestry Regulation Task Force. Further actions may also arise as the National Adaptation Programme is developed during 2012, following publication of the first National Climate Change Risk Assessment in January 2012.

The revised UKFS and its under-pinning Forests and Climate Change Guidelines provide a catalyst for activity. Practical guidance will be developed (and then communicated) as part of a wider research and evidence programme that addresses some of the priority research issues identified in the Read Report². Implications of the

² Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P. (eds). 2009. Combating climate change – a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change. The Stationery Office.

UKFS Forests and Climate Change Guidelines for the English Woodland Grant Scheme and the implementation of forestry regulations will be considered following Government's response to the Forestry Regulation Task Force and in preparation for the new Rural Development Programme in 2013.

On the PFE, the Climate Change Action Plan will begin to be implemented, focusing on increased diversification to reduce risk using Forest Design Plans (FDPs) as the key instrument to ensure resilience. Increased emphasis will be placed on using continuous cover systems of management, and the creation of mixed age and mixed species stands. A wider palette of species, increasing diversity at both forest and stand level will be used. The planting stock of these species will be from more southerly origin. The FDPs will also be used to plan for the unexpected (forest fires, increased water run-off, more frequent storms and more pest and disease outbreaks), also ensuring that design specifications for forest infrastructure accommodate climate change projections. Forest Design Planning will consider whether it is necessary or practical to incorporate additional measures for reducing the spread of forest fire. The existing approach to new build and major renovation projects will continue, adopting industry excellence standards and accommodating climate change projections at design stage.

FCE's contribution to delivery of landscape adaptation will largely be through woodland creation and the work of the Woodland Carbon Task Force (including 'rolling out' the Woodland Carbon Code) and partnership working on water catchment management, supported by changes to the English Woodland Grant Scheme. FCE's involvement in 'The Big Tree Plant'³ will contribute to adapting the urban environment.

Barriers to adaptation

Four issues underlie the majority of barriers to adaptation and will require careful consideration if an effective adaptation programme is to be implemented.

- Adaptation measures must be appropriate to both the present and future climate.
- The woodland management sector encompasses a broad set of objectives, ranging from commercial timber production to protecting the biodiversity associated with England's ancient and semi-natural woodland.

³ 'The Big Tree Plant' was launched in December 2010 and is a Government-led campaign to increase the number of trees planted in towns, cities and neighbourhoods throughout England. It is a national partnership bringing together the wide range of organisations who already plant trees, as well as civic and community groups working with Defra and the Forestry Commission. Further details are available from <http://www.defra.gov.uk/bigtreeplant/>.

- The life cycle of trees and the planning horizon for forestry are both long term and actions implemented now may only bear fruit in 50-100 years time. Decisions taken now for the future may be at odds with policies working over shorter timeframes.
- England has a relatively poor tree flora and Great Britain, as an island, has physical barriers to the migration of species; definitions of nativeness for immobile species such as trees become fundamental to developing adaptation measures.

Practical barriers relate to uncertainty in the future climate and the lack of clear guidance on what are appropriate measures. While species diversification represents a low-regrets measure, the availability of suitable planting stock is a current issue as there has been little demand in the nursery sector for many of the minor species that would contribute to a more diverse approach to planting. The same is true for the majority of 'new species to forestry in the UK' that the Read Report identified as worthy of consideration and for alternative (more southerly provenances) of both commercial (introduced) and native species. Conversion to alternative to clear-fell methods of management has been highlighted as an appropriate adaptation response. However, conversion of existing stands is a long process that may incur additional management costs and reduce timber income and profitability and there is limited understanding and familiarity associated with its practice. Although timber prices have risen recently and may continue to do so, partly as a result of the woodfuel agenda, forestry is not a highly profitable sector and margins are small. Any adaptation measure that involves significant cost – primarily changes to forest infrastructure including culverts, bridges, roads and reservoirs/fire ponds – is unlikely to be implemented unless required to do so by law/regulation. Where woodland creation is identified as an appropriate adaptation measure, land availability is likely to represent a significant barrier as a result of competing land use pressures, other policy objectives and lack of financial incentive.

The forestry sector is, by the very nature of its long planning horizon, conservative. This acts as a barrier to the introduction of alternative species and practices. Application of the 'precautionary principle' could also be seen as representing a significant barrier to adaptation.

A number of economic, institutional and cultural barriers also exist, including current financial constraints, both in the public and private sector, and the need for clear objectives for forestry in England. Government's forthcoming responses to the Independent Forestry Panel and Forestry Regulation Task Force provide the opportunity to clarify arrangements and ensure a good match between ambition and resource.

Assessment of unmitigated risk

Generally, adaptation is embedded across most of FCE's functions, with a range of initiatives in train to address the major risks. However, implementation of the measures identified may be limited by a lack of capacity on both the PFE and, particularly, in the private sector, where ~45 Woodland Officers have the task of providing advice and guidance to approximately 60,000 owners, the majority of whom have not had contact with the Forestry Commission in the past 20 years. Enabling the sector must therefore be a key focus for Forest Services' activities.

One of the more significant unmitigated risks posed by climate change is how to address uncertainty in the future climate, set against the long timeframe for forestry planning. Potential adaptation measures have been identified for most risks, but mal-adaptation is also a possibility. Monitoring as part of the process of '*adaptive forest management*' will be critical to reverse cases of mal-adaptation that arise.

The Climate Change Action Plan for the PFE makes it clear that a risk averse approach has not been taken because of the urgency for action. However, it should be noted that, including the management of the PFE, only a small proportion of woodlands in England are felled and replanted each year (2,800 ha in 2010 – or 0.2% of woodland area in England). This low level of opportunity for adaptation in existing woodlands heightens the need for early action and, in itself, represents an unmitigated risk. For new woodland planting, the limited capacity to implement adaptation each year again highlights the need for early action; annual woodland creation rates (~2,500 ha/yr) also only represent about 0.2% of woodland cover. As most woodland creation is carried out by the private sector and is therefore dependent on facilitation and encouragement, the ability to implement adaptation is further diminished. A significant unmitigated risk is therefore the inability to implement widespread adaptation.

Pest and disease outbreaks and their interactions with the changing climate remain an area of concern. The Biosecurity programme, developed by FC and Defra, was agreed to address the threat of current pest and disease outbreaks. Given future uncertainties, it is not possible at this stage to predict which diseases/insect pests will be introduced or become more damaging, and how they will interact with the changing climate. The Tree Health Action Plan addresses the question of monitoring, ensuring vigilance against future outbreaks, but cannot eliminate the risk.

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1 Introduction

1.1 Climate Change Act and Reporting Power

The Climate Change Act 2008 makes the United Kingdom (UK) the first country in the world to have a legally binding, long-term framework to cut carbon emissions and establishes a framework for building the UK's ability to adapt to climate change. The Act requires the Secretary of State to lay before Parliament, a series of assessments of the risks posed to the UK by climate change. It contains powers that allow Government to direct bodies with functions of a public nature (priority reporting authorities – see Figure 1.1; Defra, 2010a) to report on how their organisation is assessing and acting on the risks and opportunities of a changing climate.

In addition to bodies providing public services and infrastructure, a number of organisations have been invited to report on a voluntary basis, including Forestry Commission England. 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. An independent risk assessment is also being carried out for the UK forestry sector to support the UK's first National Climate Change Risk Assessment which will be laid before Parliament in January 2012.

Strategy for selecting who will be asked to report

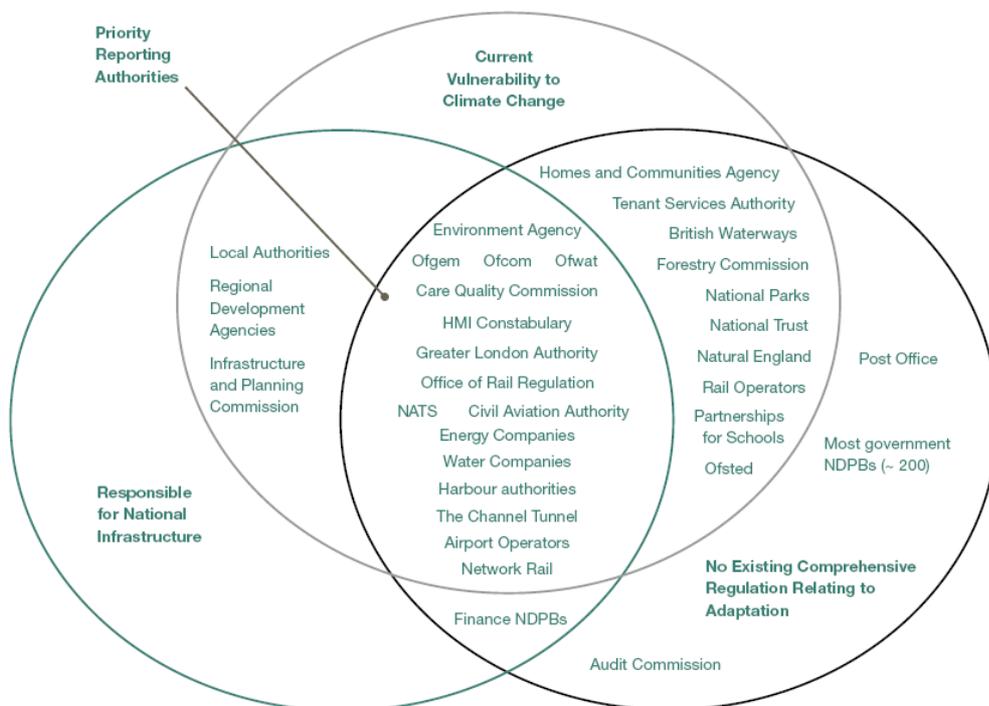


Figure 1.1. Selection of priority reporting authorities under the terms of the Climate Change Act (2008) Reporting Powers (Defra, 2009). NDPBs: non-Departmental Public Bodies.

1.2 Forestry Commission England's role

1.2.1 The Forestry Commission

The Forestry Commission is a non-Ministerial Government Department, and part of the Defra network of Arms Length Bodies. Forestry is a devolved matter and so the structure of the Forestry Commission reflects differing responsibilities at both Great Britain and devolved levels. The Forestry Commission is responsible for protecting, expanding and promoting the sustainable management of woodland, and increasing its value to society and the environment. At a Great Britain level, the Forestry Commission takes the lead in development and promotion of sustainable forest management and to support its achievement, nationally. Forestry Commission England (FCE) has responsibility for advising on, implementing and delivering forestry policies in England. This Risk Assessment focuses on the work of Forestry Commission England; work at a Great Britain level is included only where particularly relevant to work in England, for example in providing strategic leadership and direction and in reserved activities including plant health and research commissioning.

1.2.2 Forestry policy in England

Strategic forestry policy in England is the responsibility of Defra Ministers and is set out in broad terms in the Natural Environment White Paper (Anon, 2011). A new policy and delivery framework for forestry is currently being developed that will affect the way in which FCE operates. This change in direction is outlined in the Public Bodies Reform Programme. In March 2011, the Independent Forestry Panel was established by the Secretary of State for Environment, Food and Rural Affairs to advise government on the future direction of forestry and woodland policy in England and on the role of the Forestry Commission in implementing it. The terms of reference of the Panel are given at Annex 1.

1.2.3 FCE's strategic objectives

As set out in the Corporate Plan for 2011-15 (FCE, 2011), 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 Business Plan 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:

Protection: protecting the woodland resource and increasing its resilience, for example, to pests, diseases and the impact of climate change;

Improvement: improving the woodland resource to enhance benefits including biodiversity, landscape quality and a range of other ecosystem services;

Expansion: Promote and incentivise the planting and natural regeneration of trees, woods and forests of the right type in the right place.

FCE will deliver this by:

Empowerment and Engagement: empowering and enabling people to engage with trees, woods and forests, so that they can determine the benefits that they wish to see delivered;

Economic Activity: promoting a competitive, thriving and resilient forestry sector alongside a wide range of private sector business partners.

Key functions will include carrying out statutory regulatory functions (for example in relation to tree felling, plant health and environmental impact assessment), managing the Public Forest Estate and grant schemes, and providing expert advice (both nationally and locally). In addition there are new or increasing areas of activity, such as biosecurity, the Big Tree Plant⁴, the work of the Woodland Carbon Task Force⁵ and engagement with the 'Big Society'. Urban trees and woodland are covered by the UK Forestry Standard and within FCE's remit, including a significant contribution to managing 'The Big Tree Plant'; however, urban trees are not currently a focus of FCE's activity.

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 framework (see Annex 2) has been developed (FCE, 2011) outlining the intended impact of delivery, focussing on the strategic objectives outlined in Section 1.2.3.

Under the Grants and Regulation function of Forest Services, FCE issues about 2,500 felling licences each year and has approximately 20,000 active grant schemes. These grant schemes are funded by the Rural Development Programme for England, primarily through the English Woodland Grant Scheme (EWGS). EWGS supports woodland planning, woodland creation, woodland improvement/management, woodland access and woodland regeneration. FCE is also responsible for administration of the Energy Crops Scheme, Farm Woodland Scheme and for

⁴ 'The Big Tree Plant' was launched in December 2010 and is a Government-led campaign to increase the number of trees planted in towns, cities and neighbourhoods throughout England. It is a national partnership bringing together the wide range of organisations who already plant trees, as well as civic and community groups working with Defra and the Forestry Commission. Further details are available from <http://www.defra.gov.uk/bigtreeplant/>.

⁵ The Woodland Carbon Task Force is led by FCE, working with Government Agencies, business and civil society organisations. It was set up in 2010 to establish conditions for a major increase in woodland creation and woodland management. For further details, see www.forestry.gov.uk/england-wctf.

supporting economic activity in the forestry sector through co-delivery of RDPE Axis 1 grants that have been funded by Regional Development Agencies. Forest Services also provides delivery policy support and direction, including national-level engagement and empowerment, through its National Expertise Team.

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 258,000 ha of land, 2% of the total land area of England, and 15% of England's woodland in 1,500 sites. It comprises 202,000 ha of wooded habitat and 56,000 ha of non-wooded habitat and includes over 67,000 ha of SSSI (of which 99% are in favourable 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 900 people (as of April 2011).

1.3 Governance and organisational structure

1.3.1 Great Britain level Governance

At Great Britain level, the work of the Forestry Commission is governed by a Board of Commissioners including both Executive (Director General, Director England, Director Wales and Director 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 Great Britain Executive Board, which is chaired by the Director General.

1.3.2 Organisational structure

FCE is organised as two separate bodies. Forest Enterprise England manages the Public Forest Estate. Forest Services' delivery to the wider forestry sector in England is based on evidence-based standards, expert advice, communications, partnerships, grants and regulation. It also liaises with Defra's other Arms Length Bodies (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 Human Resources, communications and finance.

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 Deputy Director for Sponsorship, Landscape and Recreation 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 (post now combined with that of Director General), Chief Executive FCE, Chief Executive Forest Enterprise, Head of Finance, Head of Communications, Director Forest Services and senior HR Business Partner.

1.4 FCE's approach to addressing climate change

FCE's work on climate change, including both adaptation and mitigation, is evolving to meet new priorities and objectives, including those that stem from Defra's Business Plan, Defra's Departmental Adaptation Plan and the Natural Environment White Paper. Evolution of the climate change programme includes new working arrangements and embedding of climate change actions as routine, rather than as a separate workstream. The components of this new programme are described in the Outline Adaptation Plan (Section 6). However, much of the programme of work that is underway or has recently been completed flows from the Strategy for England's Trees Woods and Forests (Defra, 2007) and its associated Delivery Plan (FCE and NE, 2008). The following sections describe the objectives, aims and actions that comprise the programme of work in the context of the current strategic priorities of Protection, Improvement and Expansion.

1.4.1 Climate Change Programme

The Programme has five objectives, each to be delivered through a number of specific activities and actions, in many cases, in partnership with other Government Departments, Agencies, charities and civil society. Examples of relevant climate change initiatives in progress across the country to support the Programme objectives are outlined in Section 1.11. Research programmes currently being undertaken by Forest Research, the Forestry Commission's Research Agency, to support Forestry Commission climate change initiatives and those of the wider forestry sector are summarised in Section 1.12.

Enabling society to increase the resilience of trees and woodlands

- Improve evidence and guidance on adaptation, using information from tree collections, species trials and private⁶ sector woodlands; communicate the resulting guidance on species choice to managers.
- Prepare a Climate Change Action Plan for the Forestry Commission estate.
- Evaluate whether grant schemes, good practice, standards and regulations support and promote adaptation and mitigation and revise them where appropriate.
- Establish a monitoring framework for tree health and woodland condition to evaluate the impacts of climate change, to inform developing adaptation strategies.
- Develop indicators of progress for adaptation.

Adapting the rural environment

- Appraise the benefits of tree planting and woodland creation for climate change adaptation including the development of habitat networks, flood prevention and alleviation; agree priorities to enable appropriate targeting of new woodland.
- Integrate trees and woodland more fully into measures to protect natural resources (water quality, soil function, air quality) from the impacts of climate change.

Adapting the urban environment

- Develop and publish guidance on the choice of 'climate-proofed' species for the urban environment.
- Strengthen evidence on the contribution trees and woods can make to adapting the urban environment to the impacts of climate change and communicate this to local authorities.
- Embed trees and woodland in plans that cover adaptation of the urban environment to climate change.

Mitigating climate change

- Develop carbon management standards and a framework of best practice for woodland/ land managers linked to greenhouse gas reduction schemes.
- Support woodland bioenergy plantation trials with accompanying feasibility studies, monitoring of impacts and development of good practice.
- Promote the role of sustainable forest management in climate change mitigation, achieving greater use of wood products and woodfuel.
- Encourage the forestry sector to reduce its carbon footprint, for example by increasing recreational use of local woods and forests, exploring more sustainable transport solutions and reducing emissions from timber processing.

⁶ 'Private sector' woodland is used in this report to mean non FC-managed woodland and includes woodland owned by individuals, institutions, civil society organisations, Local Authorities and Government Agencies.

Communicating climate change

- Assess the current understanding of the role of trees and woodlands in climate change, including that of children, young people and the education sector.
- Establish the Forestry Commission's role in communicating climate change and conduct an assessment of forestry and climate change.
- Develop common messages, on how trees and woodland can address climate change and develop partnerships to convey those messages using all available media and resources, including forest visitor centres.

1.4.2 Corporate Plan climate change priorities for 2010-11

The Climate Change Programme outlined in Section 1.4.1 was supported by a range of actions and initiatives which aimed to support the Corporate Plan priorities for 2010-11 (FCE, 2010a). These priorities include a new focus on woodland creation as a measure to mitigate climate change:

- Publish a framework for woodland creation and develop funding mechanism(s) to support the new drive for woodland creation in England in the UK Low Carbon Transition Plan.
- Establish a Woodland Carbon Task Force to develop new business models and pilot projects to realise the role of woodlands in the Low Carbon Transition Plan and the Renewable Energy Strategy.
- Establish a tree-based focus for urban adaptation working with the Homes and Communities Agency, CLG, local government and the Local Government Association.
- Work with Defra and Natural England on developing new quantitative indicators of adaptation for trees and woodlands in both urban and rural landscapes.
- Work with Defra and DECC to establish a reporting framework for domestic forest carbon reduction projects.
- Work with Defra, DECC and a broad range of stakeholders to help attract private finance for woodland creation to address the climate change agenda.
- Prepare a Risk Assessment for the impacts of climate change on England's trees and forests and an adaptation plan to address those risks.
- Begin to implement opportunities for wind energy on the public forest estate, in liaison with DECC.
- Publish and start to implement the Climate Change Action Plan for the Public Forest Estate.
- Use the Public Forest Estate, and encourage private sector woodlands, to communicate to visitors how woodland and management can combat climate change.

1.4.3 Forestry actions in Defra's Climate Change Plan

Alongside the commitments on adaptation made in FCE's Corporate Plan for 2010-11, a number of actions on forestry were included in Defra's Climate Change Plan, published in March 2010 (Defra, 2010b), the majority of which were to be delivered by FCE, working in partnership with Defra. Although these have recently been updated (see Section 6), they are included here (Table 1.1), together with a short commentary on progress, to indicate the scope of recent work on adaptation.

Table 1.1. Forestry adaptation commitments in Defra's Climate Change Plan 2010 (Defra, 2010b).

Commitment	Progress
We will prioritise and implement research recommendations outlined in the Read Report over the next 5 years.	FC suggest that this process is taken forward through the revision of the ' <i>Science and Innovation Strategy for British Forestry</i> ' in 2012-13.
We will develop new quantitative measures of adaptation for woodlands in both urban and rural landscapes.	An indicator framework has been developed; also see Section 6.6 on further potential adaptation indicators.
By summer 2010 we will make a web-based resource on species choice and wider adaptation issues, available online.	Decision support system available on-line (https://www.eforestry.gov.uk/forestdss/) for 60 species. Research Note on adaptation in England published in September, and supported by additional web-based resource developed as England-specific guidance underpinning the UKFS Guidelines on Forests and Climate Change.
In 2010 the Forestry Commission will provide training on climate change for all public-facing staff, to assist understanding by woodland owners/managers and the public.	Training programme complete: total of ~300 staff attended.
The Forestry Commission will work with the UK Fire and Rescue Services, Communities and Local Government (CLG), Natural England and stakeholders to establish improved fire monitoring for forest and heathland fires and develop a risk assessment approach.	Forestry Commission has been working via the South East England Wildfire Group (SEEWG) and in partnership with the Fire and Rescue Statistics User Group (FRSUG) to develop a robust wildfire reporting framework.
The Forestry Commission will complete a review of Grants and Regulations in the context of climate change in 2010 and feed into a wider review in 2011.	Changes in hand; see Section 6.4.
We will complete a Climate Change Action Plan for the Public Forest Estate in 2010 and begin its implementation.	Published and being implemented; see Section 6.5.
The Forestry Commission and Northern Ireland Forest Service will publish Climate Change Guidelines to support the revised UK Forestry Standard in 2010 and implement the adaptation measures included as requirements for grants-aid.	Published November 2011; see Sections 1.10 and 6.4.
We will work with key stakeholders to develop landscape approaches for adaptation through targeting grants for woodland creation.	Ongoing work through RDPE mid-term evaluation, CAP reform, Review of Grants and Regulations in the Context of Climate Change and the work of the Woodland

	Carbon Task Force.
The Forestry Commission, in conjunction with Defra, FERA and the Scottish and Welsh Governments, will work through its Forest Biosecurity Programme Board to revise the strategy for dealing with pests and diseases and develop a new biosecurity code of practice.	An Interim Tree Health Strategy was published by FC in 2011. Subsequently, the Tree Health and Plant Biosecurity Action Plan was developed by FC, Defra, FERA and forestry/horticultural sector representatives and published in October 2011.

1.5 Scope of this report

This Risk Assessment and associated Outline Adaptation Plan (Section 6) is largely based on FCE's functions as outlined in the Corporate Plan for 2011-15.

The report considers the risks and opportunities presented by climate change to the management of the Public Forest Estate in England, to FCE's corporate and operational functions and to the activities of FCE's Forest Services, including grant administration, forestry regulation and sector engagement. In the context of the functions of Forest Services, the impacts of climate change on England's trees, woods and forests beyond the 15% managed by Forest Enterprise (i.e. the PFE) are relevant. Activities that are not devolved (for example, research commissioning, international forestry, setting of standards) are not considered, except where they have a direct bearing on the execution of FCE's responsibilities (for example, England-specific guidance in support of the UK Forestry Standard). Four functions are therefore considered in this report:

- Empowerment and engagement with the forestry sector and promotion of economic activity
- Forest Services grant administration and forestry regulation
- Management of the Public Forest Estate
- Corporate and operational activity

1.6 Current impacts of climate change on FCE

Climate change is already happening. Global average temperatures have risen by 0.8°C since the late 19th Century. It is likely that global emissions of man-made greenhouse gases (GHGs) have contributed significantly to this increase. The detection of climate trends is easier on a global basis than for the UK due to the variability in the weather. There are a number of observed trends in the UK climate (Jenkins *et al.*, 2007). Central England Temperature has risen by about 1°C since the 1970s, with 2006 being the warmest in the 348-year record. Although highly variable, seasonal rainfall has shown a slight trend over the last 250 years for decreased

rainfall in summer. It is likely that these signals are an indication of what is to come if we do not act to reduce GHG emissions now to mitigate future changes.

Forestry and tree species distribution in semi-natural woodland is dependent on a range of factors including soil characteristics, grazing levels, past seed dispersal and climate. When planting woodland, species are chosen that are well suited to both site and climatic conditions. The long cycle of forest trees coupled to the variable climate experienced across England mean that woodlands and forest management have evolved to cope with 'weather' and extreme climatic conditions. Evidence suggests that climate change is already having impacts on UK woodlands. These include effects on productivity, tree condition, leaf emergence, woodland soil function, woodland fauna and flora, forest hydrology and, probably, also the incidence of insect pest and tree disease outbreaks (Broadmeadow *et al.*, 2009a). However, to date, the limited changes to the climate of England have not had a significant impact on FCE's work, when compared to the impact of extreme weather events that are a function of forest management. The one possible exception to this observation relates to the incidence of pest and disease outbreaks in England's woodlands. Although the evidence of a direct link to climate change is limited, the past decade has seen a number of serious pests and disease outbreaks on trees and woodlands in England. Since interactions between trees and insect pests/pathogens are, in many cases, climate dependent, there is a distinct possibility that climate change may be implicated. If this proves to be the case (on the balance of evidence) in all or some of these outbreaks, including red-band needle blight of pine species, *Phytophthora ramorum* infection of larch, *Phytophthora lateralis* infection of Lawson Cypress, *Phytophthora pseudosyringae* infection of *Nothofagus obliqua*, horse chestnut leaf miner (*Cameraria ohridella*), oak processionary moth (*Thaumetopoea processionea*) and Acute Oak Decline, then it can be said with confidence that climate change is having a very significant impact on FCE's business. Critically, research suggests that climate change is likely to increase the frequency and severity of pest and disease outbreaks (Broadmeadow *et al.*, 2009b), representing a very real risk to FCE and the wider forestry sector.

1.7 Previous Reporting

Although the FC has published a number of documents on the likely impacts of climate change on woodlands and forestry in England and Great Britain since 2000 (see Section 1.8) there has been no formal climate change risk assessment.

In 2009, the National Audit Office published an overview of Government policy on adapting to climate change in response to a request from the Environmental Audit Committee (NAO, 2009). The review covered the implications of the Climate Change Act (2008), the cross-government Adapting to Climate Change Programme, and progress across Government Departments in identifying and managing risks from future climate change impacts. The report concluded that the Forestry Commission

scored well across the self-assessment framework, as a whole, and considered itself at the stage of implementing climate change risk management strategies. The NAO's narrative on the FC's self-assessment is given below.

Leadership

In 2006 the Commission's Executive Board appointed a climate change policy lead, and climate change is one of five principal delivery areas. The Commission believes that climate change is embedded as a priority within its businesses and corporate planning processes. Climate change risks are discussed at Board level frequently, although in an *ad hoc* manner.

Policy and Strategy

The Commission has a clear and agreed plan for taking forward its work on assessing and managing climate change risks. In 2009 it intends to draft a Climate Change Action Plan for the Public Forest Estate. The Commission has also identified grant-aid and forestry regulations as policy areas that need to assess and manage climate change risks as a priority.

People

The Commission's work on climate change adaptation is coordinated at the UK and regional levels. At the GB level, activities are coordinated by the Climate Change Strategy Group, chaired by the Director General. In England, a group of policy specialists work together informally with specific initiatives and project documentation requiring sign-off by the Executive Board.

Partnerships

The Commission has published a Delivery Plan for the Strategy for England's Trees, Woods and Forests which details adaptation-related actions that have been agreed by approximately thirty organisations. The Commission works closely with Natural England, the Environment Agency and industry representative bodies. It also works closely with the Department for Communities and Local Government and the UK Fire and Rescue Services in relation to forest fire risks.

Processes

Policy appraisals and impact assessments for open habitats, the Public Forest Estate, the UK Forestry Standard, and Ancient and Native Woodland Practice Guidance have included the risks posed by climate change. In looking at the impact of climate change on re-stocking forests and woods, the Commission has identified areas where risks need to be taken into account. Addressing the risks posed by climate change is now incorporated into the Forest Design Planning process. Assessment and management of risks utilises the Ecological Site Classification decision support system for species selection. The Commission is developing other tools to help create woodland in locations where it can contribute most to landscape scale adaptation.

1.8 Published evidence

1.8.1 FC publications

The Forestry Commission first published an assessment of the likely impacts of climate change on forestry in Great Britain in 2000 (Information Note 31: *Climate change - implications for forestry in Britain*; Broadmeadow, 2000). This was followed by a more in-depth analysis in 2002 (Bulletin 125: *Climate change - implications for forestry in Britain*; Broadmeadow, 2002) and an updated summary of likely impacts, incorporating the UKCIP02 climate scenarios in 2005 (Information Note 69: *Climate change and British woodland*; Broadmeadow and Ray, 2005). Specific topics relevant to climate change have also been covered (e.g. Information Note 86: *The role of forest genetic resources in helping British forests respond to climate change*; Hubert and Cottrell, 2007 and Research Note 2: *Red band needle blight of conifers in Britain*; Brown and Webber, 2008) while evidence of the impacts of climate change have been reported from Forest Research's Intensive Forest Health Monitoring Network (Information Note 88: *Ten years of intensive environmental monitoring in British forests*; Vanguelova *et al.*, 2007) and the Environmental Change Network site (Research Note 1: *The Environmental Change Network at Alice Holt Research Forest*; Benham, 2008). More recently, country specific reports on the impacts of, and adaptation to, climate change have been published, including for England in 2010 (Research Note 201: *Climate change: impacts and adaptation in England's woodlands*; Ray *et al.*, 2010). This last publication includes a significant body of practical guidance for adapting existing and new woodlands to the impacts of climate change (see following section) while a research report on adaptive forest management has also been published (Research Report: *Human dimensions of adaptive forest management and climate change: a review of international experience*; Lawrence and Gillett, 2011). Social research and public understanding of climate change issues have been addressed through the inclusion of specific questions on climate change adaptation and mitigation in the biennial '*Public Opinion of Forestry*' survey (FC, 2007; FC, 2009; FC, 2011) and a study of the understanding of climate change issues of young people and their teachers (*Wood you Believe it?: Lovell and O'Brien, 2009*).

1.8.2 The Read Report

In 2008, FC commissioned an independent report examining the potential of the UK's trees and woodlands to mitigate and adapt to climate change – the Read Report (*Combating Climate Change: a Role for UK Forests*; Read *et al.*, 2009). It was commissioned as a response to the Intergovernmental Panel on Climate Change's (IPCC) 4th Assessment Report published in 2007 (IPCC, 2007) providing evidence at UK-level for the forestry sector. The study was considered to be the first national assessment of its kind in the world and has attracted interest from other countries

keen to form their own climate change plans and policies. The headline messages were:

- A clear need for more woodlands;
- UK woodlands are an asset to be managed wisely;
- The *status quo* is not an option;
- Harvesting and use of wood increases forestry's mitigation potential;
- Trees help people to adapt.

More specifically, the key findings regarding the impacts of and adaptation to climate change were:

- Impacts of climate change are beginning to become apparent in the UK's woodlands, including effects on productivity, tree condition, woodland soil function, woodland fauna and flora and forest hydrology.
- There is increasing concern over the number of outbreaks of novel pests and diseases in forestry and arboriculture. Forest pests and diseases could compromise the ability of woodlands to adapt and contribute to meeting the challenge of climate change.
- The regulatory framework and sustainability standards for UK forestry will need to be maintained and, in some cases, adapted to address climate change. A similar approach should be put in place for the management of urban trees. This will ensure that trees continue to deliver a wide range of ecosystem services.
- Since tree crops take many years to mature, the planning horizons for forestry are inherently long. Actions taken now may only prove their worth in 50–100 years time and must be appropriate for both the current and future climates. A move towards planned rather than reactive adaptation in woodland creation and management is therefore preferable.
- The creation of new woodlands and the restocking programmes of existing forests present major opportunities for adapting forests to future climate change. Changes to the selection of species and provenances for particular sites using the current range of species are required now. These choices can be accommodated using the range of species currently in use. Over longer timeframes, and if greenhouse gas emissions do not decline, we will need to consider the introduction of new species, including those from continental Europe. However, further research is urgently needed to establish which species will be best suited to the changed environmental conditions. The preference for use of native tree species and local provenances under all circumstances will need to be reconsidered.
- The changing climate raises difficult questions for conservation of woodland biodiversity. Current descriptions of native woodland communities based on species composition are unlikely to remain valid because some native members of the flora and fauna may struggle to survive.

- Trees have an important role in helping society to adapt to climate change, particularly in the urban environment, through providing shelter, cooling, shade and runoff control. Tree and woodland planting should be targeted to: (a) places where people live, especially the most vulnerable members of society, and (b) places where people gather (such as town and local centres) which currently have low tree cover.
- Forestry practitioners should engage with the public to contribute to societal understanding and responses to climate change. The changes required will challenge both policy makers and managers to adopt a more flexible approach in response to the emerging body of evidence.
- Policy incentives need to be re-designed so that adequate reward is given to the provision of the non-market benefits of forests, especially those relating to the climate change mitigation and adaptation functions of forests.

1.9 Published Guidance

Guidance on woodland management has increasingly considered climate change issues although, in many cases, it has not been possible to provide specific guidance on adaptation. In some cases, the guidance is generic across GB, while more specific guidance for England has been provided. In one case, guidance was prepared for FC Scotland, but is equally applicable to England.

Available information on climate change impacts and adaptation is brought together on the FC internet pages (www.forestry.gov.uk/climatechange). A specific resource for adaptation in England has also been developed by Forest Research and is available at www.forestry.gov.uk/fr/climatechangeengland. Practical measures to help deliver landscapes and new woodlands that are resilient to climate change are also outlined on the web-pages of the Woodland Carbon Task Force (www.forestry.gov.uk/england-wctf).

1.9.1 Ancient and Native Woodland Practice Guide

The Practice Guide (FCE, 2010b), published in 2010, supports the 'Keepers of Time' Policy for ancient woodland (Defra, 2005). Climate change is addressed in some detail, with changes to approaches made with respect to species diversity, the management of non-native species, new woodland composition and the preferred origin of planting stock.

1.9.2 Ecological Site Classification

The Ecological Site Classification decision support system (ESC – see FC Bulletin 124; Pyatt *et al.*, 2001) was developed to aid species selection for woodland creation and native woodland restoration. Climate change scenarios have been incorporated, to provide an indication of future suitability of individual species (in terms of timber

production) and native woodland types (see Ray *et al.*, 2002; Broadmeadow *et al.*, 2005; Broadmeadow and Ray, 2005). The model is available on-line (www.eforestry.gov.uk/forestdss) and its scope has recently been extended from 28 to 62 species.

1.9.3 Practice guidance supporting the UKFS Forests and Climate Change Guidelines

The Forests and Climate Change Guidelines (FC, 2011b), in common with other Guidelines under-pinning the UK Forestry Standard (FC, 2011c), consider climate change adaptation from a relatively high level and point to more detailed practice guidance. Initially, this guidance constitutes:

- Ancient and Native Woodland Practice Guide.
- Research Note 201, *Climate change: impacts and adaptation in England's woodlands* and associated web-based resource on adapting England's woodlands (www.forestry.gov.uk/fr/climatechangeengland).
- Internet-based, accessible, practice guidance in support of the UKFS guideline on Forests and Climate Change (www.forestry.gov.uk/climatechangeengland). The guidance includes the information provided to Forest Enterprise to support implementation of the Climate Change Action Plan for the Public Forest Estate.

1.9.4 Operational Guidance Booklets (OGBs)

Operational Guidance Booklets are published by FC's Inventory, Forecasting and Operational Support Division (IFOS) to support the management of Forestry Commission woodlands (the Public Forest Estate: PFE) in England, Scotland and Wales. OGBs are available (on request) to, and used by, private-sector forest management businesses and public sector forest owners including local authorities and the Defence Infrastructure Organisation. As OGBs are revised on a 5-10 year schedule, climate change considerations are incorporated on a rolling basis. The most recent example relevant to climate change is OGB 34 on continuous cover forest management.

1.9.5 Climate Change Information Pack

An Information pack on woodland, forestry and climate change-related issues was published to support a climate change training course for FCE staff (300 attendees) and more general communication of climate change issues. The pack is available to the wider forestry sector, including both as single sheets on specific topics and as an internet-based resource ([www.forestry.gov.uk/pdf/eng-trees-and-climate-change.pdf/\\$FILE/eng-trees-and-climate-change.pdf](http://www.forestry.gov.uk/pdf/eng-trees-and-climate-change.pdf/$FILE/eng-trees-and-climate-change.pdf)).

1.9.6 Climate Change Education Pack

An education pack on forestry and climate change, applicable to Key Stage 2 was developed under the Climate Change Programme. It considers the role of trees,

woodlands and the forestry sector in climate change impacts, adaptation and mitigation. The original material has subsequently been further developed and published through a partnership project with the Crown Estate (http://www.thecrownestate.co.uk/media/12812/forests_for_the_future.pdf).

1.9.7 Climate change and continuous cover forestry (CCF)

An evaluation of the use of continuous cover forestry in climate change adaptation was carried out by Forest Research for FC Scotland (Stokes and Kerr, 2009). The work is equally applicable to forestry in England and gives guidance on how CCF can be employed to deliver different aspects of climate change mitigation and adaptation.

1.10 Forestry regulations relevant to Climate Change impacts and adaptation

1.10.1 UK Forestry Standard

The UK Forestry Standard (FC, 1998; 2011c) represents the national definition of sustainable forest management and follows commitments made at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro, and at the second Ministerial Conference on the Protection of Forests in Europe (MCPFE) in Helsinki in 1993, that the Government would formally adopt a forestry policy to promote sustainability. A revised version has recently been published (November 2011), incorporating updates to, and alignment of, the underpinning series of seven UKFS Guidelines. The revision process reflected advances in research and in approaches to sustainable forest management practice and also included the drafting of new 'Forests and Climate Change Guidelines' which underwent public consultation in autumn 2009 (FC, 2009b).

The purpose of the UK Forestry Standard is to set out standards for the sustainable management of all forests and woodlands in the UK. It is the centrepiece of a system to guide and monitor forestry. The Standard is linked to the developing international protocols for sustainable forestry. It is used in the UK as a basis for assessing and monitoring sustainable forest management practice and for the UK Woodland Assurance Standard (UKWAS, 2006: third party certification accredited to the internationally recognised Forest Stewardship Council). It can also be used for assessing compliance with environmental management standards such as ISO 14000 and EMAS (Eco-Management and Audit Scheme). The Standard takes into account the main aspects of sustainable forest management: soils, water, air, production, biological diversity, workforce, communities, heritage and landscapes. The UK Forestry Standard is supported by, and is a requirement of, a number of instruments, including:

- the forestry/woodland grant schemes (of all four countries comprising the UK);
- Forest Plans (for private sector woodlands);
- Forest Design Plans (for FC/Northern Ireland Forest Service woodlands);
- Felling Licence regulations;
- Environmental Impact Assessment regulations.

1.10.2 Forest and Climate Change Guidelines

The Forests and Climate Change Guidelines (FC, 2011) underpin the UK Forestry Standard and address both climate change mitigation and adaptation. See Section 6.4 for further detail. The Guidelines are written around three requirements for good forest management practice:

- Forest management should contribute to climate change mitigation over the long term through the net capture and storage of carbon in the forest ecosystem and in wood products.
- Forest management should maintain or enhance the resilience of forests and forest ecosystems in order to reduce the risks posed by climate change to their sustainability.
- Forest management should enhance the potential of forests to protect society and the environment from the various effects of climate change.

In turn, climate change adaptation is considered through five adaptation 'factors', as detailed below:

Forest planning: Forest design, structure and composition needs to be resilient to the effects of a changing climate and extreme weather events.

Adaptive management: Approaches to management that are flexible, reactive and anticipatory will help forests and woodlands adapt to the changing climate.

Tree and shrub species selection: introducing diversity in tree species and origins will ensure some thrive should others decline.

Landscape Ecology: Woodland and trees can be used to develop ecological connectivity between habitats to enhance the ability of woodland ecological communities to adapt to climate change.

Environmental protection: Woodland and trees that are appropriately located can help to alleviate the impacts of climate change on society and the environment.

1.10.3 EIA (Forestry) Regulations

Under the relevant Environmental Impact Assessment (EIA) regulations, an Environmental Statement (ES) is required where, in the opinion of the forestry

authority, a proposal for planting, deforestation, forest roads and quarries is likely to have a significant effect on the environment. Climate is one of the potentially affected aspects of the environment; thus afforestation and, particularly, deforestation are relevant to climate change.

1.10.4 Plant Health Act

This Act identifies the FC as the competent authority in Great Britain for the protection of forest trees and timber, empowering the Forestry Commissioners to make orders to prevent the introduction and spread of forestry pests and diseases. The Plant Health (Forestry) Order (2005) lays down a number of conditions and prohibitions to support these objectives. The scope of the Act allows FC to introduce additional requirements to protect forest trees and timber, should new pest threats become apparent as climate change progresses with additional measures being justified through the established Pest Risk Analysis process.

1.10.5 Forestry Act

The 1967 Forestry Act (as amended) and the Forestry Act (Northern Ireland) 1953, provide powers for the Forestry Commissioners and Department of Agriculture and Rural Development (Northern Ireland) to regulate forestry and promote good forest practice in order to fulfil their statutory duties. Sustainable forest management implies a presumption against the loss of forest area and carbon stocks by ensuring trees are replanted after felling forest. The presumption in favour of re-stocking does not apply for woodland loss to natural events (for example windstorms) or to pests and diseases, including when Notice of Felling is given for phyto-sanitary reasons.

1.10.6 Felling Licence Regulations

To help protect Britain's forests, a felling licence from the Forestry Commission is required to fell trees. It is an offence to fell trees without a licence if an exemption does not apply. Felling licences are generally granted on condition of restocking. Unconditional felling licences may also be granted for removal of woodland to convert to another land use (for example for open habitat restoration). A felling licence is not required if planning permission has been granted under the terms of the Town and Country Planning Act.

1.10.7 Forest Reproductive Material (FRM) Regulations

These regulations, (which implement EC Directive 1999/105), provide a framework for controlling plant materials used in forestry. The Forestry Commission is responsible for the FRM Regulations in England, Scotland and Wales. Separate Regulations apply in Northern Ireland. Species not covered by FRM can be planted, but the use of good seed material from high quality stands and the recording of all relevant details is encouraged.

1.11 Examples of climate change initiatives in progress

The climate change initiatives catalogued in the following sections provide an indication of the breadth of partnership projects that address climate change adaptation. It should be noted that climate change adaptation (or mitigation) was not, in many cases, the main driver behind taking the project forward. The list is far from exhaustive, and does not include many of the Rural Development Programme-funded regional initiatives delivered through the English Woodland Grant Scheme.

1.11.1 North West England

North West Climate Change Action Plan: FCE is contributing to Natural England's initiative to produce a region-wide framework of place-based adaptation priorities for the natural environment, and a demonstration of the contribution that the natural environment can make to reduced flood risk and carbon sequestration. Previous work on the potential for woodland creation to reduce soil erosion in the Bassenthwaite lake catchment has contributed to the project, while an information resource on the potential of individual Landscape Character Areas to absorb an increase in woodland area has also been developed through the project. A process to develop the information resource on woodland creation potential is now being taken forward at national level through the Woodland Carbon Task Force.

Adaptation in the Northwest's Community Forests: FCE is working with the Community Forests on a range of green infrastructure initiatives to promote urban adaptation to counter the urban heat island effect. This collaboration includes the Green and Blue Space Adaptation for Urban Areas and Eco Towns (GraBS) project.

Lake District Still Waters Partnership: FCE has been working with the Bassenthwaite Lake restoration Programme (BLRP) and Windermere Catchment Restoration Programme (WCRP). The aim of the groups, ultimately, is to enhance the water quality of the lakes and catchments but, in doing so, many climate change issues are being addressed including flood alleviation in the context of the Cocker mouth floods.

Northwest Woodland Creation Manifesto: FCE is a member of the group that has developed the Northwest Regional Forestry Framework. The work has included the development of an ambitious vision for woodland creation to deliver resilient rural and urban landscapes. The manifesto aims to put in place a programme that will double the Northwest's woodland cover by 2050.

1.11.2 Yorkshire and the Humber

Forestry and Flooding Project: The project builds on the work from the *Slowing the Flow* Project and includes a regional level assessment of potential woodland creation sites to reduce flood risk. Woodland Creation schemes are supported via EWGS

including a specific additional contribution of £2000 per hectare for approved schemes.

Forest Habitat Network study: Forest Research, working with FCE, is leading a region wide forest habitat network study (which extends over the regional boundary for the National Parks and the Southern Pennines areas). The study will be used to provide evidence on the current extent of the networks and make recommendations for future work which can then be supported through EWGS to promote landscape scale adaptation.

Undermanaged Woodland Woodland Improvement Grant (WIG): FCE has developed a specific undermanaged woodland WIG targeted at the region's higher (biodiversity) value woodlands. It is designed to improve their current condition, regeneration capacity and, as a consequence, their resilience.

Woodland creation in National Parks: FCE is working in partnership with Yorkshire Dales and the North York Moors National Park Authorities to both increase the level of woodland cover and consider issues surrounding climate change and wider land use planning. This includes consideration for climate change adaptation through aspects such as the National Park Management Plans.

Enhanced woodland mapping: A better understanding of the nature and condition of woodland across the region has been secured through a doubling of the sampling frequency of the National Forest Inventory field survey across Y&H, funded by Yorkshire Forward. This improved data resource will provide a baseline for monitoring the impacts of climate change on woodland condition and an evidence base for future decisions on woodland management priorities, including the prioritisation of necessary adaptation responses.

1.11.3 East of England

Sea buckthorn: FCE is a partner with InCrops (an ERDF funded enterprise hub based at UEA) in a series of trials of sea buckthorn (*Hippophae rhamnoides*), including one in Thetford Forest. It is a drought and saline tolerant crop, hence suitable for climate change threatened areas in the East of England. InCrops is supporting local businesses to develop new sea buckthorn markets. Using varieties sourced from the Lisavenko Research Institute in Russia, which has developed varieties for over 60 years, some 6000 plants have been established on four trial sites across the East of England. Planting took place in spring 2011.

Species and provenance choices in the East of England: Partly in response to Red Band Needle Blight, and partly with an eye on future impacts of climate change, the Forestry Commission in the East of England has been reviewing tree species and provenance choices for replanting clearfell sites on particular soil types. In total some 22 novel species are being trialled in Thetford Forest, including familiar timber species

such as Scots Pine and Douglas-fir, but also less commonly used species such as eucalyptus, Italian alder and maritime pine.

1.11.4 West Midlands

Woodland Creation Priority areas: An additional contribution of £2000/ha is available to establish climate change resilience for woodland habitats and to favour declining species, particularly woodland birds, by significantly increasing the connectivity of woodland landscapes. Targeting of woodland creation will also play a role in limiting water run off during peak rainfall periods to reduce flood risk in urban areas.

Stoke: FCE is working with Stoke City Council and Natural England on changes to open-space management to improve climate change resilience, reduce costs and deliver ecosystem benefits; for example, by planting trees on previously mown grassland.

Birmingham: FCE is working with a range of organisations to develop a robust green infrastructure network and a Birmingham Forest initiative to help the city adapt to climate change in the 2050s and beyond. The work incorporates several projects including the Birmingham Trees for Life partnership.

Black Country: FCE is part of the Environment Forum which is committed to rolling out more functional Green Infrastructure to deliver adaptation benefits via the planning process and Environmental Infrastructure Guidance.

Heartwoods: FCE is providing partnership funding to Heartwoods, through the SmallWoods Association to promote woodland management to secure adaptation benefits and the use of woodfuel to mitigate climate change.

1.11.5 Southwest England

Southwest Forest 1999-2009: FCE has funded and contributed expertise to a woodland creation initiative with significant community involvement. Woodland creation was targeted to expand and link concentrations of existing ancient woodland in the region to increase the resilience of those woodlands and facilitate landscape-scale adaptation processes. The advisory programme delivered 3,107 ha of new planting over the period, 64% of which was broadleaved woodland.

Ward Forester Project 2009-2012: FCE is working in partnership with Devon County Council to develop the Ward Forester concept, building on work from the Southwest Forest initiative, with the intention of rolling the concept out across the region. A 'Ward' Forester focuses on the management of newly established and under-managed woodlands. The project encourages clusters of owners (pilot areas focussed on Teign, North Devon and Tamar) to collaborate through a professional forester, known as the Ward Forester who supports the cluster (or ward) to achieve economies

of scale. Through encouraging management of undermanaged woodland, the project will promote natural regeneration and adaptive capacity.

Carbon neutral Exmoor project: FCE is working with the National Park Authority to establish the potential contribution of woodland creation, woodland management and timber/woodfuel utilisation in reducing the carbon footprint of the Exmoor National Park. Although focussing on climate change mitigation, through careful targeting of woodland creation, building on the work of the Southwest Forest, woodland resilience will be enhanced at a landscape scale, while the negative impacts of climate change on soil erosion, water quality and flooding will be addressed.

1.11.6 Southeast England

North Kent Woodfuel Pilot: FCE is leading a landscape-scale project to bring woodlands back into management to meet climate change adaptation and wider habitat objectives and deliver climate change mitigation. The project is part of the work of the Woodland Carbon Task Force and aims to meet its objectives through the development of robust supply chains.

Updating of the Ancient Woodland Inventory: Southeast England has the largest concentration of ancient woodland in the country, a resource that is potentially at risk due to the effects of climate change. The original draft inventory of Ancient Woodland Sites is being updated and strengthened to include information on the nature of the woodland and its condition. This will provide a valuable baseline for tracking the impacts of climate change and prioritising adaptation measures to address declining condition.

1.11.7 London

Retaining tree canopy cover: FCE is working with a range of partners to provide guidance and support for the retention of large canopy trees to provide shade and evaporative cooling. Much of this work to prepare London for the climate of the future is being taken forward through the Tree Design and Action Group. Initiatives include development and dissemination of the CAVAT and I-TREE systems for tree valuation; development of the Joint Mitigation Protocol to protect trees, where feasible, in connection with tree-root insurance claims; dissemination of guidance on tree root protection to utility companies; publication, by CIRIA, of a document outlining the role of trees in urban development and the need to incorporate them in development plans, using cost-benefit analysis as a driver; provision of guidance to Tree Officers on increasing canopy cover through appropriate management and maintenance.

Enhancing canopy cover: FCE is working on a range of tree and woodland planting initiatives, with partners, to prepare London for the climate of the future. Initiatives include targeted delivery of the London Tree and Woodland Grant Scheme (LWGS) to Boroughs in most need of an uplift in canopy cover; dissemination of the 'Right Trees

for a Changing Climate' database (www.right-trees.org.uk) to ensure that London's increasing tree cover is resilient to climate change; support for the delivery of the national 'The Big Tree Plant' in London, led by Defra and administered by Groundwork London; publication by the Royal Institute of British Architects (RIBA) of guidance, and an on-line Knowledge Community aimed at architects, on improved integration of tree planting into new development.

1.11.8 East Midlands

Woodland Birds Project: FCE is working with the Royal Society for the Protection of Birds (RSPB) on a high profile project bringing woodlands back into management and creating new native woodlands in response to declining populations of vulnerable species of woodland birds. By increasing the habitat available to bird species such as the willow tit and the marsh tit, the project hopes to increase the resilience of these species to climate change by promoting population recovery and movement.

The Case for Trees: FCE is carrying out a programme of outreach seminars with local planning authorities following publication of *The Case for Trees document* (FCE, 2010c). Working with the Royal Town Planning Institute and with Greenspace East Midlands the programme aims to let planners know about the benefits of urban trees and woodland. The benefits range from providing networks for species to move through urban areas to providing areas of shade for people in urban centres.

1.11.9 Northeast England

Cheviot Futures: FCE has been working in partnership with EA, NE and the Northumberland National Park Authority to set a future vision for the Cheviots that accommodates the impacts of climate change. This includes a detailed assessment of the future suitability of a range of tree species and the future role of forestry in the rural economy.

1.12 Research and evidence

The Forestry Commission undertakes research to provide a robust evidence base in support of the protection and expansion of Britain's forests and woodlands. Funding from the UK Parliament covers the Forestry Commission's activities in respect of England and those areas, such as research which are, by agreement, carried out on a Great Britain-wide basis. The Forestry Commission's Science and Innovation Strategy sets out how research programmes are determined and how they are linked to forestry strategies and the wider policy objectives of the UK Government and the devolved administrations. Four priority areas have been identified:

- **Climate change mitigation and renewable energy:** Where the wider benefits of forests and woodlands are recognised for their key role in supporting the Government's objectives on climate change.

- **Sustainable consumption and production:** Where the UK forest resource plays its full role in supporting a strong and sustainable economy.
- **Natural resource protection and environmental enhancement:** Recognising that the natural heritage and landscape of much of the UK is enriched by well-designed forests, which support a wide range of ecosystem services.
- **Sustainable communities:** Which benefit from the opportunities provided by both urban trees and rural woodlands for recreational, tourism, health, skills, and economic benefits.

Key themes, in turn, follow from the priority areas:

- Counting the Carbon - **Climate change** theme
- Protecting what we have - **Forest monitoring and biosecurity** theme
- Working towards a sustainable future – **Sustainable forest management** theme
- Underpinning a thriving forest economy – **Wood and timber properties** theme
- Supporting a resilient environment - **Ecosystems and biodiversity** theme
- Trees and forests for society - **Social, Economic Development & Urban Greening** theme
- Understanding our resource - **Inventory and forecasting** theme

Forest Research, an agency of the Forestry Commission, is the main contractor undertaking research programmes for the Forestry Commission and is the principal organisation in Britain involved in forest and tree-related research. This evidence provides support for the whole UK forestry sector. Of the total Forestry Commission GB research budget, 92% is spent with Forest Research. The remainder is used to collaborate in partnership projects, support CASE and PhD studentships, underpin work on standards, and commission research from external providers. Forestry Commission England also purchases some research independently although, in 2011/12, this is due to decline to accommodate the Spending Review settlement. FCE, alongside FCW and FCS contributes to the direction and commissioning of each of the research programmes through Programme Advisory Groups, for each of the themes.

1.12.1 FORCCAST research programme

Forest Climate Change Adaptation Strategies is the research programme that covers climate change impacts and adaptation. The main outputs of the current programme are:

Work Area 1 - Vulnerability assessment tool at broad scale: For targeting where adaptation action is critical. Incremental development over 2-3 years. Various options for its development, including use of multi-criteria decision analysis (MCDA), will be tested.

Work Area 2 - Risk assessment tools at forest design plan and stand scale:

The development of a range of tools capable of working with UKCP09 climate projections to explore risk to forest growth and productivity, stability, phenology, chilling requirement and dormancy. To also include an economic assessment of impacts and approaches to landscape planning.

Work Area 3 - Adaptation Measures: Informed by recent reviews, reports, data and expert judgement and linking to other adaptation projects, the project will consider Forest Design Plan and operations adaptation; information on species and provenance choice; organisational and professional aspects of adaptive capacity; survey and assessment of sector preparedness; adaptive capacity, and; the scoping and analysis of costs & benefits of different adaptation scenarios.

Work Area 4 - Case Studies & Supporting Experiments: To trial and explore multi-disciplinary aspects of adaptation including management, scenario modelling and dissemination of ideas and results to stakeholders at regional level. The work area will include scoping and developing analysis of costs & benefits of different options and links to EU-funded projects.

Work Area 5 - Dissemination and Knowledge Exchange:

1.12.2 Other climate change-related research

Many of FR's other research programmes also include elements of climate change research. These elements are briefly summarised below, include those funded solely by the Forestry Commission and those co-funded by the EU and other non-FC bodies. The list of projects also includes an indication of their key objectives:

Directly funded by the Forestry Commission

ESC AND DSS – Ecological Site Classification for climate change and decision support for biodiversity: Better matching of species and provenance to site and future climate conditions to support adaptive forest management. Development of stand-based and spatial climate change impact and adaptation tools, including new modules to assess the risk of biotic and abiotic impacts of projected changes to weather patterns. Process-based (3PGN) modules to be integrated into ESC.

Pests and pathogens in a changing climate: Assessment of the effects of temperature and water stress on disease severity, reproduction and survival of major oak root pathogens, including the development of models to assess climate risk. Development of phenology models for insects in protected environments using bark beetles & weevils as study organisms, to enable the prediction of geographic variation in insect phenology and pest impact under a changing climate.

Insects & continuous cover forestry – the impact of changing management on insect diversity & abundance: Testing the hypothesis that increasing the structural complexity of forest stands will lead to greater insect diversity and hence

fewer pests problems. In a climate change context, the study investigates whether increased stand structural complexity might be associated with greater resilience of forest systems to environmental change.

Climate Change and Street Trees: The development of a system for valuing the benefits of street trees through providing the evidence base for street trees. The drafting and communication of best practice guidance, together with robust assessment, evaluation and dissemination tools, will enable the risks and benefits of street tree placement to be more fully assessed by policy makers and planners. The programme will extend the evidence-base supporting 'The Big Tree Plant' in England.

Species and Provenance Trials for Climate Change: The highest priority is provenance testing of Scots pine with an emphasis on more southerly and/or improved seed sources. Experiments will be set up in Thetford, East Scotland and at least one other contrasting site. The next highest priority is to test conifers for use as alternatives to Corsican pine in areas affected by red band needle blight. Slightly lower priorities include provenance trials of sweet chestnut and the screening of a wider range of alternative species. Alongside new species/provenance testing, data will be collected from existing plots to understand drought and winter cold response of relevant species.

Projects receiving EU and/or other co-funding

ForeStClim – Transnational Forestry Management Strategies in Response to Regional Climate Change Impacts (Interreg IVb): The overarching objective is to develop and test transnational forestry management strategies for addressing the impacts of climate change. The main tasks are: downscaling regional climate scenarios; developing tools for assessing the implications of climate change for forest planning and management; designing robust forest management strategies to preserve public benefits such as soil and water protection, flood mitigation, and carbon sequestration; and testing the implementation of the climate-proofed strategies at a regional level.

REINFFORCE – REsource INFrastructure for monitoring and adapting European Atlantic FOREsts under Changing climatE (Interreg): To establish a network of new 'arboretums' from Portugal to Scotland to monitor trends in mortality and growth of the most common European tree species under climate change, on a long term perspective.

MOTIVE – Models for Adaptive Forest Management (EU FP7): To provide an integrated assessment of forest management strategies that simultaneously considers multiple ecosystem goods and services rather than focusing on individual aspects such as timber production or biodiversity alone; to translate scientific state of knowledge

about expected climate change impacts into decision support for policy makers and forest practitioners.

FUTUREforest – helping Europe tackle climate change (Interreg IVc): To explore European forestry issues and measures in relation to climate change and exchange experiences of adaptation and solutions to challenges.

ECHOES – Expected Climate cHange and Options for European Silviculture (COST): To mobilise and integrate existing scientific knowledge on climate change for European forest policymakers and managers who have to make decisions relating to adaptation to, and mitigation of, climate change.

TRANZFOR – Transferring Research between EU and Australia-New Zealand on Forestry and Climate Change (EU FP7 Marie Curie): The project aims to strengthen research partnerships on forestry and climate change through staff exchanges, networking and dissemination activities between research organisations in Europe, Australia and New Zealand.

Northern ToSIA – Assessing Sustainability of Forest-based Activities in Rural Areas of the Northern Periphery (EU Northern Periphery Programme): To investigate options for improving the sustainable use of forest resources in selected regions of the NPP area using an innovative sustainability impact assessment tool (ToSIA) and applying it in regional development and business.

Forest Adaptation to Climate Change – National Forest Provenance Planting Trial (NFC): To establish and monitor, in the long term, a series of 'climate-change adapted' tree provenance trials in the National Forest. These will serve as research-demonstration plots that are testing various proposed approaches to increase the resilience of native broadleaf species to climate change.

Multi-For – MultiFunctionality of Forests (Interreg IVa): To improving the effectiveness of forest site selection and monitoring, including the design and implementation of forest management plans that will optimise economic, ecological and social interests in the context of global climate change. This will be applied to multifunctional forest management demonstration sites in northern France and southern England, forest sites open to the public, sites designed to promote woodfuel and sites selected to improve connectivity between existing woodlands through planting and re-forestation. The aim is to educate, enable access to and raise awareness of forests and multi-functional forest management.

2 Risk Assessment Methodology

2.1 Approach

By its very nature, forestry is affected by climate which is therefore an ongoing consideration of management planning, management activity and the wider functions of the Forestry Commission. Drawing out the current effects of climate and extreme weather on FCE's functions is, as a consequence, not straightforward as dealing with such issues is a routine function of forest planning. A slightly different approach to the Risk Assessment compared to other organisations has therefore been adopted, as detailed below.

Phase 1 of the Risk Assessment involved an initial mapping of the likely impacts of climate change projections, using the extensive evidence base that has been generated through both FC-funded (see Sections 1.8 and 1.12) and other research programmes. To fully explore the full range of risks to forestry and the forestry sector prior to an evaluation of the likely impact on the functions and responsibilities of FCE, the initial phases of the risk assessment considered impacts on a number of areas of activity, with a focus on implications for forest management. These areas of activity do not align completely with the four principal functions outlined in Section 1.5 and evaluated in Section 4. This reflects the reality that many impacts will be common to both the Public Forest Estate and private sector woodlands, and therefore to more than one of the four principal functions of FCE. These same areas of activity, as listed below, were evaluated through phases 2 to 4:

- Forest management
 - *Woodland and woodland ecosystems*
 - *Arboreta*
 - *Open habitats and other ecosystems*
 - *Forest soils and water*
 - *Forest civil engineering*
- Nursery operations and seed supply
- Grants, regulation and private sector engagement
- Built estate and business activity
 - *Buildings*
 - *Transport*

Phase 2 tested the initial impacts mapping with experts across all of FCE's functions, filling gaps where identified. A preliminary evaluation of each impact was also undertaken, on the basis of the broad headline messages from the UKCP09 Climate projections (Murphy *et al.*, 2009) for the 2080s:

- Hotter, drier summers (up to 4 degrees warmer; up to 30% less summer rainfall);

- Milder wetter winters (up to 3 degrees warmer; up to 20% more precipitation);
- Less snowfall;
- More extreme weather events.

Potential adaptation responses were also considered for each impact but not, at this stage, any indication of any process for implementation. The scale of the impact, its likelihood and potential cost to the organisation and relative urgency for action to address the risk was assessed, as outlined in Section 2.2.

Phase 3 tested the risk assessment more widely across FCE together with representatives from Government Agencies, Civil Society organisations, private-sector forestry companies and forestry agents at a workshop (see Section 2.3). Comments from the workshop were incorporated into the risk tables (Annex 5) that were the basis of the formal assessment of priority risks developed in **phase 4**, as presented in Section 3. The workshop also considered interdependencies and externalities that may influence the impacts of climate change on the ability of FCE to undertake its principal functions.

Phase 5 evaluated the implications for delivery of FCE's principal functions and responsibilities, as outlined in Section 4. Phase 5 also considered the responses needed to address the priority risks identified in phase 4, giving due consideration to the interdependencies outlined in Section 5. This process resulted in the Outline Adaptation Plan for FCE presented in Section 6, covering all of FCE's functions and activities. It should be reiterated that this is an *outline* adaptation plan, and neither details nor timelines are available at this stage.

Phase 6 will involve future monitoring and evaluation of the effectiveness of the measures implemented, and any necessary changes to the adaptation plan that become apparent. In terms of managing the Public Forest Estate and providing guidance on, and facilitating, action in private sector woodlands, phase 6 will encapsulate the concept of 'Adaptive Forest Management'⁷ (see Lawrence and Gillett, 2011). This concept is important for forest management because of the long planning horizons and the need to implement some adaptation measures in advance of certainty in the evidence of those actions being optimal. In some cases, these will deviate from a 'win-win' approach – as a risk-averse approach is unlikely to deliver the necessary measures because of the 40-80 year planning horizon associated with forestry. Monitoring and rerecording to identify which measures are appropriate are underpinning and essential components of 'Adaptive Forest Management'.

⁷ Adaptive [forest] management is a structured, iterative, process of decision making in the face of uncertainty based on systematic monitoring. It is particularly appropriate for application to climate change adaptation in the forestry sector.

2.2 Framework for Evaluation

The initial Framework for Evaluation that was used for phases 1 to 3 considered both impacts and the likely consequences of each of the impacts for FCE and its ability to deliver its key objectives. Both threats and opportunities were included in the evaluation. Each potential climate impact (identified on the basis of individual climate ‘phenomena’) was evaluated using a basic risk matrix as a product of likelihood and impact, as outlined in Figure 2.1.

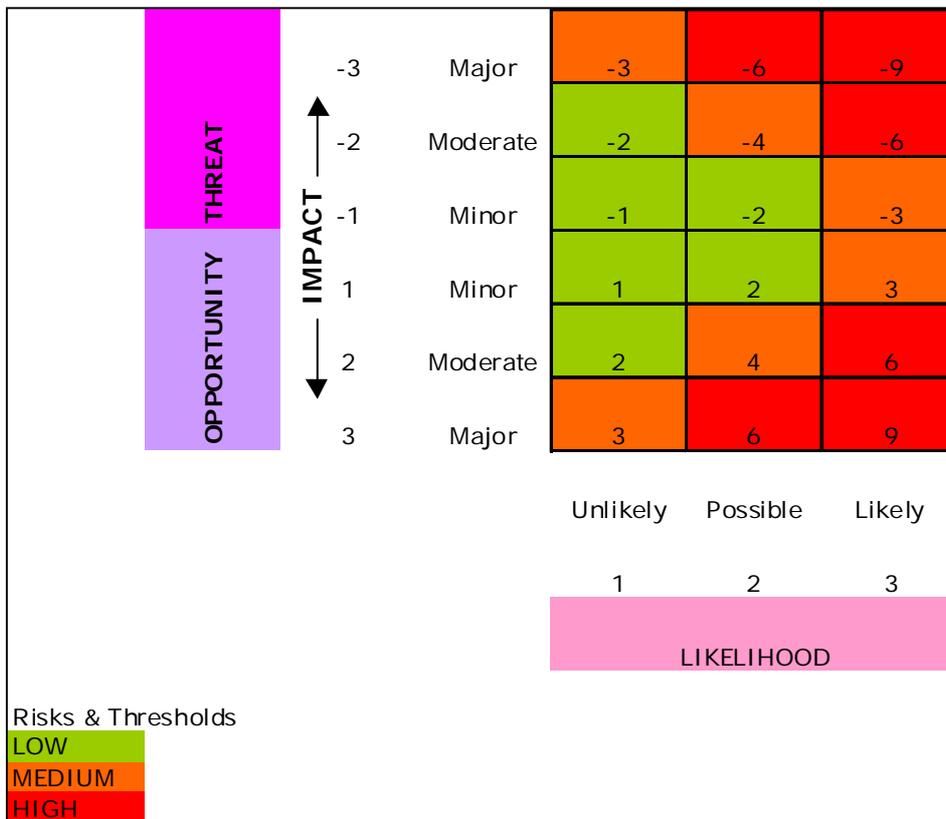


Figure 2.1. Initial evaluation framework for identifying priority risks, as used for phases 1 to 3 of the Risk Assessment process.

This basic risk evaluation was then considered alongside the urgency for action to address the risk (proximity: see discussion, below) and the cost to the organisation if measures were not put in place to mitigate the impact. In both cases, a 3-category scoring system was used. In the case of cost to the organisation, ‘Low’ was defined as either zero or minimal cost and could be absorbed within operational budgets; ‘Medium’ was defined as having a significant impact on operational budgets but could be delivered through re-prioritisation (in some cases at a significant scale) of existing budgets; ‘High’ cost was defined as requiring either a major new capital programme or fundamental change to existing budgets and priorities.

As a result of the long planning horizon associated with the forestry sector, adaptation measures often need to be implemented long in advance of the likely impacts. For this reason, there are two separate aspects of proximity – the timing of impacts (conventional proximity) and the necessary time-frame for action. The framework for evaluation of risk therefore differed from many conventional risk assessment frameworks as outlined in Table 2.1 to separate these two aspects of proximity. Through this approach, the concept of '*urgency for action*' was incorporated within the additive risk framework while the timing of impact remained as a subsequent proximity qualifier.

Table 2.1. Revised Evaluation framework for identifying priority risks.

Evaluation framework			
Likelihood	Certain	Probable	Possible
	3	2	1
Impact	High	Medium	Low
	3	2	1
Urgency to take action	Immediate (5-10 years)	Medium term (10–40 years)	Long term (40+years)
	3	2	1
Overall risk	High priority	Medium priority	Low priority
	9-8	7-6	5-3
Risk qualifiers			
Proximity (when will the impact be seen)	Short term (5-10 years)	Medium term (10–40 years)	Long term (40+years)
	S	M	L
Cost to the organisation	High (requiring new capital programme)	Medium (requiring re-prioritisation of activity)	Low (could be absorbed within existing budgets)
	H	M	L

2.3 Expert workshop

An expert workshop was held on 14th December 2010 to test the phase 2 assessment more widely across the forestry sector in England. Representation included Natural England, the National Trust, Area of Natural Beauty co-ordinators, the Woodland Trust and independent forestry agents, who also represented the English Woodland Grant Scheme Applicant's Focus Group.

The objectives of the workshop were: (i) to raise awareness of FCE's work on the Climate Change Risk Assessment; (ii) to give those present the opportunity to comment on the provisional findings from Phases 1 and 2, including options identified

to mitigate against the priority risks, and; (iii) to help FCE understand the interdependencies with its key stakeholders in relation to climate change.

The workshop was organised around three interactive break-out sessions that considered three separate issues:

- Assessment of risk – what was missing or incorrectly categorised?
- Identification of interdependencies.
- Whether the proposed adaptation responses were appropriate and adequate.

Each break-out session considered risks to (timber) production, access and recreation, Grants and regulation, civil engineering and nurseries and seed supply, separately, reflecting the focus of the workshop on impacts of climate change. The feedback received throughout the workshop has helped to shape the CCRA and has been fully integrated into the identification of priority risks and the Outline Adaptation Plan that will address those risks.

3 Identification of priority risks

3.1 Initial evaluation of risk: phases 1 to 3

As outlined in Section 2.2, the evaluation of the climate risks to the activities of FCE was based on the scientific literature, the expert views of FCE staff and the input of representatives of the wider forestry sector in England. The risk to the existing woodlands that comprise the public forest estate (Section 4.1) is also considered in the evaluation. The full range of risks considered in Phases 1 to 3 of the risk assessment process are presented as risk tables in Annex 5, using the evaluation framework described in Section 2.2. As well as the risks, their potential consequences and available measures to address those risks are also evaluated. The evaluation is broken down into 4 discreet areas, with impacts on FCE staff an integral consideration of each.

3.2 Overview of priority risks

The risks identified in Annex 5 have been prioritised according to the criteria defined in Section 2 – namely those with medium to high certainty of a significant impact for which immediate/short term action is required to address the risk. In some cases, these go beyond the direct impacts of climate change on the functions undertaken by FCE to include impacts that will arise due to the need to mitigate climate change.

The priority risks can be broken down into three distinct areas:

- Impact on the trees, ecosystems and infrastructure comprising the Public Forest Estate;
- Impact on the ability of FCE to protect, expand and improve England's woodland resource;
- Direct impact on FCE's processes, business and Corporate activities.

The first two are inter-related, in the sense that the direct effects of climate change will be common – or at least similar – across the Public Forest Estate and private sector woodlands. It is these impacts that will determine whether FCE continues to be effective in empowering and motivating landowners and managers, businesses, civil society organisations and local communities to protect, improve and expand England's woodland resource.

3.2.1 Impact on woodland and forest management on the Public Forest Estate

There is clear evidence that there will be, over coming decades, major impacts on the performance, survival and distribution of woodland species. This will impact on

woodland biodiversity, timber production and the economic sustainability of the timber industry and the wider services that woodlands provide for society. The Priority risks to woodland species, associated ecosystems and forest management have been identified through the risk evaluation framework, as outlined in Table 3.1. While the analysis was undertaken in the context of the Public Forest Estate, most are equally applicable to private sector woodlands and are therefore relevant to the delivery of Forest Services functions, as outlined in Section 3.2.2.

- Extremes of summer drought and temperature will be beyond conditions that some species in some locations are capable of withstanding;
- Insufficient genetic diversity and provenance selection/distribution provides limited resilience and capacity to adapt to climate change;
- Current silvicultural systems, predominantly based on single species, clearfell models have limited resilience to climate change and current biosecurity concerns;
- The distribution of timber species may be inappropriate to the changing climate, resulting in risk to future productivity and consequent maintenance of UKWAS certification, in the absence of adaptation;
- Changing climatic conditions will favour some non-native invasive species presenting risks to woodland biodiversity and increasing management costs if woodland SSSIs are to be maintained in good condition;
- Trees under (climatic) stress at greater risk of insect pest and disease, coupled to changing climatic conditions more favourable to some insects and pathogens;
- Inability of the National Arboreta to maintain the current collections;
- In the absence of management, larger populations of deer and squirrels benefitting from milder winters;
- 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;
- 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.

Climate change also presents opportunities for the Public Forest Estate and wider forestry sector. Primarily these opportunities are associated with the increase in productivity that will result from higher temperatures, longer growing seasons and rising atmospheric carbon dioxide levels (Broadmeadow and Randle, 2002), where sufficient water availability prevails. These opportunities may be reinforced by declining productivity and tighter controls on sustainable management practices in some current timber producing regions (in a global sense), although the dominance of imported timber (~80% of wood consumption in 2009: FC, 2010) is likely to continue.

Opportunities may also arise for the National Arboreta and other tree collections to help maintain forest biodiversity as the climate changes.

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

The majority of the priority risks outlined in Section 3.2.1 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 through the evaluation framework are:

- 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;
- 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);
- 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.

Climate change will also present a number of opportunities for FCE's role in facilitating the wider woodland sector to enhance the resilience of the landscape to climate change. For example, climate change may act as an additional driver for woodland expansion, to (i) contribute to flood alleviation; (ii) counteract soil erosion and declining water quality resulting from more intense rainfall events; (iii) reduce thermal stress in freshwater habitats by providing shade, and; (iv) develop woodland habitat networks and increase 'patch size' to aid landscape adaptation of woodland biodiversity.

3.2.3 Impact on business and corporate activities

The main impacts of climate change on business and corporate activities will be common to most organisations, and relate to working conditions, working patterns, energy use and the ability of the FC's built estate to cope with a changing climate. Specific priority risks identified through the evaluation framework include:

- Climate change policies increasing energy and water costs with the consequent economic impact on the organisation;
- Risk to buildings and staff where offices are located in flood plains;
- Rising fuel costs (in response to climate change policies) reducing net financial returns from timber harvesting and transport.

3.3 Evaluation of priority risks

Risks identified through the evaluation framework (see Section 2.2) as high priority (i.e. high likelihood, high impact and urgent need for action) are listed in Table 3.1. Each risk is considered in terms of both the direct impact of specific climatic variables, and the consequence for delivery of FCE's main functions and responsibilities.

Table 3.1. High priority risks identified through the evaluation framework. Key for consequences:

Risks	Opportunities	Impacts on staff
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Forest management		
Phenomenon	Likely Impacts	Consequences
Woodland		
Hotter, drier summers; more frequent and severe extreme events	Extremes of soil moisture and temperature	Trees will experience stress conditions which many species are not adapted to. Some will not prove resilient
	Genetic diversity within species may not be adequate	Some native species will become moribund. Conifer species of more northerly origin will lose productivity and fail to regenerate
	Failure of mono-culture and clearfell systems	Premature removal of crops following disease outbreaks, resulting in poor financial returns
	Distribution of timber species unsuited to future climate	Declining productivity and consequent economic impact; failure to maintain UKWAS certification in the absence of adaptation
	Improving conditions for some invasive species	Damage to woodland ecosystems and inability to maintain woodland SSSIs in good ecological condition
Hotter summers; milder winters	Winter chilling requirement of some species not met	Declining success of natural regeneration in semi-natural woodland
	Increased winter survival of insect/mammal pests and pathogens.	Damage to crops will increase. Trees becoming stressed as a result of the changing climate will be particularly vulnerable. Increased grazing pressure (deer) will limit natural regeneration
Arboreta		
Milder winters; hotter drier summers; more frequent/severe extreme events	Trees will experience conditions which many species are not adapted to	The 'picturesque' style at the National Arboreta may be compromised by decline of key species Trees currently not considered endangered will become endangered; enhanced role in global conservation of biodiversity
Open habitats and other ecosystems		
Hotter drier summers	Habitat change and more wildfires	Loss of priority habitat, risk to public

Forest Soils and Water		
Wetter winters; hotter, drier summers;	Rising water temperature and reduced low flows	Increased woodland planting in riparian zones will provide shade
Forest Civil Engineering		
More frequent and severe extreme events	Reservoir capacity and stability compromised	Breaches, flooding erosion, interruptions to operations, impacts on society and safety risk
	Weakening of stability on slopes	Erosion of soils and land slips. Interruptions to operations, impacts on society and safety risk

Nursery operations and seed supply		
Phenomena	Likely Impacts	Consequences
Warmer, wetter winters; hotter drier summers; more frequent extreme events	Urgent need for new species and southerly origin planting stock	Demand for transplants not being met, leading to use of inappropriate planting stock
		New business opportunities for responsive tree nurseries

Grants, regulation and private sector engagement		
Phenomena	Likely Impacts	Consequences
Warmer, wetter winters; hotter drier summers; more frequent and severe extreme events	Increased competition for land between food and forestry	Inability to achieve a step change in the rate of woodland creation
	Advice to private sector may not address future risks	Woodland condition will decline with consequent impact on timber supply, carbon stocks and income to woodland owners
	Advice to, and regulation of, private sector on species choice may not address future risks	New woodland will not be resilient to impacts of climate change. Poor return on public funding through EWGS
	Under-managed woodland may not be resilient	Forest health will decline and carbon sequestration will not be optimised
Hotter drier summers	More frequent wildfire events	Loss of life, property, and ecosystems

Built estate and business activity		
Phenomena	Likely Impacts	Consequences
Buildings including power, waste and water		
More frequent and severe events	Increased flooding of river flood plains	Property could be flooded, paper and electronic records lost
Transport		
Warmer, wetter winters; hotter drier summers; more frequent and severe extreme events	Society will demand that business reduces use of non renewable energy and minimises its carbon footprint	Transport of timber will be become increasingly expensive

4 Assessment of risk for Forestry Commission England

The degree to which trees and woodlands are affected by climate change will have a significant influence on the majority of FCE's functions, including the management of the Public Forest Estate (PFE) and the ability of Forest Services to influence and empower the wider forestry sector through advice, standards, effective regulation and grant-aid. The risk assessment for the various functions of the organisation is therefore preceded by an assessment of risk for the existing woodlands that comprise the PFE.

Although the detailed information linking forest stands to specific soil types is only available for the PFE, a similar distribution of species is seen for most regions in public and private sector woodlands (see Regional Inventory Reports for the National Inventory of Woodland and Trees, published in 2002). It can therefore be inferred that, at sub-national level, the implications of climate change are likely to be similar for private and public sector woodlands; this analysis of impacts on trees and woodlands therefore underpins all relevant elements of this climate change risk assessment.

4.1 Assessment of risk to trees and woodland on the Public Forest Estate

4.1.1 Ecological Site Classification

The Ecological Site Classification (ESC) decision support system has been developed over a number of years to enable the impact of climate change on individual tree species and native woodland types to be evaluated (see Pyatt *et al.*, 2001). Most outputs have been in the form of maps of suitability for new planting and have been based on the dominant soil type in a given 5 km grid and therefore do not fully reflect the matching of species to site (particularly soil type) that is standard silvicultural practice, nor site modification such as drainage that may have been undertaken in the past. The analysis presented in the report links species information for individual stands from FC's sub-compartment data-base (SCDB) to soil type based on 1:250,000 soil maps (NatMap). Although this resolution of soil information is far from perfect for this purpose, and the mapping of forest soils is relatively poor, the approach does represent a significant step forward in the analysis of risk to existing forestry crops.

ESC is a knowledge-based system, linking climate and edaphic (soil) variables to known species performance. Climate variables are temperature (annual accumulated temperature sum), summer moisture deficit, exposure (windiness based on the DAMS

wind hazard classification system) and 'continentality' (using the Conrad continentality index). Edaphic factors are soil nutrient regime and soil moisture regime. Full details are given in Pyatt *et al.*, 2001; Ray *et al.*, 2002 and; Broadmeadow *et al.*, 2005). In the standard ESC model, suitability classes are **very suitable** (greater than 75% of maximum productivity observed in the UK); **suitable** (50 to 75% of maximum productivity) and **unsuitable** (less than 50% of maximum productivity). For the purposes of this evaluation, a further category of '**marginal**' has been added (30 to 50% of maximum productivity). The marginal category reflects that the objectives of management on the PFE (and woodlands more generally) are not limited to timber production and that trees, native species in particular, will continue to form part of valuable woodland ecosystems on sites where they are not a commercially viable crop. It also reflects that expectations of acceptable productivity for commercial timber production may change as a direct result of climate change (i.e. a lower productivity may be deemed acceptable, than is currently the case), particularly if there is a declining global timber resource.

An evaluation of the risk that climate change presents to species suitability across the Public Forest Estate is given in Section 4.1.3; an assessment of risk to productivity is given in Section 4.1.4.

4.1.2 Approach

The analysis represents risk to the current species distribution on the PFE, based on the High emissions scenario of the UKCIP02 climate change scenarios (Hulme *et al.*, 2002). The assessment of risk is therefore based on relatively extreme, but still credible, climate projections. There is no evaluation of probability as provided by the more recent UKCP09 Climate Projections (Murphy *et al.*, 2009), and the analysis therefore takes a slightly different approach to those presented in a number of the other sector and Priority Reporting Organisations' reports. There are also a number of important assumptions and caveats to consider:

- The impact of forest pest and disease outbreaks is not considered; as outlined in the Read Report (see Broadmeadow *et al.*, 2009b), pest and disease impacts may well become more prevalent as either a direct or indirect impact of climate change, while future developments in global trade and biosecurity agreements for timber, wood products and live plants (see section on interdependencies) is also a consideration.
- The beneficial effects of rising atmospheric carbon dioxide (CO₂) levels on tree growth is not considered; the analysis therefore overestimates any negative impacts on tree growth and forest productivity although, where water supply is limiting, this 'CO₂ fertilisation effect' may be negligible (Broadmeadow *et al.*, 2009b).
- Although the small changes in wind-speed represented in the UKCIP02 climate scenarios are included in the analysis, catastrophic storm events and any change in

the distribution of wind speeds within the mean are not (see Quine and Gardiner, 2002 for further detail).

- This risk assessment considers existing crops and assumes no change in species, provenance, silvicultural system or quality of planting stock; i.e. in the absence of any adaptation measures. This would contravene the requirements of the revised UK Forestry Standard and Forests and Climate Change Guidelines (published in autumn 2011). Since all FC woodland is managed to UKFS as a minimum standard, this risk of non-adaptation is hypothetical.
- Where mixed species stands are denoted in the SCDB, all species are included in the analysis. The total area considered (268,000 ha) is therefore greater than the total area of woodland on the Public Forest Estate (202,000 ha).
- Pedunculate/ sessile oak and silver/downy birch are generally not identified separately in the SCDB. This affects the conclusions of the analysis, particularly since mixed broadleaves (as denoted in the SCDB) are assumed to be birch, which is acknowledged to be a far from correct assumption.

4.1.3 Evaluation of Climate change and Species suitability

Baseline: The analysis of current (baseline) suitability indicates that species are extremely well matched to site across the PFE as a whole, with less than 1% of the PFE assessed as being planted with 'Unsuitable' species. More than 90% of stands are either Suitable or Very Suitable with over 50% of commercial conifer stands assessed as Very Suitable (see Figure 4.1). The proportion of broadleaf woodland assessed as Marginal (12%) is twice that for conifer woodland, possibly reflecting the inability to differentiate between the two oak and birch species. This is born out by the proportion of broadleaf woodland in southeast England assessed as Marginal varying between 6 and 26%, depending on which of the four combinations of oak and birch are selected. The comparative figures are 16 and 32% for northwest England. Of the conifer species, Douglas-fir has the largest area that is defined as Marginal or Unsuitable (22%), with all others being Suitable or Very Suitable across more than 90% of their area (see Annex 3).

2050s: By the middle of the century, there is a risk that slightly more than 20% of the PFE would be Unsuitable or Marginal (in terms of commercial timber production) should the more extreme climate scenarios be realised and in the absence of adaptation. Of this area, only 5% would be deemed Unsuitable, although it should be noted that the Marginal category would currently be seen as Unsuitable and therefore assumes that the attitude of forest managers to acceptable levels of productivity adapts to changing conditions. For both conifers and broadleaves, more than 75% of the PFE remains as either Suitable or Very Suitable under the relatively extreme climate change scenarios assessed here.

For conifer stands, the implications are that even in the absence of adaptation when restocking at the current time, there is a likelihood that those stands would remain suitable through the majority of the rotation (~40-60 years, depending on species). However, any delay in implementing adaptation measures with respect to species choice would increase the proportion of rotations subject to the risk for the latter half of the century (i.e. 2080s).

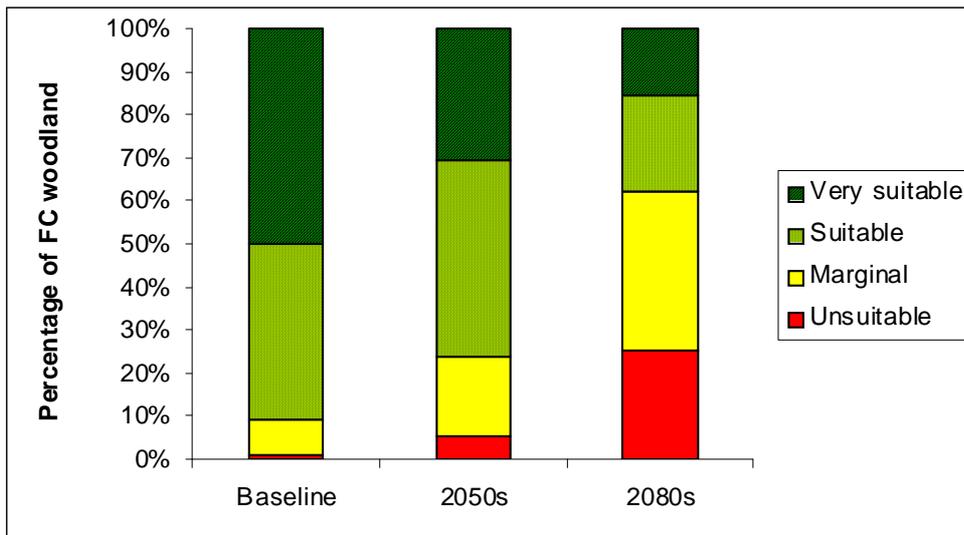


Figure 4.1. Ecological Site Classification assessment of suitability for all woodland on the Public Forest Estate, based on UKCIP02 High emissions scenarios for the 2050s and 2080s.

For broadleaf species, a risk assessment for the middle of the century should not be considered in isolation as a significant proportion of their rotation (generally >100 years) would be beyond this time-frame. The exceptions to this generally benign risk assessment for the middle of the century are all larch species, for which nearly 80% of the current area would be defined as Unsuitable or Marginal by the middle of the century and, to a lesser extent, sycamore, for which nearly 50% of the area would be Marginal/Unsuitable. Stands of birch are also at enhanced risk, although the inability to differentiate between species invalidates this assessment to some extent. This is demonstrated by the comparison of southeast and northwest England for individual species of birch, which indicate that, in each case, if only the most suitable species is chosen, the area defined as Unsuitable/Marginal declines from 48% as a national average for silver birch (82% for downy birch) to 22% and 19% for NWE and SEE, respectively.

2080s: The relatively benign risk assessment for the middle of the century (i.e. 2050s) is replaced by a much more serious picture towards the end of the century. Across the PFE, only 38% of stands would be considered Suitable or Very Suitable under current definitions. The situation for conifers is particularly worrying, with 32% of stands classified as Unsuitable in this analysis. In contrast, only 11% of broadleaf stands would be defined as Unsuitable, with the majority (58%) assessed as Marginal.

Although this indicates that impacts on tree composition in native woodlands may not be that significant, where timber production is an important objective, the implications are more serious, particularly given the much longer rotation of broadleaf species compared with conifers. This evaluation concurs with projections of climate space for native broadleaf species summarised in the Read report (Broadmeadow et al., 2009b), which indicated that although the southern boundary of climate space for most broadleaved species may move close to the south of the UK, climate space is likely to be retained, at least for the IPCC B2 emissions scenario (IPCC, 2000: equivalent to the UKCIP02 Medium-High emissions scenario). However, alternative approaches to management of broadleaf native species are available, including growing them over much shorter rotations with woodfuel and pulp as the main markets (short rotation forestry or SRF). If SRF was adopted more widely, this would avoid the dramatic changes in productivity that are associated with climate change projections over longer rotations.

An assessment of the risk to individual species towards the end of the century indicates that Corsican and lodgepole pine are likely to fair relatively well with more than 80% of stands evaluated as remaining either Suitable or Very Suitable. In contrast, more than 80% of stands of larch would be defined as Unsuitable. However, there are serious plant health issues associated with all three species (red-band needle blight in the case of the two pine species and *Phytophthora ramorum* in the case of larch), making this little more than an academic exercise at the present time. Douglas-fir is currently considered a species that may benefit from climate change; however, on the sites that it is currently planted, less than 20% of the area would remain Suitable in this analysis, with the majority in the Marginal category (67%). However, it must be restated that this risk assessment is based on relatively extreme climate scenarios. Of the broadleaf species, less than 10% of the area of ash, beech, and oak are assessed as at risk of becoming Unsuitable, with the majority, Marginal. However, more than half the area of pedunculate oak (if that was the species chosen on those sites) would remain Suitable. Chestnut, unsurprisingly given its geographic origin, fairs relatively well with more than 70% of existing stands of the species remaining Suitable or Very Suitable.

4.1.4 Evaluation of climate change and productivity

When aggregated across the whole of the Public Forest Estate, there is a risk that productivity (or yield class) could decline by 7% by the 2050s under the High emissions scenario of UKCIP02 and by 35% by the 2080s (Figure 4.2), in the absence of adaptation. The implications are more serious for broadleaf woodland for which there is a risk of a 49% decline in productivity by the 2080s (15% by the 2050s), reflecting the larger proportion of broadleaf woodland on the PFE in those regions where the climate projections indicate more serious summer droughts are likely. For the main productive conifer species, there is a risk that productivity could decline by 32% by the 2080s (5% by the 2050s). However, this coarse analysis conceals a large

degree of regional variation with increased productivity possible in Northwest England, but a much larger decline than the national average in the south and east. It also assumes that silvicultural practice will remain unchanged, which is unlikely if woodland condition were to decline significantly.

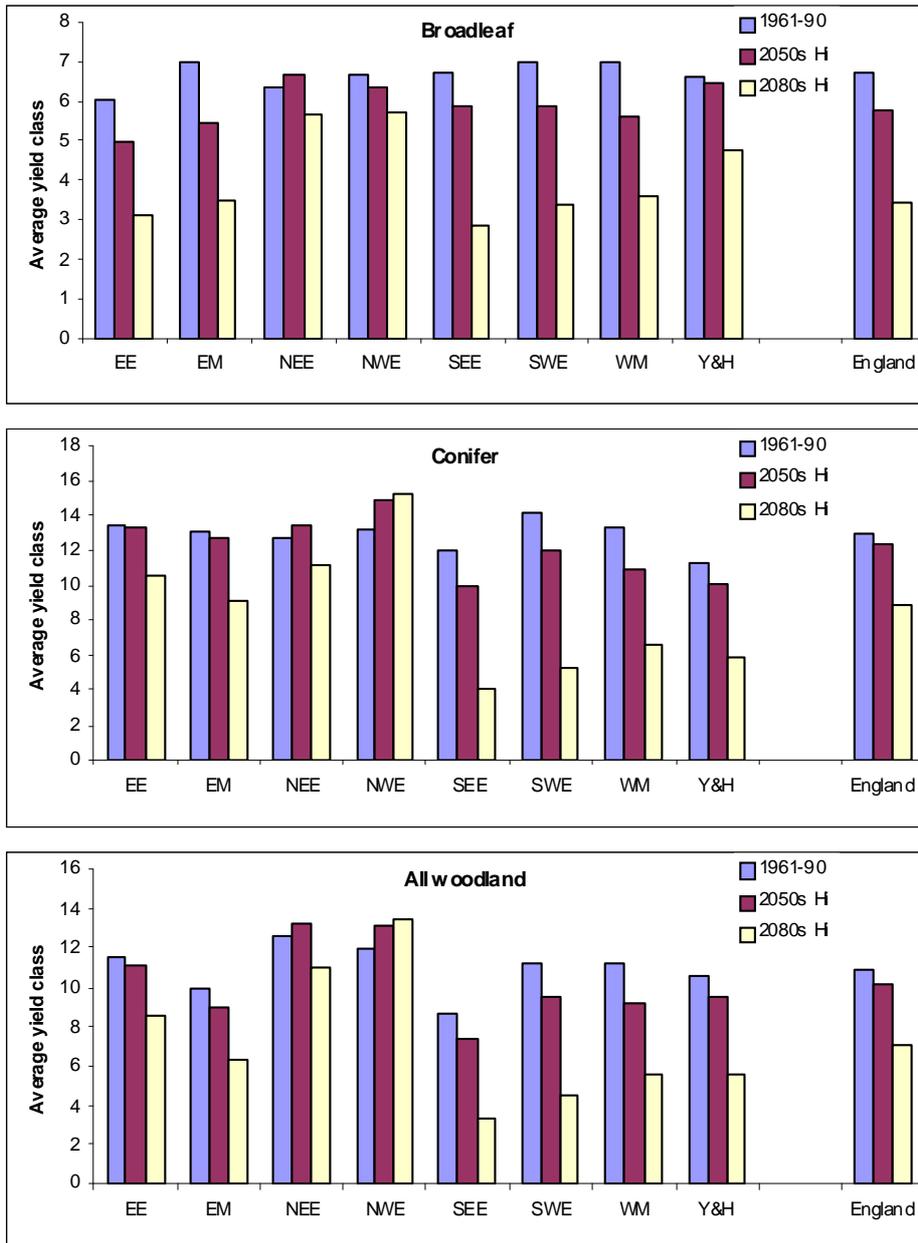


Figure 4.2. ESC evaluation of changes in productivity for broadleaf (top), conifer (middle) and all woodland (bottom) across the public forest estate in England under the UKCIP02 2050s and 2080s High emissions scenario. Key: EE – East England; EM – East Midlands; NEE – Northeast England; NWE – Northwest England; SEE – Southeast England; SWE – Southwest England; WM – West Midlands; Y&H – Yorkshire and the Humber. Note London Region is excluded from the analysis due to the low woodland cover.

The risk varies between individual species, in part reflecting their varying distributions across the PFE (Fig 4.3). The one species that may increase in productivity across the PFE as a whole is sweet chestnut (SC), even though the Southeast is the region with by far the largest area planted with SC. All other broadleaves are at risk of a significant decline in productivity, with the two birch species likely to be affected to the greatest extent and ash and pedunculate oak, the two species likely to be most resilient, given their current distribution. Of the conifers, pine species (Corsican and lodgepole) appear to be most resilient, but this analysis does not consider the effects of red-band needle blight which currently precludes the planting of Corsican pine. On the basis of their current distribution, both larch species, Norway spruce and, to a lesser extent, Douglas-fir appear to be at risk. Surprisingly, given its requirement for moist conditions, Sitka spruce on the PFE appears to be at limited risk, probably reflecting its predominant distribution in the wetter regions of England. Further detail of risks to particular species in specific regions is given in Annex 4.

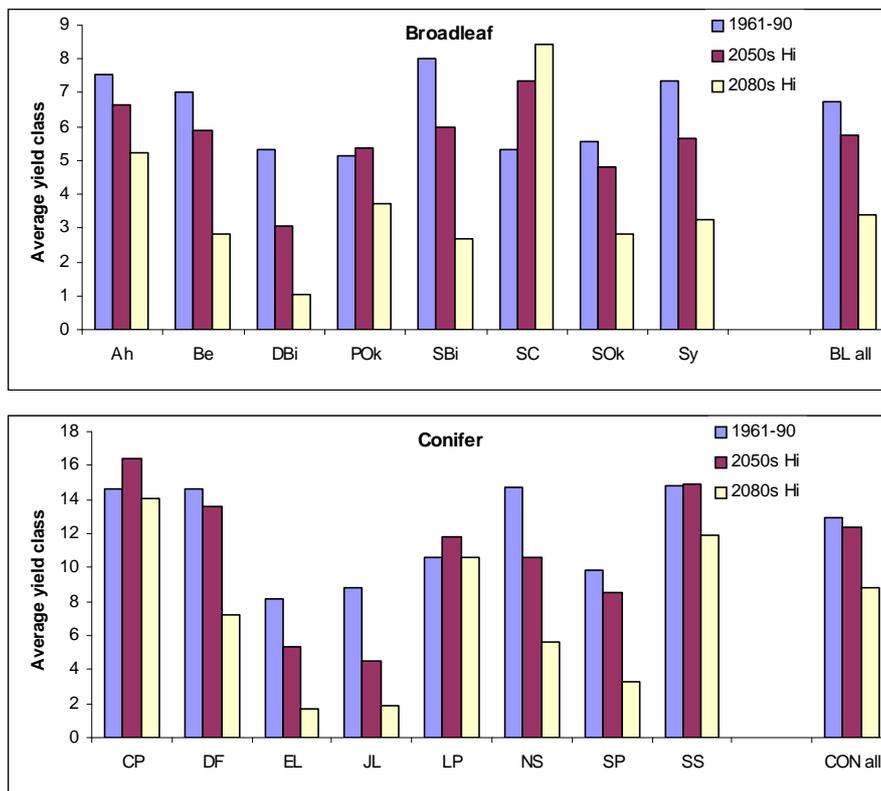


Figure 4.3. ESC evaluation of changes in productivity for individual broadleaf (top) and conifer (bottom) species across the Public Forest Estate in England under the UKCIP02 2050s and 2080s High emissions scenarios. For further detail of regional breakdown, see Annex 4. Key: Ah – ash; Be – beech; DBi – downy birch; POk – pedunculate oak; SBi – silver birch; SC – sweet chestnut; SOk – sessile oak; Sy – sycamore; BL – broadleaf; CP – Corsican pine; DF – Douglas-fir; EL – European larch; JL – Japanese/hybrid larch; NS – Norway spruce; SP – Scots pine; SS – Sitka spruce; con – conifers.

4.1.5 Implications

If adaptation measures are not implemented in species choice when restocking existing stands, there will be serious implications and there is a risk that nearly two thirds of the public forest estate would be considered unsuitable for commercial timber productions by the end of the century, under current expectations of timber yield.

It is important to restate that the assessment of risk presented here assumes no change in planting stock. As a result of the considerable geographic range and genetic variability of most tree species (see Broadmeadow *et al.*, 2005), there is significant scope for provenance selection and tree breeding programmes to enhance resilience without requiring a change in species. This is reflected in the draft Forests and Climate Change Guidelines and the Ancient and Native Woodland Practice Guide (FCE, 2010b) that both point to the planting of more southerly provenances as an adaptation measure.

4.2 Empowering and engaging the forestry sector

Much of FCE's work is achieved through partnerships - nationally, regionally and locally - helping to turn strategic policy into practical and positive action on the ground. Examples of partnership projects relevant to climate change adaptation are summarised in Section 1.11. There is now an increased focus on the use of 'enabling frameworks' to facilitate change, reducing direct intervention by FCE but establishing conditions to encourage others to take actions to achieve Government's wider objectives on forestry. In the context of climate change adaptation, the principal enabling frameworks include the PFE's role as an exemplar of adaptation (Section 4.3), the UKFS Forests and Climate Change Guidelines coupled to requirements for receiving grant-aid (Section 4.4) and the work of the Woodland Carbon Task Force in attracting private finance to woodland creation and management (also covered in Section 4.4).

Civil society is invaluable to delivering FCE's desired outcomes and includes charities, the voluntary sector, not for profit organisations, Non-Governmental Organisations (NGOs) and social enterprises. We have worked with Natural England and the Environment Agency to produce a joint statement on our work with the Third Sector.

4.2.1 Aims and Objectives

FCE will focus on

1. *Protection*: protecting the woodland resource and increasing its resilience, for example, to pests, diseases and the impact of climate change.
2. *Improvement*: improving the woodland resource to enhance benefits including biodiversity, landscape quality and a range of other ecosystem services.

3. *Expansion*: Promote and incentivise the planting and natural regeneration of trees, woods and forests of the right type in the right place.

This will be delivered by:

- *Empowerment and Engagement*: empowering and enabling people to engage with trees, woods and forests, so that they can determine the benefits that they wish to see delivered
- *Economic Activity*: promoting a competitive, thriving and resilient forestry sector alongside a wide range of private sector business partners.

4.2.2 Implications for delivery of objectives

The specific impacts of climate change on FCE's two main 'enabling frameworks' – the Public Forest Estate and grant administration and forestry regulation are outlined in Sections 4.3 and 4.4. The objectives of the 'enabling frameworks are to address current issues, including climate change adaptation, through establishing conditions and encouraging others to take action to deliver FCE's desired outcomes. It is therefore inappropriate to assess the likely impacts of climate change on FCE's empowerment and engagement function in isolation. Rather, this section briefly outlines, as context for the detailed risk assessments presented in Sections 4.3 and 4.4, how climate change impacts and adaptation are being accommodated into priority actions supporting *protection*, *improvement* and *expansion*, respectively, as outlined in FCE's Corporate Plan for 2011-15 (FCE, 2011). Priority actions are listed below, amended in bold where climate change adaptation can be accommodated within those actions.

Protection

- Implement the Forestry Commission Biosecurity Strategy with the Plant Health Service, Forest Research and the Food and Environment Research Agency (FERA), **including consideration of the possible interactions between climate change and pest and disease outbreaks.**
- Monitor the health of our trees and woodlands, **including the effects of both biotic and abiotic agents.**
- Run events to disseminate best practice on plant health, **taking opportunities to cover climate change adaptation where appropriate.**
- Address plant-health threats in England through expanded partnerships, **using those same partnerships to promote climate change adaptation.**
- Publish a Climate Change Risk Assessment and Adaptation Plan for Forestry Commission England, **using them to promote the need for and practical implementation of adaptation actions, respectively.**

- Communicate the UK Forestry Standard and take a risk based approach to integrating it into our grants and regulations, **including measures to support the Forests and Climate Change Guidelines.**
- Inspire local communities to come forward with Nature Improvement Areas. Focus our resources on those that involve forestry **and incorporate actions to support site and landscape scale adaptation.**
- Influence implementation of the England Biodiversity Strategy so it reflects the evidence about ecosystem services **and the specific need of adaptation within woodlands.**

Improvement

- Deliver The Big Tree Plant funding scheme, **ensuring messages regarding the role of trees and woodland in adapting the urban environment are recognised.**
- Target communications to woodland owners most likely to start managing their woodlands, **including opportunities for adaptation.**
- Deliver the Woodfuel Implementation Plan, **using it as a vehicle for introducing forest planning and adaptation into England's woodlands.**

Expansion

- Embed the Woodland Carbon Code as the standard for domestic woodland carbon projects, **including the need to accommodate climate change projections in species choice.**
- Develop an interactive map that shows priority areas for new woodland creation, **including for landscape-scale adaptation.**
- Train land based advisors on woodland creation options, **and species choice appropriate to the changing climate.**
- Influence Common Agricultural Policy reform so it better reflects the value of ecosystem services in woodland creation **and its contribution to landscape-scale adaptation.**

4.3 Management of the Public Forest Estate

The Public Forest Estate is managed by Forest Enterprise England (FEE), which was established as an Executive Agency of the Forestry Commission on 1 April 2003 following the Forestry Devolution Review. Formally, the main role of the Agency is to manage the Public Forest Estate placed at the disposal of the Forestry Commissioners by the Secretary of State for Environment, Food and Rural Affairs.

4.3.1. Aims and objectives

The overall aims and objectives of Forestry Commission England is outlined in FCE's Corporate Plan for 2011-12 and are subject to the views and recommendations of the Independent Panel on Forestry in England and Government's response to them.

The overall aim remit for the Agency (FEE) is:

"To manage the Public Forest Estate owned by the Secretary of State for Environment, Food and Rural Affairs in accordance with the remit set by the Forestry Commission's National Committee."

Broad objectives of the Agency include:

- **Sustainable forest management** – To manage the Public Forest Estate in a sustainable manner.
- **Economic** – To develop the contribution of the Public Forest Estate to the economy.
- **Environmental** – To conserve and enhance the biodiversity, landscape and cultural heritage of the Public Forest Estate.
- **Social** – To promote the use of the Public Forest Estate and develop recreational opportunities, and; to use the Public Forest Estate to improve the quality of life of disadvantaged communities and bring Brownfield land into beneficial public use.
- **Efficiency and standards** – To be cost-effective and environmentally aware in all operations; to generate income from activities that both deliver public benefits and help to fund the delivery of wider benefits on the estate; to provide high quality services to customers; to be a fair employer that promotes diversity, and; to maintain safe working practices and a safe environment for visitors.

4.3.2 Main direct and indirect climate risks to the management of the Public Forest Estate

Sustainable forest management

To manage the Public Forest Estate in a sustainable manner.

The Public Forest Estate has been established over many years, matching species requirements to site conditions and assuming a relatively stable climate. This key assumption no longer applies. The changing climate therefore presents a challenge to the management of the PFE in England because of impacts on tree growth and suitability, which will vary by region and species. The negative impacts of climate change will be more severe in the south and east than in the north and west. A detailed evaluation of risk to species suitability and productivity is given in Section 4.1, highlighting the risks associated with continuing to plant the same range of species and provenances and adopting the same management systems that have proved successful over the past 90 years.

Declining productivity in many regions as a result of climate change will require that changes in species choice are accommodated in Forest Design Plans in order to comply with the principles of sustainable forest management (SFM) and the requirements of the UK Forestry Standard and the UK Woodland Assurance Standard.

Tree health issues, including red-band needle blight of pine species, *Phytophthora ramorum* infection of larch, *Phytophthora lateralis* infection of Lawson Cypress, *Phytophthora pseudosyringae* infection of *Nothofagus obliqua* and Acute Oak Decline represent a serious current challenge to the management of the Public Forest Estate, and one that is likely to have far greater impact than climate change alone in the short to medium term. However, there is also a risk that climate change will enhance the severity and frequency of pest and disease outbreaks and present an increasingly suitable climate for pests and pathogens that are yet to be introduced.

Current approaches to management will also be challenged by the changing climate, as outlined in the detailed evaluation of risk in Section 3 and Annex 5. For example, drainage regimes will require reconsideration in the light of changing soil moisture regimes, rotation length is likely to be affected by changing growth rates and susceptibility to windthrow and establishment success will be affected by changing seasonality and soil water regimes. Furthermore, climate change may affect the period when management activity can take place through, for example, limiting access for thinning/harvesting as a result of waterlogged soils or a change in the timing of periods in the life cycle of priority species when they are at heightened risk from management activity.

Climate change, particularly changing rainfall patterns, is also likely to present a risk to the PFE's infrastructure, meaning that current specifications for roads, paths, culverts, bridges and some reservoirs may not meet future needs. Again, the ability to comply with SFM principles may be compromised by climate change if adaptation measures are not taken to address the changing climate.

Unsurprisingly, given the inherent link between forestry and climate, all aspects of forest management are likely to be affected to a greater or lesser extent and, in turn, these may make some of the IT and decision support systems used to support management on the PFE either redundant or in need of revision.

Economic

To develop the contribution of the Public Forest Estate to the economy.

The economic health of the Public Forest Estate is dependent on the health and productivity of trees and forest ecosystems. Changes in growth rates will affect harvest rates across the PFE, having a direct impact on timber income. Climate change, and the associated rises in CO₂ levels, will increase tree growth in the north and west of England, but lead to a decline in the south and east. Economic impacts could be particularly serious if pest and disease outbreaks become more frequent or

severe as a direct or indirect effect of climate change. In some cases it will be necessary to implement 'sanitary felling', harvesting the trees before economic maturity, as is the case with the current outbreak of *Phytophthora ramorum* on larch in the west of England. A further economic consequence is depressed market prices for larch and additional harvesting costs associated with bark removal.

Although there is a high level of uncertainty associated with windspeed projections and the frequency of windstorms, the economic impact of more widespread wind damage would be significant, both in terms of loss of growing stock and the much larger management costs associated with harvesting windblown stands. An increased frequency of wildfires as a result of the hotter, drier conditions outlined in climate change projections would also have a direct economic impact, both through loss of growing stock and staff management costs associated with both the fire itself and the subsequent 'clear-up' operations. The cost to Fire Services for responding to wildfires are also significant, and have been estimated as between £35 and £49 million per annum across the UK (i.e. not restricted to forestry or the Public Forest Estate: R. Gazzard: pers. Comm.).

Recreational income has become increasingly important to the PFE. If the impacts of climate change (tree mortality, wildfires) were to lead to a deterioration in the appearance of PFE woodlands, visitor numbers and associated income may decline. Furthermore, many third-party businesses are associated with the PFE. Recreational income would also be affected if forests had to be closed during periods of heightened fire risk or during/following storm events. However, longer and more frequent visits to woodland and urban greenspace have been shown to enhance perceived 'well-being' during times of heat stress (Laforteza *et al.*, 2009) and so increased temperatures may lead to an increased number of visitors to woodlands, potentially leading to an increase in recreational income. It should be noted that evidence of the links between climate and visitor numbers is limited or anecdotal in nature.

As indicated in Sections 3, changing rainfall patterns are likely to place increased pressure on forest infrastructure, including roads, paths, culverts and bridges. Costs of repair may be significant, although they have not been quantified at this stage.

Environmental

To conserve and enhance the biodiversity, landscape and cultural heritage on the Public Forest Estate.

The changing climate raises difficult questions for the conservation of woodland biodiversity. Current definitions of native woodland community composition may not be sustained as a result of climate change and it may prove increasingly difficult to maintain SSSIs on the Public Forest Estate in 'good or recovering' condition if conservation objectives are not amended in response to the changing climate. A number of invasive non-native species may benefit from climate change, placing an

additional challenge to the management of priority woodland and non-woodland habitats.

A particular challenge is the restoration of plantations on ancient woodland sites (PAWS) to native species in support of the Keepers of Time policy (Defra, 2005). In such cases, where restocking is through natural regeneration and in the absence of enrichment planting, there is a risk of native woodland establishing that is of limited species diversity, of species that may not thrive in the future climate and of genotypes adapted to the past rather than the future climate. However, guidance on the re-establishment of 'climate resilient', native woodland on PAWS is provided in the recently published Ancient and Native Woodland Practice Guide (FCE, 2010b). Similar issues over the long-term resilience of some non-woodland habitats apply, as outlined in the evidence supporting the policy for the restoration of open habitats in England (FCE, 2009).

There is strong evidence (Irvine *et al.*, 2007) that warmer winters are likely to lead to reduced mortality for both deer and grey squirrels and that this impact is already occurring. Larger populations, with consequent impacts on regeneration and woodland condition, will result if control programmes are not significantly increased.

Increased winter rainfall and more intense rainfall events may increase sediment run-off during forest operations impacting negatively on the freshwater environment.

Although not a direct impact of climate change, changing species composition across the PFE as an adaptation response may impact on landscape character and will continue to be a material consideration in forest design planning.

Non-woodland priority habitats on the PFE are at particular risk from climate change. Peatlands are at risk of drying out with consequent impacts on species composition and peat degradation. Lowland heaths are regularly subject to wildfires with impacts on both habitat and wildlife. Modelling indicates that fire risk will increase significantly as a result of climate change.

Social

To promote the use of the Public Forest Estate and develop recreational opportunities;

To use the Public Forest Estate to improve the quality of life of disadvantaged communities and bring Brownfield land into beneficial public use.

The main negative social impacts, as outlined earlier in this section, are likely to relate to climate change directly affecting (a) the quality of PFE woodlands through drought-related mortality, pest and disease outbreaks and wind damage, (b) the accessibility of PFE woodlands through degradation of forest infrastructure and (c) limited access to PFE woodlands during times of high fire risk and following significant storm events.

Although evidence is limited, hotter summers may increasingly make woodland an attractive place to take recreation because of the cool, shady environment. Increased visitor numbers may therefore result, particularly if there is a move to UK-based holidays in response to a drive for society to reduce air travel. Although this would represent an opportunity for the PFE, there may be tensions, particularly if wildfire incidents increase as a consequence.

Efficiency standards

To be a cost-effective and environmentally aware in all operations;

To generate income from activities that both deliver public benefits and help to fund the delivery of wider benefits on the estate;

To provide high quality services to customers;

To be a fair employer that promotes diversity;

To maintain safe working practices and a safe environment for visitors.

Climate change will have a significant impact on the resource that the PFE manages as outlined in the previous sections, all of which relate to the overall management efficiency of the PFE. Climate change will also affect the staff that manage the PFE, colleagues who work for FEE and society that uses it. Working conditions are a key area, including vehicles, machinery, offices and the wider forest. Investors in People accreditation demonstrates FCE's commitment to the development of its staff and their working conditions, a process that will need to continue as the climate changes and, at times, working conditions become less pleasant as a result of rising summer temperatures.

The health and safety of FCE staff and visitors to the PFE are key considerations and protocols are in place to protect them during wildfires and during windstorms. Both phenomena may become more frequent, enhancing any unmitigated risk. The incidence of Lyme's disease in staff, which is transmitted by ticks, has increased in recent decades. Analysis suggests that tick populations are likely to increase as a result of climate change, therefore presenting a heightened risk of Lyme's disease to both staff and visitors to the PFE.

Two offices are located close to or within the 100-year flood risk zone (Santon Downham and Kielder: S. Broadmeadow, pers. com.) placing them at enhanced risk, although local site assessments based on previous flood events within the locality suggest that the risk is minimal.

4.3.3 Opportunities that may arise from climate change

Production of timber

Where soil moisture availability is not a limiting factor, the longer growing season coupled to rising CO₂ levels will result in significant increases in yield. Initially, climate

projections indicate that this increase may be widespread, but over time restricted to areas of higher rainfall in the north and west. Further increases in timber production could be achieved through appropriate species choice at restocking, including opportunities to plant species which have been temperature-limited in the past.

The drive for sustainable use of materials and replacement of fossil fuels will see wood increasingly being sought as a resource. The increase in demand, in part driven by renewable energy requirements (see below), is likely to result in rising timber prices and a more sustainable economic outlook for the Public Forest Estate.

Wood, as a renewable source of energy and heat, will be increasingly in demand, responding to the rise in fossil fuel prices and policies promoting renewable energy, particularly the Renewable Heat Incentive. As a consequence, thinning operations are likely to become financially viable, providing economic benefits and improvement in woodland habitat quality on the PFE.

Society

More people than ever are using the Public Forest Estate as a place for recreation. FEE has taken the opportunity to develop significant business for itself and also encouraged a wide range of small to medium businesses to develop. Changes in the climate are likely to make woodland an even more attractive place to take recreation (Lafortezza *et al.*, 2009). It is therefore probable that businesses associated with woodland recreation will grow, as may the value of PFE woodlands as outdoor classrooms.

Reputation

The Forestry Commission in England is the lead department in all matters relating to forestry. The PFE is seen as an exemplar of best practice to many within the industry. Innovation is encouraged. The implementation of the Climate Change Action Plan – based on the application of guidance provided by Forest Research to comply with the requirements of the UKFS and its Forests and Climate Change (and other) Guidelines – will provide a clear example of leadership enhancing the reputation of FEE and FCE more generally.

Woodland creation

Currently the Forestry Commission has no mandate to expand the PFE. However, it is widely recognised that a step change in woodland creation would make a significant contribution to UK emissions reduction targets in the medium to long term. Strong signals have been given that the majority of investment will need to come from the private sector and the Natural Environment White Paper has mandated the Independent Panel on Forestry in England to advise on an appropriate level of woodland creation and market mechanisms required to achieve it. Opportunities may arise for the involvement of FEE, building on past experiences and recent projects

such as Newlands (in Northwest England), Jeskyns (Southeast England) and Thames Chase (East of England).

4.3.4 Implications for the delivery of the objectives

The management of the PFE deals with extremes of weather on a regular basis and the assessment of risk from windthrow and drought, for example, are included as routine management decisions in rotation length and species choice through the forest design planning process. In the short term, it will therefore be difficult to identify the direct effects of climate change and implications for delivery will be minimal over this timeframe. However, failure to implement the Climate Change Action Plan (CCAP) risks damaging the reputation of FEE and the wider FC, as the issues of limited species diversity, dominance of clear-fell management systems and species distribution based on past climate have been well documented. Failure to implement the CCAP would also represent a lack of leadership in the sector and affect the ability of the Forestry Commission to facilitate adaptation in the 85% of England's woodland resource that it is not responsible for the management of. Reputational damage may also arise if actions on the PFE in support of Ancient Woodland Policy (Defra, 2005) and Open Habitat Restoration Policy (FCE, 2009) deliver native woodland on PAWS and non-woodland habitats that are seen as vulnerable to climate change as a result of their structure, species composition or genetic diversity. The requirement for planting a minimum of 80% locally native species, as outlined in the Ancient and Native Woodland Practice Guide, will come under greater scrutiny if species diversity and resilience to climate change prove to be limited on restored PAWS.

In the medium to long term, failure to implement the CCAP would become increasingly serious, affecting timber income, recreational businesses on the Public Forest Estate and, therefore, its economic resilience. Failure to make necessary adjustments to the specifications of infrastructure on the PFE as part of routine maintenance/renewal programmes (at limited costs) would lead to greater impacts on future forestry operations and larger costs if remedial action is required outside routine cycles.

There will, inevitably, be costs associated with the implementation of adaptation measures. These will be both increases in management costs and reductions in timber income. However if adaptation, as outlined in the CCAP, becomes standard practice, costs should be minimised. As outlined elsewhere in this risk assessment, there are many uncertainties surrounding the impacts of climate change and appropriate responses to it, which may act as a barrier. Furthermore, due to the long timescales associated with forestry it will be some time before it is known whether the adaptation measures have been successful. However, an adaptive management approach, supported by senior management and effective internal communication, will help to address this barrier. The role of the Public Forest Estate in testing some of these actions will also need to be recognised and communicated, while Forest Research will

have a critical role to play in the process. Lessons learned on the Public Forest Estate should also be shared with the wider forestry and woodland management sector.

4.3.5 Possible responses to address risk.

Since tree crops take many years to mature, the planning horizon for forestry is inherently long and actions taken now may only prove their worth in 50 to 100 years time. Critically, those actions must be appropriate to both current and future climate. A move towards planned, rather than reactive adaptation in woodland creation and management is therefore necessary. Such an approach presents real challenges because of the uncertainty associated with climate change and the response of trees to it. This uncertainty should not prevent adaptation but, instead, should direct woodland managers to implement measures to increase resilience whatever climate change brings, or that are likely to bring the greatest rewards in the future.

The Forestry Commission recognises that there is an urgency to start adaptation processes and implement mitigation strategies. To achieve this a 'Climate Change Action Plan' (Annex 6) has been developed and is now being implemented in the field. The CCAP covers species and provenance choice, adoption of continuous cover systems of management and upgrading specifications for forest infrastructure. Adaptation of buildings, work practices and transport-related issues relevant to the operation of the PFE are also included, although these areas are largely covered by the Environmental Management System (EMS) and associated ISO14001 Standard (see Annex 6). The Plan will be revised in five years time, to reflect advances in climate science and in approaches to adaptation.

4.4 Grant administration and regulatory function

Forest Services' grant administration and regulatory functions are important enabling frameworks for the delivery of FCE's objectives. The ability to carry out these functions, effectively, will be impacted by climate change, while they also represent key mechanisms for encouraging and implementing adaptation across England's woodland resource.

Background to forestry regulation and grant-aid

The 1967 Forestry Act (as amended) provides powers for the Forestry Commissioners to regulate forestry and promote good forestry practice in order to fulfil their statutory duties. Current forestry regulations are outlined in Section 1.10, although it should be noted these are subject to Government's response to the report of the industry-led Forestry Regulation Task Force that was published in October 2011.

European Council regulation 1698 Ford/2005 requires member states to implement a seven-year programme for rural development. The regulation identifies the support member states should give the rural development by:

Axis 1: Improving the competitiveness of the agricultural and forestry sector

Axis 2: Improving the environment and the countryside

Axis 3: Quality of life in rural areas and diversification of the rural economy

Axis 4: The leader approach

Axis 5: Technical assistance.

Defra is the Managing Authority for the Programme in England. The programme known as the 'Rural Development Programme' is co-financed by Europe and the Exchequer. The administration of those elements of the scheme affecting forestry is delegated to the Forestry Commission, including the payment of grant-aid.

The Forestry Commission is also the relevant or Competent Authority for a variety of regulations:

- A Felling Licence is normally required from the FC for the felling of trees.
- Environmental Impact Assessment (EIA) – consent is required for woodland creation, deforestation, road or quarry operations that could have a significant effect on the environment.
- Habitat Regulations - a licence may be required for woodland operations that affect European Protected Species, notably dormouse, otter, great crested newt, sand lizard and all species of bat.
- Countryside & Rights of Way (CROW) – approval is required to restrict public access in a woodland that has been dedicated under CROW.
- Plant Health - to protect forests and the timber industry by applying rules on the import and export of forestry material and its movement within the EU.
- Forest Reproductive Material (FRM) – to provide a system of identification and control of seeds, cuttings and planting stock used for forestry purposes in Great Britain.

4.4.1 Aims and objectives

To implement effective forestry regulation in England and deliver the three key objectives of the Rural Development Programme for England:

- To safeguard and enhance the rural environment.
- Improve the competitiveness of agricultural and forestry sectors.
- Foster competitive and sustainable rural businesses and thriving rural communities.

Through the delivery of these three objectives Forestry Commission England must also ensure that its actions, or the actions facilitated by FCE, meet the minimum standards of the 'United Kingdom Forestry Standard'.

4.4.2 Main direct and indirect climate risks to the objectives

Forestry grants and regulations in England were recently subject to an internal review, the main findings of which are summarised in Section 6.4.1. The key conclusion was that although the grant and regulatory framework does not adequately address climate change issues, there is sufficient flexibility to do so in response to the requirements of the revised UK Forestry Standard and its Forests and Climate Change Guidelines.

To safeguard and enhance the rural environment

England's woodland resource has developed over many years under a relatively stable climate, but this key assumption no longer applies. Although there may be differences between the species composition of private sector woodlands and the PFE and different approaches to management may apply, the main impacts of climate change are likely to be similar, as summarised in Section 4.1 and 4.3.2. The main differences are that a high proportion of private sector woodlands are either unmanaged or under-managed (see Woodfuel strategy for England; FC, 2007) and, typically, smaller and more fragmented than their PFE counterparts. Furthermore, the private sector woodland resource is owned by approximately 60,000 woodland owners (S. Ward, pers. comm.), leading to significant challenges for monitoring the impacts of climate change (and pest and disease outbreaks) and to increase the resilience of those woodlands to the effects of climate change. An additional issue is that regeneration tends to decline in unmanaged woodland, reducing adaptive capacity, while the low level of harvesting and restocking (on average, 1,000 ha per annum out of the total resource of 1,100,000 ha) limits the ability to implement adaptation measures.

The current requirements for receiving grant-aid for woodland creation, woodland improvement and woodland management through the English Woodland Grant Scheme do not account for the changing climate, in large part requiring that site-native woodland species assemblages of local origin (where available) are planted. In the absence of adaptation, there is therefore a risk that those woodlands planted/restocked under grant-aid will not prove resilient and therefore may represent poor investment of public finance.

Improve the competitiveness of the agricultural and forestry sectors

Grant-aid supporting the competitiveness of the forestry sector is largely for woodland management and post-harvest wood processing and includes the recently launched Woodfuel Woodland Improvement Grant. Although the efficacy of the programme is unlikely to be affected by climate change in the short term, the programme is likely to play a part in increasing the resilience of woodlands to climate change through supporting woodland management and promoting regeneration.

In the longer term, the assessment of changes in productivity outlined in Section 4.1 suggest that in some regions, the forestry sector may become more competitive as a

result of climate change and, in others, less so. However, those changes are likely to be outside the scope of this and the next Rural Development Programme.

Foster competitive and sustainable rural businesses and thriving rural communities

No effects of climate change on the efficacy of grant-aid to support rural businesses and communities are foreseen in the short to medium term (see Section 6.4.1). However, as climate change increasingly impacts on forest productivity (both positively and negatively) it may affect rural communities, possibly requiring a response from support mechanisms operating at that time.

Implementing forestry regulations

Climate change is likely to have limited impact on the implementation of forestry regulations. Possible exceptions to this rule include Habitats Regulations if habitat requirements of priority species' ranges change, and Plant Health regulations, if pest and disease impacts become more frequent or severe as a result of climate change. The application of the FRM regulations may also prove problematic if species not currently covered by them are widely planted in response to climate change projections and associated guidance.

Climate change could have implications for Environmental Impact Assessment (Forestry) determinations for the suitability of specific sites for woodland creation, although these are likely to be related to climate change projections rather than the direct effects of climate change in the short to medium term. The key issue is likely to be the impact of very large areas of woodland creation on water availability, due to the increased water use of woodland, particularly conifer woodland, compared with other land uses. Impact on water resources is already a material consideration in EIA determinations; climate change is therefore unlikely to affect the ability of FCE to undertake this function.

4.4.3 Opportunities that may arise from climate change

Engagement with woodland owners

The need to adapt to climate change driven, at least in part, by the new UKFS Guidelines on Forests and Climate Change may provide new opportunities for grants and regulations teams to engage with private sector woodland owners and to enable others with an interest in climate change adaptation to work with woodland owners and managers. This will help to deliver objectives for increased levels of woodland management and woodfuel delivery. The mutual benefits of climate change adaptation and woodfuel production that can be achieved through bringing woodlands into management provide real opportunities to facilitate the delivery of both objectives. Increased engagement with woodland owners will also help to communicate the need

to reduce pressures from rising populations of deer and grey squirrel through the development and implementation of effective population control programmes through, for example, the Deer Initiative.

Woodland creation

The rate of grant-aided woodland creation has declined below RDP targets in recent years. The contribution of woodland creation to deliver landscape-scale flood alleviation, water quality management and habitat network initiatives provides an additional incentive for landowners to create new woodland, and a wider body of land management advisors promoting woodland creation. The anticipated increase in the availability of private sector carbon finance to further incentivise woodland creation following the launch of the Woodland Carbon Code is also thought likely to increase planting rates.

4.4.4 Implications for delivery of FCE's objectives

The need to ensure that England's woodlands are resilient in the face of climate change and play their full role in sequestration of CO₂ will make FCE's role in providing high quality guidance on appropriate adaptation measures increasingly important. The provision of guidance will also be critical for enabling behaviour change and promoting partnerships for action on adaptation. Although some guidance is available on species diversification, alternative management systems and alternative approaches to management, this is not currently available in a clear format. There is therefore a reputational risk to FCE if clear guidance to support the UKFS Forests and Climate Change Guidelines is not published during the initial period of the Outline Adaptation Plan presented in Section 6. Furthermore, because there are many uncertainties associated with climate change, definitive guidance will only be possible for some no-regrets measures; there is therefore a future risk to FCE's reputation if inappropriate guidance is given. An urgent requirement for monitoring and communication across the sector is clear, facilitated by FCE's Grants and regulations team, to enable iterative sharing of knowledge.

An increased focus on management plans is likely to facilitate the take-up of adaptation measures, as outlined in the Forests and Climate Change Guidelines. The development of management plans will also deliver some of the wider objectives of forestry grants and regulations, although actions in the Government's response to the recommendations of the industry-led Forestry Regulation Task Force will need to be accommodated.

Given the current focus on pest and disease issues, there is likely to be limited capacity for mainstreaming climate change adaptation. However, because biosecurity and climate change are closely linked and, in some cases, require similar measures to address them (particularly species diversification, monitoring and adaptive

management), opportunities should be taken for communication and delivery of adaptation through biosecurity initiatives, including plant health days.

There is, however, a significant barrier to the delivery of adaptation. However urgent the apparent need for species change becomes to address the risks presented by climate change, the potential for intervention is limited due to the low levels of restocking and new woodland planting relative to the overall size of the woodland resource (a total of ~5,000 ha/yr in 2010 – or 0.4% of England's woodland resource). If serious impacts of climate change become apparent (highlighting the critical nature of effective monitoring and the role of the National Forest Inventory) a decision may have to be taken as to whether a radical, high intervention, approach is needed.

4.4.5 Possible responses to address risk

As outlined in Section 6, the current grant and regulatory framework in England is highly flexible and can accommodate a range of potential adaptation measures (although subject to Government's response to the Forestry Regulation Task Force). There is therefore a need to turn research into clear measures to be adopted by the grant and regulatory framework.

It is widely acknowledged that a step change in planting coupled with bringing more woodland into active management will help increase the resilience of England's woodlands to climate change. However there are issues, not least financial, to this being achieved. The establishment of the Woodland Carbon Task Force in 2010 will help deliver these objectives, with its overall aim to 'establish the conditions for a step-change in the level of woodland creation and management'.

Although the Climate Change Action Plan for Public Forest Estate was written for FC woodlands in isolation, the measures included in it have potential for application more widely across England's woodland resource, particularly on large estates. The Plan was drawn together through close co-operation between Forest Research and Forestry Commission field staff. The Plan can therefore be used as an exemplar of adaptation in action, particularly forest planning, and to give confidence to private sector woodland owners. There is also a critical role for the PFE to play in giving forestry nurseries the confidence to grow 'adapted planting stock' for both the PFE and private sector woodlands.

4.5 Corporate functions

4.5.1 Delivering the vision – FCE's role

Forestry Commission England (FCE) is responsible for protecting England's forests and woodlands and increasing their value to society and the environment. We will work with a wide range of partners to deliver the functions and priorities set out in Defra's Business Plan.

FCE will focus on:

- **Protection:** protecting the woodland resource and increasing its resilience, for example, to pests, diseases and the impact of climate change;
- **Improvement:** improving the woodland resource to enhance benefits including biodiversity, landscape quality and a range of other ecosystem services;
- **Expansion:** Promoting and incentivising the planting and natural regeneration of trees, woods and forests of the right type in the right place.

FCE will deliver this by:

- **Empowerment and Engagement:** empowering and enabling people to engage with trees, woods and forests, so that they can determine the benefits that they wish to see delivered;
- **Economic Activity:** promoting a competitive, thriving and resilient forestry sector alongside a wide range of private sector business partners.

4.5.2 Corporate risk management and climate change

The FCE Risk Management policy is detailed in the 'FC England Risk Policy & Guidance' document available to all managers and staff on the organisation's intranet.

Corporate risks to FCE are contained on the England Executive Board's (EEB) Risk Register and include risks relating to:

- Plant Health
- Business continuity
- Finances
- IT
- Certification
- Business change

Currently there are no risks relating specifically to the impact of climate change recorded on the EEB Risk Register. However, it is possible to consider and discuss the impact of climate change on each area of risk.

Plant health

The issue of plant health is very current due to the emergence of a number of tree diseases and forest insect pests in recent years, including *Dothistroma* needle blight on pine, *Phytophthora Ramorum* on larch, the syndrome of acute oak decline and oak processionary moth, and is managed specifically at Board level. However, plant health is an on-going issue that pervades all species to some degree and extent and is a key responsibility for FCE to manage. Climate change is a significant factor to be considered in plant health but is not included in the current register. The impact of extreme weather events is viewed as a plant health issue at Board level and specific

reference to climate change in risk literature will reflect a more strategic view of plant health/climate change issues and encourage adaptation measures to be promoted.

Finances

The Financial risks managed at corporate level tend to reflect concerns over budget allocation from Defra and the failure to manage funding appropriately. When economic evaluations of the risk of climate change are available, climate change will appear as a separate entry on the Board risk register. Until that time, climate change will be included in discussions as a threat or opportunity in financial risks.

Information technology

Forestry Commission GB (FCGB) provides information technology (IT) support to FCE. In terms of corporate risk, the main IT issue is business continuity and sustaining the business in the event of a major disaster at Silvan House. Several programmes are underway to mitigate this risk but the impact of climate change is not directly referenced and at this time would not be considered as a strategic factor. In the future however, the significance of warmer summers may need to be addressed as maintenance of air-conditioning systems required to provide suitable operating environments for servers could present a significant risk to business continuity. The effects of increased temperatures may be several years away, but it is at this time that options for mitigation can be planned and forecast. Such forward planning will ensure resources are available at the time they are required and measures are implemented during routine renewal cycles.

Certification

Currently, the entire Public Forest Estate (across Great Britain) is certified to the UK Woodland Assurance Standard (UKWAS). The Forestry Commission was the first Government forestry Department in the world to have all its forests certified. The importance of this achievement was recognised by the World Wildlife Fund (WWF) and the Forestry Commission was awarded the 'Gift to the Earth' award in 2000. UKWAS will be updated over the coming years to reflect revisions to the UK Forestry Standard, including adoption of the new Forests and Climate Change Guidelines. To maintain certification the Forestry Commission must successfully implement the new recommendations. Risks to maintaining UKWAS certification are explored in Sections 4.3.2 and 4.3.4.

Business change

FCE, like other Government Departments is undergoing significant change over the next four years as a result of the 2010 Spending Review settlement. The business is working to identify the significant strategic risks associated with change. In future, FCE will need to consider new ways of operating, communicating and delivering its outputs. This must include the increased demands resulting from climate change,

including additional expenditure necessary to implement the Climate Change Action Plan and realise opportunities that climate change may present to the organisation.

4.5.3 Strategic opportunities arising from climate change

Protection

Much of the both the PFE and private-sector woodland resource is of limited species diversity and managed within clearfell systems. This is acknowledged as a high risk strategy, in terms of both biosecurity and climate change. Climate change provides an opportunity to plant a wider range of species, some of which may have proved marginal in the past due to temperature limitation. Increased adoption of continuous cover systems of management, in appropriate locations, as an adaptation measure is also likely to increase resilience to pest and disease outbreaks and deliver a number of other objectives including biodiversity, landscape and water quality.

Improvement

Many of the measures that are required to adapt existing woodlands to the impacts of climate change can only be achieved through bringing England's under-managed woodlands into management. Climate change adaptation, alongside climate change mitigation and renewable energy objectives, provides an additional argument and rationale for this important corporate objective.

Expansion

Woodland creation is acknowledged as providing a wide range of 'ecosystem services' including timber production, new habitat, recreation, water protection and cost-effective abatement of greenhouse gas emissions (UKNEA, 2011). Climate change adaptation provides a further driver for woodland creation through its role in (a) increasing the climate resilience of the existing woodland resource; (b) linking woodland habitats to aid the movement of woodland species; and (c) flood alleviation. Urban tree planting and woodland creation, including the restoration of brownfield sites, also contribute to the adaptation agenda through providing shade and urban cooling. Climate change adaptation therefore provides an important additional driver for one of FCE's key objectives – expanding the woodland resource.

Empowerment & engagement – strategic partnerships

The Government has signalled its intention to work more closely and in partnership with individuals, the private sector and civil society organisations - the 'Big Society'. The Forestry Commission has a long and proven track record of engagement with communities through the forest design planning process, partnership projects both on and off the public forest estate and with the forestry industry. FCE is already engaged in a number of sub-national partnership projects on climate change adaptation, as outlined in Section 1.11. Climate change adaptation provides additional opportunities

for partnership working at both landscape and stand level, particularly given FC's critical role in supporting implementation of the UKFS Forests and Climate Change Guidelines.

Economic activity

The climate change agenda provides a range of opportunities for economic activity within the sector. The current focus on woodland creation and management require the sector to expand its skills base. Climate change adaptation cannot be separated for climate change mitigation nor the needs of future society. Wood as a source of renewable energy is seen as increasingly important while the need for timber as a sustainable, low carbon, resource is now widely recognised. Climate change therefore represents a real opportunity for increased confidence and economic resilience of the wider forestry sector, helping to achieve one of FCE's key objectives.

4.5.4 Implications for delivery

If risks to Corporate objectives are to be minimised and the opportunities for delivery are to be grasped, climate change needs to be considered as standard practice in FCE's decision making processes. These include:

- Planning for the future – building climate change into corporate risk models and horizon scanning.
- Increased costs of operating at a time of diminishing resources - top level budget and forecasting needing to reflect the impact of a changing climate.
- Changing the way we do business – incorporating climate change (both adaptation and mitigation) into corporate values.
- Increasing the use of scientific experts – to evidence and support activities, monitor success and adopt the approach of 'adaptive management'.

4.5.5 Corporate response to climate change

Climate change leadership

A Climate Change Strategy Group (CCSG) was established in 2007 to steer and coordinate FC's work on climate change across England, Scotland and Wales. The CCSG is Chaired by the Director General and includes the Head of Policy and climate change leads from each country, the Head of Communications, the Head of Forest Research's Centre for Forestry and Climate Change, the Head of Corporate Forestry Support (CFS) and CFS's Principal Advisor on climate change.

Through the CCSG, the FC has taken a leading role in promoting the importance of acting in the face of climate change. This was initiated by a one-day conference in central London in 2007 which brought together senior policymakers, influencers, and climate change experts from Government, Civil Society and the private sector. The conference aimed to set out accurate information about the role woodlands play in

tackling climate change and provide clear take-home messages about the actions that are needed. This was supported by the publication of a video the 'Convenient Truth' which focussed on six challenges:

- protect** what we already have
- reduce** deforestation
- restore** the world Forest cover
- use** wood for energy
- place** other materials which would
- plan** to adapt to our changing climate

In 2008, FC commissioned an independent report examining the potential of the UK's trees and woodlands to mitigate and adapt to climate change – the Read Report (Tackling Climate Change – a role for UK Forests: see Section 1.8.2). The report provides the evidence-base for FCE's response to climate change, including issues of high uncertainty where further evidence of likely impacts and appropriate responses is required.

Risk management policy & guidance

Forest research has a wide-ranging Internet resource detailing the risks and challenges facing the UK's woodlands. Forestry Commission England has used this advice, and other sources, to create its own risk assessments. A Climate Change Action Plan for the PFE based on this information and the risk assessment presented in this report (particularly Sections 4.1 and 4.3) is currently being implemented. This report completes the current risk assessment for the Forestry Commission's other roles and will be used in conjunction with FCE's enabling frameworks to implement the remedial measures recommended.

Joint working with other government bodies

Forestry Commission works in partnership, sharing knowledge and expertise with other Government Departments and environmental arms length bodies (ALBs) including Natural England (NE) and the Environment Agency (EA). The recent establishment of a joint Executive Board (FC, EA, NE) will help to drive the joint-working initiative forward. Examples of joint working on climate change adaptation are given in Section 1.11. An Adaptation Delivery Group (ADG), comprising representatives from Defra, FCE, EA, NE and MMO (Marine and Maritime Organisation) was established in 2010 to achieve efficiencies and provide more holistic, joined up, advice to Defra on climate change adaptation, making best use of relatively small scale, and reducing, resources in each body to maximise the impact of ALB expertise in this important work area. The key objectives of the ADG are:

- Better strategic coordination of effort;

- Aligned responses to formal consultations and informal requests for advice where appropriate;
- A more coherent approach to research programmes;
- More consistent advice and messages from land use planning advisers;
- More consistent and efficiently-delivered advice to farmers and land managers;
- Increased focus on Defra/other customer requirements;
- Single point of contact for Defra and other customers when sourcing advice on adapting to climate change;
- Increased focus at the strategic level to work on projects in each of the climate change units.

5 Interdependencies

The Risks to FCE's functions identified in Sections 3 and 4, and the likely effectiveness of the responses to them, will be dependent on a range of other factors, policies, processes and initiatives operating at local, national and international scales. Some of these interdependencies will be directly relevant to forestry and/or climate change; others will be totally independent. The interdependencies assessed in this section are grouped into six categories, and are based on discussions with FC staff and from input received at the sector workshop (see Section 2.3):

- Policy – national
- Policy – international
- Economic
- Environmental
- Social
- Technical

All interdependencies raised through this process are listed in Table 5.1, alongside an indication of potential impact and likelihood. The most significant interdependencies are explored further in Section 5.1

5.1 Assessment of key interdependencies

The analysis presented below considers the role of the interdependencies listed in Table 5.1 on the ability to deliver key functions, and includes both positive and negative outcomes. Three key groupings of those interdependencies are identified.

Many of the interdependencies relate to influencing the level of woodland creation and management. In general, this assumes that increased levels of woodland creation represents a positive adaptation outcome, through increasing woodland habitat area and connectivity and providing opportunities for the planting of woodland more resilient to climate change. It is also assumed that, for the most part, increased levels of woodland management are a positive adaptation outcome through promoting regeneration, reducing other pressures (e.g. deer browsing) and providing opportunities for enrichment planting and species diversification. However, it is also acknowledged that increased levels of woodland creation and management can have negative adaptation outcomes if, for example, unsustainable management practices are promoted or there is an undue focus on non-native and potentially invasive species for woodland creation or woodlands are created in inappropriate locations such as on deep peat.

5.1.1 Woodland condition, growth and survival

Although the current and future impacts of pests and diseases are likely, at least in part, to be a result of climate change, biosecurity is a key interdependency that should be considered in its own right. Pest and disease outbreaks will limit the range of species available for planting (for example, the current moratorium on planting Corsican pine as a result of red-band needle blight) and could influence landscape approaches to climate change adaptation (increasing connectivity) through concerns over the movement of pests and diseases.

The (unintended) importation of pests and diseases will be dependent on national (Plant Health Act) and international (EU Plant Health Directive) biosecurity policies and also wider international Trade agreements (for example WTO) and quarantine arrangements operating at national and European levels.

Other pressures on woodland ecosystems, including air pollutant deposition, the (licensed) disposal of waste to forests and, critically, the control of invasive plant species (e.g. rhododendron, Japanese knotweed) and deer/squirrel populations that limit regeneration. In turn, these are dependent on a range of policies and interventions, many of which operate at landscape-scale and require engagement with, and participation by, landowners – for example, the Deer Initiative.

While the woodfuel/biomass agenda will increase the level of management in England's woodlands and therefore promote adaptation in the most part, there is also a risk that high woodfuel/timber prices and limited availability coupled to limited knowledge of forestry regulations in some parts of the sector could lead to unsustainable exploitation of the woodland resource. However, the development and adoption of sustainability criteria by UK Government for liquid and solid biomass is likely to secure the protection afforded by the UKFS, as outlined in guidance published by OFGEM (Office of the Gas and Electricity Markets) in December 2011. The balance between renewable energy drivers and the adoption of UKFS and sustainable forest management practices supported by regulation will determine whether increased levels of management result in increased or diminished resilience to climate change. An increased demand for wood and the resulting increase in management activity may mean that each Woodland Officer will face a larger work-load. Although FCE have maintained front-line staff through the recent restructuring process, the ability to effectively enforce the requirements of the UK Forestry Standard will be a challenge if the level of felling increases.

5.1.2 Ability to realise appropriate woodland expansion

New woodland planting has the greatest potential for climate change adaptation – both in terms of enhancing the resilience of England's woodland resource and increasing its contribution to helping society and biodiversity to adapt. However, there are significant barriers to the creation of new woodland including landscape character, food security, agricultural economics and land values (including perceived land

values). In particular, the low income from woodland compared to agricultural land is cited as limiting woodland creation. However, carbon finance together with other funding opportunities (biodiversity offsets, payments for ecosystem services such as improved water quality and 'development' funding) will help to address this balance. The success, or otherwise, of the Woodland Carbon Code and the initiatives being taken forward by the Woodland Carbon Task Force to complement existing income streams for woodland creation will therefore be critical.

The development of local planning policy and the National Planning Policy Framework may also have implications, for the delivery of woodland expansion but at the time of writing these are unknown

5.1.3 Ability to effect adaptation measures

The implementation of adaptation measures will be dependent on the availability and communication of clear, agreed, guidance that is consistent with national and international policy. Development of this guidance will be dependent on FCE's continued access to, and the ability to influence, relevant research – and that sufficient public/industry funding is available to support that research. It will also require that the research covers the full spectrum of woodland types and objectives so that a balance is achieved between commercial timber production and conservation management.

The interactions between forestry and other policy areas have the potential to both promote and limit the implementation of adaptation measures. For example, national non-native invasive species policy and the EU Habitats Directive provide protection against inappropriate adaptation measures; however, if implemented in an inflexible way, they could restrict necessary adaptation for commercial forestry. This interaction between biodiversity and economic forestry will be key to the development and implementation of adaptation across the forestry sector as a whole.

Adaptation is likely to incur additional short-term costs, requiring a thriving forestry sector to achieve widespread implementation. Timber and woodfuel prices, availability of grant-aid and the development of carbon markets that benefit the woodland owner (including the FC) are therefore key interdependencies.

A co-ordinated approach to adaptation is likely to be most effective, requiring both leadership and scale. The future role of the Forestry Commission, including its Public Forest Estate, is therefore a key consideration. The recently published Climate Change Action Plan is predicated on the basis of a single, co-ordinated management unit. Transfer of ownership to a smaller number of organisations with established adaptation strategies would limit this risk and, it could be argued, could enhance resilience through bringing forward a range of approaches to adaptation. However, the opportunities that the 258,000 ha PFE presents for operational trials (coupled to effective monitoring), exploration of best practice, influencing plant supply from commercial nurseries and creating a range of practical demonstrations of adaptation

could be difficult to reproduce if co-ordination of activity was not maintained under alternative ownership/management arrangements.

Coupled to the future of the Public Forest Estate is the future role of the Forestry Commission. A reformed Forestry Commission that focuses on research, advice, Standards and regulation could continue to provide direction, facilitation and enable woodland owners to implement adaptation measures. However, its continued effectiveness in this role would be dependent on:

- Continued access to, and ability to influence, climate change research;
- Continued ability to influence and guide Rural Development support for the forestry sector, as an enabling framework;
- Availability of Standards that address climate change adaptation;
- An appropriate regulatory framework enabling the application of standards.

The views of the Forestry Regulation Task Force and the Independent Panel on Forestry together with Government's responses to their two reports are therefore key interdependencies, as is the availability of grant-aid (RDPE post-2013) for influencing the wider sector and encouraging application of the UK Forestry Standard. Critically, if FCE is to be effective in enabling the uptake of adaptation measures across a large part of England's woodland resource, the way in which the private sector are engaged will have to change, as will the proportion of the 60,000 woodland owners that FCE are engaged with.

Table 5.1. Assessment of factors (interdependencies) that may influence the ability of the Forestry Commission to address climate change in performing its key functions.

Category	Positive impact	Negative impact
Policy – national		
Future of the Public Forest Estate in England	<p>Alternative ownership/management arrangements could result in more diverse approaches to management and species selection, increasing the PFE's resilience to climate change.</p> <p>Alternative ownership/management arrangements would offer the potential for an increased level of management, particularly in broadleaf woodland, resulting in increased regeneration and adaptive capacity.</p> <p>Alternative ownership/management arrangements could lead to</p>	<p>Alternative ownership/management arrangements could limit the ability to implement the existing Climate Change Action Plan for the Public Forest Estate and, potentially, reduce the woodland area in England subject to UKFS and implementation of under-pinning Climate Change Guidelines.</p> <p>Potential for alternative ownership/management arrangements to focus on optimising timber production in the short term (reducing species diversity) with the result of less resilient woodlands.</p> <p>Potential for a reduced level of management in alternative ownership/</p>

	increased realisation of commercial deer management opportunities, improved control of deer populations and increased natural regeneration and adaptive capacity.	management arrangements, resulting in reduced natural regeneration and adaptive capacity. The potential for a lower level and less co-ordinated deer management resulting in reduced natural regeneration and adaptive capacity. Reduced ability to influence plant supply from nurseries and ability to diversify species selection.
Future function of the Forestry Commission	An increased focus on facilitation, regulations and Standards could enhance the implementation of adaptation strategies across FCE's grant and regulations functions.	Reduced resources and a lesser focus on sector leadership could limit the ability of FCE to enable adaptation across the sector.
Research funding	Increased funding targeted at specific aspects of forestry (biomass, timber supply, carbon sequestration) could broaden sector-wide adaptation strategies.	Reduced levels of public/industry for forestry research could limit the ability to develop sector-wide adaptation strategies.
RDPE post 2013	Greater presence of adaptation measures and availability of funding for woodland creation and management to support a range of environmental outcomes (e.g. water, soil, biodiversity) would promote adaptation.	Reduced funding for woodland measures would limit the ability of FC to influence the sector through targeting and implementation of UKFS.
Renewable energy policy – biomass	Increased funding for well-designed woodland creation and incentives for woodland management would contribute to landscape and stand-scale adaptation, respectively.	Risk of poorly designed energy forests (particularly in combination with reduced regulation) resulting in negative impacts on the ability of new woodland to contribute to landscape-scale adaptation. Potential for increased biomass demand to lead to the adoption of unsustainable management practices, reducing the resilience of woodlands.
Renewable energy policy – wind energy		Loss of woodland on the Public Forest Estate, potentially leading to fragmentation and reduced habitat. Also potential risk of enhanced soil erosion on vulnerable sites.
Planning regulations	Continued protection for ancient woodland and stronger requirements for mitigation and compensation where woodland is lost to development would maintain ancient woodland area and aid in landscape-scale adaptation through	Reduced protection for woodland, to support local development, could degrade and further fragment the woodland resource.

	<p>new woodland creation.</p> <p>Promotion of woodland creation through development funding could enhance landscape adaptation.</p> <p>Promotion of woodland creation through development funding, principally through the Community Infrastructure Levy (CIL) could enhance landscape adaptation. Planning conditions can also be applied to new development, under the terms of the Town and Country Planning Act, to 'make adequate provision by the imposition of conditions for the preservation or planting of trees'.</p>	
Non-native invasive species	Strong but flexible policies on the introduction of non-native species could facilitate adaptation in the forestry sector and species diversification in native woodlands and commercial forestry, while protecting against the risk to biodiversity of invasive non-native species.	Precautionary approaches to the planting of non-native species could limit the ability to diversify species choice for timber production and new native woodland planting.
Timber demand – Code for sustainable homes	Increased use of timber in construction could stimulate woodland management and woodland creation.	Risk of increased demand for timber leading to unsustainable management practices, and reduced species diversity through focusing new woodland planting on the current limited range of species used in construction.
National adaptation policy framework	A strong national adaptation policy framework could drive forward the implementation of adaptation across FCE's functions.	A requirement for holistic cross-sector adaptation strategies to be developed could delay the implementation of CC adaptation across FCE's functions.
Changes in forestry regulation (industry-led Task Force)	<p>Reduced regulation ('hassle factor') could encourage woodland creation and therefore landscape-scale adaptation.</p> <p>Reduced protection for woodland could encourage woodland creation (and landscape adaptation) through addressing issue of permanent and</p>	<p>Reduced regulation through the concept of 'earned recognition' could result in unsustainable management practice and reduced implementation of UKFS and CC Guidelines.</p> <p>Reduced regulations could result in inappropriate woodland creation and negative impacts on the ability of</p>

⁸ Reduced scrutiny and administrative burden for woodland owners with a track record of good forest management practice through the introduction of the concept of 'earned recognition' was recommended by the Forestry Regulation Task Force in their report published in October 2011.

	<p>irreversible land use change</p> <p>More stringent implementation of UKFS (and Climate Change Guidelines) would promote climate change adaptation.</p> <p>Reduced administrative burden associated with felling licenses through the introduction of 'earned recognition^B' could encourage woodland management and opportunities for adaptation.</p>	<p>biodiversity to adapt to climate change.</p>
Biodiversity/nature conservation policy	<p>Strong support for the role of woodland in landscape-scale adaptation (for example through Natural Environment White Paper would enhance the ability of FC to achieve adaptation through G&R and enabling functions.</p>	<p>A very strong focus on native biodiversity – at the expense of a consideration of European/ global biodiversity could limit adaptation on the PFE and through forestry regulation and guidance.</p>
Policy – international		
Global trade agreements	<p>Changes in global trade tariffs and shipping costs could reduce the relative costs of domestically produced timber, increasing the economic resilience of the sector.</p>	<p>Global trade agreements (coupled with EU policy on Plant Health) could be viewed as, currently, limiting the ability to prevent the importation of insect pests and diseases of forest trees.</p>
EU Water Framework Directive (WFD)	<p>WFD is a strong driver for woodland creation, and is likely to enhance the effectiveness of Forest Services in enabling the forestry sector to contribute to landscape level adaptation through woodland creation.</p> <p>The WFD will provide a strong focus for joint working with NE and EA, helping to deliver FCE's desired adaptation outcomes beyond specific WFD objective delivery.</p>	<p>Water resource limitations in some areas could limit the potential for woodland creation (and the development of woodland habitat networks).</p> <p>Meeting WFD requirements could lead to reversal of drainage schemes on PFE, reducing productivity and enhancing susceptibility to wind throw.</p>
EU Soils Framework Directive	<p>Soil protection would be a driver for woodland creation on erosion-prone agricultural and moorland soils.</p>	<p>Potential for increased management costs on PFE if soil protection measures become more stringent (in combination with increased rainfall).</p> <p>Increased protection for peat soil carbon could result in increased woodland loss on PFE, fragmenting and reducing area of woodland habitat.</p>
EU Habitats Directive		<p>Inflexible national interpretation (with respect to native and protected species) could limit adaptation on the PFE and</p>

		through forestry regulation and guidance.
EU Renewable Energy Directive	Increased demand for biomass could enhance funding for well-designed woodland creation and incentives for woodland management contributing to landscape and stand-scale adaptation, respectively.	Risk of poorly designed energy forests (particularly in combination with reduced regulation) resulting in negative impacts on the ability of new woodland to contribute to landscape-scale adaptation. Potential for increased biomass demand to lead to the adoption of unsustainable management practices and reducing the resilience of woodlands.
EU Climate Change Directive	Uncertain, but may present opportunities for funding of adaptation measures (delivered through Grants, Regulations and enabling functions).	Uncertain, but may place constraints on adaptation programme for the PFE.
United Nations Framework Convention on Climate Change (UNFCCC)	A global climate change agreement could present new opportunities for funding woodland creation through carbon markets and trading. Changes in the way carbon in harvested wood products are accounted for could enhance the use of wood in construction, promoting management (and adaptive capacity).	A strong carbon market promoting carbon storage in biomass could reduce the level of management in English woodland, limiting adaptive capacity.
Convention on Biological Diversity (CBD)	New opportunities for arboreta to contribute to conservation of global biodiversity (and increased recognition of their value).	Inflexible national interpretation (with respect to native and protected species) could limit adaptation on the PFE and through forestry regulation and guidance.
Common Agricultural Policy (CAP) reform	Potential for increased funding of woodland creation and management, if CAP reform places a greater emphasis on environmental (axis 2) measures and CC adaptation.	Increased agricultural subsidies and reduced axis 2 funding could limit opportunities (and funding) for woodland creation.
Renewable Transport Fuel Obligation (RTFO)	Increased demand for biomass could enhance funding for woodland creation and incentives for woodland management contributing to landscape and stand-scale adaptation; dependent on development of second generation biofuels that use woody biomass as a carbon-efficient feedstock.	Risk of poorly designed energy forests (particularly in combination with reduced regulation) resulting in negative impacts on the ability of new woodland to contribute to landscape-scale adaptation. Potential for increased biomass demand to lead to the adoption of unsustainable management practices, reducing the resilience of woodlands.
Economic		
Biodiversity	Potential funding source for	

offsets	woodland creation to enhance landscape adaptation and new habitat.	
Land use competition		Perceived and/or real barrier to woodland creation, with the potential to act as a bar to woodland expansion.
Agricultural pressures	A thriving agricultural sector could provide funding and opportunities for woodland creation and to meet additional costs associated with adaptation measures.	A thriving agricultural sector could limit opportunities for woodland creation (particularly if land stewardship payments decline or are further separated from woodland incentives).
Fossil fuel prices	Increasing fossil fuel prices would promote the woodfuel sector, woodland management and woodland creation.	Increased demand for woodfuel could lead to poorly designed energy forests and unsustainable practices, reducing resilience at landscape and stand scale.
Economic resilience of forestry sector	A strong forestry sector could enhance levels of woodland creation and management and provide funding for the additional costs associated with implementing adaptation measures.	Impacts of global economics, currency fluctuations and global supply/demand dynamics could weaken the UK forestry sector and limit woodland creation and management.
Global timber availability	Declining global timber availability will enhance the economic resilience of the forestry sector promoting woodland creation and management.	Declining timber availability could lead to unsustainable management practices and reduced climate change resilience.
Carbon markets	Funding opportunities for woodland creation, including possibly on the PFE.	If biodiversity and carbon objectives are not in balance (i.e. native woodlands and commercial forestry), the ability to adapt woodland biodiversity to CC would be limited.
Nitrogen fertiliser prices	Increasing prices could make land use change to woodland a more attractive option. Increasing prices would make woody biomass a more attractive feedstock for second generation biofuels due to high C:N ratio – promoting woodland creation.	
Changes in tax regime for forestry	Changes in the tax regime that promoted woodland creation and management could enhance resilience.	Changes in the tax regime that promoted woodland planting or commercial forestry could lead to inappropriate woodland creation – but low risk due to EIA regulations and UKFS.
Environmental		
Water Quality	Measures to promote water quality present opportunities for woodland	

	creation.	
Water availability	In water-limited catchments, native broadleaf woodland is a more attractive option, providing greater opportunities for adapting biodiversity to climate change.	As summer water availability becomes restricted (as a result of climate change), there may be pressures for woodland removal in water-restricted catchments, reducing woodland habitat connectivity.
Flood severity/frequency	Flood alleviation provides opportunities for woodland creation as a 'soft engineering' solution. Opportunities for Forestry (flood plain woodland) as an alternative (productive/ economic) land use on land that is increasingly inundated.	
Windstorm/catastrophic events	Disturbance events provide opportunities for regeneration and adaptation through natural processes; there are also opportunities for enrichment planting in existing woodlands.	Loss of woodland habitat (in short term); economic losses to the forestry sector, potentially compounded by timber 'flooding' the market and reducing prices.
Waste disposal	May provide funding opportunities for the forestry sector, enhancing its economic resilience and promoting woodland creation and management.	Waste disposal (sewage sludge/ 'water polishing') to woodland is likely to impact negatively on woodland ground flora, reducing its resilience to climate change.
Land quality change	Climate change (among other factors) is likely to alter the quality of agricultural land (e.g. loss of peat in fenland) providing opportunities for forestry as an alternative land use.	
National/global GHG emissions	Contribution to domestic GHG emissions reduction targets likely to promote woodland creation and management for renewable energy. May be particularly important for reducing farm-level GHG emissions.	Risk of unsustainable management practice and inappropriate woodland creation to help meet national GHG emissions reduction targets – unlikely due to UKFS, EIA and Felling Licence regulations.
Social		
Consumer-led environmental pressure (carbon foot-printing)	Farm-level GHG accounting to reduce the 'carbon intensity' of agricultural commodities to meet consumer/retailer requirements would promote woodland creation and management (woodfuel).	
Food security policy	Sustainable intensification of food production could provide opportunities for woodland creation and	May limit opportunities for woodland creation.

	management, promoting adaptation.	
Farm diversification	Likely to present opportunities for woodland creation and management as alternative income stream.	
Change in land ownership	Changes in rural land ownership, with less of a focus on agricultural production, would promote woodland creation.	
Energy security	Promotion of domestic woodfuel market could promote woodland creation and management.	Potential for uptake of unsustainable forest management and inappropriate woodland creation.
Human health asthma/ hay fever and sport/ recreation policy	Promotion of outdoor recreation and potential opportunities for revenue generation for woodland sites (PFE and private sector).	Limitation on range of species available for restocking and new planting, particularly in the urban environment. Potential barrier to woodland creation.
Education/ public understanding	Opportunity to increase understanding of the need to adapt to climate change and take difficult decisions (in a forestry and landscape context).	Lack of understanding of the benefits of woodland management (including deer control) could affect the ability to enhance resilience. Public resistance to landscape change could limit woodland creation opportunities.
Practical contribution of Big Society	Community led initiatives could enhance the level of woodland creation and management and bring forward adaptation measures.	Reduced role for Government/FC coupled to lack of effective community-led initiatives could result in a lack of uptake in woodland creation, woodland management and effective adaptation measures.
Recreational demand	Potential income stream promoting woodland creation and management.	Additional pressure on woodland ecosystems, including 'anti-social behaviour', reducing resilience. Conduit for pest and disease transfer between woodlands. Requirement to maintain woodland infrastructure in good condition, set against increasing direct pressures from climate change.
Technical		
Quality of adaptation guidance	High quality, detailed, adaptation guidance is likely to promote the uptake of appropriate adaptation measures.	A lack of high quality guidance (due to limited research funding or for 'technical reasons' (i.e. agreed adaptive solutions not available)).
Approach to	If progress is made in developing	The planting of GM trees could lead to

genetic modification (GM) in forestry	GM planting stock and is acceptable to EU/national policy and society, potential for pest/ disease resistant and drought resilient material for new woodland creation, also widening the choice of species.	public reaction and resistance to woodland creation in general. Potential negative impact on native biodiversity and resilience to climate change.
Development of biosecurity solutions (chemical and silvicultural)	Wider palate of species for woodland creation (i.e. those currently subject to moratoria could become available again).	Potential negative impact on native biodiversity and resilience to climate change.

6 Outline Adaptation Plan

The current focus of climate change actions are outlined in Defra's refreshed Climate Change Action Plan, published in May 2011, as summarised in Table 6.1, below. These replace the forestry actions committed to in Defra's Climate Change Plan 2010, published in March 2010 and described in Section 1.4, the majority of which have now been completed.

Table 6.1. Forestry actions from Defra's Departmental Adaptation Plan Update, May 2011.

Completed actions
<ul style="list-style-type: none"> • A Climate Change Action Plan for the Public Forest Estate in England has been completed. • Climate Change Guidelines (and practical guidance) to support the UK Forestry Standard have been completed and are awaiting publication. • The Woodland Carbon Task Force has been established, with leading roles for the private sector and civil society, promoting landscape scale adaptation as one of the key benefits of woodland creation.
Proposed future actions
<ul style="list-style-type: none"> • The Woodland Carbon Task Force will develop a strategic framework to help target woodland creation to where it can best deliver adaptation co-benefits, including flood alleviation and the creation of woodland habitat networks to help biodiversity to adapt. • The work of the Biosecurity Programme Board will help to ensure that new and existing woodlands are resilient to the future risks presented by pests and diseases, climate change, and interactions between them. • The Forestry Commission will report under the Adaptation Reporting Power in early summer and develop practical guidance to support implementation of the revised UK Forestry Standard and its Forest and Climate Change Guidelines. • The Forestry Commission and Defra will work to incorporate woodland adaptation measures in the post 2013 Rural Development Process and CAP reform. • The Read Report recommendations on adaptation will be prioritised through the Forestry Commission publishing a 'Climate Change and Forestry Research' extension to the 'Science and Innovation Strategy for British Forestry'.

Although the majority of actions are already being progressed, all are subject to Government's response to the recommendations of the Independent Panel on Forestry (April 2012) and the Forestry Regulation Task Force (October 2011). Further actions may also arise as the National Adaptation Programme is developed during 2012, following publication of the first National Climate Change Risk Assessment in January 2012.

Further details on some of those actions listed above, together with an indication of how they (and other actions) will be delivered through FCE's main functions, are given in the following sections.

6.1 Governance

At a strategic level, the climate change agenda will continue to be led at Great Britain-level by the Climate Change Strategy Group chaired by the Director General (and Director England) and involving climate change and policy leads for each country.

In England, climate change adaptation will be championed at Executive Board Level (and through the England National Committee) by the Head of Forest Services. In turn, responsibility for adaptation on the Forest Enterprise Management Board (FEMB) and Forest Services Management Board (FSMB) will be through the Head of Forest Management and the Head of Sustainable Woodland Management, respectively. Risk registers for both FEMB and FSMB will be updated to explicitly include climate change.

In response to the need to restructure FCE to meet the SR10 settlement and following a comprehensive staff consultation, the National Expertise Team (formally Policy and Programmes Group), Grants and Regulations and Regional Engagement functions have been brought together as a single unit - Forest Services. This new structure will streamline the implementation and facilitation of adaptation measures across the wider woodland resource of England, through better alignment of policy and delivery functions.

6.2 Evidence

The plan takes its evidence, in the main, from Forest Research. Climate modelling for future impact studies will continue to use resources published by the UK Climate Impacts Programme (UKCIP02 Climate Change Scenarios and UKCP09 Climate Projections: Hulme *et al.*, 2002; Murphy *et al.*, 2009). Research on impacts and adaptation that has been undertaken to date, including recommendations for practical action in England's woodlands (Ray *et al.*, 2010), can be found in a series of Forest Research publications (see Sections 1.8 and 1.9) which are available from the Forest Research website. FCE have also published internet-based guidance to support implementation of the UKFS Forests and Climate Change Guidelines. Further evidence and practical guidance will be made available to support the Climate Change Action

Plan for the Public Forest Estate and adaptation in private sector woodlands. Guidance will include release, in early 2012, of an updated internet-based version of Ecological Site Classification that includes climate change projections (ESC-CC). Forest Research's current climate change-related research programmes are outlined in Section 1.12.

The Read Report – Combating Climate Change: a Role for UK Forests (Read *et al.*, 2009) – was published in 2009, providing evidence at UK-level on climate change impacts, mitigation and adaptation for the forestry sector. Sixty seven research gaps were identified, with those relevant to adaptation summarised in Table 6.2. One of the actions committed to in Defra's Departmental Adaptation Plan (Table 6.1) is to prioritise research to address these evidence gaps through the Forestry Commission publishing a 'Climate Change and Forestry Research' extension to the 'Science and Innovation Strategy for British Forestry'. This will be achieved through the review of the Science and Innovation Strategy in 2012/13.

Table 6.2. Research priorities relating to climate change impacts and adaptation identified in the Read Report.

Research priorities: understanding future impacts
<ul style="list-style-type: none"> • Developing modelling capacity at the operational level combining the practical applicability of knowledge-based decision support systems with the more theoretical, stand-level, process-based models. • Identifying the effects of rising temperatures on germination and other critical processes. • Learning from climate analogues to explore tangible impacts of likely climate change to accompany predictions based on model simulations. • Understanding risks to biosecurity, including through Pest Risk Analysis and epidemiological modelling of future outbreaks under a changing climate.
Research priorities: Adapting UK woodlands to the changing climate
<ul style="list-style-type: none"> • Development of databases and knowledge on how different species are expected to respond to climate change matched by studies on how their populations and distributions are actually changing. • Improved understanding as to which factors will become limiting for which species at a regional level. • Improved understanding of how climate change factors will change disturbance regimes of wind, fire, pests and pathogens. • Exploration of the scope for, and limits of, 'technical fixes' such as species translocations and genetically improved trees. • Improved modelling of how climate impacts on other land uses and societal behaviour will impact on trees, woods and forestry. • Improved monitoring and modelling of the degree to which more varied composition and structure improves resilience including economic. • Improved understanding of appropriate decision making methods, including methods of dealing with uncertainty and the integration of multiple societal values. • Developing practical ways of applying research results to effect change across landscapes.

Research priorities: Helping society to adapt

- Decision support systems are required to integrate understanding and to characterise the structure, function and economic benefits of urban and peri-urban trees and woodlands.
- A better understanding of the nature and extent of trees and woodlands in towns and cities and inclusion of urban and peri-urban trees and woodlands in national forest inventories.
- An improved understanding of the interactions between interception of precipitation by trees, urban tree effects on soil infiltration and sustainable urban drainage.
- Guidance on the optimum tree and woodland component of green infrastructure, and further research on the role of woodlands and forests in flood management.

6.3 Outreach and Guidance

6.3.1 The challenge

The changing climate presents a challenge for forest management in England. Tree crops take many years to mature, and the planning horizons for forestry are inherently long. There are many uncertainties associated with climate change, and this has proven to be a barrier to the implementation of adaptation strategies.

Numerous studies on the impacts of climate change on woodlands in the UK have been published. Recommendations on how practitioners can adapt their forests and increase resilience are also available. However, this information is often not accessible in a way that practitioners are likely to use or learn from. Furthermore, uncertainty around climate projections and the likely consequences have led to caution in much of the available guidance and a desire not to 'upset the *status quo*' until the evidence is much clearer. This has resulted in the focus being on 'win-win' or 'no-regrets' actions, often with a degree of ambiguity as to what actions woodland managers should be taking. Decisions on more extreme interventions – for example, planting tree species that have only been planted on a trial basis in England, to date – tend to be deferred. However, because of the long planning horizons for forestry those decisions need to be taken now for them to be effective in the climate of the future. The forestry sector therefore stands apart in needing to take, in some cases, radical decisions set against a relatively high level of uncertainty. Considerable support is required to establish conditions that will enable woodland owners to take those decisions, including the provision of advice, exemplars of best practice, incentives and effective regulation.

Landowners and forest managers often work in some isolation from each other. Those in the forestry sector tend to be pragmatic and work but show caution when asked to work with new ideas, and are uncomfortable with uncertainty. However, forestry fora and societies, such as the Royal Forestry Society, Institute of Chartered Foresters, regional Silvicultural Groups, the Country Land and Business Association, and trade shows where practitioners gather to discuss current issues, provide opportunities for effective communication on adaptation. These meetings are often field-based, looking at practical implementation of expert advice. It is this hands-on learning that engages

best with field managers. However, the lack of clear guidance on adaptation actions has generally resulted in adaptation being discussed as a theoretical concept rather than as an issue requiring urgent action. This is born out by the lack of requests to plant nurseries for more southerly planting stock rather than the more conventional planting stock of local origin.

Associated downstream industries, such as nurseries, are critical in the overall supply chain. To grow on and supply planting material for which there has not been a market in the past carries with it an element of risk. For them to take on this risk they will need to know that field managers will buy their stock. However this will not happen unless adaptation strategies are shared in the field.

6.3.2 The Risk

If field practitioners are not engaged with, and shown what needs to be done, they will not implement adaptation strategies that are considered to carry any risk. This means forests will not become more resilient to the changing climate leading to degrading woodland condition over time and a decline in the ecosystem services, including timber production, provided by those woodlands. This is a particular challenge because those actions need to be taken now, but set against an uncertain future and for 'theoretical gain'.

6.3.3 Implications

Communication, using appropriate tools and language, are critical if adaptation processes are to be initiated with some urgency. Recommendations must also encompass uncertainty in a way that avoids ambiguity and delays action. This will require the development and implementation of a communication strategy and plan which goes across the forestry sector. This plan will need to recognise the different learning styles of different practitioner groups. Those that deliver the plan will need to make scientific language simple and clear cut, but allow for different approaches to adaptation. It will also be important to acknowledge that there will be mistakes, making effective monitoring and recording together with the sharing of lessons learned (success and failures) critical – the approach of adaptive forest management.

The importance of case studies and exemplars of actions, was recognised when the Climate Change Action Plan for the PFE was drafted. The Plan will be shared with others in the industry as an example of adaptation in action. The Plan recognises that risk is an issue, and encourages staff to not be risk averse, and encourages innovation and learning.

6.3.4 Response

FCE will work with forestry sector organisations in England to:

- interpret the advice of scientists into unambiguous practical solutions;
- develop a communication strategy;

- develop a communication plan;
- deliver effective communications in support of the UKFS Forests and Climate Change Guidelines.

The Plan will need to be delivered in a practical, hands-on, manner by colleagues with experience and knowledge if it is to be credible. They will need to know the answers to challenges such as plant supply of new species or origin. They will need to be able to call on expert advice, as required, and have a sound understanding of the financial incentives available and regulations surrounding these.

The plan will use a range of media including:

- hands-on visits to exemplar stands and case study sites;
- meetings between practitioners;
- clear concise written guidance;
- web resources, including social media.

The uncertainties of climate change, and the best way to adapt England's forests, means that there are inherent risks for practitioners. This is dealt with for the PFE within the Climate Change Action Plan. Within the private sector lost revenues and inappropriate decisions requiring future corrective action are key concerns. These risks will therefore need to be highlighted, including mechanisms to minimise them.

6.4 Regulation and grant-aid

The response to climate change risks for FCE's regulatory and grant-aid functions are, at least in part, covered by other functions of FCE, FCGB and FR. Many of the regulatory aspects are outwith the remit of FCE, while the advisory role associated with both enforcement of regulations and the requirements of the UK Forestry Standards and the administration of grant aid for woodland creation and management are dependent on high quality guidance emerging from the FC's Research Programmes.

6.4.1 Scoping review of grants and regulations in the context of climate change

A scoping review to establish how fit-for-purpose the current regulatory framework and English Woodland Grant Scheme are in the context of climate change was undertaken in 2009. The objective was to identify those aspects of regulation and grant aid that either acted as a barrier to climate change adaptation (and mitigation) or did not actively support adaptation measures. The review was based on the requirements of the revised UK Forestry Standard and, in particular, on the draft Forests and Climate Change Guidelines (FCCG). As a result of the delayed publication of the revised UKFS (November 2011), the scoping review has not been progressed, although modifications to EWGS are in train responding to publication of the Practice

Guide for Ancient and Native Woodland in England, and to the new threats posed by pests and diseases (specifically, *Phytophthora ramorum* infection of larch).

6.4.1.1 Assessment of ability of existing grants and regulatory framework to support and implement the Forests and Climate Change Guidelines

An analysis of the ability of the regulatory framework and English Woodland Grant Scheme to support the individual Guideline bullets relevant to climate change adaptation is presented in Table 6.3. The conclusion drawn, largely on the basis of workshop discussions involving representatives from FCE Policy and Programmes Group, FCE Grants and Regulation, Forest Enterprise England, Natural England and Environment Agency was that, to a large extent, there was sufficient scope and flexibility in the regulatory framework to accommodate the requirements of UKFS and the Forests and Climate Change Guidelines. An important caveat was, however, applied to this conclusion; that implementation can only proceed if appropriate and adequate guidance is provided, including any policy conflicts being addressed.

Table 6.3. Analysis of the ability of the existing grant-aid and regulatory framework to support Guideline bullets from the draft Forests and Climate Change Guidelines (FC, 2009b).

Guideline bullet	Potential Activity (and potential perverse outcome).	Potential Regulatory Measures
Forest Design and Planning		
Aim to diversify age and species composition at the forest level.		Scoring system adjustments and simplification.
Review species suitability (see below) over time in Forest Plans.		Advice as available.
Consider alternatives to clearfell systems such as continuous cover where suitable sites and species combinations allow.	Could hinder desirable species change; develop an evidence based rationale and associated guidance.	Processes flexible.
Maintain a range of stand structures and silvicultural approaches.	Encourage continuous cover forestry	Complex approaches to grants needed, but under consideration.
Develop contingency plans for wind, fire, pest and disease outbreaks, appropriate to scale of forest.	Increased emphasis on forest planning; interpret this as strategies to minimise impacts.	Could modulate grants effectively to shift emphasis; incorporate in planning template.
Consider projections of changes to rainfall patterns when specifying culvert and road design.	Environment Agency could provide new recommended designs.	Advice.
Adaptive management		
Review rotation lengths in response to changing productivity and wind risk.	Shorter rotations might be appropriate if faster growth and windier; impacts on processing	Accept through felling licensing.

	sector.	
Review planting seasons in response to changing conditions and establishment success and promote natural regeneration.	No measures	
Consider augmenting natural regeneration through planting where species diversity is likely to be limited.		Modify scoring/requirements.
Review pest and pathogen risk management plans as conditions change, and further evidence becomes available.	Require mandatory plans from applicants – “risk assessment”; phyto-sanitary felling may conflict with more standing deadwood.	Modify scoring/requirements.
Species selection		
Consult the relevant climate change guidance on species choice and risks of new pests and pathogens when selecting species.	Use idea of “site adapted”.	
Diversify the range of species planted to meet management objectives and reduce risk wherever soil conditions and predicted climate allow.	<i>Nothofagus</i> replaces beech, as an example.	Modify scoring/EWGS WCG requirements.
Consider planting a range of origins of native species, including local origin material.		Amend EWGS guidance.
Consider a proportion of non-locally native species in new native woodlands; restrict choice to continental European origin and take advice from JNCC and/or FR.	Redefine or avoid term native; accept near native or near continent natives (“Frontier species”); consider future ecological roles.	Could be restricted by forestry act and felling licence conditions, replace like for like.
Adaptation and landscape ecology		
Avoid fragmenting existing priority habitats and consider the impacts of new woodland on the ecology of adjacent sites.	More new woodland which links or buffers fragmented woods.	Adjust scoring to favour projects linking woodland habitats.
Improve the ecological connectivity of the landscape for woodland species by extending and linking woodland habitats.	Prioritise for woodland creation; “JIGSAW” England-scale projects. FCE need to consider scale of aspirations with others.	Adjust EWGS Scoring and locational supplements.
Control or remove populations of problem invasive non-native species from woodlands and their surroundings.		Develop standard cost models; adjust EWGS Scoring.

Take opportunities to extend existing semi-natural woodland.	Buffer planting field margins near woodlands.	Relax cross compliance/ Environmental Stewardship requirements; adjust EWGS scoring.
Environmental protection		
Plan drainage and riparian areas in accordance with the Forests and Water Guidelines.	Can be complex, e.g. delay of flood peak can be unhelpful at confluence.	
In siting new woodland, consider the potential benefits in relation to flood alleviation, water quality and other ecosystem services.	Win-win measure, delivering other objectives.	Adjust scoring under EWGS.
In urban situations, consider the potential benefits of woodland and trees in reducing the impacts of the climate change.	More urban woodland, and street trees.	Planning – compensatory planting.

6.4.1.2 Measures demanding further exploration to deliver climate change objectives

The scoping review also concluded that 15 potential measures demanded further exploration, covering both mitigation and adaptation (and, for some, combined delivery). All 15 measures are included in the following section to reflect co-delivery and that some mitigation measures may also have implications for adaptation. Some measures have already been implemented through ongoing work to improve delivery of EWGS. Others are subject to Government’s response to the recommendations of the Independent Panel on Forestry (April 2012) and the Forestry Regulation Task Force (October 2011). Practice guidance developed to support the revised UK Forestry Standard and the nature of forestry (and other) measures that comprise the next Rural Development Programme (post 2013) will also be of relevance. The ongoing work of the Woodland Carbon Task Force, particularly in relation to new financial models for incentivising woodland creation and management, interactions with grant-aid and uptake of the Woodland Carbon Code are also material considerations.

Potential measures to reduce emissions

1. Greater protection of forest soil carbon through EWGS: primarily a mitigation measure; however, retention of soil carbon will also maintain soil water holding capacity and nutrient sustainability. Specific measures identified include (a) withdrawal of payment for cultivation of organic soils and the application of negative scores for Woodland Creation Grant and (b) greater consideration of soil carbon in EIA determinations.

Potential measures to enhance forest sinks

2. Increase in woodland creation rates through EWGS: Primarily a mitigation measure, but significant opportunities for landscape adaptation (habitat networks, water management) through woodland creation. Specific measures include enhanced Woodland Creation Grant (WCG) payment. Issue largely overtaken by work of the Woodland Carbon Task Force and the aspiration to increase the level of woodland creation through private finance⁹.

3. Use of EWGS to increase sequestration through greater use of conifers, particularly in regenerating existing woodlands: Largely mitigation, but diversification of species and woodland types also represents an adaptation measure. Could be achieved through increasing WCG intervention rate. Support for enhanced regeneration payments currently being considered in the context of *Phytophthora ramorum*.

4. Supporting short rotation forestry (SRF) under EWGS: Primarily mitigation, but also potential landscape adaptation role (water management). WCG could be extended to apply to SRF. A significant barrier to uptake is the permanent nature of woodland creation; relaxation of Felling Licence regulations for SRF could address this issue, although the cessation of the presumption in favour of restocking could be viewed as deviating from the principles of Sustainable Forest Management.

5. Relaxation of Felling Licensing to facilitate utilisation of neglected woodlands for woodfuel: Delivers both climate change mitigation (renewable energy) and adaptation (enhanced regeneration and diversity of structure) objectives. Four options were considered: (a) reduced information burden for applicants; (b) raised threshold for requiring a Felling Licence application; (c) establish link between Woodland Planning Grant and 10 year 'blanket' permissions for estates; (d) amend the Forestry Act so that thinning is an exempt activity if UKFS conditions are met. All are relevant to the recommendations of the industry-led Forestry Regulation Task Force.

6. Use of EWGS to facilitate more management for woodfuel and to widen options for resilience: Would deliver both mitigation and adaptation objectives. Greater EWGS support identified as a potential measure, which has subsequently been superseded by the Woodfuel Woodland Improvement Grant and enhanced funding for access.

Potential measures to promote adaptation

7. Use of EWGS to implement continuous cover forestry for more diversity of structure and composition: Likely to enhance resilience to climate change and pest/disease outbreaks. Could be achieved through enhanced Woodland Improvement Grant payments including support for uneconomic thinning, cleaning, spacing, deer/squirrel management and enrichment planting.

⁹ The Natural Environment White Paper (Anon, 2011) outlined Government's aspiration for increased woodland creation.

8. Promoting new emphasis on integrated woodland management plans through EWGS: Woodland planning and monitoring is a key component of adaptive forest management. Currently woodland planning grants, funded as part of EWGS only cover a 20 year timeframe. Amendments could be made to the Plan template to cover a longer timeframe, specifically with respect to species suitability, in line with requirements of the UKFS Forests and Climate Change Guidelines.

9. Supporting a more flexible approach to origin and provenance in native woodland: Adaptation measure to (a) increase genetic diversity and (b) plant more southerly (including non-native) provenances. This measure is supported by both the UKFS Forests and Climate Change Guidelines and Ancient and Native Woodland Practice Guide and should therefore become implicit in receiving an EWGS Woodland Creation Grant. Implementation dependent on availability of stock and adequate guidance.

10. Promoting greater use of non native species from mainland Europe or elsewhere: An adaptation measure that also presents some risks in the absence of adequate guidance and future monitoring. Current EWGS WCG encourages using native species of local provenance. UKFS Forests and Climate Change Guidelines and Ancient and Native Woodland Practice Guide both support limited use of non-native species to encourage species diversification.

11. Support for large scale creation of riparian woodlands supported through EWGS: Adaptation measure promoting flood alleviation and thermal regulation of watercourses through shade. At present, minimum width requirement (30 m) limits applications through EWGS, although the measure is also supported through HLS. Land values also represent a significant barrier, as do costs if stock fencing is required. High costs will, at least in part, be addressed through the recent request to increase EWGS WCG intervention rates to meet water management objectives.

12. Developing grant mechanisms to achieve a major "re-treeing" of the English landscape, both urban and rural, through small woodland features: This adaptation measure is covered, at present, by Environmental Stewardship but not supported by EWGS. Woodland definitions could be amended to incorporate within EWGS. In the urban and peri-urban environment, the London Woodland Grant Scheme is a focus of activity, together with other projects underway in England that support the planting of street trees and groups of trees, including 'The Big Tree Plant'.

13. Use of EWGS to promote the development of England-scale woodland habitat networks: This adaptation measure, aimed at enhancing landscape-scale permeability and resilience could be achieved through locational supplements being paid on the basis of a national woodland habitat network map, such as that developed by Natural England. Changes to WCG scoring systems would also be required, such as those used in the JIGSAW programmes funded under previous Rural Development Programmes.

14. Promotion of woodland creation through unmanaged natural regeneration on marginal agricultural land: Adaptation and mitigation measure for which there is some

uncertainty over the current situation. Scrub removal is expected under Cross-compliance to maintain land in 'Good Agricultural Condition', although exemptions are available. Alternatively, a minimum Woodland Creation Grant could be made available to allow landowners to retain Single Farm payment.

15. Promoting reduced use of pesticides and fertilisers under EWGS: Although an issue in some countries, fertiliser and pesticide use is rare in England and not supported through EWGS standard cost models. No actions are proposed.

6.4.2 CAP reform/RDP development post-2013

The reform of the CAP is due to take effect from 2014. Draft regulations have been published which indicate that some significant changes to its first pillar, direct support to farmers, are highly likely. However support available to the forestry sector under the second pillar (Rural Development) will be somewhat enhanced; the changes are in response to the 'Opinion' of the EU Standing Forestry Committee, to which the UK made a significant contribution, on the current Rural Development Regulation.

Response to climate change will be one of the key objectives of the next CAP and consequently the Rural Development Regulation (RDR) with support available to address both mitigation and adaptation, including specific mention of the role of forestry in carbon sequestration and the development of a low carbon economy. The various measures within the RDR will facilitate the type of activity that is required to address the issues identified in Section 6.4.1.2, including support for outreach and advice and the Farm Advisory Service to be provided under the first pillar of the CAP must include forestry aspects that relate to climate change mitigation and adaptation. The design of the next Rural Development Programme is likely to commence in the second half of 2012 but final proposals will not be possible until the next RDR is approved by both the European Council and Parliament, probably not until the second quarter of 2013.

One of the issues with the current RDR of particular relevance to forestry in England in the context of climate change adaptation is the ineligibility of the impact of biotic factors in respect of the measure that would support activities to restore forestry potential in forests damaged by natural disasters and fire and for introducing appropriate preventative actions. This has been resolved in the next regulation and support will be available to establish and improve monitoring facilities as well as preventative and restorative activity. However, probably the most significant issue for the next Rural Development Programme for England will be the available budget.

A UK-wide workshop was recently held to elicit the forestry sector's response to the draft regulation. Climate change was considered in these discussions. FC will continue to work closely with Natural England, Environment Agency and Defra to ensure that appropriate adaptation measures are supported by the next Rural Development Programme including the delivery of a range of ecosystem services. Defra Arms

Length Body joint-working groups, including the Adaptation Delivery Group (see Section 4.5.5), will provide input to this process.

6.5 Climate Change Action Plan for the Public Forest Estate

The Plan is written for practitioners managing the Public Forest Estate. It is a concise document using internet and intranet links to expert advice and intranet (see Annex 6). The plan acknowledges that the woodland managed by FCE has been established over many years in a relatively stable climate. This key assumption no longer applies. The Plan calls practitioners to recognise the urgency to act as the forests they are managing today will mature in a very different climate. The Plan acknowledges that there are uncertainties, but guides and assists staff to begin to implement adaptation measures now.

The Climate Change Action Plan (CCAP) will ensure that the woods managed by the Forestry Commission play their part in responding to the challenges of climate change. FCE's programme of work will contribute to both adaptation and mitigation, creating the best opportunity for woodlands and trees to continue to deliver the multiple benefits of sustainable forestry. The plan is complimentary to the Forestry Commission's Environmental Management System that is intended to reduce the Forestry Commission's carbon foot print, but also addresses issues of adaptation on FCE's built estate.

The CCAP outlines actions to increase the resilience of woodlands in the middle of the century under a range of greenhouse gas emissions scenarios. If global emissions are not effectively reduced and a High emissions scenario becomes a reality, a greater level of intervention will be required to transform FC forests to ensure their long-term survival. The measures outlined within the plan will increase the resilience of woodlands in a changing climate and, through implementing adaptive management (i.e. incorporating monitoring and review), put forest managers of the future in a position to react to change.

Although the CCAP is written specifically for the Public Forest Estate it is anticipated that it will provide an exemplar of action on adaptation for the wider forestry sector. The information provided to practitioners on the Public Forest Estate has also been made publicly available to support implementation the UKFS Guidelines on Forests and Climate Change and encourage adaptation across England's woodland resource.

The Plan:

- adopts the principle of anticipatory adaptation as this offers the highest potential gains for forest resilience and the benefits that forests provide;
- takes an approach that is not risk averse;

- identifies who will participate in the activities, when this will happen, the process of review and learning and how we will be able to monitor and evaluate the rate of progress towards the outcome;
- Will be monitored annually and reviewed every five years.

Progress in implementing the Plan and achieving the intended outcomes will be independently verified by:

- implementing the recommendations contained within the revised UKFS and its underpinning Forests and Climate Change Guidelines; progress will be independently audited against the UK Woodland Assurance Standard, accredited by the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC).
- By managing FCE's business in a sustainable way, within an environmental management system (EMS), consistently reducing FCE's demands on non-renewable resources. Progress against this will be independently audited against the ISO 14001 Standard.

The key implications of climate change on forestry in England are identified for the Public Forest Estate in its current condition. The Plan then goes on to describe the desired outcomes for 2050, and the necessary actions to achieve those outcomes.

6.5.1 Key imperatives of the plan

Increased diversification to reduce risk:

- in age structure;
- in species;
- genetics within species;
- in silvicultural systems used.

Forest Design Plans are the key instrument in ensuring resilience. Increased emphasis will be placed on using CCF, and the creation of mixed age and mixed species stands. A wider palette of species, increasing diversity at both forest and stand level, will be used. The planting stock of these species will be from more southerly origins. There will be some under-planting within stands managed on a continuous cover basis to introduce more southerly origin planting stock to PFE woodlands, while the introduction of more shade tolerant species will improve the functionality of this silvicultural system.

Managing carbon within the forest:

- protecting forest soils;
- optimising sequestration;
- minimising GHG emissions associated with road construction.

Operational plans will adhere to best practice as outlined in the UK Forestry Standard. Timber harvesting will seek to optimise the yield taken from the forest while not allowing the harvesting of stumps. Branch wood harvesting will only be allowed on certain sites according to best practice guidance. New technologies will be implemented for our civil engineering on the PFE to ensure that the minimum amount of stone is used to meet the structural strengths required.

Planning for the expected:

- forest fires;
- increased water run-off;
- more frequent storms;
- more insect pest and disease outbreaks.

Forest Design Planning will consider whether it is necessary or practical to incorporate additional measures for reducing the spread of forest fire. As these plans will create a more diverse forest age structure, this should also mitigate against the worst wind blows. The design capacity of culverts associated with roads and bridges will be increased by 30%. The increased diversity of species and use of mixtures will mitigate against the worst impact of disease and insect attack.

The Climate Change Action Plan is summarised in Table 6.4, as a series of actions to be undertaken by specified units to achieve desired outcomes within the 5-year cycle of the Plan. Table 6.4 also indicates the frequency and nature of reporting on progress.

Table 6.4. Summary of actions and outcomes from the Climate Change Action Plan for the Public Forest Estate. PSSB – plant and seed supply branch; LISS – low impact silvicultural systems; BMR – business monitoring report; HMO - Harvesting and Marketing Officer.

Outcome	Activity – we will	Who	When	Reporting
Our forests are resilient and we manage our emissions.	Review our activity and progress in implementing the CCAP and EMS.	FD	March BMR	Annual FD report
Managing our woodlands sustainably	Manage our woodlands to a minimum standard accredited under independent audit to UKWAS. In doing so we will implement the UKFS Guidelines on climate change.	All	Ongoing	UKWAS audit
That this plan is implemented	Implement an “adaptive forest management” process.	FEE FD FR FS	Ongoing	CCAP yr5 review; FEE & district annual report
FEE is exemplar of best practice for adaptation	Set up, then promote, field-scale case studies of best practice, as part of “adaptive forest management”.	FEE FR	Ongoing	CCAP year 5 review
Species and genetic diversity	Identify species/provenances at short-term risk to CC.	FR	2011	Report to FEE

Outcome	Activity – we will	Who	When	Reporting
	Produce and implement guidance on species selection, use of mixtures and origin. We will use more species in planting schemes, creating diversity at stand level.	FEE FR	2011	Intranet
		FD	Ongoing	Annual district and FEE report; CCAP 5 year review
	Identify seed stands for minor species across southern England.	FEE PSSB FR	Ongoing	CCAP year 5 review; Annual district and FEE report
Diversity in stand management	Identify stand types at immediate risk to climate change.	FR	2013	CCAP year 5 review
	Review and consolidate current CCF, LISS and coppice intentions within FDPs, looking for sustainable increases in CCF, LISS and coppice.	FD	Ongoing	CCAP year 5 review
	Widen membership and awareness of the CCF group.	FEE FD	Ongoing	CCAP year 5 review; FEE & District annual report
Resilience to pests and disease	Produce and implement biosecurity guidelines, and deliver forest health days to regions.	FR FEE	2011/12	UKWAS audit; CCAP Publication; Annual district and FEE report
Resilience to fire	Review Forest Design Plans to plan for future fire mitigation.	FD	Ongoing	UKWAS audit
Our woodlands increase landscape permeability	Seek to work in partnership with others, to ensure FDPs are linked at landscape level.	FD	Ongoing	UKWAS audit
We are contributing to sustainable water management, and reducing the use of carbon to build and maintain our roads	Implement the UKFS, in particular Forests and Soils, and Water Guidelines.	FD	Ongoing	UKWAS audit
	Review the capacity of the forest infrastructure to cope with increased precipitation.	FCE	Ongoing	UKWAS audit
	Review our management of reservoirs to ensure compliance with 'Flood and Water Management bill'.	FCE	Ongoing	UKWAS audit
	Work with others to explore the opportunities PFE forests offer to help with water management.	FD	Ongoing	CCAP year 5 review
	Use ground penetrating radar technologies to reduce the amount of aggregates used in forest roads.	FCE	Ongoing	CCAP year 5 review
	Adopt, where practicable, new technologies to reduce the impact of haulage on our roads, such as central tyre inflation systems.	FCE HMO	Ongoing	CCAP year 5 review

6.6 Indicators

Adaptation indicators fall into two categories – outcome and process indicators. The former are, necessarily, mostly longer term. However, process indicators provide

greater scope for indicating progress on adaptation at an earlier stage. Those indicators from FCE's Indicator Framework that could be interpreted as adaptation indicators are outlined in Section 6.6.1, while initial thinking on a wider suite of candidate impacts/adaptation indicators for the forestry sector are outlined in Sections 6.6.2 and 6.6.3. It should be noted that the National Forest Inventory will provide a comprehensive suite of source data for reporting changes in forest condition, composition, structure, intensity of management, timber resource and carbon storage. This will allow the development of new indicators, but a clear picture of the current position (baseline) will only become clear in 2015, preceded by an interim report in 2013.

An outstanding action from FCE's Corporate Plan for 2010/11 is to scope indicators to track the impacts of climate change on England's woodlands, establish an understanding of their resilience and to report on progress in implementing adaptation measures. This work (see Sections 6.6.2 and 6.6.3) will be taken forward with Forest Research as a component of the Climate Change Risk Assessment and Adaptation Research Programme and working with Natural England and the Environment Agency on common themes. As for so many aspects of the forestry sector, the long life cycle (rotation length) of trees makes the interpretation of trends (in terms of impacts and resilience) more difficult than for annual crops; for example, mensuration (or growth and yield) assessments are conventionally only made every five years.

6.6.1 FCE's Indicator framework

A number of the impact indicators and 'State of England's Woodland Indicators' from FCE's Corporate Plan for 2011-2015 (FCE, 2011) are relevant to woodland resilience (including to the changing climate) as outcome or process indicators for climate change adaptation. Both sets of Indicators are part of FCE's indicator Framework and are part of FCE's wider commitment to the Government's Transparency agenda, providing information of value to FCE's stakeholders.

6.6.1.1 Impact indicators

- Maintain UKWAS certification on the Public Forest Estate;
- Percentage of woodland in active management (including the Public Forest Estate);
- Hectares of woodland created (gross);
- Hectares of woodland brought into management by the Woodfuel Woodland Improvement Grant.

6.6.1.2 State of England's Woodlands indicators

- Number of tree diseases in England that are considered 'high risk' by the FC;
- Measure of how well woodlands are set up to cope with changes such as climate change based on size and how well species can move between them;
- Rate of annual increment in England's forests;

- Measure of the conservation condition of woodlands using information from the National Forest Inventory;
- Percentage of woodland SSSIs in target condition;
- Measure of what is happening to the number and variety of species that live in woodland using Woodland Birds' data;
- Area of woodland (total and change over time);
- Area of woodland in England that is certified as sustainably managed.

The degree to which each of these 'State' indicators is influenced by climate change and adaptation responses to it are uncertain. This is likely to mean that each can only be seen as a 'contextual' indicator. However, as part of the work on State of England's Woodland Indicators, FCE have also committed to the development of a new indicator of resilience of woodland at a landscape scale:

'Measure of how well woodlands are set up to cope with changes such as climate change based on size and how well species can move between them'.

6.6.2 Candidate adaptation measures – outcome indicators

FCE's indicator framework does not provide a comprehensive measure of either the impact of climate change or on progress in enhancing resilience or implementing adaptation measures. A number of candidate impact and adaptation measures are listed below, which will form the basis of further work on the development of climate change indicators to help identify progress in addressing the challenge of climate change and where further action is necessary.

Tree growth: Growth measurements as collected conventionally by field survey, and fed into mensuration growth and yield models. Examples include dbh (diameter at breast height) and top height. There may be difficulties in distinguishing impacts of climate change (and the results of adaptation) from more general forest management effects and the impact of other environmental drivers.

Tree survival (including density of plantations): As collected in research experiments and by FEE through Operational Guidance Booklet (OGB) 4.

Forest fire damage: Temporally and geo-referenced by Fire and Rescue Services and more effectively reported than before.

Resilience of individual species: Using evolved measures based on ESC-based predictions and species composition over an appropriate scale of measurement. Evidence available on the ground from FE's sub-compartment data-base at a range of scales. Difficult to capture from private sector except perhaps via UKWAS certification auditing.

Silvicultural resilience: Using evolved measures based on expert and process-based systems predictions of suitability for different silvicultural systems under climate change. For example, ForestGales for modelling wind exposure.

Environmental resilience: Using measures of, for example, water quality from well characterised and monitored catchments in relation to indicator information captured above. Water quality could potentially be used as an overall summary indicator for forest environmental quality, and its consequent impact on other ecosystems.

Wind damage: Capture of volume and areal extent of significant windblow. To complete feedback, relevant to relate to environmental information, tree species, age/height, time of year and silvicultural management.

6.6.3 Candidate adaptation measures – Process indicators

Uptake of tree species climate change (and biosecurity) guidance: Evidence of restocking with change of species or provenance.

Establishment of adaptation communication systems (gauging adaptive capacity): To share experience of changing silvicultural practice and of its outcomes (e.g. new species survival/performance).

Updating of production forecasting models to take account of climate change projections and 'extreme events': Related to economic outcomes.

Tree health surveillance: Evidence of staff commitment to monitoring evidence of tree health/ill-health.

7 Concluding remarks

Forestry represents a particular challenge for climate change adaptation because of the timeframe associated with forest planning, the range of climatic drivers that trees are influenced by and the need for any actions taken to be appropriate to both the current and future climate and associated extreme events. These challenges are compounded by the pest and disease outbreaks that are currently of such great concern to the sector, and are also likely to be influenced by the changing climate. The long planning cycle and the implications of non-adaptation (see below) mean that the forestry sector needs to embrace climate change adaptation at an earlier stage than most other sectors and against a greater degree of uncertainty in those actions being successful. Such early action is relatively straightforward to justify for the management of the Public Forest Estate, although decisions will require a high level of scrutiny as the PFE is a Government asset. However, justification of the use of regulation to encourage early action by the private sector may be more difficult because of the higher risk of mal-adaptation and, as a consequence, threat to the forestry sector and future impacts on the reputation of Government (i.e. FCE).

The risk assessment presented here is thorough and inclusive of the full range of functions of FCE. The analysis of measures that *could* address those risks is also comprehensive. However, with the exception of the Climate Change Action Plan for the Public Forest Estate and corporate functions, the adaptation programme is an outline of future direction and is subject to the views of the Independent Panel on Forestry and Government's response to its final report. The Adaptation Programme will be further elaborated when the work of the Independent Panel and the response from Ministers is complete.

It should be noted that climate change does present opportunities for FCE. Climate change is likely to be beneficial to tree growth in the north and west of the country, at least up to the middle of the century (as outlined in Section 4.1). The need to adapt to climate change also raises the profile of woodland creation and the ability of FCE to perform one of its key functions – increasing the woodland resource.

7.1 Cost of adaptation versus non-adaptation

No attempt has been made to conduct a formal economic assessment of the costs of adaptation, although such an analysis is a component of Forest Research's Climate Change Risk Assessment and Adaptation research programme. A qualitative commentary is, however, provided.

Across most areas of activity, the costs of implementing adaptation measures are relatively small. For Corporate activity, research procurement, provision of advice, administration of grants and regulation and empowerment of the private sector,

adaptation should be embedded as 'business as usual' by FCE at minimal additional cost. The activity with highest associated cost is likely to be development of the evidence base and drafting of associated guidance; however, this activity is encompassed by the past and current research programme funded by the Forestry Commission. A higher level of cost to FCE will apply to both measures implemented on the Public Forest Estate (direct) and, potentially, in private sector woodlands (through enhanced levels of grant to promote adaptation).

For forest management activities, there will initially be costs associated with sourcing alternative planting material. However, as adaptation is mainstreamed, it is likely that nurseries will respond such that additional costs decline to zero. Amending specifications for forest infrastructure (reservoirs, bridges, culverts, roads, footpaths) to cope, particularly, with more intense rainfall events may represent additional expenditure. However, upgraded infrastructure will cope better with extreme events under the current climate, potentially reducing maintenance costs to offset capital costs. Alternative approaches to management (i.e. alternative to clear-fell) are likely to lead to reduced timber income in the medium term (up to 50 years), which may be offset in the longer term through higher value products. An important consideration for cost-benefit analysis of adaptation in the forestry sector is timeframe, with many measures implemented over a number of decades.

A good example of the long timeframe mitigating adaptation costs is the potential consequence of changing species (and therefore timber performance) on the wood processing sector. At first sight, costs to the processing sector would be high if processing equipment and market requirements were to change. However, timber processing equipment has a replacement cycle of approximately 20 years – or half the rotation length (as a minimum). There would therefore be sufficient time for the processing sector (and associated market) to respond in the unlikely event of a step-change in planting stock at national scale.

The costs of not adapting to climate change are difficult to quantify, largely because of the uncertainty of the cost of reputational damage to FCE/Government and the non-market benefits that woodlands and the forestry sector provide. Direct financial costs to the forestry sector in England would be substantial in the absence of adaptation – whether through direct action on the PFE or through facilitation/regulation in private sector woodlands. The level of these potential costs becomes clear from the analysis of species suitability across the PFE (see Section 4.1), with 63% of the estate at risk of failing to meet current expectations of commercial productivity by the end of the century in the absence of adaptation measures being implemented.

The costs of not adapting would rise further if the non-market benefits were also considered, including the ~200 MtCO₂ locked up in the trees that comprise England's woodlands. Although all the services provided by woodlands in England would not be lost, a combination of reducing employment, lost recreational opportunity, impacts on biodiversity and carbon storage and declining timber production would imply very high

costs when set against recent valuations of these services by Crabtree *et al.* (2005) and Jaakko Poyry (2008) of £2-11 billion.

One cost that is often overlooked – whether adaptation measures are taken forward or not – is the cost of monitoring. Monitoring is essential to the process of *Adaptive Forest Management*, as outlined above, acting as a check against inappropriate adaptation measures and confirming those that should be implemented more widely. If adaptation measures are not implemented, monitoring will provide evidence of the increasingly urgent need to address adaptation as climate change unfolds. At national scale, repeat cycles of the National Forest Inventory will provide a suitable platform. However, more detailed recording of the location and success (or otherwise) of adaptation measures is fundamental to adaptive forest management.

7.2 Urgency of action for FCE

The analysis of risk presented in Sections 3 and 4 highlighted the difference between proximity of impact and urgency of action. Indeed, many of the impacts that would be expected over the longest timeframes are the most urgent to address, mostly relating to species choice for restocking and new woodland planting.

To meet climate change adaptation objectives in isolation, the analysis presented in Section 4.1 indicates that there is a ten year window to embed increased diversity and amended species choice when planting or re-stocking. To achieve this timeline will require that forest design plans are updated and supporting guidance/regulations for the private sector are effecting change within 5 years, so that nurseries can grow on the necessary planting stock. To address the often-related threat posed by pest and disease outbreaks requires still more urgent action on species diversification. It is therefore clear that FCE's functions that relate to adapting species choice, whether on or off the Public Forest Estate, and including further development of the evidence-base and associated guidance, have the highest level of urgency attached to them. However, it should be acknowledged that there is a risk of mal-adaptation because of the need for early action.

A second suite of adaptation measures that require urgent adaptation are those that facilitate tree/woodland planting where adaptation is delivered by the presence of mature trees. Such initiatives include urban woodland and street tree planting to reduce the urban heat island effect, riparian planting to reduce thermal stress in the freshwater environment, floodplain woodland planting as a flood alleviation measure and planting to further develop woodland habitat networks. There are limited opportunities, currently, on the Public Forest Estate. Most of the urgent measures in this category will fall to Forest Services, including through the work of the Woodland Carbon Task Force.

Given the urgency to implement those priority measures outlined in the preceding paragraphs, it will be essential that governance and corporate processes are flexible and fleet-footed enough to allow the necessary changes in forestry practice, forestry regulations and forestry (and other land management) grants to be made. Adaptation of governance and corporate functions is therefore a pre-requisite for the more far-reaching measures to be implemented as a matter of urgency.

7.3 Barriers to Adaptation

The main barriers to adaptation have been outlined throughout this Risk Assessment, particularly in Section 5 on Interdependencies, Section 6 on the Outline Adaptation Plan and elsewhere in this concluding section. Four issues underlie the majority of barriers to adaptation and will require careful consideration if an effective adaptation programme is to be implemented.

- Adaptation measures must be appropriate to both the present and future climate.
- The woodland management sector encompasses a broad set of objectives, ranging from commercial timber production to protecting the biodiversity associated with England's ancient and semi-natural woodland.
- The life cycle of trees and the planning horizon for forestry are both long term and actions implemented now may only bear fruit in 50-100 years time. Decisions taken now for the future may be at odds with policies working over shorter timeframes.
- England has a relatively poor tree flora and Great Britain, as an island, has physical barriers to the migration of species; definitions of nativeness for immobile species such as trees become fundamental to developing adaptation measures.

Each barrier will need to be analysed separately, although the grouping presented below – physical/practical and institutional/cultural, will enable some generic responses to be developed to overcome the barriers.

7.3.1 Physical/practical barriers

Unlike most sectors, where implementing adaptation measures represents a win-win measure that provides additional resilience against extreme weather event under the current climate, this is not true for the natural environment; measures must be appropriate to the full range of climatic factors under both the current and future climates. As an example, if flood defences are raised beyond what is necessary to address future climate change, they will simply provide additional protection against current flood events; this is not the case for the natural environment as, if action is premature or the adaptation measures are excessive (in terms of species choice), they may not survive the current climate. This requirement inevitably acts as a barrier against adaptation and is compounded by uncertainty in the future climate. In practical terms, if future climatic conditions were present now, the knowledge of what

species to plant where and how to manage them is clear. However, the forestry sector does not, and can't, have that level of clarity.

Uncertainty in the climate of the future presents a further challenge in that clear, detailed and specific guidance on species choice, is not available. This lack of a step-wise 'adaptation recipe' contributes further to the barrier presented by the conservative nature of the forestry sector.

Generic guidance on species choice is available, where species diversification is the key outcome. However, the availability of suitable planting stock is a current issue; there has been little demand in the nursery sector for many of the minor species that would contribute to a more diverse approach to planting. As a result, the wider suite of minor species required as an adaptation measure is not available. The same is true for the majority of 'new species to forestry in the UK' that the Read Report identified as worthy of consideration. The Public Forest Estate has a key role to play in breaking down this barrier, through placing orders early and in significant enough numbers to give confidence to the nursery sector and, also, to the private sector.

The same issue of limited availability of planting stock is the case for alternative (more southerly provenances) of both commercial (introduced) and native species. In the case of the former, this is largely a result of history and 'convention'. The PFE again has a key role in breaking down this barrier by giving a clear lead and, also, providing a link between the research community and the nursery sector as to which origins are likely to prove appropriate. However, a further issue is emerging, with the importation of seed from some 'climate-appropriate' locations prevented due to biosecurity concerns. In the case of native species the policy of promoting local provenance, to which the nursery sector has only recently adapted, represents an additional barrier which is compounded in some cases by an unwillingness to plant non-native stock.

Conversion to alternative to clear-fell methods of management has been highlighted as an appropriate adaptation response. However, conversion of existing stands is a long process that may incur additional management costs and reduce timber income and profitability, at least in the short term. There is also some scepticism over continuous cover forestry and, to an extent, a lack of understanding of its practice. These latter barriers are being addressed through practical guidance emerging from the research community and by strong advocates for the practice, such as the Continuous Cover Forestry Group.

Although timber prices have risen recently and may continue to do so, largely as a result of the woodfuel agenda, forestry is not a highly profitable sector and margins are small. Any adaptation measure that involves significant cost – primarily changes to forest infrastructure including culverts, bridges, roads and reservoirs/fire ponds – is unlikely to be implemented unless required to do so by law/regulation. Such financial barriers are a lower order priority because there is a much shorter 'lead time' when

compared with issues associated with species choice and adaptation measures will be implemented as the need to do so becomes clearer.

Where woodland creation is identified as an appropriate adaptation measure – either to provide a resource more resilient to climate change or to contribute to land management approaches to flood alleviation or meeting water quality objectives – land availability is likely to represent a significant barrier as a result of competing land use pressures, other policy objectives and lack of financial incentive (whether through public or private finance). This barrier would clearly impact on the ability of Forest Services to achieve one of its key objectives. This barrier is being addressed by the Woodland Carbon Task Force.

7.3.2 Institutional/cultural barriers

A number of economic, institutional and cultural barriers also exist, including current financial constraints, both in the public and private sector, and the need for clear objectives for forestry in England. Government's forthcoming responses to the Independent Forestry Panel and Forestry Regulation Task Force provide the opportunity to clarify arrangements and ensure a good match between ambition and resource.

The current financial constraints, particularly on Forest Enterprise, that have resulted from the SR10 settlement mean that only essential programmes have funding and climate change adaptation may be seen as a second order issue that can be addressed at a later date. The clarity provided in the Climate Change Action Plan for the Public Forest Estate, its support from the Forest Enterprise Management Board and effective communication within the 'practitioner community' will help to break down this barrier. In particular, communicating adaptation as 'business as usual' activity with minimal marginal costs is likely to prove the most effect route to achieving effective adaptation.

The forestry sector is, by the very nature of its long planning horizon, conservative. This acts as a barrier to the introduction of alternative species and practices. This barrier can be broken down by strong evidence, clear guidance, market mechanisms, regulation and, above all, by strong advocacy for the need for change.

The lack of demand for new species and the inability of sawmills to process minor or alternative species is often cited as a barrier to the planting of alternative species. Given that the service life of processing equipment is significantly less than that of even a short conifer rotation and that the properties, uses and markets for different species are well-documented globally, this should not be seen as a real barrier but as another facet of the conservatism of the sector.

The 'precautionary principle' could be seen as representing a significant barrier to adaptation, depending on how it is applied to the forestry sector and the development of forestry policy. Many adaptation measures are not implemented on account of the

precautionary principle being applied. In such cases, the definition of the precautionary principle is that there should be no action until we have certainty and that it is important to protect what we have without compromising any current objectives. There is, however, an alternative view that if the precautionary principle is followed we should be implementing actions now that will not result in significant disbenefits if climate change does not progress as anticipated, but that will reap significant benefits if it does. Such actions may, in a small way, be counter to current policy objectives. Uncertainty is often cited as the rationale for the former definition of the precautionary principle being applied. However, climate change is a far from certain science and waiting for certainty could be seen by future generations as 'fiddling while Rome burns'. Again, strong evidence, clear guidance and advocacy for appropriate actions will be needed to break down this barrier.

The approach to planting non-native (or new native/frontier) species in new native woodland is a clear example where the definition of the precautionary principle could act either as a barrier to change or as a driver of change. By including a proportion of species from continental Europe which currently experience the hotter drier climate projected for England towards the end of this century and that form functional ecosystems alongside species native to England, it would be expected that the resilience of the new woodland resource would increase as a whole. However, because the native range of species is defined as their range 5,000 years ago, the introduction of 'near native' species runs counter to some aspects of biodiversity policy and to the stated objectives of many woodland management plans. Ultimately, the barrier to adaptation is the English Channel limiting both (natural) species movement and a pragmatic approach to species selection in native woodland.

7.4 Adaptation delivery of other objectives

As outlined in the Read Report, Natural Environment White Paper (Anon, 2011) and National Ecosystem Assessment (UKNEA, 2011), woodland creation and management deliver a range of goods and services, alongside climate change adaptation. For woodland creation, they can be summarised as:

- New habitat for wildlife
- A timber/woodfuel resource for a future low carbon society
- Soil protection
- Water quality protection
- Flood alleviation
- A new recreational resource
- Health benefits
- Contribution to aesthetic improvement, particularly in the urban environment

For woodland management:

- A renewable energy supply (woodfuel)
- Income for woodland owners
- Improved habitat condition for wildlife
- Improved access for recreation

The most relevant co-delivery of objectives at the present time is the diversification of species choice as a measure to address uncertainty in the future climate, also delivering more resilient woodlands in the face of pest and disease outbreaks. In turn, current biosecurity issues have highlighted the risks to woodland resilience of the very narrow species range adopted, particularly across the PFE, by the forestry sector in England.

The intention to introduce continuous cover systems of management across a wider proportion of the PFE as an adaptation measure to improve conditions for successful establishment and promotion of evolutionary adaptation will also help to deliver a number of other objectives. These include increased structural diversity in woodlands that benefits wildlife, reduced impact on the landscape following harvesting, less impact on water quality and woodland habitat at harvest and increased woodland carbon stocks. There is also some evidence that the larger trees that tend to be harvested in continuous cover systems of management attract higher timber prices.

7.5 Contribution of adaptation measures to climate change mitigation

Clearly, those measures that increase the resilience of woodlands to climate change (species diversification, amended species choice) protect woodland carbon stores (~200 MtCO₂e in England) and should therefore be seen as mitigation as well as adaptation measures. As discussed in the preceding section, continuous cover systems of management will enhance the time-averaged amount of carbon stored by woodlands, although there may be some reduction in the ability of harvested wood products to substitute for fossil fuels directly or indirectly if productivity is reduced in these systems.

Woodland creation activities to achieve landscape-scale adaptation (e.g. flood alleviation, habitat network development, water quality management) also have a clear and direct contribution to mitigation targets through sequestration in growing biomass, as outlined in the Read report.

Introducing woodland management into undermanaged woodlands to encourage natural regeneration (potentially supported by species diversification through enrichment planting) is slightly more complex. Although the woodfuel produced through such measures leads to direct fossil fuel substitution and the associated carbon savings, the amount of carbon stored in those woodlands declines. In the short term, there may therefore be net carbon emissions. However, accelerated growth of

the woodland following management intervention and repeated harvest (thinning) cycles typically lead to significant carbon savings in the longer term, with the 'carbon payback period' highly dependent on the method of intervention and the nature of the woodland, as outlined by Bates *et al.*, 2011.

Adaptation measures implemented across the built estate will address climate change adaptation and mitigation in an holistic way, as office refurbishments/relocated are undertaken.

7.6 Assessment of unmitigated risk posed by climate change

Generally, adaptation is embedded across most of FCE's functions, with a range of initiatives in train to address the major risks. However, implementation of the measures identified may be limited by a lack of capacity on both the Public Forest Estate and, particularly, the private sector, where ~45 Woodland Officers need to provide advice and guidance to approximately 60,000 owners, the majority of whom have not had contact with the Forestry Commission in the past 20 years. This highlights the need for FCE to establish conditions through guidance, Standards and incentives to enable and encourage the wider forestry sector to adapt.

One of the more significant unmitigated risks posed by climate change is how to address uncertainty in the future climate, set against the long timeframe for forestry planning. Although potential adaptation measures have been identified for the great majority of risks assessed in Section 3 with a process to deliver many in the short term outlined in Section 6, mal-adaptation is a possibility. Monitoring as part of the process of '*adaptive forest management*' will be critical to reverse cases of mal-adaptation.

The Climate Change Action Plan for the Public Forest Estate makes it clear that a non-risk averse approach has been taken because of the urgency for action. However, it should be noted that only a small proportion of woodlands in England are felled and replanted each year (2,800 ha in 2010 – or 0.2% of woodland area in England), reducing the risk of mal-adaptation as a significant issue. However, this low level of opportunity for adaptation in existing woodlands heightens the need for early action and, in itself, represents an unmitigated risk.

For new woodland planting, the limited capacity to implement adaptation each year again highlights the need for early action; annual woodland creation rates (~2,500 ha/yr) also only represent about 0.2% of woodland cover and will still be less than 1% of woodland cover if the more ambitious option alluded to in the Natural Environment White Paper were realised. As most woodland creation is carried out by the private sector and is therefore dependent on facilitation and encouragement (supported by regulations, the UK Forestry Standard and Grant-aid requirements), the ability to

implement adaptation is further diminished. A significant unmitigated risk is therefore the inability to implement widespread adaptation.

Pest and disease outbreaks and their interactions with the changing climate remain an area of concern. The Biosecurity programme, developed by FC and Defra, was agreed to address the threat of current pest and disease outbreaks. Given future uncertainties, it is not possible at this stage to predict which diseases/insect pests will be introduced or become more damaging, and how they will interact with the changing climate. The Tree Health Action Plan addresses the question of monitoring, ensuring vigilance against future outbreaks, but cannot eliminate the risk.

Those risks outlined above that are unmitigated but for which responses are available represent a further risk to the reputation of the Forestry Commission and the Government. Even if draconian regulations requiring the implementation of adaptation measures were put in place, both on the PFE and across private sector woodlands, FCE would be unable to effect change over a short (20-year) timeframe. This could be viewed as incompetence or an inability to deliver effective adaptation. Targeting those areas in greatest need of action, as outlined in Section 4.1 of this Assessment, becomes still more important in this context.

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Annex 1: Terms of reference for the Independent Panel on Forestry

1. To advise the Secretary of State for Environment, Food and Rural Affairs on the future direction of forestry and woodland policy in England.
2. To advise on the role of the Forestry Commission in implementing policy on forestry and woodland in relation to England.
3. In formulating this advice, the Panel should consider:
 1. how woodland cover can be increased, given competing pressures on land use for food production, energy and development;
 2. options for enhancing public benefits from all woodland and forests, in the light of the Lawton Report and the Natural Environment White Paper, including:
 - public access for recreation and leisure;
 - biodiversity, wildlife protection and ecological resilience, including through restoration of open habitats and plantations on ancient woodland sites;
 - climate change mitigation and adaptation;
 - economic development, particularly to support a sustainable timber industry and a wide range of small and medium sized enterprises, including social enterprises; and
 - engagement and participation of civil society.
 3. constraints and competing demands on public expenditure for this Spending Review period and beyond;
 4. the role of Forest Enterprise England as the manager of productive forestry resources;
 5. the value for money and cost-effectiveness of the public forest estate in England and options for its future ownership and management.
4. In formulating its advice to the Secretary of State, the Panel will be expected to engage and take evidence from the widest range of views and interest.
5. The Panel will report to the Secretary of State in April 2012, with a progress report in the autumn of 2011.

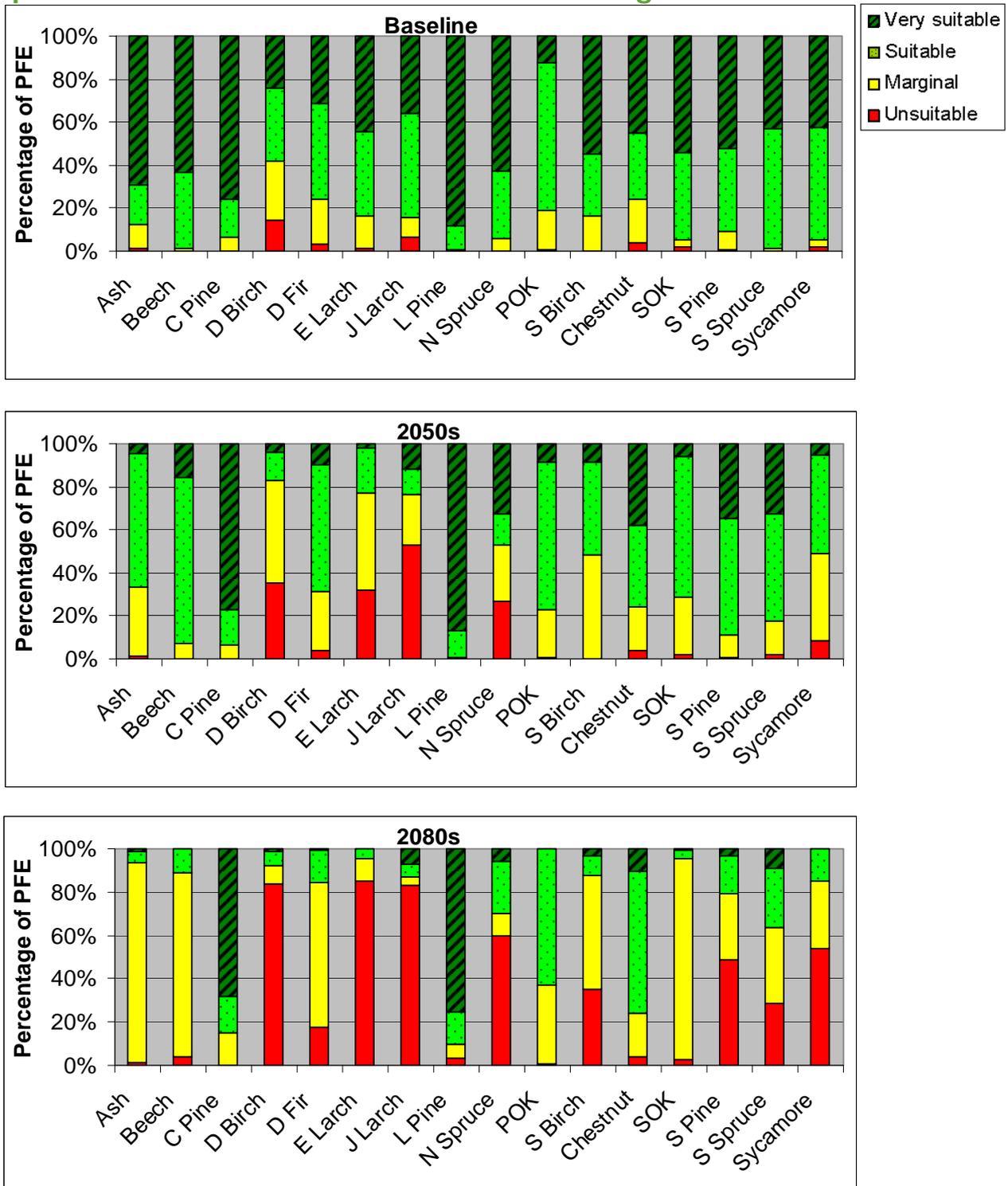
Updated 18th April 2011

Annex 2: FC England's Indicator Framework

No	Priority	Indicator	Publication	Breakdown
Outcome indicators				
1	Protection	Hectares of woodland covered by plant-health notices (includes notices issued on the Public Forest Estate)	Quarterly	National
2	Protection	Percentage of known tree felling that is carried out with Forestry Commission approval (i.e.: the % of felling that is licensable by the Forestry Commission that is not illegal felling. This excludes felling with development approval)	Quarterly	Subnational
3	Protection	Maintain UKWAS Certification on the Public Forest Estate	Annual	National
4	Improvement	Percentage of woodland in active management (including the Public Forest Estate)	Biannual	Subnational
5	Improvement	Hectares of restoration of plantations on ancient woodland sites (PAWS) and open habitat	Annual	National
6	Expansion	Hectares of woodland created (gross)	Annual	Subnational
7	Expansion	Projected carbon capture to 2050 on Woodland Carbon Code woodland creation projects	Annual	National
8	Empowerment	Percentage of priority people close to accessible woodland	Biannual	Subnational
9	Empowerment	Customer satisfaction rating for visits to the Public Forest Estate from the interactive "rate my visit" facility	Quarterly	Subnational
10	Empowerment	Number of agreements for locally led events and activities on the Public Forest Estate	Annual	Subnational
11	Empowerment	Number of households in the Discovery Pass scheme for the Public Forest Estate		
12	Economic Activity	Hectares of woodland brought into management by the Woodfuel Woodland Improvement Grant	Annual	Subnational
13	Economic Activity	Number of private sector businesses operating on the Public Forest Estate	Annual	Subnational
14	Economic Activity	Number of felling licences issued	Annual	Subnational
15	Restructuring our Business	Number of employees (FTEs)	Quarterly	National
16	Developing our Staff	Number of training days completed per employee (FTE)	Annual	National
17	Developing our Staff	Number of significant work-related accidents per 100 employees	Annual	National
18	Customer Service	Percentage of grant and felling licence transactions completed on time or early	Biannual	Subnational

Input indicators				
1	Protection	Cost of providing tree health service including surveys and staff time (£'000s)	Annual	National
2	Improvement	Improvement Grant and Woodland Regeneration Grant (£m)	Annual	Subnational
3	Expansion	Grant paid for woodland creation (total and GBP per hectare)	Annual	Subnational
4	Empowerment	Cash spent on partnerships and engagement by Forest Services	Annual	National
5	Economic Activity	Value of Woodfuel Woodland Improvement Grants	Annual	Subnational
6	Restructuring our Business	Cost of managing the Public Forest Estate (per hectare)	Biannual	National
State of England's woodland indicators				
1	Protection	Number of tree diseases in England that are considered 'high risk' by the FC Biosecurity Board	Biannual	National
2	Protection	Measure of how well woodlands are set up to cope with changes such as climate change based on size and how well species can move between them	Annual	National
3	Improvement	Rate of annual increment in England's forests	Annual	National
4	Improvement	Measure of the conservation condition of woodlands using information from the National Forest Inventory	Annual	Subnational
5	Improvement	Percentage of woodland SSSIs in target condition	Annual	Subnational
6	Improvement	Measure of what is happening to the number and variety of species that live in woodland; using Woodland Birds' data	Annual	National
7	Expansion	Area of woodland (total and change over time)	Annual	National
8	Expansion	Projected amount of carbon captured by England's woodlands	Annual	National
9	Empowerment	Percentage of people actively engaged in woodland	Biennial	National
10	Empowerment	Number of visits to woodland from Natural England Monitoring of Engagement with the Natural Environment survey (MENE)	Annual	Subnational
11	Economic Activity	Number of apprentices and university students entering forestry (from Lantra)	Annual	National
12	Economic Activity	Gross Value Added from domestic forestry	Annual	National
13	Economic Activity	Volume of timber brought to market per annum from the Public Forest Estate and other English sources	Annual	National
14	Economic Activity	Percentage of the total amount of wood that grows in English woods that is harvested	Annual	National
15	Economic Activity	Installed capacity of medium sized wood-fuelled boilers (REA data in MW thermal)	Annual	Subnational
16	Economic Activity	Area of woodland in England that is certified as Sustainably managed	Biannual	National

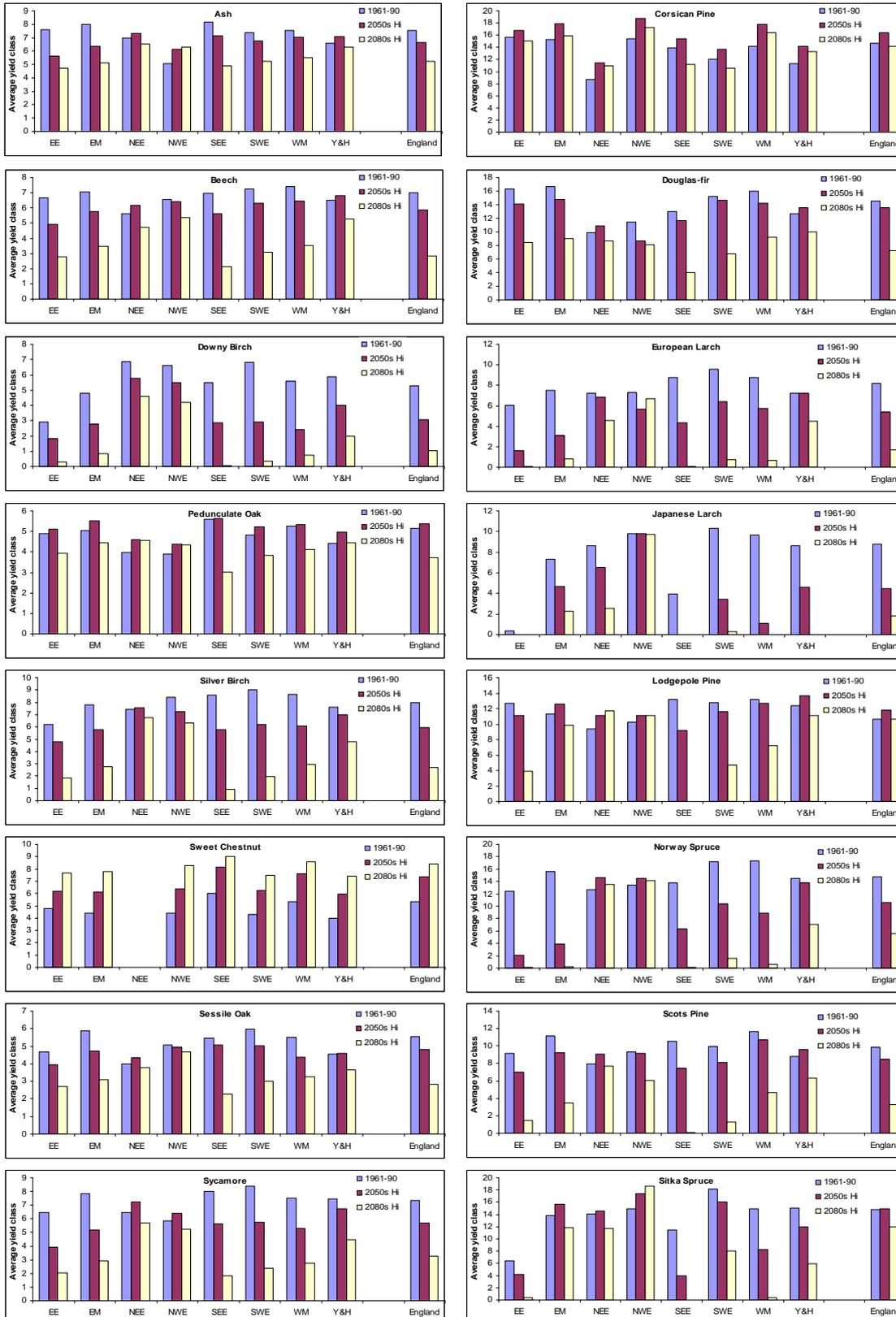
Annex 3: Evaluation of climate risk to the suitability of individual species across the Public Forest Estate in England



Note: This risk assessment is based on the UKCIP02 High emissions scenario and therefore represents the upper bound of likely impacts. It also assumes no adaptation of planting stock or approaches to management. It should therefore not be considered only as a risk assessment rather than as a potential outcome for the Public Forest Estate.

Annex 4: Evaluation of climate risk to the productivity of woodland on the Public Forest Estate in England, for individual species and regions.

Key: EE – East England; EM – East Midlands; NEE – Northeast England; NWE – Northwest England; SEE – Southeast England; SWE – Southwest England; WM – West Midlands; Y&H – Yorkshire and the Humber.



Annex 5. Detailed climate change risk tables for the functions and activities of FC England

Key:	Risks	Opportunities	Risks to staff		High Priority	Medium priority	Low priority		
Forest management									
Phenomena	Likely Impacts	Consequences	Likelihood	Impact	Urgency to take action	Score 0 - 9	Proximity	Cost to Organisation	Adaptation Response
Woodland									
Warmer, wetter winters; hotter, drier summers; more frequent and severe extreme events	Extremes of soil moisture and temperature, and mechanical pressure from the wind	Trees will experience stress conditions to which many species are not adapted. Some will not prove resilient	3	3	3	9	2	H	CCAP UKFS and UKWAS. Assess species at immediate risk. Increase species diversity. Amend provenance choice
	Genetic diversity within species not wide enough for adequate adaptation through natural processes	Some 'native species', particularly to the south and east, may become moribund. Conifer species of more northerly origin will lose productivity and fail to regenerate	3	3	3	9	2	H	CCAP, UKFS and UKWAS. Introduce more southerly origin when regeneration opportunity presents itself. Consider near native in southern England
	Failure of mono-culture and clearfell systems	Premature removal of crops for hygiene reasons, resulting in poor financial returns	2	3	3	8	M	M	CCAP, UKFS and UKWAS
	Distribution of timber species unsuited to future climate	Declining productivity and consequent economic impact; failure to maintain UKWAS certification	3	3	3	9	L	H	CCAP UKFS and UKWAS. Assess species at immediate risk. Increase species diversity. Amend provenance choice

	Improving conditions for some invasive species	Damage to woodland ecosystems and inability to maintain woodland SSSIs in good ecological condition	3	2	3	8	M	M	CCAP, UKFS and UKWAS	
Hotter, drier summers; warmer, wetter winters	A longer growing season	Increased risk of damage from unseasonal frosts. Increased mammalian pest winter survival and associated damage	2	3	2	7	S	H	CCAP, UKFS and UKWAS. Match species/origin to site. Species diversity. Wildlife management plan. Increased use of CCF	
	Winter chilling requirement for some native species not met	Declining success of natural regeneration in semi-natural woodland	2	3	3	8	L	L	CCAP, UKFS and UKWAS. More southerly origin planting stock	
	Increased winter survival of insect/mammal pests and pathogens	Damage to crops will increase. Trees becoming stressed as a result of the changing climate will be particularly vulnerable	2	3	3	8	M	M	CCAP, UKFS and UKWAS. Bio-security protocol. Species diversity	
	A longer warmer growing season	Ticks and other human parasites increase in range and number		3	3	1	7	M	L	Raised awareness to issues such as Lyme's disease. Annual health awareness and chemical deterrent
		Increased tree growth rates may result in weaker timber. Lamas growth may be susceptible to wind and frost damage		1	2	1	4	L	L	CCAP UKFS and UKWAS. Harvested vulnerable species before issues such as drought crack take effect
	A longer warmer growing season, with increased CO ₂ levels	Growth rates will increase in the west and north, or where moisture is not a limiting factor		2	2	3	7	M	L	CCAP, UKFS and UKWAS. When regeneration opportunity arise, diversify and adapt origin/species choice. Note local constraints including frost risk
	More people will be using the Forest for recreation	Increased fire risk and potential for disease spread. Forest recreational infrastructure may be over-used		3	2	2	7	M	H	CCAP. Increase use of CCF, education interpretation, awareness raising such as through the 'Discovery Pass'

Hotter, drier summer	Moisture deficit, which will be more severe in the east and south	Establishment will become increasingly difficult. Trees that are not drought tolerant will struggle in the east and south. Insect populations will take advantage of poor tree health	3	3	1	7	M	M	CCAP UKFS and UKWAS. Increased use of CCF, under planting and minimal ground preparation
	Dry vegetation during summer as well as spring	Wildfire will be a significant hazard, particularly on heathland and other open habitat	3	3	1	7	S	H	CCAP. Wildfire groups and FR work. Planning for the unexpected Operational Guidance Booklet (OGB17)
	Society will increasingly be using the forest for recreation	CCF will be welcomed, and recreational users will seek more shade	2	2	1	5	M	L	CCAP
	More sunshine	Over-exposure to the sun for staff and visitors	3	2	2	7	M	L	Annual health awareness booklet. Personal Protection Equipment and sun block
Warmer wetter winters	Soils may become water-logged more frequently	Anaerobic conditions may be detrimental to tree health. Crops may become less stable	1	2	1	4	L	L	CCAP, UKFS and UKWAS. Diversify species, age, and silvicultural systems
More frequent and severe extreme events	Storms will blow and snap trees	Trees will be harvested before they reach economic maturity; pest and disease outbreaks	2	2	1	5	L	M	CCAP, UKFS and UKWAS. Diversify for species, age, and silvicultural system. Forest closure plans
		Forests made unsafe for people	2	3	1	5	L	H	'Planning for the unexpected' OGB implementation. Forest closure procedures
	Erosion and landslips	Badly aligned drainage will erode, while unstable slopes may collapse	2	2	1	5	L	M	CCAP, UKFS and UKWAS
	Storms and flooding	Forest hard infrastructure may fail, leading to erosion	2	2	2	6	M	H	CCAP, UKFS and UKWAS
		Health and safety hazard to staff and 3 rd parties	2	3	2	7	M	H	'Planning for the unexpected' OGB implementation. Forest closure procedures

Arboreta									
Warmer, wetter winters; hotter drier summers; more frequent and severe extreme events	Extremes of soil moisture and temperature, and mechanical pressure from the wind	Trees will experience conditions to which many species are not adapted. Some will not prove resilient. This will be more severe at the National Pinetum	3	3	3	9	M	M	Arboreta has a Long Term Planning Group and an Advisory Committee. National tree collections initiative. Amend accessions policy
		Globally, species currently not considered endangered will become endangered	3	1	2	6	M	L	IUCN conifer specialist group. Ex-situ conservation programmes. Amend accessions policy.
Warmer, wetter winters and hotter, drier summers	Longer growing season	Increased risk of damage from unseasonal frosts. Increased insect and disease attacks. Increased mammalian winter survival and associated damage	3	2	2	7	M	L	CCAP. Amend accessions policy. Biosecurity protocol. Wildlife management plan. UKFS and UKWAS
	Longer growing season ²	The Arboreta will be able to grow a wider range of more southerly species while using Scotland as a refuge for species under threat within the collections	3	2	3	8	M	L	CCAP. Accessions and successions policy. Partnership within FCTC, IUCN, ICCP Kwando BGI
Hotter, drier summers	Moisture deficit, which will be more severe to the east and south	Establishment of trees will become increasingly difficult. Trees that are not drought tolerant will struggle in the east and south. Insect populations will take advantage of poor tree health	3	2	2	7	M	L	CCAP. Work with Botanical Gardens Society to research, implement and promote good practice
	The shady Arboreta will be more attractive to visitors	The Arboreta will be able to promote the importance of trees to more people. Visitor income may increase	2	2	1	5	M	L	CCAP
	Dry vegetation during summer as well as in spring	Wildfire will be a significant hazard, particularly on heathland and other open habitat	3	2	2	7	M	L	CCAP. Sward management and raising public awareness
Warmer wetter winters	More frequent water-logging	Anaerobic conditions detrimental to tree health. Crops become less stable. More visitors could increase soil poaching	2	2	1	5	M	L	5 year management cycle. Accessions and successions policy. Visitor facility inspection regime

More frequent and severe extreme events	Storms will blow and snap trees	Storms may damage or kill trees of importance or cause damage to 'the landscapes' of the arboreta	2	3	2	7	M	L	Wind stability plans, 5 year management cycle and successions policy
		Risk of injury or death to visitors or financial loss through closures	2	3	2	7	M	L	Recreational inspections and storm closure procedures
Open habitats and other ecosystems									
Warmer, wetter winters; hotter, drier summers; more frequent and severe extreme events	Extremes of soil moisture and temperature, and mechanical pressure from the wind	These ecosystems will evolve and change with some species of flora and fauna adapting more successfully than others	3	3	2	8	M	L	CCAP. Forest Design Plans and biodiversity action plans provide linkages between sites. Partnership working. UKFS compliance
Warmer, wetter winters and hotter, drier summers	Longer growing season	The dynamics of wetlands and heaths may change. Woodland will move up the hill onto uplands	3	2	2	7	M	L	CCAP, UKFS and UKWAS. Design plans and biodiversity action plans linking sites. Partnership working
		Intervention to maintain habitats may prove unsustainable	2	3	2	7	M	M	Working with FR and NE, seek sustainable solutions
Hotter, drier summers	Moisture deficit	Forest fire could damage sites; drought impacts on flora and fauna. Wetlands may dry out and change in character	3	3	2	8	M	H	CCAP, UKFS and UKWAS. Wildfire groups
Warmer wetter winters	Soils may become water-logged more frequently	Anaerobic conditions may be detrimental to existing flora	2	2	2	6	M	L	CCAP, UKFS and UKWAS . Design plans and biodiversity action plans. Partnership working
		Where summer moisture deficit will not be a constraint, bog restoration will be more practicable	2	1	2	5	M	L	CCAP, UKFS and UKWAS
More frequent and severe extreme events	Floods, storms	Risk of erosion	2	3	2	7	M	H	CCAP, UKFS and UKWAS

Forest Soils and Water									
Warmer, wetter winters; hotter Drier, summers and more frequent and severe extreme events	Extremes of soil moisture and temperature, with fluctuations in levels of water bodies	Increased decomposition and release of CO ₂ and methane, from organic soils. Flora and fauna dependant on stable conditions will decline	2	3	2	7	M	H	CCAP, UKFS (Forests and Water and Forests and Soils Guidelines). No residue harvesting on organic soils. No stump harvesting other than for forest health
		Water supplies for society may be compromised. Flooding will be more frequent	2	3	2	7			CCAP, UKFS and UKWAS 'Planning for the unexpected' implementation
Hotter, drier summers	Severe soils moisture deficits	Trees may struggle to access adequate water while peat soils may degrade	3	3	1	7	M	H	CCAP, UKFS and UKWAS. Increased CCF, no residue harvesting on peat
	Rising water temperature and reduced low flows	Increased woodland planting in riparian zones will provide shade	3	2	3	8	L	L	CCAP, UKFS. Grant-aid (EWGS/HLS)
Warmer, wetter winters	Soils may become water-logged more frequently	Anaerobic conditions may lead to decline of flora and fauna. Crops may become less stable. Operations may increasingly damage soils	2	2	2	6	M	L	CCAP, UKFS UKWAS
		Positive role of forests in retaining water and alleviating flooding	2	2	2	6	M	L	CCAP, UKFS and UKWAS. Working with others in river basin management planning. Forest design planning
More frequent and severe extreme events	Floods, storms	Wind-blow and flooding may limit access to forests creating logistical challenges in emergencies	2	3	2	7	M	M	CCAP. 'Planning for the unexpected' OGB
	Rivers may breach their banks	Floods affecting society	3	2	2	7	M	H	CCAP. Work with others in river basin planning. Forest design planning
		The opportunity to retain water in forests and manage peak flows	3	2	2	7	M	H	CCAP. Working with others in river basin planning. Forest design planning

Forest Civil Engineering									
Warmer, wetter winters; hotter, drier summers; more frequent and severe extreme events	Design capacity for roads and tracks will be exceeded	Drainage via culverts and bridges will not cope with volume of water	2	3	2	7	M	M	CCAP. Plan to increase capacity by 30% from current standard. Monitoring via GIS assets database
	More water will pass through engineered drainage systems	Opportunity to manage and direct water flow	2	3	2	7	M	M	CCAP. Working with others in river basin management planning. Forest design planning
Warmer, wetter winters and hotter, drier summers	Longer growing season will allow increased vegetation growth on roads and in drains	Risk of woody growth in road corridors creating damp micro-climate, drains holding moisture and vegetation growing on the road; all creating a weaker road	2	2	1	5	M	L	Regular vegetation management
Hotter, drier summers	Dry roads and drainage systems	Wind and vehicle erosion to running surface, vegetation growth in ditches impeding run off	1	2	1	4	M	L	Control vehicle speed. Drains and road side vegetation management
Warmer wetter winters	Roads will be water-logged	Carrying strength of surfaces may fail with high moisture content	2	2	2	6	M	H	CCAP. Assess strength using ground penetrating radar. Re-define which routes can be used in winter
More frequent and severe extreme events	Reservoir capacity and stability compromised	Breaches, flooding erosion, interruptions to operations and safety risk to society and staff. Insufficient spillway capacity results in reduced reservoir freeboard - greater stresses on structure or potential overtopping	2	3	3	8	M	H	CCAP. Compliance with 'Flood and water management bill'. Monitoring via GIS assets database
	High velocity water movement and weakening of stability on slopes	Erosion and deposition of soils, and land slips. Interruptions to operations. Safety risk to society and staff	3	3	2	8			CCAP. Increase capacity of drainage by 30% from current standard. Establish vegetation on steep slopes and practice CCF

Nursery and Seed Supply									
Phenomena	Likely Impacts	Consequences	Risk Assessment						Adaptation Response
			Likelihood	Impact	Urgency to take action	Score 0 - 9	Proximity	Cost to Organisation	
Warmer, wetter winters; hotter, drier summers; more frequent and severe extreme events	Political uncertainty and trade restrictions, global disease issues	Inability to source seed from around the globe	2	2	3	7	S	L	Work more closely with the EU and CONFOR nursery group to secure a secure, sustainable seed supply resource
	Inability to source desired tree seed	Need to identify UK seed sources, create of orchards, and partnership working with EU	2	2	3	7	S	M	Work more closely with the EU and CONFOR nursery group to secure a secure, sustainable seed supply resource
	Urgent need from the industry for new species and southerly origin not being met	Industry will not create resilient woodlands	3	3	3	9	S	M	FC nurseries to source seed as requested to meet CCAP. Engage with private sector nurseries
	Foresters may be reticent to order trees if supply in doubt	Nurseries to anticipate species/origin requirements, hence starting supply chain and new business opportunity	3	3	3	9	S	M	Work more closely with the EU, and CONFOR nursery group to secure a sustainable seed supply resource
	Extremes of soil moisture and temperature, and mechanical pressure from the wind	Forest trees will experience stress conditions to which many species are not adapted. Some will not prove resilient	2	2	2	6	M	H	Nurseries to use seed of proven quality, from identified sources supporting tree breeding programmes such as BIHIP
Warmer, wetter winters and hotter, drier summers	Longer growing season	Longer period when crops can be damaged by insects, disease, weed competition and unseasonable frosts	2	3	2	7	M	H	Increased use of cell grown stock to optimise water use. Increased use of shade and mulching. Implementation of rigorous biosecurity measures

	Difficulty germinating and growing healthy stock	UK nurseries could develop innovative ways to produce stock; new business opportunity	2	3	2	7	M	M	Work with FR and CONFOR specialist nursery groups
Hotter, drier summers	Loss of soil moisture and intense heat	Need to irrigate or accept slower growth and higher mortality	2	3	2	7	M	H	Increased use of cell grown stock to optimise water use. Increased use of shade and mulching
Warmer, wetter winters	Water-logged soils	Unable to work machinery to prepare beds and harvest trees	2	2	2	6	M	M	Increased use of cell grown stock to optimise water use. Increased use of shade and mulching
More frequent and severe extreme weather events	Soil loss: surface run-off washing out beds and causing erosion	Loss of fertility / pollution	2	2	2	6	M	H	Compliance with UKFS

Grants, regulation and private sector engagement

Phenomena	Likely Impacts	Consequences	Risk Assessment						Adaptation Response
			Likelihood	Impact	Urgency to take action	Score 0 - 9	Proximity	Cost to Organisation	
Warmer, wetter winters; hotter, drier summers; more frequent and severe extreme events	Competition for land between food and forestry	Inability to achieve a step-change in woodland creation	2	3	3	8	S	H	Woodland Carbon Task Force to work with others to find balance and release land for planting
	Forests currently under-managed, and may not be resilient to climate change	Forest health will decline and carbon sequestration will not be optimised	2	3	3	8	S	H	Woodland Carbon Task Force and Woodfuel Implementation Plan
	Society recognises the value of woodland and its role in a low carbon economy	Well informed communications supported by an 'adaptive management programme' could facilitate a well balanced response to CC and an increase in planting and forest management	2	2	3	7	S	M	Woodland Carbon Task Force. Adaptive management communications strategy

Hotter, drier summers, Warmer, wetter winters	Woodland resilience is compromised: periods of drought/increased SMD/waterlogging affects establishment/ survival	Existing woodland may not be resilient to impacts of climate change	3	3	3	9	S	H	Ensure regulations take account of UKFS/FR good practice. Changes in G&R and focus on long term management plans. Communications strategy
	Private owners unsure of how to increase resilience of existing woodlands	Inappropriate advice given resulting in non-resilient woodlands	3	2	3	8	S	M	Develop a communications strategy for engaging with private sector
	Difficult establishment	Challenging conditions and uncertainties may discourage new planting	2	2	2	6	M	L	Ensure regulations take account of UKFS/FR good practice. Changes in G&R and focus on long term management plans. Communications strategy
	Private owners unsure of actions to make woodlands resilient	Private sector will look to PFE as an exemplar, sharing best practice	2	2	3	7	S	L	Develop a communications strategy for engaging with the private sector
	Current advice to, and regulation of, private sector on species choice may not address future risks	New woodland will not be resilient to impacts of climate change. Poor return on public funding through EWGS	2	3	3	8	M	L	Ensure regulations take account of UKFS/FR good practice. Changes in G&R and focus on long term management plans. Communications strategy
Hotter, drier summers	Increase in wildfires	Loss of life (including staff), property, and ecosystems	3	3	2	8	M	H	Engage with Fire Service, CLA, ConFor, FEE and FR to build on best wildfire practice. Financial assistance for long term planning
More frequent and severe extreme events	Damage to roads and other civil engineering infrastructure	Erosion, pollution, disruption to operations and recreation	2	2	2	6	M	H	Communication strategy to promote good practice to minimise damage. Forest road guidance being developed for private sector by FCE/G&R
More frequent and severe extreme events	Standing crops impacted by wind-throw	Cost of clearing timber is increased and glut enters market, reducing prices. Conditions created for disease outbreaks	2	2	2	6	M	M	Communications strategy and engagement with industry to develop contingency plan.
	Forest erosion - soil and debris loss	Pollution, increased flood risk, failure to meet UKFS	2	2	1	5	M	M	Communications strategy and engagement with EA river basin management

Corporate Business sustainability and Environmental Management									
Phenomena	Likely Impacts	Consequences	Likelihood	Impact	Urgency to take action	Score 0 - 9	Proximity	Cost to Organisation	Adaptation Response
Warmer, wetter winters; hotter, drier summers; more frequent and severe extreme events	Extremes of weather likely (heat waves and cold snaps)	Working conditions may become less comfortable; society increasingly demands that business reduces its carbon footprint	2	2	2	7	M	M	Business Sustainability Plan and 'Environmental Management System'. New build and major refurbishment to achieve BREEM excellence or equivalent standard
	People will be looking for solutions to address impacts of climate change	Opportunity to promote the role of trees in adaptation and the importance of sustainable living, using FC buildings as exemplars of best practice	3	2	2	7	M	M	CCAP. FEE interpretation and recreation plan and education programmes
Warmer, wetter winters and hotter, drier summers	Climate conducive to the survival of flora and fauna	Increased populations of insects, rats, mice, fungal decay and possibly infectious human disease	2	2	2	6	M	H	Business Sustainability Plan and 'Environmental Management System'. New build and major refurbishment to achieve BREEM excellence or equivalent standard
Hotter, drier summers	Higher temperatures; may lead to reduced humidity and an increase in pollen and dust levels	Excessive heat could make the work environment less comfortable. Increased risk of pollen allergies. Water as a resource will be limited	3	2	2	7	M	H	Good building design to cover natural ventilation, air quality, glare control and water efficiency
	Hot sunny days with less cloud cover	Opportunity for solar energy	3	2	2	7	S	M	Consider opportunities for solar energy production
	More visitors will be going to FCE visitor centres	Opportunity to promote the role of trees in adaptation and the importance of sustainable living, using FC buildings as exemplars of best practice	2	2	2	6	S	M	Communications strategy

Warmer wetter winters	Temperatures on average will be warmer, but cold events will occur	Office temperatures will be more comfortable but cold spells will still occur	2	2	2	6	M	M	Consider aspects of thermal comfort. Ensure adequate insulation, and flexibility
	More winter rainfall	Opportunity to capture water for use in buildings	2	2	2	6	M	M	Investigate opportunities for water recycling from roofs
More frequent and severe extreme events	Storms and intense rain events	Drainage capacity may be compromised, with some properties potentially flooded while structural strength of buildings maybe challenged by storms	2	3	2	7	M	H	Ensure adequate storm drainage systems in place, and that plans for managing flood risk are tested. Design buildings to meet future requirements
	Increased flooding of river flood plains	Property could be flooded, paper and electronic records lost	3	2	3	8	S	M	Check properties that are in EA flood plan risk areas. Develop appropriate contingency plans
	Society will be seeking renewable energy opportunities	Opportunities for wind farms, hydroelectric and solar schemes	3	2	2	7	S	H	CCAP
	Intense summer rain events	Opportunity to capture water for use in buildings	3	2	2	7	S	M	Investigate opportunities for water recycling from roofs
Transport									
Warmer, wetter winters; hotter drier summers; more frequent and severe extreme events	Extremes of weather likely (heat waves and cold snaps). Society will demand that business reduces use of non-renewable energy and minimises its carbon footprint	Higher fuel costs for car travel	3	1	3	7	S	M	Move to low emissions vehicles (hybrid, small engine size). Driver training courses. Vehicle maintenance
		Staff will be expected to use public transport or IT for meetings	2	2	3	7	S	M	Investigate increased use of audio and video technology and ensure offices are equipped and staff are trained
		Transport of timber will be become increasingly expensive	3	3	2	8	M	H	Work with industry to explore improved logistics
		Reduced home to office commuting will become important to reduce emissions	2	2	2	6	M	M	Opportunities to encourage use of public transport. Promote remote-working through improved IT and culture change

ANNEX 6: Climate Change Action Plan for the Public Forest

Climate Change Action Plan

A strategy for the Forestry Commission estate in England

1st August 2011

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1 Introduction

This document summarises much of the work available on the subject of climate change. Links are provided within the document to this more detailed work which is held on the FC England [Climate Change Resource intranet site](#).

1.1 Background

Climate change is a matter of international importance and has become increasingly prominent in the Government's policy agenda.

The Climate Change Act, published in 2008, sets a challenging and legally binding target to reduce greenhouse gas emissions by 80% by 2050. The Act also introduced powers for Government to ask public sector organisations and 'statutory undertakers' to report on their assessment of the risks climate change poses to them, and the actions they are going to take in response. Forestry Commission England has been invited to report under the terms of these 'Reporting Powers'.

Our woodlands have been established over many years assuming a relatively stable climate. **This key assumption is unlikely to apply in the future.**

We need to ensure that our forests and associated habitats are resilient to climate change and have the capacity to adapt to its likely effects. We must implement adaptation strategies today, as the forests we manage will be maturing in a very different climate.

Over-arching objectives for forestry in England include addressing key climate change issues, both on the land we manage and for the benefit of others.

[The Read report](#) (Combating Climate Change 2009) states, "UK's forests and trees have the potential to play an important role in the nation's response to the challenge of the changing climate. Substantial responses from the UK forestry sector will contribute both to mitigation by abatement of green house emissions and to adaptation, so ensuring that the multiple benefits of sustainable forestry continue to be provided in the UK".

In November 2011 the new United Kingdom Forestry Standard (UKFS) Guideline on ['Forests and Climate Change'](#) was published alongside the six other Guidelines and the revised Standard. The UKFS Guideline states; "Guidance on adapting to climate change is inevitably provisional because of the uncertainty associated with climate change projections. **However, there are actions that can be taken now to mitigate the effects of climate change and adapt to its effects. It is these actions on which these guidelines are initially focussed.** The publication will be updated and improved as climate change science develops and our understanding of its effects on forests increases".

[Forestry Commission Research Note 201](#), 'Climate change: impacts and adaptation in England's woodlands', describes the likely changes in climate, its impacts on forests, and offers factors that forest managers should consider when planning to make their woodlands resilient to climate change. The Research Note explains how climate projections are made in the UK, and describes scenarios for a future climate based on the amount of green house gas emissions already as well as those possibly emitted into the future. These are described as high and low emissions.

2 The Climate Change Action Plan (CCAP)

The climate change action plan will ensure the woods managed by the Forestry Commission play their part in responding to the challenges of climate change. Our programme of work will contribute to both adaptation and mitigation, creating the best opportunity for our woodlands and trees to continue to deliver the multiple benefits of sustainable forestry. This plan is complementary to the Forestry Commission's ['Business Sustainability Plan'](#) that is intended to reduce the Forestry Commission's carbon footprint.

We will do this by:

- implementing the recommendations contained within the new UKFS. Our progress will be independently audited against the UK Woodland Assurance Standard (UKWAS), accredited by the Forest Stewardship Council (FSC) and the Programme for the Endorsement of Forest Certification (PEFC).
- managing our business in a sustainable way, within an Environmental Management System (EMS), consistently reducing our demands on non-renewable resources. Our progress against this will be independently audited against the ISO 14001

In summary 'sustainable work practices' should be a consideration of everything we do.

- We will adopt the principle of **anticipatory adaptation** as this offers the highest potential gains for forest resilience, and the benefits they provide.
- We will take an approach that is **'not risk averse'** (that is, we will take considered risks, rather than doing nothing, or act only on proven facts).
- We will identify who will participate in the activities, when this will happen, and how we will be able monitor and evaluate the rate of progress towards the outcome.
- The plan will be monitored annually and reviewed every 5 years.

This plan outlines actions to increase the resilience of our woodlands to the middle of the century under a range of greenhouse gas (GHG) emissions scenarios. If global emissions are not effectively reduced and a 'high emissions scenario' becomes a reality, a greater level of intervention will be required to start transforming our forests to ensure their long-term survival.

The measures outlined within this plan will increase the resilience of our woodlands to a changing climate and, through practising *adaptive management*, should put forest managers of the future in a position to react to such dramatic change.

2.1 The underlying assumptions

- England's woodlands and forests have developed within a relatively stable climate.
- An important consideration for native woodlands and their associated biodiversity is that the English Channel has been a barrier to natural migration for more than 8,500 years – however it is no barrier to climate change.
- England has warmed by around one degree Celsius since 1970.
- Under a medium emissions scenario, warming is predicted to increase by a further degree during the next decade and by up to four degrees by 2080.
- This projected rate of warming is equivalent to southern England moving south **at three miles per year!**
- Winters are predicted to become wetter and summers drier, with more frequent and severe periods of summer drought and intense rainfall events.
- England's woods and forests have not been subjected to such rapid change since the last ice-age.
- These changes are predicted to be more severe in the east and south.
- Due to the inability of the earth's climate system to respond to past emissions quickly, we are locked into a certain level of climate change over the coming decades.
- Global emissions are currently tracking close to some of the more extreme emissions scenarios that have been published.

2.2 What will be the impacts on the Forestry Commission Estate?

- The current range of broadleaf species, assuming that we use the right species and origin/provenance, will probably remain suitable for forestry across much of England. Towards the end of the century, south and east England are likely to prove the exception.
- Where water is not limiting, and pests and diseases present no threat, tree growth rates are predicted to increase as a result of longer growing seasons, increased warmth and the rising level of CO₂.
- Conifer crops, currently in the ground, if not affected by pests and diseases, are likely to reach maturity before there are any serious impacts.
- Forests are likely to be increasingly seen as a cool shady refuge for healthy exercise, but public access to the forests may be interrupted by closures due to storm damage, and roads and paths being washed away.
- The impacts of climate change are likely to be first seen with declining tree health in some species, increasingly difficult establishment, and limited mortality. However, as climate change progresses, some mature trees will die as a result of both direct and indirect impacts.

- Even where the composition of the tree canopy of woodlands remains unchanged, the composition, structure and character of the ground flora may change significantly.
- It is very likely that climate change will have serious impacts on drought sensitive tree species on shallow free-draining soils, particularly in southern and eastern England.
- The current range of timber producing tree species is very narrow and planting in monoculture is common. The risks associated with an over reliance on a few key species has been highlighted by serious outbreaks of Red Band Needle Blight (RBNB) in forest stands dominated by Corsican Pine and the more recently with *Phytophthora ramorum* infection of Japanese Larch.
- Pests and diseases of forest trees, both those present in the UK and those that may be introduced, probably represent a greater threat to woodlands than the direct effects of climate change.
- Extreme rainfall is likely to cause flooding and the current forest road drainage network may be inadequate.

3 Assessment of probable impacts

Table 1: Assessment of probable impacts

Species suitability, growth, and climatic impacts				
Factor	Response	Implication	Impact	Likelihood
Longer growing season	Earlier bud burst, later bud set, more lammas growth	Increased frost damage to sensitive species. Increased yield for Others	Medium	Medium
Warmer growing season increased CO ₂ concentration	Potential for increased growth rates	Increased productivity	Low	High
Reduced summer rainfall	Potential for reduced growth, increased drought stress, increased fire frequency	Loss of yield for sensitive species Forest loss	Medium	Medium rising to High in South East
Increased winter rainfall	Increased water logging and anaerobic conditions	Increased wind damage, increased soil erosion	Medium	Medium
Disturbance, management, and natural impacts				
Factor	Response	Impact	Risk	Likelihood
Longer growing season	More generations of insect pests per	Loss of yield. Deterioration in Forest Health	High	High
Milder winters, warmer growing season, increased CO ₂ concentration	Increase in woodland mammals, tree invertebrate pests and tree diseases, colonisation of alien invasive species	Loss of yield. Difficulties in early plant survival	Medium	Medium rising to High
Increased windiness predicted in some	Increased wind damage and associated dead wood	Loss of yield	Medium	Low rising to medium

possible scenarios	leading to, increased bark beetle damage and bluestain fungi			
Reduced summer rainfall	Increased frequency of fire and drought damage, and secondary pest/pathogen outbreaks. Increased risk of secondary infection from drought stress	Poor forest health and forest loss	High	Medium
Increased winter rainfall	Anaerobic stress; endemic windthrow due to water logging; slope failure Flooding	Poor forest health Forest infrastructure failure, erosion	Medium	Medium

4 The Vision for our woodlands

4.1 Woodland structure

The majority of our conifer woodlands are planned for harvesting within a clearfell silviculture system; this is an inevitable consequence of the inheritance of even aged monoculture forests created by new woodland planting since the Forestry Commission was formed. However, over the last 20 years, forest design planning has been breaking plantations into coupes to increase age and species diversity to reflect more modern policies on what forests are for. Most ancient broadleaved woodlands have been managed by more traditional self regeneration systems and are therefore less uniform.

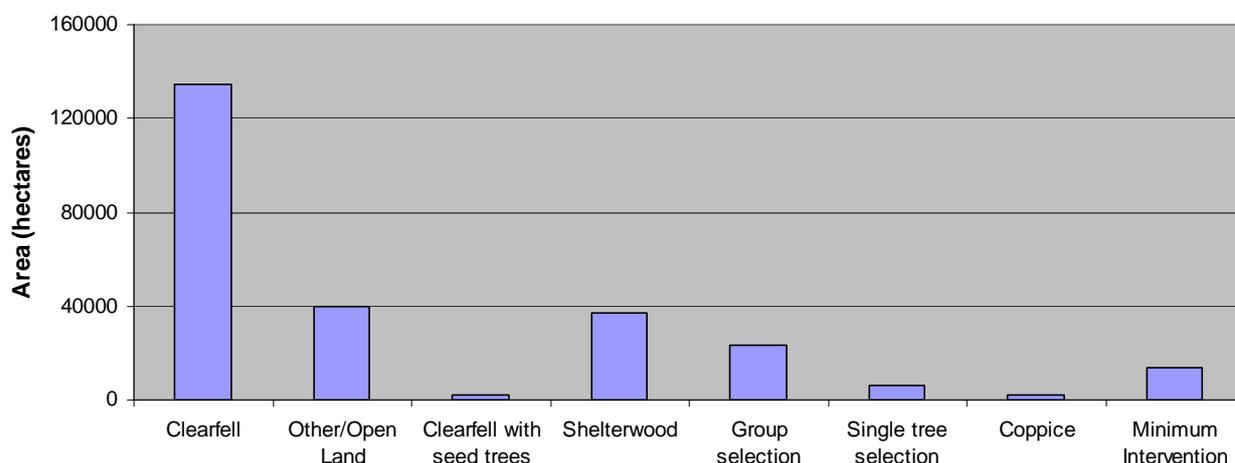


Figure 1 Silvicultural systems on the Public Forest Estate in England in 2010.

During the last decade there has been an ever-increasing interest in types of continuous cover silviculture – see Operational Guidance Booklet (OGB) No 7 – [Managing Continuous Cover Forests](#). These systems create diversity in stand and age structure, and often create opportunities to increase species diversity. The

microclimate within these systems can mitigate the worst extremes of wind, moisture deficit and temperature.

It is not envisaged that clear felling as a management system, especially for high wind risk sites and fast growing light demanding species, will be completely replaced by continuous cover, but such systems should be considered on appropriate sites.

33,000 ha of FC woodlands are classed as 'Plantation on Ancient Woodland Sites' (PAWS) and there are plans to restore these sites. The transformation of these areas to sites with a diverse range of native species, often of mixed ages, is likely to improve their resilience to climate change. See: [Managing ancient and native woodlands](#).

4.1.1 General outcomes by 2050

Our woodlands, and/or stands are likely to have a significantly greater diversity of;

- age structure,
- silvicultural management systems
- species and provenance

4.2 Broadleaved woodlands, 55,000 ha

Most of our broadleaved woodland comprises native species, native species out of their historical range, or species adopted from the near continent, such as sweet chestnut and sycamore. Most of these species occupy a wide climatic range across Europe.

Before the 1800s much of the broadleaved woodland of England had been managed under some form of coppice system with an important productive understory. Most of the timber was used as fuel, for example domestic cooking heating or industrial heat, or to fulfil local markets for small diameter material. This practice gradually lost favour as energy sources shifted to fossil fuels and markets for many rural products declined.

From the 18th century onwards there was a growing interest in managing woodlands as high forest and there has been a tendency to create monoculture. Oak has replaced mixed woodland and beech and sweet chestnut have been established and then managed as monocultures.

The planting site records are generally poor preventing a full evaluation of genetic diversity in existing woodlands. However, there is much evidence to show that trees from a range of origins were planted in the past and irregular seed years have caused nurseries to seek seed from distant sites, often from continental Europe.

4.2.1 Our broadleaved woodlands by 2050

Our broadleaved woodlands should be resilient in all regions other than the south and east, where some sites on free-draining soils in these areas are expected to suffer from summer drought. The potential for improved productivity from oak and beech in the north and west may offer opportunities for the greater use of broadleaves as a

productive crop. The climatic range of most species considered native reaches well south across Europe, so we can plan to use provenances that may be better adapted to the climate of the future.

The long length of rotations reduces the crops' ability to adapt naturally. It will be important to intervene frequently to promote adaptation through planting or to encourage natural regeneration.

- Those woods that are either ancient, native, or which have retained key features of ancient woodland, should be managed to conserve important biodiversity and heritage, while not unnecessarily compromising timber production.
- Unless there are overriding environmental or social constraints, broadleaved woodland should be managed to maximise the crops' value by balancing quality and timber yield, recognising the importance of keeping the native character of our ancient woodland.
- We should have increased our use of sweet chestnut and other broadleaved species from the near continent that can take advantage of the changing climate.
- Young woodlands and regenerated woodlands will contain mixed provenance, including some local and others up to five degrees south; planting material will be sourced from improved stands, where available.
- Opportunities will be taken to diversify the species mix within woodlands; this will include the planting of native species outside their natural range in the north and west.
- We will be planting some broadleaved species new to forestry in England, particularly in the south and east.
- The character of the English landscape will be retained through our proactive, anticipatory approach to adaptation that will give us the best opportunity to establish healthy woodlands.
- There should be an increase in harvested timber volume.
- Coppice and coppice with standards should be practised more extensively as silvicultural systems for managing existing woodlands.
- In areas where abiotic and biotic factors limit the ability to grow quality broadleaves (such as East Anglia), short rotation forestry is likely to be widespread.
- Forest design plans should target the location of 'biomass plantations' close to 'bio-energy' plants to minimise haulage distances and to meet demand.
- Forests will probably be regarded by society as a cool refuge for summer recreation.

4.3 Conifer woodlands 201,000ha

These woodlands are dominated by only five species, Sitka spruce (SS), Corsican pine (CP), Scots pine (SP), Larch (L) and Douglas fir (DF), as shown in Figure 2. 77% of the northern plantations are dominated by SS, while 74% of East Anglia's plantations are planted with only CP. In both cases these species were chosen because of their

high productivity and timber quality, relative to other species that could have been grown on the same site.

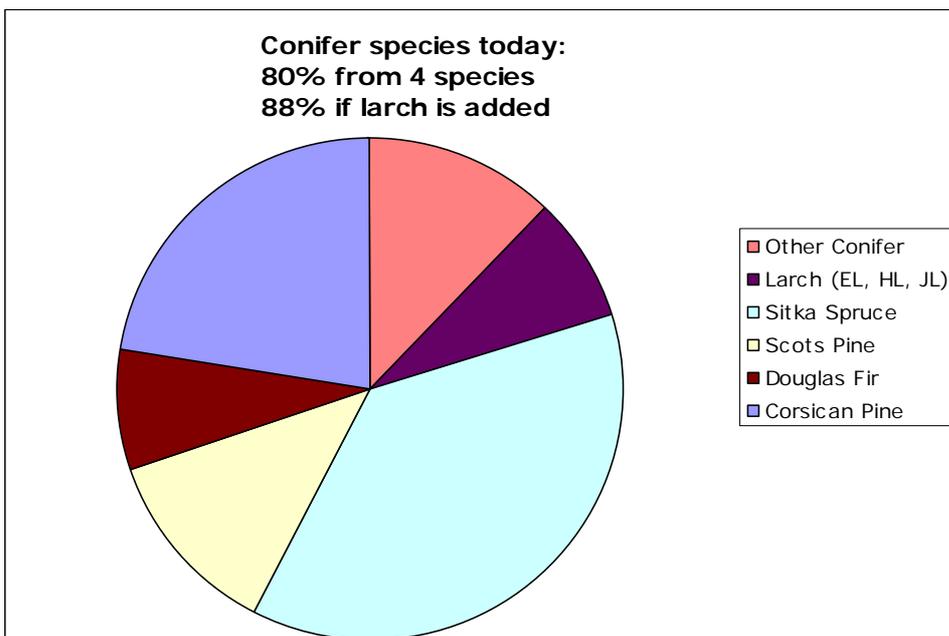
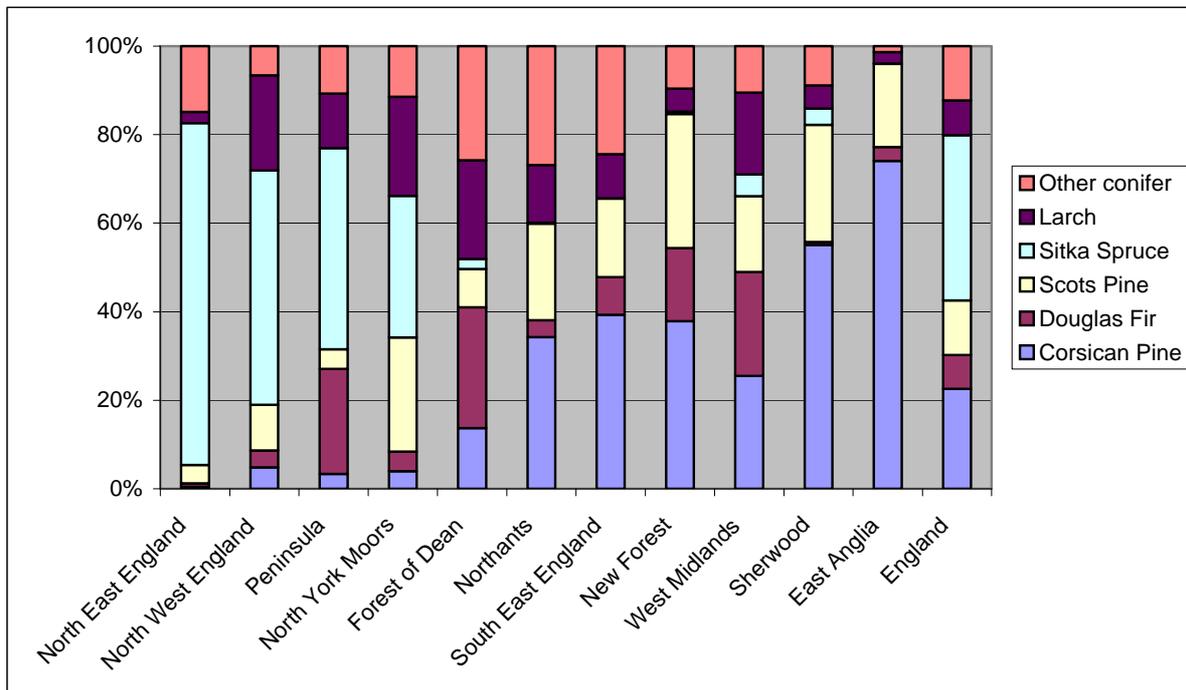


Figure 2 Breakdown of conifer species across the Public Forest Estate in England by Forest District (top) and nationally (bottom).

Monoculture is potentially a high-risk strategy. The speed which Red Band Needle Blight (RBNB), a fungal pathogen of CP and other pines, spread is attributed to the fact these species are mainly grown in monoculture.

A closer examination of the minor species found within forests, species trials and arboreta, shows us that we can grow a much wider range of species with good timber

properties. Furthermore, only a small proportion of the species available, globally, have been tested in UK conditions.

Not only do the coniferous plantations of England have limited species diversity, their genetic diversity is limited to a relatively narrow range of origins. All tree breeding and seed collection has been undertaken in the context of the climate of the mid 20th century – see OGB 31 – [Seed Sources](#).

4.3.1 Our conifer woodlands in 2050

The most serious impacts on forest health will be in drought years, particularly in the south and east. Some conifer species will find the increasing moisture deficit a limiting constraint, and by 2050, SS in eastern areas will on many sites become considered unsuitable as a productive crop.

Much of the rest of the country is likely to have a climate similar to that currently experienced across north-west France and southern England. Most species that are commonly used for forestry in England are either native across this geographic range or have been planted within this geographic range as successful timber crops.

- Pre-2011 conifer plantations should be managed to optimise carbon sequestration, within the chosen silvicultural system unless there is overriding economic, environmental or social constraints.
- Where considered appropriate, there will be an increase in the area managed using Low Impact Silvicultural Systems.
- In lowland England, only about 10% of the woodland managed within a clearfell system will have been established prior to the implementation of this plan. In upland forests a figure closer to 20% will be likely.
- Restocking should be correcting poor practices of the past, for example drainage that was carried out prior to publication of the *Forests and Water Guidelines*.
- Where existing species are replicated at restocking, many should be of more southerly origin (the timing of this change will be dependant on specific site conditions, such as frost-risk).
- Where site conditions permit, conifer plantations established after 2011 should have a greater diversity of species. Where necessary, some loss of yield will be acceptable.
- Some stands planted after 2011 should include species that have not previously been planted as timber crops in England.
- Forests and/or individual stands should have a greater diversity of origin within each species.
- Forests should be more diverse, through increased diversification of age structures and silvicultural systems.
- Some forests will be more productive, requiring management over shorter rotations to maintain stability (this may, in turn, help further diversification).
- Forest design and operational plans should be revised at renewal stage to mitigate against increased fire risk.

- Appropriate biosecurity should be as embedded in practice as health and safety is today.
- Opportunities should be taken to diversify species and stand structure after storm events or high mortality in pest/disease outbreaks.
- Forests will probably be regarded by society as a cool refuge for summer recreation.

4.4 Arboreta

The importance and relevance of the [Arboreta](#) has never been greater than today. How the tree species within the collections behave in a changing climate will provide critical information to all involved with trees. There are species within the collection that have not been considered for use more widely to date. Practitioners are encouraged to take the time to visit the collections and consider using new species for forestry use.

However, the collections are of world importance as heritage landscapes. Climate change will have a negative impact on the health and vigour of some species that play a critical role in creating this attractive landscape. These threats are true for much of the designed landscapes that are characteristic of the English countryside. Work within the Arboreta will endeavour to ensure these landscapes stay resilient.

4.4.1 Outcomes by 2050

- The collections should have adapted their picturesque landscape, using new species where required
- Species from warmer climates should be growing as possible future candidates for wider use by society
- The Arboreta should continue to be recognised as a repository of tree expertise

4.5 Open habitats + other ecosystems 57,000 ha

Our woodlands and forests are a dynamic matrix of woodland, open space and other habitats. It is by maintaining these man-made and natural ecosystems that we can make our greatest contribution to conserving and enhancing biodiversity.

These will be managed in accordance with our [‘Open habitat Strategy’](#).

4.5.1 Intended outcomes by 2050

- Where feasible, we should have restored raised bogs and removed adjacent areas of forest that adversely affect their hydrology.
- All priority habitats should be managed within a framework which ensures they continue to provide ecosystem services in a changing climate.

- Forest design planning should be making the most of our ability to improve ecological connections across the landscape.
- Where appropriate our planners will be increasingly working with adjoining landowners and others to make sure our woodlands play their role in creating landscapes suitable for wildlife conservation.

4.6 Forest soils and water

The Forestry Commission Estate has been managed to UKFS and its *Forests and Water* and *Forests and Soil Guidelines* for more than a decade and the requirements are embedded in forest practice. Measures to protect soils and waters are implemented through Operational Site Assessments (Ops 1's/OSA), contracts, constraint maps and detailed Practice Guidance is available.

Harvesting companies are now seeking to harvest branchwood. On sites where guidance shows us that this is sustainable, we will consider [harvesting branchwood](#).

We do not allow stumps to be harvested for biomass to protect soil carbon stocks, soil structure and archaeological remains. Stumps removed for reasons such as forest health will be considered for biomass.

4.6.1 Intended outcomes by 2050

- We should continue to protect and enhance the carbon stored within the forest ecosystem.
- Forest design planners should be working with the Environment Agency and other bodies to improve water management and alleviate flooding from the predicted increase in extreme weather events.

4.7 Forestry Civil Engineering

FCE have designed culvert drainage for a minimum 50-year rainstorm. Recent evidence suggests that this may not be enough for the current and future climates.

Recent developments in 'Ground Penetrating Radar', have given engineers the ability to assess existing road structure to work out accurately where they need to strengthen it. This offers significant savings by targeting repairs rather than the current overall treatments.

Recent developments have seen the introduction of low ground pressure systems to lorries to reduce road pressure. The use of these systems, offer the potential to significantly reduce road wear.

Intended outcomes by 2050

- We should have increased waterway capacity of all culverts and/or bridges by at least 30% from our [current standard](#).

- We should increase the number of cross-culverts during maintenance to minimise the volume or speed of run-off and reduce scouring in roadside drains.
- We should continue to use the minimum stone practicable to maintain roads, minimising the carbon costs of road haulage.
- The use of technologies such as low ground pressure systems should be widespread

4.8 Business Sustainability and Environmental Management

The [Business Sustainability Programme \(BSP\)](#) is responsible for the environmental management of the Forestry Commission's corporate business, which includes building construction and utilisation, corporate management activities such as waste management, water and energy use, transport, procurement, and human resources.

Government departments are required to adopt a credible [Environmental Management System \(EMS\)](#). An EMS is a framework through which an organisation's environmental performance can be monitored, improved and controlled.

During the plan period we will consider the implications of applying the EMS to **all** our forest operations. Operational Guidance [Booklet 43 –Business Sustainability](#) is the Action Plan for implementing and maintaining the EMS.

Our [Environmental Policy Statement](#) sets out a commitment to 'prepare, promote and instigate a Sustainable Development Action Plan for the Forestry Commission'.

The Environmental Policy Statement states that EMS will be implemented "in all parts of our business". The current programme applies "mainly to our offices, administrative and support functions". The intention is to widen the work areas to improve the sustainability of our field infrastructure and operational activities.

The Forestry Commission is working towards [ISO14001](#) accreditation, an internationally recognised Standard that addresses environmental issues.

The Forestry Commission Estate will continue to be managed and operated to the UK **Woodland Assurance Standard (UKWAS)**. To complement this, our new **Environmental Management System (EMS) and the ISO 14001 standard** will apply to our offices, administrative and support functions, thus making sure that we sustainably manage environmental impacts across all aspects of our business

Together these programmes will ensure that we are continually reducing the negative impacts to the environment of our business, while finding and implementing positive contributions to a low-carbon economy.

5 Monitoring our progress

The following tables are the actions required within our Climate Change Action Plan during the period 2011 to 2016, with progress being reported annually.

Climate Change Action Plan, monitoring our progress.

Key measures: to be reported on annually

Districts

Adaptive forest management

Concise report describing 'process activity' within the FD e.g. staff days in participation with CCF groups etc (List event and man days)

Diversification of species

Number of species ordered in COGNOS

Biosecurity

Record of incidents reported to FR pathology
Area under plant health notices

National office

Collate the above

Every 5 years:

Full report against CCAP

Climate Change Action Plan

Outcome	Activity – we will	Who	When	Measure of direction of travel
Our forest are kept resilient and we manage our emissions.	Review our activity and progress in implementing the CCAP and BSP	FD	March BMR	Annual FD report
Managing our woodlands sustainably	Manage our woodlands to a minimum standard accredited under independent audit to UKWAS. In doing so we will implement the UKFS guideline on climate change.	All	Ongoing	UKWAS audit (UKWAS). FSC PEFC
That this plan is implemented	Implement an “adaptive forest management” process.	FEE FD FR FS	Ongoing	CCAP year 5 review Annual district and FEE report
FEE is an exemplar of best practice in adapting woodlands in the changing climate	Set up, then promote, field scale case studies of best practice, as part of “adaptive forest management”	FEE FR	Ongoing	CCAP year 5 review
Species and genetic diversity	Identify species/provenance at short-term risk to CC.	FR	2011	Report to FEE.
	Produce and implement guidance on species selection , use of mixtures and origin . We will use more species in planting schemes, creating diversity at stand level.	FEE FR	2011	Intranet.
		FD	Ongoing	Annual district and FEE report CCAP 5 year review
	Find seed stands for minor species across southern England.	FEE PSSB FR	Ongoing	CCAP year 5 review Annual district and FEE report

Climate Change Action Plan

Outcome	Activity – we will	Who	When	Measure of direction of travel
Diversity in stand management	Identify stand types at immediate risk to CC.	FR	2013	CCAP year 5 review.
	Review and consolidate current CCF, LISS and coppice intentions within FDPs, looking for sustainable increases in CCF, LISS and coppice.	FD	Ongoing	CCAP year 5 review
	Widen membership and awareness of the CCF group .	FEE FD	Ongoing	CCAP year 5 review Annual district and FEE report
Resilience to pests and disease	Produce and implement biosecurity guidelines, and deliver forest health days to regions	FR FEE	2011/12	UKWAS audit. Publication CCAP. Annual district and FEE report
Resilience to fire	Review forest design plans to plan for future fire mitigation.	FD	Ongoing	UKWAS audit. Number plans review to CC
Our woodlands working with others to create landscape permeability	Seek to work in partnership with others, to ensure FDPs are linked at landscape level.	FD	Ongoing	UKWAS audit.
We are contributing to sustainable water management, and reducing the use of carbon to build and maintain our roads	Implement the UKFS, in particular Forests and soils, and water guidelines	FD	Ongoing	UKWAS audit.
	Review the capacity of the forest infrastructure to cope with increased precipitation	FCE	Ongoing	UKWAS audit.
	Review our management of reservoirs to ensure compliance with ' Flood and Water Management bill .'	FCE	Ongoing	UKWAS audit.
	Work with others to explore the opportunities our forests offer to help with water management.	FD	Ongoing	CCAP year 5 review

Climate Change Action Plan

Outcome	Activity – we will	Who	When	Measure of direction of travel
	Use ground penetrating radar technologies to reduce the amount of aggregates used in forest roads.	FCE	Ongoing	CCAP year 5 review
	Adopt, where practicable, new technologies to reduce the impact of haulage on our roads, such as central tyre inflation systems.	FCE HMO	Ongoing	CCAP year 5 review

FC Forestry Commission (Edinburgh)

FR Forest Research

FEE Forest Enterprise England (National Office)

FD Forest District

FCE Forest Civil Engineering

HMO Harvesting Marketing Officer

L+D Learning and Development

PSSB Plant Seed Supply Branch

BSP Business Sustainability Programme

EMS Environmental Management Statement

CCAP Climate Change Action Plan

CC Climate Change

GHG Green House Gases

UKFS United Kingdom Forestry Standard

UKWAS United Kingdom Woodland Assurance Scheme

FSC Forest Stewardship Council

PEFC Programme for the Endorsement of Forest Certification

LISS Low Impact Silvicultural Systems

CCF Continuous Cover Forestry

BMR Business Monitoring Report

6 Links to further information

[eConnect Climate Change England](#). This section contains a wide range of resources for FC England staff, from educational and interpretation materials, to tree information, and includes specific advice to our staff on species and diversity within species and origin/provenance.

[Forest Research – Climate Change England](#). This will be specific advice for England and will include species recommendations by climatic zones and suitability as climate change advances. There will be supplementary notes on species and advice on origin and provenance.

[Combating Climate Change - A Role For UK Forests: Main Report: An Assessment of The Potential of The UK's Trees and Woodlands to Mitigate and Adapt to Climate Change](#). You can download the report electronically as sections or complete.

[Forestry Commission - The UK Forestry Standard](#). The Standard and Guideline documents have recently been revised. You will find the Forests and Climate Change Guidelines here.

[Forestry Commission - climate change - forests and climate change](#). The FC's headline web area. Strategic statements, resources and links.

[Forestry Commission - Climate Change in England](#). Key messages, guidance and resources to support implementation of the UKFS Forests and Climate Change Guidelines in England.

[Forest Research - Climate change](#). General expert advice and guidance which headlines above country specific advice.

[Forestry Research Electronic Decision Support Tool](#) Various expert decision making tools. The 'Ecological Site Classification' (ESC), supports decisions on species selection within the changing climate. The EMIS tool helps decisions in ground preparation and brush harvesting to be made in the knowledge of their carbon impact.

[Forest Research - Continuous cover silviculture](#). Guidance and support tools in managing CCF or in conversion of stands to CCF.

[Forest Research - Woodfuel](#). A wide range of advice on the subject and links to the biomass centre and others.

[Forestry Commission - Woodfuel in England](#). Specific guidance for England.

[Forest Research - Tree improvement and forest genetics](#). Information on conifer breeding and links to others such as BIHIP.

[Forest Research - Slowing the Flow at Pickering](#). Case study of flood management near Pickering in Yorkshire.

Forest Research –Case studies of Climate Change Adaptation. Pages that are in development and will include case studies and a user blog.

[Operational Guidance Booklets](#). FC guidance on a range of operational issues.

[UK Climate Projections - Home](#). Official climate change predictions site for the UK.

[Defra, UK - The environment - climate change](#). Government views and policy.

[Natural England - Climate change](#). Their website.

[Environment Agency – adapting to climate change: the natural environment](#)

[Climate change | RFS](#). Royal Forestry Society climate change pages.

[Met Office: Climate change](#)

[BBC - Weather - Climate Change](#)

[Home - Department of Energy and Climate Change](#)