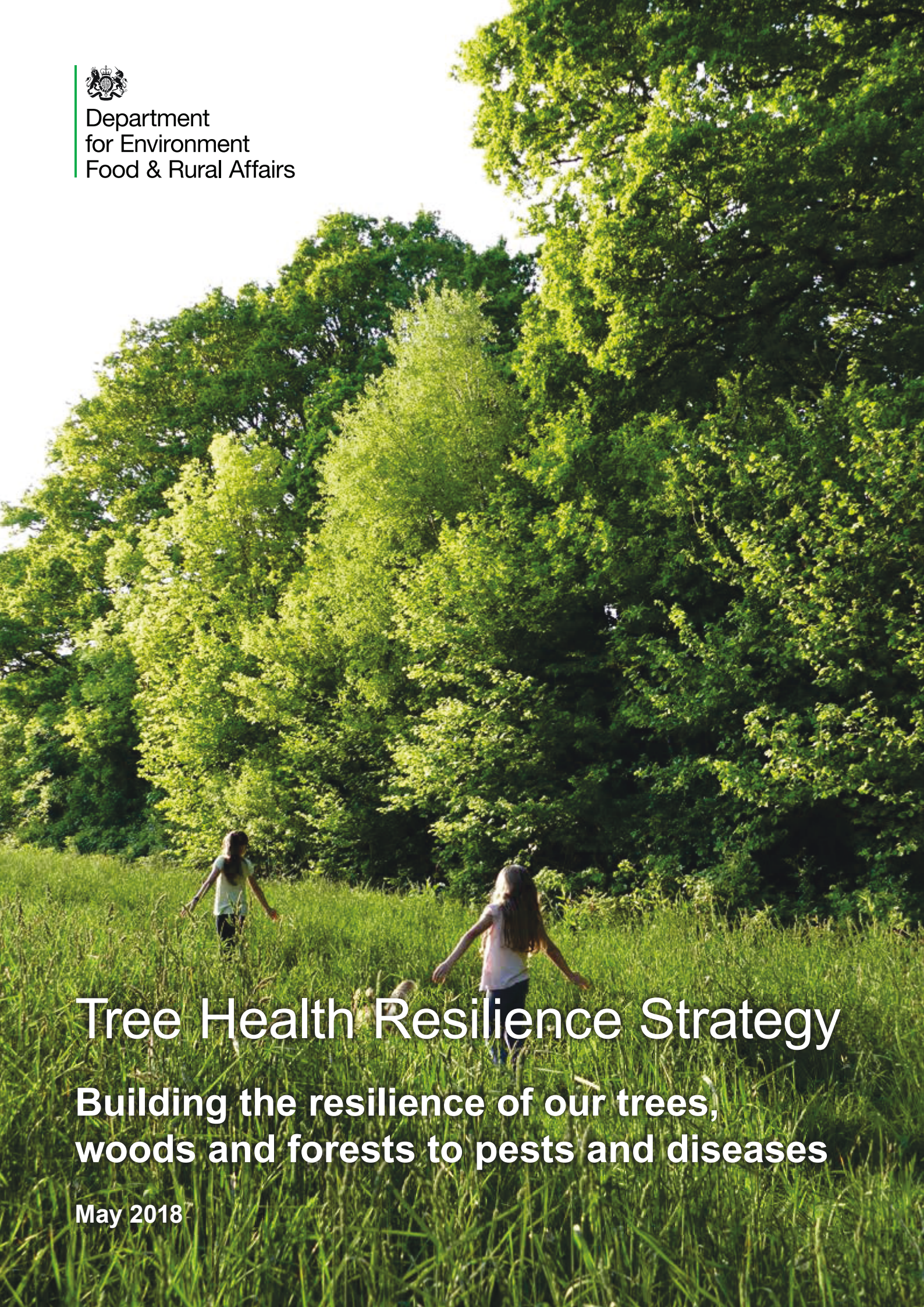

Department
for Environment
Food & Rural Affairs

Tree Health Resilience Strategy

Building the resilience of our trees, woods and forests to pests and diseases

May 2018

Cover Photograph – Edge of ancient woodland in Hampshire © Defra

OGL

This publication is available at www.gov.uk/government/publications. Any enquiries regarding this publication should be sent to us at: Defra, Area 5A, Nobel House, 17 Smith Square, London, SW1P 3JR. Email: planthealthprogramme@defra.gsi.gov.uk

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Ministerial foreword

The trees of this country are precious natural resources that sustain life. They beautify landscapes and provide habitats and food to support our wildlife. They are an essential part of every community and support our economy. For all these reasons and more, we are all passionate about the future of our trees.

Yet the threat to the health of our trees from pests and diseases is real and increasing. It is imperative that we do all we can to reduce these threats. It is this government's ambition to be the first generation to leave our environment in a better state than we found it, enhancing protections and building the resilience of our trees is key to realising this ambition.

The actions we have taken since the publication of the Plant Biosecurity Strategy in 2014 have earned us a global reputation for highest standards of biosecurity for plants and trees. We have established a risk-based approach, world leading science and research, enhanced protection, surveillance and inspection. Yet the threat level is constantly evolving and we must take further action to keep pace with changing threats. We must work collectively to minimise the risks and strengthen our approach. This includes heightening awareness of biosecurity, supporting sector led initiatives for assurance schemes and home grown trees, and exploring opportunities for UK wood production.

Leaving the European Union provides a unique opportunity to examine important areas of environmental policy. We will use this opportunity to strengthen and enhance biosecurity to confront the specific challenges facing the UK and support action which puts building the resilience of our trees firmly on the agenda.

This strategy, which has been developed with key stakeholders, sets out plans to reduce the risk of pest and disease threats occurring, and to strengthen the resilience of our trees to withstand threats. The focus is on working to improve the extent, condition, diversity and connectivity of our trees, woods and forests, and enhance protection to minimise the risk of new threats occurring.

While the challenges our trees are facing are great, for example through potential threats like *Xylella* and Emerald Ash Borer, by working collectively we can achieve the vision of this strategy to protect our trees for future generations. This spirit of collaboration is already evident through the wide number of people and organisations who have contributed their expertise to develop this strategy. I thank all the people who have contributed including, amongst others, the Plant Health Service, representatives of industry, forestry, landowners, environmental and conservation organisations and the Tree Health Policy Group.

Lord Gardiner

Parliamentary Under Secretary of State for Rural Affairs and Biosecurity

Executive summary

This tree health resilience strategy, which was developed in partnership with key stakeholders, sets out plans to protect England's tree population from pest and disease threats.

In England, the urban, peri-urban and rural landscape contains an abundance of trees, including hedgerow trees, infield trees, street trees, trees in parks and gardens, trees in orchards and woodlands, forestry plantations, and ancient and other culturally important trees and woodlands. All of these trees combined form our treescape.

Trees are vital economic, environmental and social assets. Trees contribute to our food supply, our rural economy, and are essential to the biodiversity of the country. They shape the landscape, provide timber, they are part of our heritage and support our health and wellbeing.

Trees are facing increasing threats. Globalisation of travel and trade and demands for a greater variety of plant species mean threats are ever-present, as we have access to trees and plants from new sources where different pest and disease threats may be present. Ash Dieback is a chronic fungal disease and is an example of the impact an introduced disease can have. Ash Dieback could lead to the loss of over 90% of one of our most common broadleaved trees. While we cannot eliminate all threats from occurring (e.g. airborne threats), we can strengthen protection, minimise impact and enhance the ability of our trees to resist pressures.

Protecting trees from pests and disease is essential in realising the government's ambition to leave the environment in a better state for the next generation. Outbreaks of disease are not just devastating to our natural landscapes and native species, they endanger our economy and wellbeing. The asset value of our trees is estimated (partially) at **£175bn**.

This strategy sets out how we will tackle the threat of pests and diseases by taking action to reduce the risk of the threat occurring and strengthening our trees, woods and forests to better withstand threats. The strategy focuses on delivering **three outcomes to build resilience** – (1) resistance, (2) response and recovery and, (3) adaptation.

Collectively we need to work together to build the resilience of our trees to help them resist, respond and recover from, and adapt to pests and diseases that threaten our trees, woods and forests. To achieve this, the strategy sets out priority areas for collective action summarised in a set of **behavioural goals**:

- We will work together to protect and value our trees as important natural capital
- We will put biosecurity at the heart of everything we do, from onsite activities to buying practices

- We will develop and apply the latest science and evidence on the full range of threats to tree health to inform our risk-based approach
- We will apply the principles of the environmental goals to the management of our trees, woods and forests
- We will build the knowledge and capability to apply the concepts of resilience at all levels

To improve the baseline diversity, health and condition of our trees, woods and forests, the strategy identifies **environmental goals** for tree resilience:

- **Extent** – a continued increase of trees, woods and forests
- **Connectivity** – enhancing the linear forest and matrix of trees within other habitat settings
- **Diversity** – enhancing the genetic diversity and increasing the structural diversity of our treescape
- **Condition** – encourage healthier trees and thriving woodlands and forests

This strategy sets out how we will collectively deliver the environmental and behavioural goals through a **National Action Plan** to build the resilience of our treescape and protect our trees and the important services they provide.

This strategy is intended to be used by policy makers, regulators, landowners, trade bodies, nursery owners, foresters, woodland owners, environmental charities, local authorities and other large scale planters of trees. The approach is applicable at the national, regional or local level to enable others to apply the broad concepts of resilience to the management of trees, woods and forests.

Chapter 1 – The Approach

1.1 Vision

The government's 25 Year Plan to Improve the Environment[1] sets out actions to meet the government's ambition to be the first generation to leave our environment in a better state than we found it. It calls for an approach to agriculture, forestry and land use that puts the environment first. Through the plan, the government recognises the need to enhance biosecurity and build the resilience of trees to withstand pressures, including a commitment to reach the detailed goals of this tree health resilience strategy.

Climate change, extreme weather events, pollution, land use change and invasive species can all have an impact on our environment and increase the susceptibility of our trees to pests and diseases. The 25 year environment plan provides the foundation for this tree health resilience strategy through the approach it sets out to manage a range of pressures facing the environment to protect, restore and enhance our natural capital. Set within this context, this tree health resilience strategy is focused on taking action against the pressure of pest and disease threats.

The vision for this strategy is also set within the context of several other publications, including Defra's Strategy to 2020[2] and its strategic objective to become **'a nation better protected against floods, animal and plant diseases and other hazards, with strong response and recovery capabilities.'**

Safeguarding plant health is a priority for government. Since the publication of the Plant Biosecurity Strategy for Great Britain[3] in 2014, our approach to plant health has been transformed. This is reflected in the work of the Plant Health Service[4] which acts to safeguard the biosecurity of plants whilst facilitating sustainable economic growth and protecting the natural environment. We take a risk-based approach to ensure that government intervention to protect plants and trees from pests and disease threats is targeted and proportionate to ensure the best available protection, by focussing resources on the most significant threats. The Plant Biosecurity Strategy included a vision to build a more resilient environment through species and provenance choice, design and appropriate management approaches – this tree health resilience strategy supports that vision. The Plant Biosecurity Strategy will be revised in 2020, and work set out within this tree health resilience strategy will directly inform the development of the 2020 Plant Biosecurity Strategy.

The **vision** for this tree health resilience strategy is:

To build the resilience of England's trees, woods and forests. To enhance the benefits trees provide, by mitigating and minimising the impact of pests and diseases and improving the capacity of our trees to adapt to changing pressures.

1 https://www.gov.uk/government/publications/25-year-environment-plan
2 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/501709/defra-strategy-160219.pdf
3 https://www.gov.uk/government/publications/plant-biosecurity-strategy-for-great-britain
4 Defra, the Forestry Commission, the Animal and Plant Health Agency and Forest Research.

1.2 Developing our approach

This strategy has been developed in partnership with the Plant Health Service, the forestry, horticultural and landscape sectors, landowner representative bodies, environmental organisations and scientists.

The scope of the strategy is at the national level, focusing on England's treescape. However the approach has been designed to inform the development of similar resilience strategies at the regional, local and site level, and for it to be effective and interactive, for example by allowing the transfer of data, ideas and information, between these levels. This strategy also complements the approaches in other UK administrations and reflects ongoing work between the UK government and the devolved administrations to establish where common approaches to plant health policy may be necessary after the UK leaves the European Union.

The UK Forestry Standard[5] defines resilience as:

"The ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organisation, and the capacity to adapt to stress and change."

How a system responds to a disturbance or shock depends on a combination of biotic and abiotic and social/management factors. The resilience of any system is therefore context specific and so the definition of resilience is often adapted to suit different purposes. For example, the Climate Change Accord: a call for resilient forests, woods and trees[6], published in 2015, defines resilience (in the context of climate change) as "Forests, woods and trees continue to thrive and adapt in the face of climate change impacts and associated environmental pressures, and thus deliver the multiple benefits they provide for people and wildlife, now and in the future". Rather than propose a new definition, this strategy focuses on defining the components required to build resilience at a national scale.

The strategy is therefore built around a series of decision steps to help apply the concepts of resilience to the management of trees, woods and forests.

- **Chapter 2:** Defines what we want to protect and why – the **features and values** of our treescape
- **Chapter 3:** Identifies the **threats** to our trees, woods and forests
- **Chapter 4:** Identifies the **attributes** of our trees, woods and forests that we want to enhance – setting out environmental goals for a healthy treescape

5 https://www.forestry.gov.uk/pdf/FCFC001.pdf/$FILE/FCFC001.pdf
6 https://www.forestry.gov.uk/pdf/Climatechangeaccord2015.pdf/$FILE/Climatechangeaccord2015.pdf

- **Chapter 5:** Defines the **resilience outcomes** we want to achieve – as described by a resilience circle
- **Chapter 6:** Identifies priority areas for focus and appropriate actions – setting out a **national level action plan**
- **Chapter 7:** Defines what success looks like by developing an **evaluation plan** and a suite of **indicators** to measure impact

The strategy considers the pressure of pest and disease threats on our trees, woods and forests and provides a holistic approach, applicable to a range of contexts, which identifies the outcomes we collectively need to deliver. A resilient system will be less prone to disease and will recover more quickly than a stressed one. This strategy is focused on doing what we can to strengthen our treescape to withstand pests and diseases, whilst also reducing the impacts of other pressures such as climate change, and limiting the entrance of new pests and diseases where possible. To achieve this the three outcomes which provide the focus for this resilience strategy are:

- **Resistance:** Reducing the threat or absorbing the impact of a risk with no substantial change or loss to the treescape
- **Response and Recovery:** Facilitating a speedy response when threats do occur, and allowing our existing trees to recover wherever possible after a pest or disease has been eradicated or contained
- **Adaptation:** Driving long term changes which will strengthen our natural resource and favour the survival of our trees and woods, and supporting landscapes in adapting to established pest and diseases

These outcomes are explored in detail in Chapter 5. Chapters throughout this strategy include behaviour goals – these goals, combined with the environmental goals for tree resilience set out in Chapter 4, are used to highlight priority areas where action is required to deliver against these outcomes.

1.3 Leadership and partnership

The government will continue to be at the forefront of domestic and international efforts to strengthen biosecurity and build resilience to protect and enhance trees, woods and forests for the future. We will ensure the strongest controls are in place against the highest risks, drive all to strengthen approaches and adopt higher standards, and seek opportunities to work together (for example, through scientific collaborations) within the UK and at an international level. The Defra Chief Plant Health Officer (CPHO) provides strategic and tactical leadership for managing risks and strengthening protection, and represents the whole of the UK internationally.

The Action Oak Initiative

Our native oak trees are robust and well adapted to a range of conditions, but are now facing many environmental, pest and disease pressures. England has more ancient oak trees than the rest of Europe combined. They support thousands of living organisms, but records show that the health and survival of oak trees are deteriorating.

We need to take action now to ensure the long-term survival of oak trees in the British landscape. The new public-private Action Oak partnership is committed to:

- working with owners and managers of oak trees and woodlands to help protect the trees from a range of threats
- funding research to improve our understanding of the threats to our oak trees and to inform best management practices
- using established professional and citizen science networks to record changes in the distribution, age and health of our oak trees to identify priority areas for action
- encouraging organisations to join the Action Oak Partnership and people to support Action Oak - www.actionoak.org

The CPHO will work closely with the Forestry Commission, the Animal and Plant Health Agency and the new Tree Champion announced in the 25 year environment plan, to build resilience and drive the protection of tree health across England, to deliver the vision of this strategy. Over the last year the plant health sector has also self-organised to establish a senior UK committee of representatives from across the trades and professions (nurseries, foresters, horticulture, landscapers, garden designers and retailers) that will be tasked to look at future biosecurity issues

and work with the CPHO and government to ensure preparedness for top threats such as *Xylella*.

It is essential that we continue to work in partnership to achieve greater resilience, both to deliver the outcomes set out in this strategy and also to monitor progress. Consistent with the 25 year environment plan, a collaborative approach between government, industry, landowners, forestry and arboricultural professions, the research community, tree and environmental charities, and the public is the best way to reduce the risks and ensure our tree population is more resilient to the threats from pests and disease.

- We will work collaboratively with key sectors through the **Tree Health Policy Group**[7]. The group's remit includes developing management approaches for emerging, nearly-established or established tree pests and diseases, as well as exploring how we can build resilience more widely. This group provides a critical knowledge exchange mechanism and works in collaboration to raise awareness.

- We will work in partnership on the planned implementation of the new EU **Plant Health and Official Controls Regulations**. Although the UK is preparing to leave the EU, the new Regulations will provide significant improvements in plant biosecurity and strengthen the measures to provide greater protection against the spread of harmful pests. We will keep this approach under close review.

- We will continue to build **expert national and international collaborations** with bodies such as the European and Mediterranean Plant Protection Organisation (EPPO), through participation in major research programmes (this includes the €7m Xylella EU research programme), jointly funded collaborations with the EUPHRESCO research network, or with other UK funders including Research Councils.

- We will develop **effective and innovative approaches** to how we can collectively work together to deliver the goals of this strategy. This includes supporting the innovative and ambitious public-private Action Oak initiative.

- We will continue to deliver a world leading **Plant Health Service** working pre-border (risk and horizon scanning, contingency planning, regulating trade), at the border (targeted import inspections) and inland (surveillance and response to incidents) to reduce risks. The Plant Health Service, including the Animal and Plant Health Agency and the Forestry Commission (Forest Services), will work in collaboration with key stakeholders to bring together the interests of those who manage forests, woods and trees. By using networks, including those of the Tree Council, Royal Botanical Gardens Kew, Forest Research and Forest Enterprise, to provide guidance and advice and ensure knowledge transfer between those engaged in caring for the nation's trees.

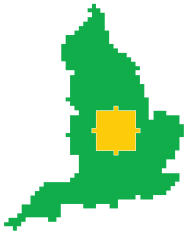
7 Membership includes the Animal and Plant Health Agency, the British Association of Landscape Industries, the Confederation of Forest Industries, the Country Land and Business Association, the Forestry Commission, the Horticultural Trades Association, the Institute of Chartered Foresters, the Landscape Institute, National Farmers Union, the National Trust, Natural England, the Royal Forestry Society, the Royal Horticultural Society, the Tree Council, Woodland Heritage and the Woodland Trust.

- Our public forests are one of our greatest national assets, and the Forestry Commission's work to enhance and expand woodlands across the country is integral to the government's environmental ambitions. After nearly a century of creating and managing Britain's forests, formal responsibility for Scotland's forests will transfer from the Forestry Commission to the Scottish government in April 2019. The Forestry Commission will remain in England, and will continue to protect, improve and expand woodlands in general and directly manage some of the country's best-known landscapes, from the Forest of Dean to Northumberland's Kielder Forest. The Forestry Commission will take on the delivery of the Plant Health (forestry) and Forest Reproductive Material functions on behalf of England, Scotland and Wales, including international surveillance for potential threats and inspections at the border, and continue to deliver these on a cross border basis to maximise preparedness and ensure that expert advice and knowledge remains available to each country. Forest Research will remain as an agency of the Forestry Commission, and new corporate governance arrangements for the agency will be developed during the year.

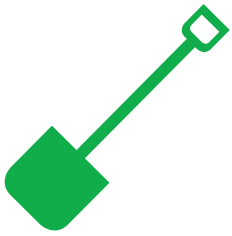
Chapter 2 – The case for action

2.1 Trees in our landscape

In England, the urban, peri-urban and rural landscape contains an abundance of trees, including hedgerow trees, infield trees, street trees, trees in parks and gardens, trees in orchards and woodlands, forestry plantations, and ancient and other culturally important trees and woodlands. All of these trees form our treescape. Some of the key features of our treescape are included in the infographic below.[8]

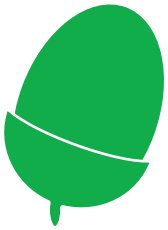


1.3m ha
of woodland in England, 10% of total land area (2017)

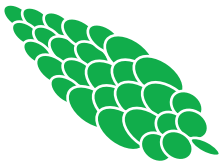


59%
of English woodlands is actively managed (2018)

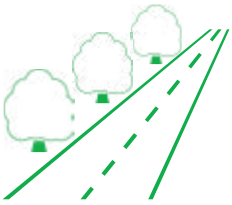
977m
broadleaf trees in English woodlands: 18 per person (2011)



oak
covers more of England than any other broadleaf species (2017)



Sitka
spruce covers more of England than any other conifer species (2017)



215k ha
of tree cover in urban locations outside of English woodlands (2017)

>100k
ancient and veteran trees in the UK (2015). There are more ancient oaks in the UK than the rest of Europe put together

London
can be classified as a forest according to the FAO definition of over 10% contiguous canopy cover (2015)

56.7m
cubic metres of wood used in the UK (2017)

12%
of wood used in the UK is home-grown (2017)

8 Top row (left to right): 1. Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf), 2. Forestry Commission Indicators (2018) (https://www.forestry.gov.uk/pdf/FCE_HEADLINE_PERFORMANCE_INDICATORS_31MAR18.pdf), 3. Forestry Commission, NFI preliminary estimates of quantities of broadleaved species in British woodlands, with special focus on ash and population data taken from the 2011 Census (https://www.forestry.gov.uk/pdf/NFI_Prelim_BL_Ash_Estimates.pdf), 4,5, Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf) Bottom row (left to right): 1. Tree cover outside woodland in Great Britain, Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/FR_Tree_cover_outside_woodland_in_GB_summary_report_2017.pdf), 2. Woodland Trust Ancient Tree Hunt (http://www.ancient-tree-hunt.org.uk/discoveries/data-reports) and Ancient oak research by Aljos Farjon (http://herbaria.plants.ox.ac.uk/bol/ancientoaksofengland), 3. Valuing London's Urban Forest: Results of the London i-Tree Eco Project (2015) (www.forestry.gov.uk/pdf/2890-Forest_Report_Pages.pdf), 4. Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/ch3_trade_fs2017.pdf), 5. Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/ch3_trade_fs2017.pdf) Calculated as (apparent consumption minus exports=retained timber) divided by (sum of imports and retained timber).

While the proportion of woodland in England (1.3 million hectares) is low compared with other European countries (10% compared with 38% average for the EU) the extent of woodland has increased by 73% since 1947, though with only a small increase in the past five years.[9] Broadleaved woodland remains more extensive (73%) than conifer woodland (27%).[10] Five species of broadleaf tree make up 59% of our broadleaved woodland and six species of conifer make up 81% of our conifer woodland in England.[11] Outside of our woodlands an estimated 4%[12] of England's land area is tree cover. Our urban landscape is composed of an estimated 89 million trees[13], with 8.4 million of these being in London.[14] There are 402,000km of 'managed' hedgerow in England and a further 145,000km of linear features such as relict hedges and lines of trees.[15] Whilst 59% of woodland in England is actively managed, we still import almost 88% of the wood[16] we use and the availability of domestic softwood is set to decline temporarily owing to a lack of conifer planting in the last 20 years.[17]

2.2 The importance of our trees, woods and forests

Trees are essential for life, and as some of the longest living organisms on earth, they give us a link between the past, present and future. For example, the Bowthorpe Oak in Bourne (Lincolnshire) is believed to be one of England's oldest oak trees with an estimated age of more than 1,000 years. Trees beautify and shape our landscapes, are part of our culture and heritage, providing us with health and wellbeing benefits. Some tree species can help absorb air pollution, they also sequester carbon, provide spaces for recreation, enhance landscapes, reduce sound, keep our environments cool, and reduce risks such as flooding. Trees provide timber and food and vital habitats for wildlife.

Protecting trees from pests and disease will be essential in realising our ambition to leave the environment in a better state for the next generation, due to the social, environmental and economic benefits they provide. By taking a natural capital approach, as set out in the 25 year environment plan, we can ensure that the value of the benefits that trees provide is incorporated into management and policy decisions.

Trees, woods and forests are dominant features of our landscapes, take years to grow, and are not quickly replaced if damaged or lost due to pests or disease. While many trees are planted or

9 Forestry Statistics 2017, Forestry Commission (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf), and Land cover statistics, Eurostat (ec.europa.eu/eurostat/statistics-explained/index.php/Land_cover_statisticshttp:/ec.europa.eu/eurostat/statistics-explained/index.php/Land_cover_statistics)
10 Forestry Statistics 2017, Forestry Commission. Data based on stocked woodland only. (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf)
11 Forestry Statistics 2017, Forestry Commission. (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf)
12 Tree cover outside woodland in Great Britain, Forestry Commission, 2017 (https://www.forestry.gov.uk/pdf/FR_Tree_cover_outside_woodland_in_GB_summary_report_2017.pdf/$FILE/FR_Tree_cover_outside_woodland_in_GB_summary_report_2017.pdf)
13 National Forest Inventory, 2011. Forestry Commission
14 Valuing London's Urban Forest, iTree/Forestry Commission, 2015. (https://www.forestry.gov.uk/london-itree)
15 Countryside Survey 2007 (www.countrysidesurvey.org.uk/content/england-results-2007)
16 Forestry Statistics, 2017. Forestry Commission (https://www.forestry.gov.uk/pdf/Ch3_Trade_FS2017.pdf/$FILE/Ch3_Trade_FS2017.pdf)
17 Forestry Statistics, 2017. Forestry Commission (https://www.forestry.gov.uk/pdf/Ch3_Trade_FS2017.pdf/$FILE/Ch3_Trade_FS2017.pdf)

regenerate naturally, in the majority of cases, individual trees are seldom linked to commercial activity now, despite the fact that in the recent past many woodlands existed for their utility (commercial) value. This often influences the prioritisation of tree health considerations. It is important that we also understand the wider social, cultural and environmental value of our trees, which is often not accounted for in traditional accounting methods.

Estimating the annual benefits of trees – Many services which trees, woods and forests provide are public goods (for example, carbon sequestration or wildlife habitats). The lack of incentive for individuals and landowners to pay for public goods can lead to their undersupply and overexploitation, which means that intervention is often required to maintain their provision. The government and others, therefore, have a role as stewards, intervening where necessary to ensure the value of these services is protected and available to all. Government intervention can include acting to protect public goods and services provided by trees through reducing the threat and impact from pests and diseases. Without intervention, there may be inadequate incentives for individuals and landowners to protect tree health. We benefit from the services provided by 3 million hectares of forests and woodlands in Great Britain (13% of land cover) and in addition the wide range of other trees that provide a further 0.75m hectares of cover (17% total land cover).[18]

Some of the value of these services can be expressed in monetary terms, either because they have a market value (forestry and primary wood processing) or through analytical techniques that allow an estimation of non-market value (forestry services provided including carbon sequestration, recreation, landscape and biodiversity). In total, the annual value of these services across the economic, environmental and social elements of our treescape that can explicitly be monetised, is **£4.9bn per year** (equivalent to just over 0.2% of national income). Figure 1 provides a summary of existing values.

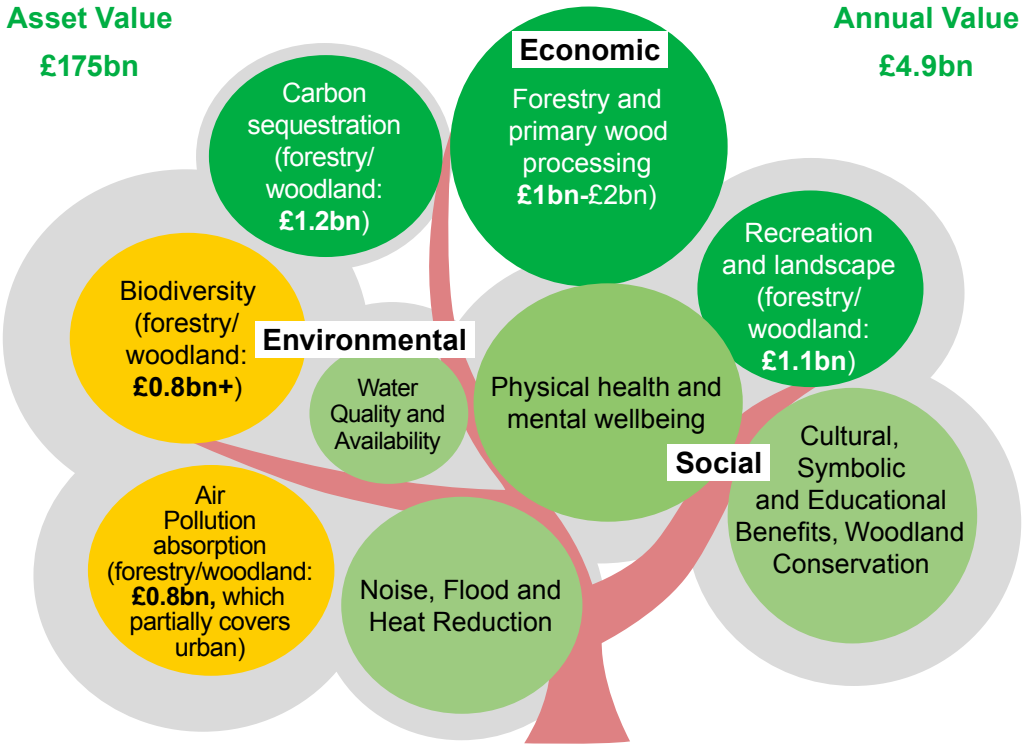
The asset value of our trees, woods and forests can then also be estimated partially at **£175bn** (by taking the estimates of annual value from Figure 1, and then projecting the expected flow of benefits over a 100 year period). See Annex A for further details.

Many factors (including location and species mix) should be considered when designing policies that aim to enhance the overall value of our trees, woods and forests. In some circumstances, poorly selected or positioned trees may cause a reduction in value, for example through damage caused by roots, or obstruction of views or air flows.[19]

18 The National Forest Inventory (https://www.forestry.gov.uk/pdf/FR_Tree_cover_outside_woodland_in_GB_summary_report_2017.pdf/$FILE/FR_Tree_cover_outside_woodland_in_GB_summary_report_2017.pdf) covers 3m hectares of forests and woodlands (where larger than 0.5 hectares). If we also include estimates of tree cover outside these forests and woodlands (including small woods, clusters/linear tree features, and lone trees/hedgerows in trees) across the rural and urban (including peri-urban) landscape, then this total rises by 0.75m hectares to 3.75m hectares (17% of land cover) – noting that the 160,000 hectares of hedgerows are not reflected in this total

19 The use of trees to improve air quality is not without negative impacts as some tree species are important sources of biogenic volatile organic compounds (BVOCs), notably isoprene. BVOCs can enhance the formation of pollutants including PM and ozone. However, BVOC emissions could be avoided by selecting low emitting species. Similarly, the choice of plant species which are known sources of aeroallergens should be avoided.

Figure 1: Summary of the Value that Our Forests and Trees Provide to Society[20]



Behavioural Goal 1: We will work together to protect and value our trees as important natural capital

20 Key to Figure 1: **Value extensively/partially monetised**; **Elements of value partly monetised**; **value understood in quantified or qualitative terms only**. Circle size indicates a judgement of the relative importance of each benefit. Estimates of uncertainty (for social and environmental values) is denoted by the outer grey circles – where the larger the uncertainty, the larger the outer circle. Annex A provides further background information about how the values described in figure 1 were calculated.

Chapter 3 – Threats to tree health

3.1 What causes a disease?

Three essential components are required for a pest or disease to occur and become damaging - a virulent pest or pathogen, a susceptible host and an environment that favours the spread and survival of the pest or pathogen. This is a dynamic system that in the case of long-lived hosts such as trees, is constantly shifting and changing.

Without the right environmental conditions (for example moist conditions, or a temperature range that favours spore production), pests and pathogens cannot cause significant harm even when susceptible hosts (tree species) are present. Conversely, the introduction of a pest or pathogen to a susceptible tree population, under favourable environmental conditions, will result in high disease potential. Stressed trees are more vulnerable to pest and disease than healthy trees, therefore managing other pressures alongside pests and diseases is vital.

When trees are infected with pests or diseases, management techniques to reduce the impacts and restore tree health often aim at disrupting this interaction, and focus on eliminating one of these three components. For example, breeding for resistance in the host species, applying pesticides or fungicides to hinder the pest or pathogen, or by employing management practices such as thinning, which affect environmental conditions, favouring the health and survival of the trees over the spread of the disease.

3.2 Increasing pest and disease pressure

The UK Plant Health Risk Register[21] tracks plant health risks and prioritises them for action. It currently contains approximately 1,000 pests and diseases, with around 5 new risks added to the register every month. Approximately 30% of the pests and pathogens listed on the register are recognised as being capable of attacking trees. Risks to tree health have increased in recent years for a number of reasons.

Globalisation – The increase in trade and travel has resulted in an escalation in the volume and diversity of plants and plant products entering the UK from sources across the world. These plant imports, estimated at around 22 million tonnes per year[22], can act as hosts or vectors, and are one of the primary ways in which new pests and diseases are introduced. Trees for the nursery trade (and UK planting activities across landscapes), and their wood in the form of timber, fuel, wooden products and packing, are imported from an increasing number and range of sources.

21 https://secure.fera.defra.gov.uk/phiw/riskRegister/
22 Estimated from HMRC data covering 2014-2016.

Figure 2: Trade in commodities of interest to plant health[23]

The Plant Health Service carries out targeted inspections of controlled and uncontrolled plant imports and wood imports, including wood packaging materials at ports and airports and risk-based inspections at nurseries and retail sites to detect any plant health issues at an early stage. Over the past five years the UK has made around 900 interceptions of harmful organisms from non-EU countries annually, consistently more than any other EU Member State (around 40% of the total for the EU)[24] and more than 5% of these species had not been previously recorded in the country. The high number of notifications by the UK may, in part, reflect differences in reporting along with differences in the volumes of trade and import routes. It is worth noting that not all the species intercepted would be damaging in the UK.

The Plant Health Service employs a range of methods to raise awareness of the risks of trade and travel, including biosecurity guidance, pest factsheets and alerts of new arrivals, articles, shows, events and social media. We also collaborate closely with stakeholder organisations such as the Horticultural Trades Association and the Royal Horticultural Society, who have their own initiatives to raise awareness of need for the safe sourcing of plant material. We have also been collaborating with industry stakeholders to develop and pilot a Plant Health Assurance Scheme which will drive improvements in biosecurity practices throughout the supply chain.

23 Estimated anual value based on a three year average (2013-2016) of UK trade in selected primary and regulated commodities which are of potential interest to plant health and biosecurity. Source: HMRC
24 EUROPHYT - Interceptions Annual Report 2016 (https://ec.europa.eu/food/plant/plant_health_biosecurity/europhyt/annual_reports_en)

Assurance Schemes and Standards

© Raoul Curtis-Machin/HTA

The threat of *Xylella* has become the number one industry concern, and after the 2015 Horticultural Trades Association (HTA) and Animal and Plant Health Agency (APHA) Biosecurity Conference 2015, a group of growers supplying the landscape trade decided to create the Plant Health Assurance Scheme to improve biosecurity practices.

The aim is to create a badged scheme which all plant buyers can specify, giving them confidence that the nurseries practice quality biosecurity management. It was initiated by the team at Boningale Nurseries, who adapted their existing ISO 9001 quality management system to share biosecurity responsibilities across the business, giving key people key accountabilities such as pest and disease identification and the justification for foreign buying decisions.

During 2017, the HTA led an industry/government partnership to test and develop the scheme so that it would work for every type and size of grower business. The industry representatives also included the National Farmers Union (NFU), Grown in Britain, and several growers. We learned a lot from this process. Some nurseries had impressive audit trails and records of their biosecurity measures in place, whereas others had very little written down. This didn't mean that they were not taking their biosecurity responsibilities seriously, but more likely that it was all kept in people's heads.

HTA drafted the first Plant Health Standard from these exploratory visits. This standard consists of non-prescriptive statements of best practice concerning Management, Plant Health Controls, Recognition and Training, and Site Housekeeping. These can be audited and the audit will be 'pass or fail' with recommendations for improvement. Constant improvement is the bedrock of the scheme, and some of the pilot nurseries have already improved their management as a result. Defra and industry are working together to look at ways to make assurance schemes a success.

Much of the raising of awareness to date has been directed at the horticultural trade or tree practioners, many of whom will be very familiar with the Forestry Commission's Keep It Clean campaign[25]. Raising awareness with the general public has been identified as an important future activity.

25 https://www.forestry.gov.uk/forestry/beeh-a6tek3

Don’t Risk It!

The European and Mediterranean Plant Protection Organisation (EPPO) has produced a series of posters with the slogan ‘Don’t Risk It’.

These are already in use in other EPPO member states and we will be using this format at the centre of our own campaign to make travellers aware of the risk of bringing plants home in 2018. We will continue to assess the risks associated with plant materials in passenger baggage, including the potential to introduce restrictions.

Airborne threats – There are also airborne threats, which themselves may be accelerated by global trade. For example, Ash Dieback which is believed to have spread to the UK by both trade and airborne spores. Emerald Ash Borer is currently spreading in the US and Russia by insect flight, but may be exacerbated by the movement of vehicles along major roads (i.e. it can be blown along, or hitch a ride). It may ultimately arrive in Western Europe by air, or by human movement.

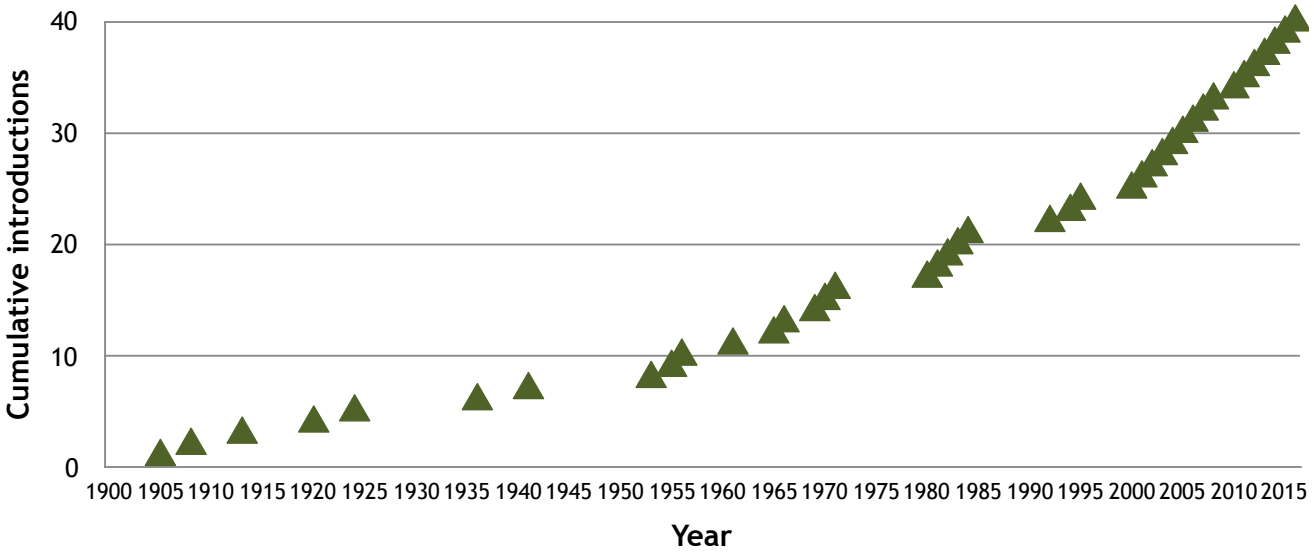
Evolution or cross-breeding of pests and pathogens – Pests and pathogens may also evolve or cross-breed, which has the potential to create something more virulent than the suite of organisms we may be familiar with.

Neglect – In the past our native woods generated a wide range of products essential to community living including fuel, timber for construction and transport, fencing materials, furniture and other household goods. Their necessity and function helped shape the landscapes we value today. An increasing lack of productive purpose, through the progressive substitution of wood products with steel, plastic, concrete and other products with high embodied carbon over the last century has fuelled the neglect of our woodlands. Many woods are now undermanaged or not managed, providing ideal environmental conditions for pest and diseases to establish undetected.

These factors have all contributed to a significant upward trend in pest introductions with major consequences in recent years (Figure 3). Some of these outbreaks, particularly if not detected early, can result in escalating management costs. Eradicating a small outbreak of Asian Longhorn Beetle, which was found in Kent in 2012, will have cost around £2 million once statutory surveillance is complete.[26]

26 Fielding et al (2016) (doi.org/10.1111/afe.12160), History and development of an isolated outbreak of Asian longhorn beetle Anoplophora glabripennis (Coleoptera: Cerambycidae) in southern England, Agricultural & Forest Entomology,

Figure 3: UK Tree Pest and Disease Introductions 1900 - 2015[27]



However, this is small compared to the cost of managing the same pest in the US, where it has become established and costs have already run into the hundreds of millions of US dollars.[28] The cost of managing and slowing the spread of *Phytophthora ramorum* in the UK (a disease that has not been eradicated) was £23 million between 2009 and 2014.

Behavioural goal 2: We will put biosecurity at the heart of everything we do, from onsite activities to buying practices

27 Forest Resilience in British Forests, Woods and Plantations - the ecological components. .Spencer, J. (2018). Quarterly Journal of Forestry 112(1), 53-61.

28 Estimated costs of $373 million, from the following Source, Haack et Al (2010) (doi.org/10.1146/annurev-en-to-112408-085427): Managing Invasive Populations of Asian longhorned beetle and citrus longhorned beetle: A World-wide Perspective, Annual Review of Entomology, Vol. 55: 521-546,

3.3 Other environmental pressures

Pests and diseases do not operate in isolation. Climate change, extreme weather events, pollution, land use change and invasive species can all have an impact on our environment and increase the susceptibility of our trees to pests and diseases. The government's 25 year environment plan, recognises these wider environment pressures and sets out government action to manage them.

Climate Change – In 2017, as part of the UK Climate Change Risk Assessment, the Adaptation Sub-Committee conducted an independent review of evidence.[29] Observed changes included an annual average UK land temperature that was 0.9 degrees celsius higher during the period 2005 to 2014 compared to 1961 to 1990; more winter rainfall fallen as heavy precipitation during the last 30 years in the north and west of the UK, and increases in winter run-off and high river flows. Milder winters, increased heavy rainfall events and flooding, may lead to the country becoming more suitable for the establishment of new pests and diseases or more susceptible to the impacts of existing pests and diseases. Our changing climate may alter the phenology or environmental suitability of some tree species. These changes could weaken or stress some trees and increase their susceptibility to both novel and native pest and disease attack. The government is committed to leading the international fight against climate change by continuing to cut greenhouse gas emissions and the use of fluorinated gases and implementing a sustainable and effective second National Adaptation Programme.

While the focus of this strategy is on resilience to pests and diseases, the broader concept of resilience requires that the actions we take future-proof our treescape, as far as is possible. Climate change adaptation strategies, such as assisted migration (the deliberate movement of tree species and populations to a new habitat), have become more prominent in recent years. In 2015, the European Forest Genetic Programme (EUFROGEN) published a paper on the use and transfer of forest reproductive material in Europe in the context of Climate Change[30]. Synthesising and adopting these guidelines, the Forestry Commission currently recommend a varied approach[31] depending on whether biodiversity or timber is the prime objective. The Forestry Climate Change Working Group[32] is a cross sector group which is producing a detailed climate change adaptation plan, and this group will support the delivering of this tree health resilience strategy in the forestry sector. The importance of increasing the genetic diversity of our trees, woods and forests is discussed further in Chapter 4.

29 The UK Climate Change Risk Assessment 2017 (https://www.theccc.org.uk/tackling-climate-change/preparing-for-climate-change/uk-climate-change-risk-assessment-2017/) Synthesis Evidence Report, Adaptation Sub-Committee of the Committee on Climate Change,

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

31 https://www.forestry.gov.uk/forestry/infd-8m7ej6

32 Members include Woodland Trust, CONFOR, CLA, Woodland Heritage, Forest Research, Forestry Commission England, Natural England, ICF, RFS, Sylva Foundation and, Defra.

Land Use – Population growth, economic development and agricultural practices all place a demand on our land. One consequence of changes in land use is that small, fragmented populations of trees are less able to regenerate, adapt and evolve. This government is committed to building more homes, but we are also seeking to embed a principle of net environmental gain from development and strengthen planning protection for ancient woodland through the revised National Planning Policy Framework.

Most of our land is used for agriculture. Leaving the EU provides a once-in-a-generation chance to change our approach to managing our land. The new approach will recognise good practices that bolster natural assets, including soil health, and provide a system of support for farmers and other land managers, that will have environmental enhancement at its heart and support landowners to grow more trees and create more woodlands, supply more home-grown timber, provide corridors for wildlife and restore habitats and landscapes.

Our plans include increasing woodland in England in line with our aspiration of 12% cover by 2060: this would involve planting 180,000 hectares of trees by the end of 2042, the creation of a new Northern Forest, to which government is contributing more than £5 million and appointing a national Tree Champion to support our approach. Planting more trees and managing existing woodlands provides not just habitats for wildlife, but will boost timber production and help reduce carbon dioxide levels and mitigate flood risk.

Air Pollution, Water Quality and Soil Health – We recognise that air pollution, poor soils and water contamination are all environmental drivers which effect a trees ability to grow and thrive. Improving our waters, ensuring healthier soils and cleansing the air of pollutants are among the goals of the 25 year environment plan. The government is committed to meeting legally binding targets to reduce emissions of five damaging air pollutants, ending the sale of new conventional petrol and diesel cars and vans by 2040 and maintaining continuous improvement in industrial emissions. The government will also ensure that by 2021, there is a reduction in abstraction of water from rivers and ground water, so that the proportion of water bodies with enough water to support environmental standards increases from 82% to 90% for surface water bodies and from 72% to 77% for ground water bodies. Lastly, the government will work with land managers to help develop soil health metrics for effective monitoring of soil health and work to reduce the amount of nitrogen-rich fertilisers.

Deer, Grey Squirrels and other mammals – Some mammal species (including mice, rabbits, feral wild boar, deer and grey squirrels) cause damage at every stage of tree growth due to browsing or bark stripping. Deer, grey squirrels and rabbits are a serious threat to trees, they prevent trees and woodlands establishing and realising their full potential.

Grey squirrels can cause major damage to our trees by stripping the bark which reduces timber quality, value and yield. If ringbarked the tree or branch will die. The damage caused by grey

squirrels can also cause wounds through which pests and diseases may gain entry. To address this, government and partners have signed the Squirrel Accord[33] which brings together 35 leading woodland, timber industry and conservation organisations in the UK. Through the Accord these organisations are developing a coordinated approach to securing the future of red squirrels and woodlands in the UK, and to managing the impacts of the introduced grey squirrel. It builds on existing national efforts to conserve red squirrels and woodlands.

All six deer species established in the UK have been increasing in number and range over the last forty years. Deer are more abundant and widespread now than at any time in the past 1,000 years. Deer have been identified as being a substantial problem for the establishment of trees and new woods and for the management and biodiversity interests of existing woods, particularly by reducing or preventing natural regeneration of trees. The issue of deer population is being addressed by the Deer Initiative[34], which is a broad partnership of statutory (including Forestry Commission and Natural England), voluntary and private sector interests dedicated to "ensuring the delivery of a sustainable wild deer population in England and Wales".

3.4 The importance of research and innovation

Science provides the foundation for our evidence-based approach to risk-management. It supports decision-making, the setting of rules and standards, development of tools to detect or eradicate pests and diseases, and innovation to solve problems. However, we do not yet have enough information to protect our trees effectively. We need more evidence to know how to respond to the problems they face. Recent research on a complex disease of native oak trees called Acute Oak Decline (AOD), has demonstrated the correlations between disease occurrence and a number of environmental factors such as water availability and nitrogen deposition. Imbalance of nutrient status has a number of negative effects that predispose trees to pest and disease.[35] We will continue to invest in research to understand the impact of environmental pressures on the susceptibility of our trees, woods and forests to pest and disease threats.

To implement our vision for greater resilience, we need access to robust evidence to provide the foundation of our decisions. Our interdisciplinary evidence base combines a long-term programme of strategic research with more applied, responsive research. We work collaboratively with the national and international research community, stakeholders and inspectors to identify and fund priority areas of research.

33 https://www.forestry.gov.uk/forestry/infd-8m7ej6
34 www.thedeerinitiative.co.uk/
35 Brown, N., Vanguelova, E., Parnell, S., Broadmeadow, S., Denman, S. (2018) Predisposition of forests to biotic disturbance: Predicting the distribution of Acute Oak Decline using environmental factors. (dx.doi.org/10.1016/j.foreco.2017.10.054) Forest Ecology & Management, 407, 145-154.

Tree Health Quarantine Facilities at Alice Holt

The Forestry Commission's Alice Holt research station in Surrey has approximately 90 staff working on the full range of forest research activity, including social scientists, silviculturalists, economists, entomologists, pathologists, disease diagnosticians, hydrologists, ecologists, climate change scientists, soil scientists and biometricians.

Facilities include growth chambers (used widely in Acute Oak Decline, Ash Dieback and Dothistroma work), seed laboratories and extraction facilities, soil and foliage chemical analysis laboratories and extraction facilities, a nationally important aboretum and important tree germplasm collections. Recent investment from Defra will fund on site improvements out to 2021, including lab refurbishments and the installation of new tree health quarantine facilities.

Between 2012 and 2019 government will have invested over £37m in tree health research covering the following areas:

Horizon Scanning & Risk Assessment - To prevent the introduction of new pests and diseases we need effective approaches to systematically examine information to identify potential threats. Our dedicated risk and horizon scanning team review, appraise and monitor threats using the UK Plant Health Risk Register. They assess biological characteristics of pests and pathogens, evaluate the effectiveness of intervention strategies and determine environmental and socio-economic impacts. As the number of threats to plant health is too large to address all evidence gaps, we use the risk register to prioritise evidence needs to make sure our actions are targeted and cost-effective.

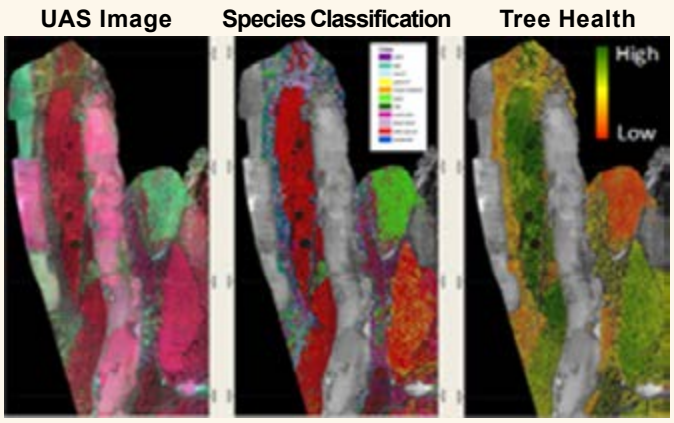
Preparedness - Evidence from horizon scanning and risk assessments allows us to prepare for the arrival of pests and diseases. We have a generic contingency plan and develop specific contingency plans to ensure a rapid and effective response in the event of pest or disease outbreaks. Where evidence gaps exist, they are addressed by interdisciplinary research programmes. We implement preparedness review processes to assess our response to serious threats. This ensures we are best able to respond and manage these threats if they arrive. We will continue to make use of extensive international networks to learn from other countries' experiences and study threats before they arrive. We also review our inspection and diagnostic capability to ensure we are best prepared to find and identify threats.

Surveillance – To establish a firm baseline on which to assess tree health we will monitor the current status of tree, woodland and forest health. We will continue to invest in remote sensing

technologies and use the National Forest Inventory (NFI) to provide data on elements of woodland and work with the NFI and others to establish monitoring programmes which provide more detail, including on trees outside woods.

Remote Sensing

Fera Science Ltd. are using remotely sensed data collected by unmanned aircraft systems (UAS) to identify and map individual tree species. Photosynthetic activity can be derived from certain spectral bands of the imagery to understand tree health variation across a woodland or forest. Fera are now using UAS imagery to train freely available satellite imagery to produce regional and UK wide species composition maps.



We will continue to deliver extensive aerial and ground-based inland surveillance programmes to monitor a range of pests and diseases, covering the wider environment, nurseries and farms, and involving government, industry, conservation groups and the public. This now also includes Observatree[36], a nationwide network of over 200 volunteer tree health surveyors trained by Forest Research, the Forestry Commission, Natural Resources Wales and the Woodland Trust, and Tree Alert[37] a simple way to report tree pests and diseases.

Management – In response to outbreaks of pest and disease our evidence programme provides practical management solutions to industry, tree and environmental charities, landowners and the public. We will invest in better diagnostic tools, surveillance methodologies, effective and innovative control options and better guidance to minimise the impacts of pests and diseases and achieve our environmental objectives. We will continue to invest in research to manage existing threats, such as Ash Dieback, Oak Processionary Moth and Sweet Chestnut Blight.

Behavioural goal 3: We will develop and apply the latest science and evidence on the full range of threats to tree health to inform our risk-based approach

36 https://www.observatree.org.uk/
37 https://www.forestry.gov.uk/treealert

Chapter 4 – Environmental goals

Collectively government and stakeholders need to work together to build the resilience of our trees to help them resist, recover from, and adapt to the impacts of those pests and diseases that threaten our tree population. To do this we need to define which of the attributes of our treescape we want to strengthen and what changes we want to bring about through a set of environmental goals for tree resilience.

Through these environmental goals for tree resilience we will improve the baseline diversity, health and condition of our treescape to equip our trees to be able to withstand future pests and diseases better. These environmental goals are critical to all components of resilience.

Environmental Goal 1:	**Extent** - a continued increase of trees, woods and forests
Environmental Goal 2:	**Connectivity** - enhancing the linear forest and matrix of trees within other habitat settings
Environmental Goal 3:	**Diversity** - enhancing the genetic diversity and increasing the structural diversity of our treescape
Environmental Goal 4:	**Condition** - encourage healthier trees and thriving woodlands and forests

4.1 Extent

A continued increase of trees, woods and forests

We want to ensure a continued increase of trees across the landscape in order for the treescape to continue to grow, expand and regenerate on a sustainable basis. This means increasing the number of trees, woods and forests and applying the principles of the environmental goals to trees in all their settings, including the linear forest, hedgerows, urban and peri-urban areas. It means more well considered planting and greater care to ensure that saplings grow into trees of stature and mature woodlands, capable of delivering maximum benefits.

The 25 year environment plan outlines government's commitment to plant 11m trees in this parliament and increase tree planting by creating new forests, and incentivising extra planting on private and the least productive agricultural land, where appropriate. We will support the planting of a forest that crosses the country in a belt of trees, using the M62 corridor as its spine. With £5.7 million of government funding, we will support the existing partnership of the Community Forests and the Woodland Trust to accelerate and develop the Northern Forest.

Through a new woodland creation grant scheme we will implement new approaches that will support extra woodland creation, incentivising more landowners and farmers to plant trees on their land, including for agroforestry and bio-energy production purposes.

We will also increase the long-term supply of English grown timber, by maintaining our Public Forest Estate and enabling industry to plant and manage sustainable, productive woodland and forests that meets the highest standards of design and management.

The new Tree Champion will drive a step change in tree planting and promote the unique blend of social, economic and environmental benefits offered by trees and forests and make sure that the right trees, in terms of biosecurity, value for money, air quality impact and biodiversity among other criteria, are planted in the right places, in line with the **UK Forestry Standard**.

4.2 Connectivity

Enhancing the linear forest and matrix of trees within other habitat settings

The role that trees in the wider landscape play in the ecological functioning and connectivity of landscapes is another dimension to building resilience within our environment. The network of trees distributed across the landscape in hedges and tree-lined routes (roads, rivers, canals and railways) connect urban and rural landscapes and offer a continuity of resources for wildlife, such as food, shelter and places to breed. It is important that trees in these environment are well managed, or they can reduce the value of these services, by providing corridors for pests and diseases or posing a health and safety risk along roads and railways. Well-chosen and well managed trees in the wider landscape increase habitat connectivity, reduce the effects of habitat fragmentation and provide multiple environmental and social benefits. The environmental goals for tree resilience must therefore also be applied to non-woodland trees. For example, we must ensure that no single species becomes dominant, particularly as we support landscapes recovering from Ash Dieback.

4.3 Diversity

*Enhancing the genetic diversity and increasing the structural diversity of our **treescape***

When planting trees or managing tree populations, it is important to consider both species diversity and genetic variation (within and among populations), as this can help our trees, woods and forests to survive and adapt to changing environmental conditions and reduce the impact and spread of pest and disease threats.

Natural Regeneration

Every time a tree produces seeds and seedlings there is an opportunity for new combinations of genes from different individuals to come together. Different pressures act on the seedlings: competition for light, water and nutrients, predation by pests, disease and so on. A few seedlings survive to become trees of seed bearing age themselves, whilst the vast majority perish. This is natural selection in action, and represents the survival of the fittest.

Abundant oak regeneration in the Wyre Forest, one of England's largest ancient woodlands © C Reid

Research shows that within only a generation or two, any particular population of trees will become adapted to the prevailing pressures in the local area e.g. droughty soils or locally present diseases. 'In-breeding' is prevented by pollen arriving from distant sites carried by the wind or on insects (known as 'out-crossing'). So, sites with regular cycles of natural regeneration benefit from natural selection and out-crossing to keep local populations both well-adapted and genetically diverse.

Actions that would support abundant natural regeneration are:

- managing browsing animals
- continuous cover forestry systems to create regular opportunities for space, light and seed sources
- enrichment planting with desired tree species where seed source is lacking
- ground preparation on open sites (e.g. adjacent to existing woods) to create a seed-bed and reduce competition from weed

Genetically diverse populations are more likely to evolve to resist new pest and diseases by natural selection, but barriers to regeneration may need to be removed. Natural regeneration relies on genetic material that is already available on a particular site, while artificial regeneration through seedling or planting, typically involves transferring forest reproductive material (FRM), from other locations to the site. This strategy recognises that both approaches will have value to different landowners, who will have different objectives for their trees and woods, and different attitudes to risk. Landowners need to be given the space to act in line with their objectives as part of the solution to resilience will come from the many different approaches that will result. For some plant pathogens, such as Ash Dieback, specific genotypes of ash may need to be selected or bred that can resist the disease threat.

The demand for imported FRM, usually in the form of seeds or cuttings, is increasing. This is partly a response to climate change as some forest managers seek tree species and provenances with perceived greater productivity potential under future climatic predictions. It also results from the demand for tree and shrub seed outstripping supply from UK sources. The FRM Regulations 2002[38] regulate the marketing of FRM and provide a system of identification and control of seeds, cuttings and planting stock used for forestry purposes in GB. They ensure that planting stock is traceable through the collection and production process to a registered source of basic material (e.g. trees from which the seed is collected or cuttings taken). This provides those who buy FRM with assurance about the provenance and origin of the material being bought. When making decisions about the sources of FRM the highest standards of biosecurity should be employed to avoid risks which could facilitate the spread of novel pests or diseases that threaten our existing trees, woods and forests.

UK Forest Genetic Resources (FGR)

The ability of UK trees to meet the present and future challenges depends strongly on genetic variation within tree species. Genetic diversity provides trees with the potential to adapt to new environmental conditions, including novel pests and diseases, through natural selection. Maintaining genetic diversity also provides the raw materials for tree improvement, which may strengthen traits involved in pest and disease resistance.

It is therefore vital that we recognise, understand and conserve this diversity. We need to know how much genetic variation our trees possess, how it is structured in the landscape and across generations, what determines its distribution, and where major genetic differences are located (both for conservation purposes and as potential sources of new variation). It is vital that we recognise and conserve this diversity.

Significant ex situ conservation of UK FGR has been achieved by the UK National Tree Seed Project, with extensive seed collections stored in the Millenium Seed Bank, RBG Kew, and available to researchers, but a more comprehensive ex situ genebank of UK FGR is still needed. Action is required to protect in situ representative populations of distinct genetic diversity. Known as ‘Gene’, a strategy for UK FGR is currently under development that aims to provide strategic direction and co-ordination in order to promote the collaboration required to meet these objectives. This will also directly support the UK National Tree Improvement Strategy.

38 https://www.forestry.gov.uk/frm

Depending on the objective, both natural and artificial regeneration can help increase the genetic diversity of a tree population. At a basic level, large areas of monoculture should be avoided and encouraging a wider range of tree species is essential. Where biodiversity is the prime objective, the Forestry Commission currently recommends a portfolio approach involving natural regeneration (where possible) and the planting of a mixture of provenances alongside the local tree population. Where the objective is timber production, then the Forestry Commission recommend, depending on the owners view towards accepting risk, that an assisted migration[39] approach be followed. In either scenario, seed should not be collected from a small number of seed trees (to avoid a narrow genetic base).

Ensuring age and size diversity in our treescape, recognising the special value of ancient woodlands and ancient and veteran trees, will also contribute to resilience. England has more ancient oak trees that the rest of Europe combined. Through the 25 year environment plan we are committed to ensuring stronger protection of our ancient woodlands, and making sure they are sustainably managed.

4.4 Condition

Encourage healthier trees and thriving woodlands and forests

Trees, woods and forests in the best condition are more resilient to stress and best able to resist the threat from pests and diseases. For our forests and woodlands, the UK Forestry Standard (UKFS) is the reference standard for sustainable forest management in the UK. By meeting the requirements of the UKFS, all our forest and woodland owners, managers and practioners can demonstrate that their activities are legal and meet good forestry practice. Although the scope of the UKFS does not extend to the management of individual trees, orchards, ornamental trees and garden trees, many of its guidelines can also be applied to trees in these settings.

Tree health is also promoted by making sure what is planted is suited to the site it is planted on, as this will minimise stress and increase the ability of a tree population to withstand disease or pest attack, a principle encapsulated in the mantra - Right Tree, Right Place. Decision support tools such as the Ecological Site Classification tool[40] can help land managers identify the right trees for their site. Consideration should be given not only to physical factors such as altitude, aspect, slope and soils, but also climatic factors such as the frequency of late frosts and biological factors like the microbial and mycorrhizal fungal community. Healthy, aerated soils with thriving soil fungi, sustain the flow of nutrients to trees.

39 https://sp.demeter.zeus.gsi.gov.uk/Sites/aa04/THSP/TH Strategy/Resilience Strategy 2018/Draft Strategy/Spreading the Risk: Species & Genetic Diversity
40 https://www.forestry.gov.uk/esc

Better consideration of the biological needs of our trees and bringing more of our trees, woods and forests into active management using a variety of techniques will not only improve tree health but also improve biodiversity and secure a functioning and dynamic treescape which provides a range of values. While 59% of woodland in England is already in active management, the UK imports around 80% of the wood it consumes so there is an opportunity for UK wood – particularly in extracting hardwoods from our broadleaved woodlands. Our commitment to explore opportunities for hardwood timber supplies, means we will focus on increasing the proportion of broadleaf woodlands that are sustainably managed.

Behaviour Goal 4: We will apply the principles of the environmental goals to the management of our trees, woods and forests

Chapter 5 – Building resilience

This strategy takes a holistic approach by defining the components required to build resilience of our trees, woods and forests to withstand pests and disease threats. By defining the components of resilience this results in a flexible approach which can be applied to different contexts – including at a national and local level. The approach also enables us to identify priority areas for action.

5.1 The resilience circle

Through applying a holistic approach to a simplified, standard resilience framework[41] we have developed a resilience circle focused on realising three outcomes – resistance, response and recovery and, adaptation – these outcomes all represent ways to increase the resilience of our treescape which involve action to reduce the risk of the threat occurring, and strengthening of our natural resource to better withstand future threats. The environmental goals set out in Chapter 4 are priorities at each stage of the resilience circle, but are particularly important as part of adaptation.

Figure 4: The resilience circle

41 Fuller and Quine (2016) (https://academic.oup.com/forestry/article/89/1/7/2465813/Resilience-and-tree-health-a-basis-for) Resilience and tree health: a basis for implementation in sustainable forest management Forestry 89 (7-19)

5.2 Resistance

Reducing the threat or absorbing the impact of a risk with no substantial change or loss to the treescape

Resistance is the first line of defence and focuses on actions that should be taken to reduce the risk of the threat occurring. The Plant Biosecurity Strategy 2014 sets out our long-term approach to reduce the risks of pests and diseases entering the country by enhancing activities across the biosecurity continuum (pre-border, border and inland). Many of the activities outlined in Plant Biosecurity Strategy support resistance, including horizon scanning and taking priority actions, such as keeping the legislative framework up to date and carrying out targeted inspections. In the context of increasing threats we will continue to assess our approach and take opportunities to strengthen biosecurity, including through the development of a new Plant Biosecurity Strategy in 2020.

5.3 Response and Recovery

Facilitating a suitable response when threats do occur, to allow our existing trees to recover wherever possible.

The response to a pest or disease outbreak will vary depending on a range of factors including assessment of risk, speed of detection, scale of the infection, environmental context in which the threat occurs, and management options. We have in place a generic contingency plan[42] which describes how we will manage an outbreak of pests or diseases in trees in England. In addition we will continue to develop, stringent, actively tested, pest specific contingency plans for key threats which enable us to take prompt action should they be detected. Where we can eradicate or reduce a pest or disease risk (through management action to contain or slow down spread) the response will often focus on hindering the pest or disease (e.g. applying pesticides or employing management practices to remove host material to limit spread).

Supporting recovery is an important part of the process. The goal of recovery is to take action to enable the treescape in which the threat occurs to recover to its previous state or transform into a very similar state which delivers the same functions and benefits. If recovery is not possible (e.g. due to the scale of the infection), then adaptation must occur.

42 https://planthealthportal.defra.gov.uk/pests-and-diseases/contingency-planning/

5.4 Adaptation

Driving long term changes which will strengthen our natural resource and favour the survival of our trees, woods and forests and supporting landscapes in adapting to established pest and diseases.

There are two key elements to adaptation:

- Adaptation is about driving long-term change to strengthen our trees, woods and forests to be more resilient to future threats. It is about improving the baseline diversity, health and condition of our treescape to equip our trees to be better able to withstand future pest and disease if they arrive. The priority areas for focus are set out in the environmental goals in Chapter 4 – it is about implementing measures and taking action to increase the extent, connectivity, diversity and condition of our trees.
- Adaptation is about supporting the treescape to adapt if a pest or disease has established. If it is not possible for the tree population to recover as the pest or disease is established, then it may be appropriate to manage trees in a way that helps transform the treescape to a new desirable state. This may require changes such as breeding new resistant genotypes of threatened species, targeted management of individual trees with naturally higher resistance, or planning of replacement tree species. Tree species are genetically diverse and have substantial potential to adapt if the conditions allow – i.e. that frequent regeneration is occurring or a managed breeding programme is being implemented.

The holistic approach outlined through the resilience circle offers a more comprehensive way to understand and build the resilience of our trees against pests and disease to protect the environmental, social and economic benefits our trees provide.

5.5 Skills and capability

To be effective at building resilience of our trees, woods and forests to pests and diseases we need to have the underlying scientific and technical capacity and capability, increase confidence and ability to apply the concepts of resilience, as well as ensuring dynamic knowledge transfer through collaborations and cross working.

Scientific and technical skills and capability – Numerous reviews of scientific capability, including a review by the Biotechnology and Biological Sciences Research Council in 2015, have highlighted a national shortage of skills in plant health and in particular, forestry (including tree pathology), plant breeding and entomology. Defra has collaborated with the Royal Society of Biology to launch a register of Plant Health Professionals and plant health is now part of the GCSE curriculum. At the higher education level, we have worked with Harper Adams University to develop a Masters Course on Plant Pathology and bespoke training modules for

post-graduates. We will continue to work across all levels of the education sector to encourage them to include plant biosecurity and tree resilience on their curriculum and support them in the development of training materials. We will also continue to work with professional bodies to embed greater awareness of plant health and resilience as a key component of professional development and training programmes.

Local Action Plans

Once a tree pest or disease moves into the recovery and adaptation phases of the resilience circle (dealing with the issues that arise as a result of the pest or disease), the impacts on the ground are often managed by local authorites, local agencies, charities and landowners.

© John Stokes

Research by The Tree Council during 2014 showed that Local Authorities and other agencies felt unprepared for the impacts of Ash Dieback and their report recommended that 'Local Action Plans' should be developed and implemented by these agencies.

The Tree Council and Fera have created a toolkit to help develop Local Action Plans. To ensure that any future pest and disease threats are managed in a strategic manner locally, they are also developing a 'Treescape Framework' which will assist local agencies in decision making about the potential impacts of future tree pests and diseases. The local treescape framework and toolkits will be updated as new best practice becomes available and both are linked to this Resilience Strategy and the National Action Plan.

Knowledge transfer – The approach set out within this strategy has been designed to inform the development of similar approaches at the regional, local and site level. To achieve this we need dynamic knowledge transfer that link scientists and specialists with advisors, practitioners and students that cuts across the disciplines of arborists, foresters, horticulturists, land managers, environmentalists and agronomists. To facilitate knowledge exchange we will update the Plant Health Portal to include a dedicated aspect on tree health.

Behaviour Goal 5: We will build the knowledge and capability to apply the concepts of resilience at all levels

Chapter 6 – Priorities for action

6.1 Our goals

Throughout this document we have identified the behavioural and environmental goals which should guide our new approach:

Behavioural Goal 1: We will work together to protect and value our trees as important natural capital

Behavioural Goal 2: We will put biosecurity at the heart of everything we do, from onsite activities to buying practices

Behavioural Goal 3: We will develop and apply the latest science and evidence on the full range of threats to tree health to inform our risk-based approach

Behavioural Goal 4: We will apply the principles of the environmental goals to the management of our trees, woods and forests

Behavioural Goal 5: We will build the knowledge and capability to apply the concepts of resilience at all levels

Environmental Goal 1: Extent – a continued increase of trees, woods and forest

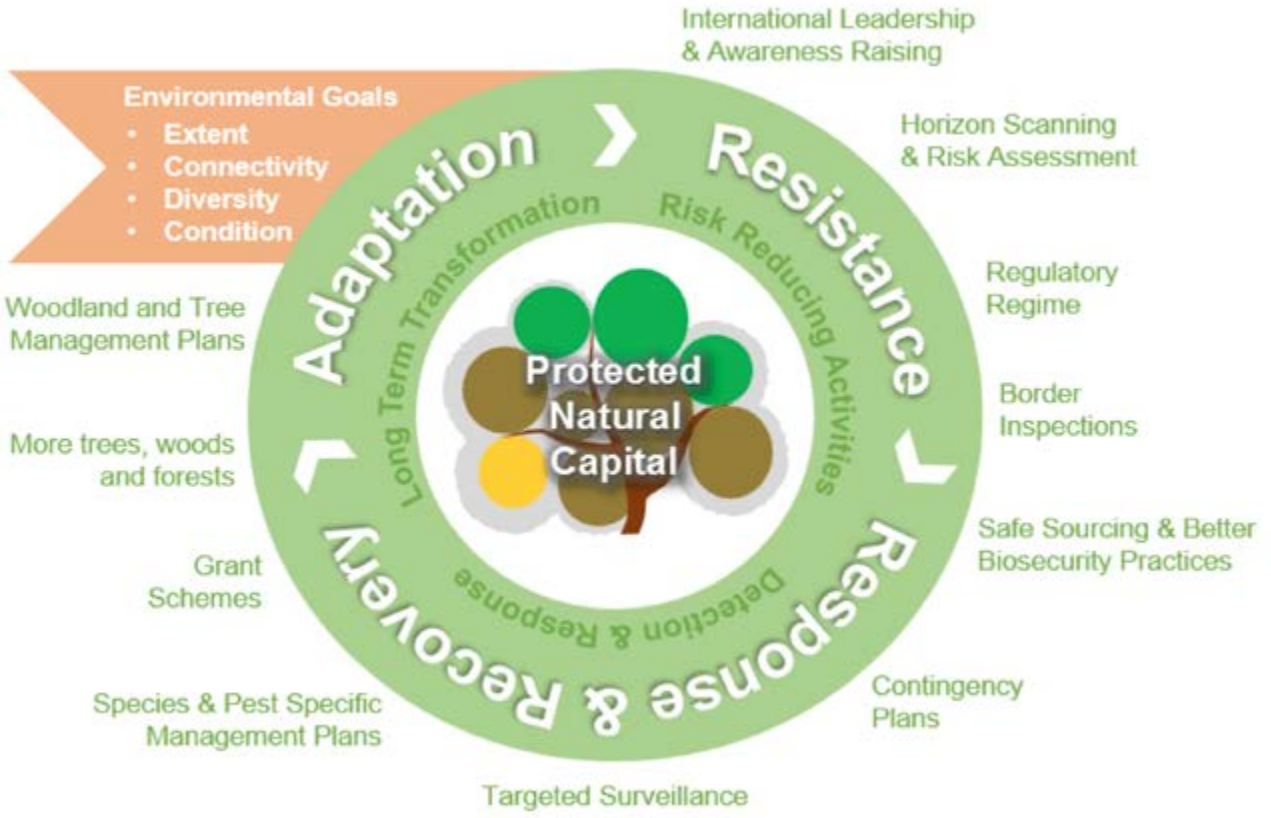
Environmental Goal 2: Connectivity – enhancing the linear forest and matrix of trees within other habitat settings

Environmental Goal 3: Diversity – enhancing the genetic diversity and increasing the structural diversity of our treescape

Environmental Goal 4: Condition – encourage healthier trees and thriving woodlands and forests

Together, these goals underpin a suite of actions that sit alongside the resilience circle and form the basis of a new **National Action Plan** that will help protect our trees and the important services they provide. The priority areas for action are summarised in the diagram below – the placement around the resilience circle indicates which resilience outcome the action will contribute towards.

Figure 5: Priority actions around the resilience circle



6.2 The National Action Plan

This National Action Plan will implement this strategy across England, and includes species level and pest specific case studies where appropriate (see Annex B). This strategy is based on the premise that the responsibility for building resilience is a shared one.

The Plant Health Biosecurity Strategy will be revised in 2020, and many of the areas of future focus identified within the National Action Plan will directly inform the development of the 2020 Plant Health Biosecurity Strategy.

Resistance

	Current Activities	Future Focus
Action 1: International Leadership & Awareness Raising – *Take a leading role in international efforts to strengthen biosecurity and build resilience. Facilitate information sharing and work collaboratively to ensure those involved in tree health are aware of risks and know what to do to reduce them.*		
Government-led	• The UK Chief Plant Health Officer (CPHO) provides strategic and tactical leadership for managing risks and strengthening protection, and represents the whole of the UK internationally. • Engage in international standard setting activities e.g. International Plant Protection Convention (IPPC), European and Mediterranean Plant Protection Organisation (EPPO), aimed at harmonising global approaches and capacity development. • Facilitation of information sharing on risk pathways and current threats.	• Publication of a new Plant Health Biosecurity strategy in 2020. • Continued awareness raising campaigns – e.g. Don't risk it, Keep it clean. • Promotion of International Year of Plant Health 2020. • Work with key stakeholders using networks to ensure knowledge transfer between those engaged in caring for the nation's trees.
Sector-led	• Develop biosecurity guidance e.g. Arboricultural Association Biosecurity Protocol, Royal Horticultural Society Plant Health Policy, Horticultural Trade Association advice on plant sourcing.	• Establishment of a senior UK committee of representatives from across the trades and professions that will drive forward better biosecurity practices. • Collaboration with government on awareness raising.
Action 2: Horizon Scanning & Risk Assessment – *Maintain our world leading risk-based approach to ensure that activity and decisions are informed by a systematic assessment of risk and targeted to deliver the best protection to unforeseen risks.*		
Government-led	• Systematic screening of new and emerging risks through UK Risk Register and shared via the Plant Health Portal. • Centre of excellence for Pest Risk Analysis. • Funding the International Plant Sentinel Network involving 28 botanical gardens world-wide to provide an early warning system. • Collaboration bilaterally and through international networks to identify and assess new and emerging risks	• Continue to maintain and develop the UK Plant Health Risk Register and Risk Group. • Develop a new tree health section on the Plant Health Portal to provide accurate and up to date information on threats to trees. • Develop further partnerships with industry, the public and stakeholders to broaden the network of those feeding into horizon scanning activities. • International collaboration to improve communication on risk.
Sector-led	• Support risk assessment activities by contributing to activities e.g. pest risk analysis	• Sharing intelligence on high risk trades and purchasing practices.

	Current Activities	Future Focus
Action 3: Regulatory Regime – *Ensure the strongest controls are in place against the highest risks, drive all to adopt higher standards.*		
Government-led	• Planning for implementation of the new EU Plant Health and Official Controls Regulations. • EU Regulations controlling the importation of live plants and plant material from outside the EU and movements of high risk material within the EU. • Annual review of EU Protected Zones for priority pests and pathogens e.g. Plane Wilt. • National movement restrictions and/or notification schemes for high risk tree species and commodities e.g. ash, oak and firewood.	• Thinking intelligently about implementation of regulations during and after our exit from the EU, particularly ensuring opportunities to strengthen biosecurity are seized. • Ensuring stronger biosecurity protection, using national measures where appropriate.
Sector-led	• Compliance with regulatory regime. • Raising awareness of responsibilities and obligations.	• Explore potential for further voluntary and self-regulation – e.g. enforced by forms of certification.
Action 4: Border Inspections – *Reduce the risk of pests and diseases being imported through trade.*		
Government-led	• Risk based checks and inspections of EU and non EU materials at points of entry.	• Enhance capability and capacity at the border. • Clearer messaging on biosecurity at the border. • Review passenger baggage allowance.
Sector-led	• Trade association guidance on sourcing of plants.	• Self-inspection on arrival of consignments and prompt reporting of anything suspicious. • Encourage collaborations within the trade to gain greater intelligence on pathways.

	Current Activities	Future Focus
Action 5: Safe Sourcing & Better Biosecurity Practices – *Work collectively to improve sourcing of material and ensure high standards of biosecurity are adopted throughout all practices*		
Government-led	• Supporting the development of nursery assurance schemes and biosecurity standards. • Raising awareness, provision of guidance and training for the trade and landowners.	• New consultation with industry on quarantine for high risk species and commodities. • Raise awareness and support the development of assurance and certification schemes, including exploring the potential for harmonisation of schemes. • Explore if public procurement strategies can be strengthened to specify safe sourcing. • Explore opportunities to support UK tree production. • Support understanding and management of Forest Genetic Resources including the new UK strategy for Forest Genetic Resources and a continued commitment to wild source seed collection to support tree conservation and identification of future species (e.g. for timber). • Explore opportunities for hardwood timber supplies, to help increase the proportion of broadleaf woodlands that are sustainably managed.
Sector-led	• Development of industry led assurance and certification schemes. • Voluntary action to reduce high risk host species and commodities e.g. host plants of *Xylella fastidiosa*. • Some nurseries applying voluntary quarantine for high risk trees/ commodities • Application of best biosecurity practices on site.	• Raising awareness of assurance and certification schemes which provide end to end assurance along the pipeline. • More widespread application of voluntary quarantines for high risk trees and commodities. • Sharing intelligence about high risk trades. • Changes to practices to specify safe sourcing e.g. Royal Horticultural Society ban on imported trees being used directly in shows, gardens or for retail. • Emphasise biosecurity in routine management operations e.g. cleaning machinery and equipment prior to movement between sites; sourcing quality planting stock; managing sub-contractors to achieve same standards.

Response and Recovery

	Current Activities	Future Focus
Action 6: Preparedness & Contingency Plans – *Work to improve preparedness and contingency planning to help ensure effective outbreak response*		
Government-led	• Generic plant health contingency plan and specific plans for priority pests. • Emergency exercises and training in emergency response. • Research to improve understanding and preparedness for future threats e.g. novel diagnostics.	• Readiness reviews of priority pests e.g. *Xylella* and Emerald Ash Borer. • Consultation on top threats for preparedness and readiness reviews. • Continued development and review of pest specific contingency plans and emergency response training as needed.
Sector-led	• Inform the development of government and site specific contingency plans.	• Preparation of site-specific (and perhaps sector-specific e.g. nurseries) contingency plans for high risk and vulnerable sites e.g. shows, collections and arboretums.
Action 7: Targeted Surveillance *Maintain strong surveillance capability and work with interested parties to increase knowledge about spread/ distribution*		
Government-led	• Extensive aerial and ground based surveillance programmes including in the wider environment and nurseries. • Funding of Observatree, a nationwide network of over 200 volunteer tree health surveyors. • Making it easier for people to report suspect cases through Tree Alert. Collation and analysis of pest and diseases reports through Tree Alert.	• Launch of Observatree phase two. • Development of new approaches to detect and identify pests and diseases, including investment in early detection/in field diagnostics. • Investment in remote sensing technologies where proven cost effective. • Analysis of National Forest Inventory (NFI) to provide data on elements of woodlands and investigate new monitoring programmes (including on trees outside woods).
Sector-led	• Training and delivery of the Observatree volunteer network. • Sector-led vigilance and monitoring of tree stock.	• Increased surveillance and reporting through routes such as TreeAlert. • Greater emphasis on surveillance in training.
Action 8: Species & Pest Specific Management Plans – *Manage priority pests and diseases already present in England in line with the resilience circle.*		
Government-led	• Pest and disease management programmes in place to minimise the impact of those present within England such as *Phytophthora ramorum*, Oak Processionary Moth. • Research and investment into potential treatment techniques e.g. stem injections, biological control and breeding for tolerant tree species.	• Evolving policies and management programmes in line with the new resilience circle (see Annex B for Case Studies). • Launch of Action Oak, a new public-private partnership model of investment in oak health. • Funding the Tree Council to work with the sector to develop Ash Dieback Local Action Plans. • Work in collaboration to provide guidance and advice and ensure knowledge transfer.
Sector-led	• Sharing responsibilities and supporting government led management plans.	• Work in partnership to manage priority pests and diseases, developing and implementing local action plans for priority pests and diseases.

Adaptation

	Current Activities	Future Focus
Action 9: Grant Schemes – *Leaving the European Union and the Common Agricultural Policy will give us the opportunity for fundamental reform.*		
Government-led	• Countryside Stewardship Scheme grants for woodland creation, woodland and tree management and specific tree health grants for felling and restocking. • Woodland carbon fund, support increase for woodland creation, predominantly productive woodland and, where possible, sought opportunities to improve public access and achieve wider environmental outcomes in line with the UK Forestry Standard.	• New agricultural policy to be underpinned by payment of public money for the provision of public goods. • HS2 Woodland Fund to support restoration of existing ancient woodland sites and the creation of new woodlands along the HS2 route (Phase 1 route only).
Action 10: More trees, woods and forests for the future – *Deliver the 25 year environment plan commitments to increase tree planting by creating new forests, and incentivising extra planting on private and the least productive agricultural land, where appropriate.*		
Government-led	• Manifesto commitment to plant 11 million trees. • Manifesto commitment to plant 1 million urban trees. • Aspiration to reach 12% woodland cover in England by 2060. • Forestry Commission advice on assisted migration. • 1 million Trees for Schools.	• Development of the Urban Tree manual to support the planting of the right trees in the right place. • Supporting the New Northern Forest. • Encouraging large-scale woodland and forest creation. • Promoting, sourcing and planting of provenances suitable to local conditions and future climate change scenarios.
Sector-led	• Provision of disease recovery packs. • Delivery of Trees for Schools.	• Delivery of the New Northern Forest comprising 50 million trees over 25 years.

	Current Activities	Future Focus
Action 11: Woodland and Tree Management – *support active management*		
Government-led	• Provision of the UK Forestry Standard (UKFS) as the reference standard for sustainable forestry management. • Strengthened protection for Ancient Woodlands. • Countryside Stewardship grants for Woodland Improvement and Woodland Management Plans. • Felling regulations, plant health regulations (Statutory Plant Health Notices) and the approval of UK FS compliant woodland management plans. • Keep the Public Forest in trust for Nation.	• Update the Ancient Woodland Inventory. • Encouraging natural regeneration, species and provenance choice and management practices which improve resilience. • Better integration of trees and woods within agriculture, including agro-forestry. • Encourage diversification (including species and structural) and promote processes that underpin genetic adaptation and resilience. • Promote public access, engagement and learning opportunities to ensure the public 'value' woodlands to complement more formal public benefit valuations. • Support the Deer Initiative and Squirrel Accord. • Duty to consult prior to felling street trees.
Sector-led	• Active practice of sustainable forest management in compliance with UKFS. • Protect trees and woods providing connectivity in landscapes from edge effects by buffering (e.g. reducing spray drift; removing adjacent hosts of high risk). • Forestry Sector Climate Change Action Plan.	• Bringing more woodland into active management and encourage actions to enhance long term resilience. • Support the new UK Strategy for Forest Genetic Resources and deliver its action plan through existing and new collaborative activities. • Support the Deer Initiative and Squirrel Accord.

Chapter 7 – An evaluation plan

7.1 Why evaluate?

To ensure the tree health resilience strategy is credible, robust and that it sets a clear direction for action, we need to define what success looks like, and how progress towards the objectives of the strategy will be measured and evaluated. This section sets out how a monitoring and evaluation framework for the strategy will be designed and delivered so that we can track progress towards the establishment of resilient systems, and adapt our interventions to respond to new challenges and as we learn from successes and failures during the delivery phase of the strategy.

7.2 Developing an evaluation framework for the strategy

The development of an evaluation framework for the tree health resilience strategy will form part of a wider programme of work to improve performance measurement across the plant health services. There is no "off the shelf" set of monitoring procedures or indicators for measuring progress towards resilience that could provide a fit-for-purpose evaluation framework for the strategy. Consequently, a structured approach will guide the evaluation design process, following six key steps:

1. **Needs:** The evaluation requirements will be defined. This will involve identifying who the interested stakeholder groups are (both 'government' and 'sector') and how they will use the information provided by the evaluation.
2. **System:** The tree health resilience 'system' will be described to define its parameters and the actors within it. This will involve identifying the actors and processes that contribute to resilience.
3. **Objectives:** The evaluation framework will reflect the Resistance, Recovery and Adaptation objectives of the strategy, which will provide the basis for performance measurement.
4. **Intervention logic:** An intervention logic will describe how the strategy works by setting out how it influences actors and their actions to drive the achievement of objectives.
5. **Indicators:** Indicators will be developed for the strategy. Indicators will be identified with reference to the intervention logic, including indicators for outcomes that reflect the strategy's objectives.
6. **Presentation:** There will be a structured output for presenting and communicating the outputs of the evaluation to different audiences.

7.3 Who needs to be involved?

The objectives of the tree health resilience strategy cannot be met by government acting alone, but will require a concerted and coordinated effort involving a wide range of stakeholders. The development of an evaluation framework for the strategy must start from a recognition that there are a wide array of actors implicated by the tree health resilience 'system'. It is the role of the strategy evaluation to assess how actors and their actions are being enabled, facilitated and coordinated to deliver resilience outcomes. The adoption of a system-level perspective will form the basis for the evaluation design, meaning that a wide range of stakeholders will be involved in the structured approach to developing an evaluation framework set out above. We will facilitate broad participation in the evaluation design process to encourage shared ownership of the framework and to ensure that the outputs of the evaluation are used at all levels of the system.

7.4 Schedule

Developing an evaluation framework for the tree health resilience strategy is part of a wider programme of work to improve performance measurement across the plant health services, which will publish a set of indicators for plant health as part of the refreshed Plant Biosecurity Strategy in 2020. Initial design work will start in 2018, with consultation on the evaluation framework design, including specific measures (indicators) for the tree health resilience strategy starting in 2019.

This assessment of the success of our measures to improve tree health resilience will contribute to the overall picture of the health of the UK environment that we will establish through a comprehensive suite of metrics developed through the 25 Year Environment Plan.

Chapter 8 – Conclusion

This strategy sets out how government, working in partnership with others, will build the resilience of our trees, woods and forests to pest and disease threats. Whilst we cannot eliminate all threats the approach outlined in this strategy centres on strengthening protection and building the capacity of our trees to protect the values our trees provide.

Our trees, woods and forests are facing multiple pressures. While the focus of this strategy is on building resilience to pests and diseases, the broader concept of resilience requires that the actions we take future-proof our treescape as far as is possible. When implementing this strategy we will work closely with others, including other parts of government, devolved administrations, and the sector, to ensure a holistic approach is taken to address the pressures on our trees, woods and forests.

The government will continue to lead efforts to strengthen biosecurity and build resilience to protect and enhance our trees, woods and forests for the future. When the UK leaves the European Union this will provide a unique opportunity to examine important areas of environmental policy. We will use this opportunity to explore how biosecurity can be strengthened in the context of challenges facing the UK.

The government will continue to build a strong interdisciplinary evidence base on pests and diseases to ensure that our risk-based approach and decisions are informed by robust evidence. The government will also improve underlying scientific and technical capability to provide expertise for the future.

The National Action Plan set out in this strategy will be delivered over the next 5 years. The strategy will directly inform the development of the revised Plant Health Biosecurity Strategy which will be published in 2020, and will include a progress report on delivery of this tree health resilience strategy.

Delivery of the strategy will require sustained and committed effort not just from government but from organisations and individuals. We will work in collaboration with industry, landowners, forestry and arboricultural professions, the research community, tree and environmental charities, and the public to make a reality of this strategy and meet our collective vision:

To build the resilience of England's trees, woods and forests. To enhance the benefits trees provide, by mitigating and minimising the impact of pests and diseases and improving the capacity of our trees to adapt to changing pressures.

Annex A – Annual and asset value that trees provide to society

Summary

We benefit from the services provided by 3 million hectares of forests and woodlands in Great Britain (13% of land cover) and in addition the wide range of other trees provide a further 0.75m hectares of cover (17% total land cover).[43] The wide range of other trees outside these forests and woodlands include small woods, clusters of trees, linear tree features such as those alongside transport routes, lone trees and hedgerows in trees, across the rural and urban/peri-urban landscape.

Some of the value of these services can be expressed in monetary terms, either because it has a market value (forestry and primary wood processing) or through analytical techniques that allow an estimation of non-market value (forestry services provided including carbon sequestration, recreation, landscape and biodiversity). UK wide estimates of monetary value are more developed for forestry and woodlands than for the range of other trees (where estimates of value are quite partial and mainly limited to air pollution absorption in some key cities). Other elements of value can be expressed in a qualitative or quantified way only (including physical health and mental wellbeing, cultural symbolic and educational benefits, woodland conservation, noise, flood and heat reduction, and water quality and availability).

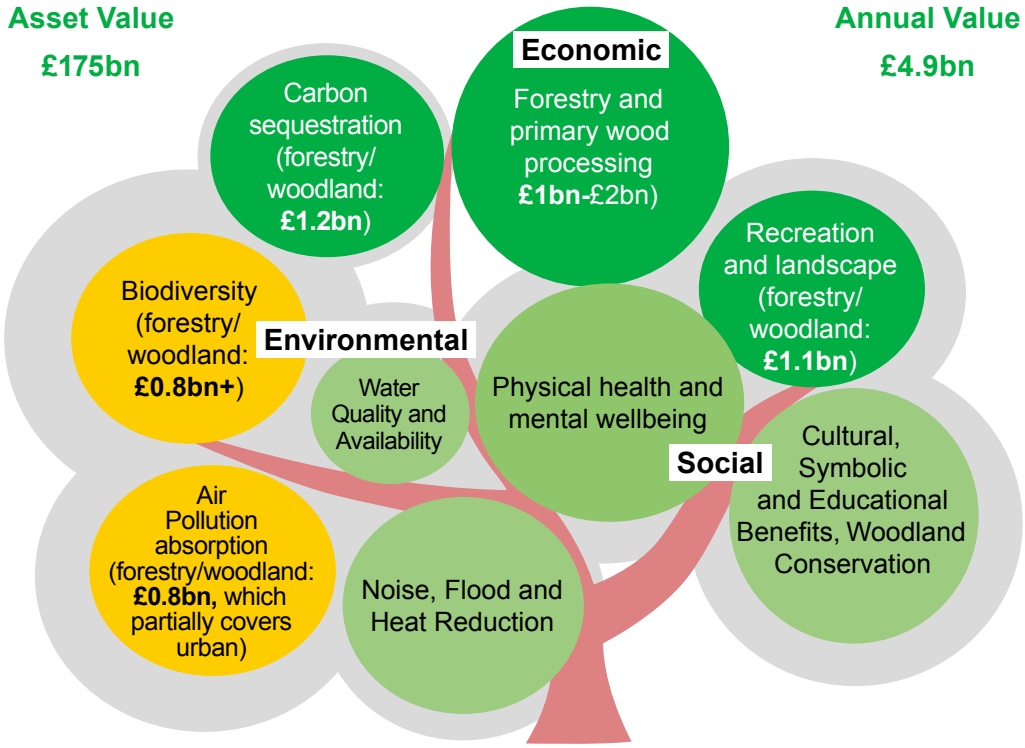
Figure 1 provides a summary of existing values (aiming to use the more robust estimate if two are available). Further detail is then provided for these estimates. It is worth noting that these values simply reflect the estimated annual flow of benefits we derive from current stocks of forests, woodlands and trees – this is quite different to assessing the asset value of the infrastructure provided by the stock of all trees (requiring a complex ecological assessment). In total the annual UK value of forests, woodlands and trees, using current very partial estimates, is **£4.9bn** per year (equivalent to over 0.2% of national income).

We can also provide an indication of the asset value, by estimating what this annual value would amount to over a 100 year period.[44] This is estimated by taking the flow of annual benefits over 100 years, then adjusted with a number of assumptions (to reflect population and income growth etc) to project these future values and then discount them back into today's terms. An initial estimate indicates that the asset value is in the region of **£175bn**.

43 The National Forest Inventory covers 3m hectares of forests and woodlands (where larger than 0.5 hectares). If we also include estimates of tree cover outside these forests and woodlands (https://www.forestry.gov.uk/pdf/FR_Tree_cover_outside_woodland_in_GB_summary_report_2017.pdf/$FILE/FR_Tree_cover_outside_woodland_in_GB_summary_report_2017.pdf) (including small woods, clusters/linear tree features, and lone trees/hedgerows in trees) across the rural and urban (including peri-urban) landscape, then this total rises by 0.75m hectares to 3.75m hectares (17% of land cover) – noting that the 160,000 hectares of hedgerows are not reflected in this total.

44 Not all elements of annual value are included (i.e. for economic value this has been restricted to timber – to focus on the physical asset rather than processed value).

Figure 1 – Summary of the Value that Forests, Woodlands and Trees Provide to Society[45]



All of these estimates of value should be treated as providing a partial indication of the size of the important value that our forests and trees provide, rather than providing exact values. Treated as such, these important values can be powerful in helping inform key decisions and priorities, and with further development can inform detailed appraisal of specific policies.

Further detail behind value estimates

The annual value we receive from our forestry and trees has been estimated based on:

- Additional forestry/woodland value to the economy per year (£1bn-£2bn of UK GVA[46]), this doesn't include wider sector benefits (e.g. contribution to value of tourism, tree fruits)
- Forestry/woodland carbon sequestration value [environmental] (£1.2bn per year, UK[47])

45 Key to Figure 1: **Value extensively/partially monetised**; **Elements of value partly monetised**; **value understood in quantified or qualitative terms only**. Circle size indicates a judgement of the relative importance of each benefit. Estimates of uncertainty (for social and environmental values) is denoted by the outer grey circles – where the larger the uncertainty, the larger the outer circle. Annex A provides further background information about how the values described in figure 1 were calculated.

46 GVA for forestry and sawmilling estimated at around £1bn in 2015 (£0.6bn from forestry and £0.4bn from sawmilling). We could also include the value of further processing estimated at £1bn (£0.3bn from panels and £0.7bn from pulp and paper), although production could be expected to continue with imported timber. The Forestry Commission (2017), Forestry Statistics 2015 data. Chapter 8 - Finance & Prices, Table 8.3, based on ONS Annual Business Survey data (https://www.forestry.gov.uk/pdf/Ch8_Finance_FS2017.pdf/$FILE/Ch8_Finance_FS2017.pdf). Note that a lower forestry GVA estimate also exists (National Accounts estimate a value of around £0.3bn rather than £0.6bn – and so the true value is likely to lie somewhere inbetween).

47 Estimated by multiplying data on carbon sequestered (Forestry sector) *(https://uk-air.defra.gov.uk/assets/documents/reports/cat07/1703161052_LULUCF_Projections_to_2050_Published_2017_03_15.pdf) non-market carbon price (latest central BEIS Values).

- Forestry/woodland value from a partial assessment of recreation [social 'active use'], landscape [social 'passive use'], biodiversity [environmental and social 'non-use'] (£1.9bn per year[48] across GB)
- Woodland value from air filtration [social 'passive use'] (£0.77bn per year, across UK)[49]
- Forestry/woodland value from benefits of flood reduction [environmental] (estimate completed for one catchment and plans in development to estimate a GB wide value)[50]
- Forestry/woodland value from water quality/availability [environmental], and health/wellbeing [social 'active use'] value (£ not well known, often captured qualitatively or included within broader green space valuation)
- Cultural, symbolic, spiritual, education/social development [social 'passive use'] value from experiencing forests/woodlands including ancient trees[51] (value non-monetisable), and woodland conservation [social 'non-use'] value from preserving trees for future
- Urban woodland/trees annual value including for many of the benefits above such as landscape, pollination, flood reduction, carbon sequestration, biodiversity, physical/mental health and quality of life improvements[52] as well as value from shade, heat and noise reduction[53] [environmental, social 'active/passive/non-use'] (£ not well known, often

48 Estimates for recreation, landscape and biodiversity based on eliciting a sample of households' willingness to pay for enjoyment/benefit of these forestry features, and then aggregating across the whole population. Based on Willis et al. 2003 for Forestry Commission: 'The Social and Environmental Benefits of Forests in Great Britain' (www.forestry.gov.uk/pdf/sebreport0703.pdf/$FILE/sebreport0703.pdf), where estimates have since been updated (i) in a 2013 Defra report (https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/200396/pb13906-chalara-socio-economic-framework.pdf) for landscape to £0.2bn per year, and subsequently (ii) to reflect the latest relevant MENE survey data on trip estimates, resulting in an aggregate increase in the value of recreation to £0.9bn per year, noting that a range of different willingness to pay estimates could be applied to calculate this value, and (iii) to reflect a wider range of biodiversity value, where the latest estimate is now £0.8bn per year. Note that this biodiversity value is a cautious estimate as higher biodiversity value estimates do exist, where (a) it is assumed that people value biodiversity in each other's countries of GB as well as their own leading to a higher estimate of £1.7bn per year, or (b) a much wider coverage of woodland has its value estimated by applying similar per hectare 'willingness to pay' estimates. We will develop our understanding of this key value in future, noting existing estimates are based on a small sample of people's 'WTP' estimates.
Note also that these estimates are partial because (i) only 3m hectares of woodland >0.5 hectares is reflected in the National Forest Inventory (but there is also an extra 0.75m hectares of smaller woodland and other trees); (ii) for biodiversity (1m of total 3m hectares of woodland included, reflecting ancient semi-natural, replanted & new broadleaf/conifer woodland); (iii) landscape (excludes woodland not visible beyond urban fringe); and (iv) recreation (excludes casual/high value visits).

49 The value of woodland vegetation removing harmful pollution was estimated to be £0.77 billion in 2015, based on the 2007 Land Cover Map. This value is based on the avoided health costs associated with respiratory and cardiovascular illnesses, and subsequent years of life gained and deaths avoided. Ecosystem Account for Woodland (https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/landandhabitatecosystemaccounts#ecosystem-accounts-for-woodland), ONS 2017, see Table 8

50 A recent FC case study provides a flood alleviation estimate for a catchment (Southwell) in Nottinghamshire at £250 per hectare per year – noting this per hectare value decreased as further areas were planted to cover 310 hectares total as this involved extending tree planting to sites where trees were less effective at flood alleviation (further similar case studies are also being considered as well as a plan to estimate a national flood alleviation value for woodland).

51 Internal Defra Report entitled "Social and Cultural Values in Plant Health – Scoping Study and Review" provides further details [available on request]. Note that there may be an element of overlap between these and the estimates of biodiversity value.

52 Qualitative assessment in a 2016 FC Urban Forest Report. (www.forestry.gov.uk/pdf/urban-forest-final-v4.pdf/$FILE/urban-forest-final-v4.pdf)

53 Partial assessment of noise and local climate regulation value, expected to be significant, included in a 2017 scoping study (randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=19843) for Defra (see table S4, page 12): Further work in development to refine estimates.

captured qualitatively or included within broader green space valuation)

- Urban woodland/trees annual value of air pollution absorption [social 'passive use'] (£0.2bn per year, across GB[54]) – this estimate is partial and included in the £0.77bn

- Annual value from other trees including hedgerows, garden and park trees, trees on transport corridors [mix of environmental and social 'passive use'] (£ not well known)

In total, the annual value across the economic, environmental and social elements of forests, woodland and trees that can explicitly be monetised, is estimated at £4.9bn per year.[55] Note that as part of a joint programme of work with Defra, the Office for National Statistics also produce estimates of the annual value of woodland in the UK woodland accounts. The reasons for the differences are set out in the footnotes below.

It is worth also noting however, that trees may also reduce the value of services, for instance through tree root damage or obstructing views. Therefore many factors (including location and species mix) should be considered carefully when designing policies, in order to mitigate negative value and maximise positive value.

54 This value has been estimated in 'Developing Estimates for the Valuation of Air Pollution Removal in Ecosystem Accounts' (https://www.ons.gov.uk/economy/environmentalaccounts/articles/developingestimatesforthevaluationofairpollutioninecosystemaccounts/2017-07-25), CEH 2017, for the ONS, see Table S16 and is based on the OS Master Map. It is likely to be a lower-bound estimated when compared to an extrapolation of the approach used in the i-Tree project entitled Valuing London's Urban Forests, a 2015 London i-Tree Eco Project. In this project, London urban tree/woodland annual value is estimated which mainly reflects air pollution removal (£0.13bn). Although some similar studies are available for several other cities with much lower £estimates, this approach could be extrapolated to reflect air pollution removal value from urban trees across the key cities in the UK (estimated at potentially into the hundreds of £millions). Small values have also been estimated as part of the London i-Tree project for carbon sequestration (£5m per year) and flood alleviation (£3m per year). Note, the relationship between trees and air quality is complex (positive or negative depending on location).

55 Note that recent reports by ONS (Environmental Accounts 2017) (https://www.ons.gov.uk/economy/environmentalaccounts) and The Economic Benefits of Woodlands by Europe Economics (https://www.woodlandtrust.org.uk/mediafile/100523043/RR-WT-060315-economic-benefits-woodland.pdf) for the Woodland Trust 2015 provide figures that reflect a similar set of values although some are provided on a different basis. The £4.9bn estimate in this analysis is an annual value, whereas the Woodland Trust (£270bn) estimate is the total value of benefits in perpetuity, to indicate the value of the entire forestry asset, for a similar but not identical set of ecosystem services. The £4.9bn annual estimate is also based on applying valuation methods more cautiously than Woodland Trust (e.g. for biodiversity and landscape value). Compared to the £2.3bn estimate of annual value in the ONS 2017 Woodland Accounts (https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/uknaturalcapital/landandhabitatecosystemaccounts), which are part of the overall ONS Environmental Accounts 2017, figures are similar for some of the components of the £4.9bn value presented here – but it is worth noting that this analysis provides a broader coverage of value (for instance includes non-use biodiversity value that individuals benefit from, the economic value reflects Gross Value Added for a broader coverage of activity as described above) and there are also some further differences due to methodologies used (for instance the recreation value here is higher due to using a higher estimate of 'willingness to pay'/wider coverage of recreational trips). The £4.9bn value is an analysis of value that is a snapshot for 2015 and so this value will change over time in reality. The ONS Woodland Accounts are part of a long term programme of joint work with Defra to develop annual natural capital accounts for the UK, both physical and monetary, flow and stock accounts. These accounts are improved each year as new information becomes available and can be incorporated into any future versions of this analysis where appropriate.

Evidence gaps

Many gaps still remain in our understanding of the full value of forests, urban trees and hedgerows – the full value would be considerably higher. Key areas for further research[56] include understanding value (which is based on understanding the underlying natural scientific relationship) that is derived from:

General aspects:

- air pollution absorption
- biodiversity
- flood reduction and water quality/availability
- conservation of woodlands
- physical and mental wellbeing

Specific aspects:

- urban tree landscape
- peri-urban landscape (such as on transport routes)
- key tree species and hedgerows

Other tools for assessing local decisions

In addition to the GB-wide estimates of value above, there are also a number of tools available for assessing the value of trees in a location specific context. For instance:

- i-Tree tool is noted above mainly in the context of valuing the environmental benefits from urban forestry
- Capital Asset Value for Amenity Trees (CAVAT) tool that allows tree officers to assess the value of local tree stocks and manage their assets
- Valuing Green Infrastructure through Tree Assessment Tools (ViTAL) is helping to expand Treezilla (a citizen science platform that allows users to map trees and obtain valuations for the ecosystem services that those trees provide to society, which currently covers around 50,000 trees)

56 Note that this list is broadly consistent with the findings of a similar 2017 FC report, see section 14 of Valuing the Social and Environmental Contribution of Woodland and Trees in England, Scotland and Wales (https://www.forestry.gov.uk/PDF/FCRP027.pdf/$FILE/FCRP027.pdf)

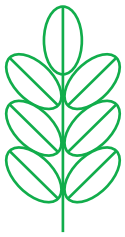
Annex B – Case studies

Case Study 1 – Ash

Importance[57]

12%
of broadleaf woodland in Great Britain is ash[1]

60m
estimated number of ash trees outside woodlands in the UK (higher end estimate)[2]



9,500
ancient, veteran and notable ash trees have been recorded in the Ancient Tree Inventory[3]

955
species associated with ash trees of which 45 are believed to have only ever been found on ash trees[4]

£230m
per/year estimated social/environmental value of ash[5]

Outline of threat

Ash Dieback is caused by the fungus *Hymenoscyphus fraxineus*, which originated in Asia (i.e. Japan, China and Korea) and is now widespread in Europe, causing the large-scale loss of European ash trees. It was first observed in the UK in 2012, although recent research has found sites where it has been present since 2004-5 (where it was probably introduced on planted stock in the 1990s). Most parts of the country are now experiencing the impacts of ash tree decline and mortality, although the speed and severity of the disease is variable at a local level. A small percentage of UK ash trees will be tolerant to the disease. Ash trees are also under threat from the Emerald Ash Borer (EAB), (*Agrilus planipennis*), a serious insect pest from Asia. It is not currently present in the UK but its detection in the USA and Canada in 2002, and in Russia in 2006 demonstrate its invasive ability. Despite intensive management and attempts to restrict long-distance spread, it has not been possible to eradicate or contain the pest in these countries and reducing the risk of entry into the UK is paramount.

57 Importance icons: 1. Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf) , 2. The Tree Council on behalf of Defra, Chalara in Non-Woodland Situations; Findings from a 2014 Study (https://livingashproject.org.uk/pdfs/Chalara%20in%20non%20woodland%20situations.%20%20Tree%20Council.pdf) 3. Ancient Tree Inventory, Woodland Trust (https://livingashproject.org.uk/pdfs/Chalara%20in%20non%20woodland%20situations.%20%20Tree%20Council.pdf) 4. Mitchell et al. 2014. The potential ecological impact of ash dieback in the UK. JNCC Report No. 483 (jncc.defra.gov.uk/pdf/JNCC483_web.pdf) 5. Defra – unpublished estimate. The social and environmental value of forest/woodland ash in Great Britain is estimated by apportioning ash forest/woodland proportion of an overall £3.9bn estimated annual value of forestry/woodland (see Annex 1), reflecting recreation, landscape, carbon sequestration, air pollution absorption and elements of biodiversity value. This estimate of value will exclude many important aspects that cannot easily be monetised (including water quality/availability, noise, flood and heat reduction, physical and mental wellbeing, and cultural, symbolic education benefits). The species percentages of overall GB stocks were calculated using Forestry Commission Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf) (Tables 1.8 and 1.9). Please note: individual species level detail on value are not available therefore these figures are broad estimations based on a number of assumptions

Priority actions

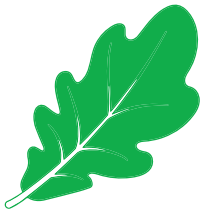
We aim to secure the long-term future of our nation's ash trees through the following:

Resistance	• Continuous review of the risk to ash, through the Plant Health Risk Group and implementation of further measures as appropriate. • Movement restrictions on ash trees in line with technical assessments of the risk posed by Ash Dieback. • Import controls on ash trees to reduce risk of introduction of EAB through trade and pre-notification of firewood imports to target high risk consignments for inspection. • Research into climatic suitability of the UK for EAB establishment and spread, management options and the susceptibility of European ash. • Raise awareness with stakeholders across the tree health landscape to include plant trade, commercial woodland owners and land managers.
Response & Recovery	• A task group of Local Authorities and landowners to manage the impact of Ash Dieback on the ground, including trees which pose a danger to the public. • Updated guidance on how to manage Ash Dieback and protect ash-associated biodiversity. • Strengthened leadership in the form of an EAB Preparedness Board, chaired by the Chief Plant Health Officer, to ensure a swift and effective response should the disease enter the UK. • A published contingency plan for EAB. • Surveillance and monitoring to understand spread of ash dieback, facilitate early detection of EAB.
Adaptation	• Planting and regeneration of suitable replacement trees, to preserve the value and character of our woodlands, parks and hedgerows. • Understand the market demand for tolerant ash trees. • Identify, develop and conduct research on ash genotypes tolerant to both Ash Dieback and EAB to ensure ash remains part of the nation's landscape.

Case Study 2 – Oak

Importance[58]

16%
of broadleaf woodland in Great Britain is oak[1]



>49k
ancient, veteran and notable oak trees recorded in the UK[2]

2000
species of insect and lichen supported by oak trees. Oak trees are Great Britain's most important tree for species biodiversity[3]

£320m
per/year estimated social/environmental value of British oak[4]

2.9tC
sequestered from the atmosphere by an oak tree over 100 years[5]

Outline of threat

The health and survival of native British oak trees have been deteriorating over the last 100 years. Gradual 'chronic' oak declines have been linked to increasing abiotic (soil, pollution, climate) stresses over the last century and deteriorating root health, whereas faster-acting Acute Oak Decline (AOD) is associated with altered trunk microbiomes. Other pests and pathogens can predispose trees towards decline including: leaf defoliators, such as oak roller, gypsy and winter moth; bark-borers, such as jewel beetles and oak pinhole borer; and fungal pathogens, such as powdery mildews. The defoliator *Thaumetopoea processionea* known as Oak Processionary Moth (OPM), native to southern Europe, was first detected in London in 2006 and has since spread outwards. Horizon-scanning tools have identified potential foreign threats to oak health, including a sub-species of the bacterial pathogen *Xylella fastidiosa*, oak wilt fungus (*Ceratocystis fagacearum*) and oak lace bug (*Corythucha arcuata*).

58 Importance icons: 1. Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf), 2. Woodland Trust Ancient Tree Inventory (www.ancient-tree-hunt.org.uk/news/oak-data.htm), 3. Ongoing work by the James Hutton Institute shows that oak supports over 2000 species. 4. Defra – unpublished estimate. The social and environmental value of forest/woodland oak in Great Britain is estimated by apportioning oak forest/woodland proportion of an overall £3.9bn estimated annual value of forestry/woodland (see Annex 1), reflecting recreation, landscape, carbon sequestration, air pollution absorption and elements of biodiversity value. This estimate of value will exclude many important aspects that cannot easily be monetised (including water quality/availability, noise, flood and heat reduction, physical and mental wellbeing, and cultural, symbolic education benefits). The species percentages of overall GB stocks were calculated using Forestry Commission Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf) (Tables 1.8 and 1.9). Also, given oak's special place in many people's minds, it may punch above its weight particularly on landscape value for example. Please note: individual species level detail on value are not available therefore these figures are broad estimations based on a number of assumptions 5. Cannell, MGR. 1999. Growing trees to sequester carbon in the UK.

Priority actions

We aim to improve the resilience and long-term future of our nation's oak trees through the following:

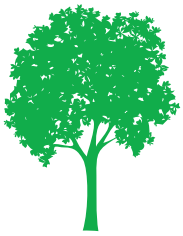
Resistance	• Continuously review of risks to oak trees using the UK Plant Health Risk Register process and identify priority actions in response to such threats. • Uphold border checks and plant passport schemes to minimise introduction of prohibited oak pests and diseases. • Maintain pre-notification of oak plants imported from the EU to target high risk consignments for inspection. • Continue to raise awareness and provide best practice guidelines to the nursery trade and landowners of the biosecurity risks and management actions in order to prevent introduction of new high priority pests, and spread of high priority pests already present including OPM.
Response & Recovery	• Support long-term surveillance programmes (including citizen science projects such as Observatree) to facilitate quick detection and long-term monitoring of high priority or emerging oak pests and diseases. • Slow the spread and reduce the impact of OPM through management programme and work with landowners to implement risk-based approaches to OPM management.
Adaptation	• Launch the Action Oak Partnership – a nationwide monitoring scheme and multidisciplinary research programme to safe-guard oak tree health in the UK. • Fund research into AOD, OPM and other priority oak pests and diseases. • Scientific research to inform and encourage management practices that promote oak tree resilience and health, e.g. sequencing oak genomes to identify resilient genotypes.

Case Study 3 – Sweet Chestnut

Importance[59]

97%
of sweet chestnut in woodlands is in England[2]

29k ha
of sweet chestnut in woodlands in Great Britain[1]



44m
sweet chestnut trees in woodlands in Great Britain[3]

70+
species of Lepidoptera have been recorded using Sweet Chestnut as a foodplant, making it an important host species[4]

£40m
per/year estimated social/environmental value of sweet chestnut[5]

Outline of threat

Threats to sweet chestnut trees have increased in recent years. Most recently, since late 2016, there have been several findings of Sweet Chestnut Blight (*Cryphonectria parasitica*) in England. The disease has been present in mainland Europe since 1938, where it has spread slowly and been less destructive than in America. This is partly because *Castanea sativa* is slightly less susceptible than its North American counterpart, but also due to the use of a natural biological control (hypovirulence) in many Sweet Chestnut Blight affected parts of Europe. At the majority of sites where Sweet Chestnut Blight has been found in England, the numbers of trees affected are low, and very few trees appear to have been killed as a result of infection, but further incidences of infection are likely to be found.

Since 2015, an increasing number of sweet chestnut stands in England have been found to be infected by *Phytophthora ramorum*, which is causing canopy dieback and decline. Prior to this point the disease was only known to infect sweet chestnut where individual trees were exposed to heavy inoculum pressure (due to proximity to other infected plant species). While

59 Importance icons: 1 and 2. Forestry Commission, Forestry Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf), 3. Forestry Commission, NFI preliminary estimates of quantities of broadleaved species in British woodlands, with special focus on ash (https://www.forestry.gov.uk/pdf/NFI_Prelim_BL_Ash_Estimates.pdf/$file/NFI_Prelim_BL_Ash_Estimates.pdf) 4. Parsons, Mark S.; Greatorex-Davies, Nick. 2006 The value of Sweet Chestnut *Castanea sativa* as a foodplant for *Lepidoptera*. Entomologist's Record and Journal of Variation, 118. 1-11.5. (nora.nerc.ac.uk/id/eprint/432/) 5. Defra – unpublished estimate. The social and environmental value of forest/woodland sweet chestnut in Great Britain is estimated by apportioning sweet chestnut forest/woodland proportion of an overall £3.9bn estimated annual value of forestry/woodland (see Annex 1), reflecting recreation, landscape, carbon sequestration, air pollution absorption and elements of biodiversity value. This estimate of value will exclude many important aspects that cannot easily be monetised (including water quality/availability, noise, flood and heat reduction, physical and mental wellbeing, and cultural, symbolic education benefits). The species percentages of overall GB stocks were calculated using Forestry Commission Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf) (Tables 1.8 and 1.9). Please note: individual species level detail on value are not available therefore these figures are broad estimations based on a number of assumptions.

cases of P. *ramorum* infection of sweet chestnut have been limited, the disease has now been found to 'cycle' from sweet chestnut tree to sweet chestnut tree, so the role that this host is playing in the epidemiology of this disease has changed.

Finally, *Dryocosmus kuriphilus*, an insect pest known as Oriental Chestnut Gall Wasp, attacks all species of *Castanea* and was found in England in 2015. Heavy infestations can cause a reduction in tree vigour, timber mass and fruit production. *Dryocosmus kuriphilus* population levels are increasing in extent and prevalence in the London area.

Priority actions

We aim to manage the cumulative pest and disease pressure on sweet chestnut by:

Resistance	• Continuous review of the risk to sweet chestnut, through the Plant Health Risk Group and implementation of further measures as appropriate. • Import requirements for sweet chestnut, so only plants from approved pest free areas can enter the UK. • Pre-notification of imports of sweet chestnut trees to target high risk consignments for inspection. • Working with industry and others to raise awareness, encourage the responsible sourcing of plants and adoption of enhanced biosecurity measures.
Response & Recovery	• A national management programme to remove *P. ramorum* infection and slow the spread and minimise impacts. • Site specific management plans for Sweet Chestnut Blight, to eradicate or contain the disease. • Grant support for restocking after the removal of sweet chestnut under a statutory notice for Sweet Chestnut Blight or *P. ramorum*. • Extensive aerial and ground based surveillance of sweet chestnut to facilitate early detection and understand spread of priority pests and diseases.
Adaptation	• Research to investigate the use of a naturally occurring biological control, (hypovirulence) to reduce the severity of Sweet Chestnut Blight. • Investigate the release of a non-native biological control agent, *Torymus sinensis*, to reduce the levels of Oriental Chestnut Gall Wasp.

Case Study 4 – Larch

Importance[60]

10%
of Britain's coniferous woodland is larch[2]

126k ha
of coniferous woodland in Great Britain is larch[1]

17
Insect species are supported by larch trees[3]

£185m
per/year estimated social/environmental value of larch[4]

£216m
estimated value of larch to woodland owners over the period 2017-2021[5]

Outline of threat

Phytophthora ramorum is a fungal-like pathogen that can cause disease in UK woodlands, heathlands, nurseries, gardens and parks. Despite the wide host range, *P. ramorum* reproduces most effectively on larch and rhododendron, and spread from these hosts causes collateral impacts on nearby plants and trees. Management approaches include the felling and removal of infected material or herbicide stem injections, all aimed at the rapid removal of hosts which would otherwise produce many infected spores. The discovery of the disease in larch trees in England in 2009, was the first time it had been found causing lethal infection on a commercially important conifer species anywhere in the world and it has since killed millions of larch trees in the UK. Infection in larch was found in Wales and Northern Ireland in 2010, and western Scotland in 2011. Spread by spores moving in atmospheric moisture (rain and mist), but the pathogen can also be moved over long distances in soil (for example, attached to vehicles) or infected plants. A major government programme has been in place since 2009 to manage *P. ramorum*.

60 Importance icons: 1 and 2. (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf) Forestry Commission, Forestry Statistics 2017, 3. Southwood, T.R.E. (1961) The numbers of species of insect associated with various trees. J. Animal Ecology 30: 1-8 Rose F. and Harding, P.T. (1978) Pasture and woodlands in Lowland Britain and their importance for the conservation of the epiphytes and invertebrates associated with old trees. Nature Conservancy Council & The Institute of Terrestrial Ecology. 4. Defra – unpublished estimate. The social and environmental value of forest/woodland larch in Great Britain is estimated by apportioning larch forest/woodland proportion of an overall £3.9bn estimated annual value of forestry/woodland (see Annex 1), reflecting recreation, landscape, carbon sequestration, air pollution absorption and elements of biodiversity value. This estimate of value will exclude many important aspects that cannot easily be monetised (including water quality/availability, noise, flood and heat reduction, physical and mental wellbeing, and cultural, symbolic education benefits). The species percentages of overall GB stocks were calculated using Forestry Commission Statistics 2017 (https://www.forestry.gov.uk/pdf/Ch1_Woodland_FS2017.pdf/$FILE/Ch1_Woodland_FS2017.pdf) (Tables 1.8 and 1.9). Please note: individual species level detail on value are not available therefore these figures are broad estimations based on a number of assumptions. 5. Forestry Commission: Unpublished. Based on an estimated 1.75 million cubic metres of larch available for felling annually in the period 2017-2021 in Great Britain. Note that the market value of structural grade timber, cladding, decking, flooring, fencing and joinery products made from larch is far higher and supports many jobs along the supply chain.

Priority actions

We aim to slow the spread and reduce the impact of P. ramorum by:

Resistance	• Continuous review of the risk situation, through the Plant Health Risk Group, and implementation of further measures as appropriate. • Maintaining import and movement requirements on known *Phytophthora* hosts to reduce the risk of it being moved in the horticultural trade. • Regulate the movement and processing of larch infected with *P. ramorum*, to prevent the spread through timber. • Continue to raise awareness, provide best practice guidance and training to the nursery trade and managers on biosecurity and management actions to limit the spread of *Phytophthora*.
Response & Recovery	• A national management programme to remove infection and slow the spread and minimise impacts. • Extensive aerial and ground based surveillance programmes in the wider environment, nurseries and ornamental and heritage gardens, to ensure timely action. • Working with the timber industry to monitor woodlands for the presence of *P. ramorum*. • Grant support to remove immature larch trees and rhododendron, and to restock sites following compliance with a Statutory Plant Health Notice.
Adaptation	• Encourage the planting of a range of alternative replacement tree species. • Investing in research to understand the pathogen's behaviour.

Case Study 5 – *Xylella fastidiosa*

Importance[61]

3
EU countries have detected xylella in the wider environment; Italy, France and Spain[1]

200+
species of plants currently known to be susceptible to Xylella[2]

$100m
annual cost of Xylella to the Californian grape industry[3]

Outline of threat

Xylella fastidiosa is a bacterial plant pathogen that is not present in the UK, but poses a threat to many of our plants and trees, including broadleaved trees such as oak, plane and sycamore, as well as popular garden plants such as *Polygala myrtifolia*, lavender, rosemary and oleander. In the environment, the bacteria is transmitted by insects such as leafhoppers and froghoppers and invades the water transporting xylem vessels in plants, blocking water movement and causing symptoms that resemble water stress such as wilts, growth stunts, diebacks and leaf scorches. As the damage expands throughout the canopy it may eventually bring about the death of the tree or shrub. *Xylella* exists as several distinct subspecies which between them can affect over 200 different host plants. The subspecies, *X. fastidiosa* subsp. *multiplex*, is particularly concerning as it has already been found to thrive in cooler climates similar to those of the UK, infecting broad-leaved trees in northern USA. Some plants which become infected by *Xylella* do not develop symptoms, but remain an infection source for other plants, which can make *Xylella* extremely difficult to detect and to manage. *Xylella* became notorious in Europe following reports of the rapid decline and death of ancient olive trees in southern Italy in 2013. Now around 1 million trees are affected in this region and subsequent outbreaks in Europe have been found in France (2015), Germany (2016), the Balearics (2016) and mainland Spain (2017). The most recent figures from Europe suggest around 150 tree and shrub species have been infected, leading to significant environmental and commercial impacts. The most likely pathway of entry in to the UK would be through infected plants imported as plants for planting and strengthened movement controls are in place.

61 Importance icons: 1. European Commission Factsheet (https://ec.europa.eu/food/sites/food/files/plant/docs/ph_biosec_xylella_factsheet_en.pdf), 2. Commission Implementing Decision (EU) 2015/789 of 18 May 2015 (eur-lex.europa.eu/legal-content/EN/TXT/?qid=1520248588045&uri=CELEX:02015D0789-20171216), 3. Economic impacts of *Xylella fastidiosa* on the Australian wine grape and wine-making industries, Australian Bureau of Agriculture and Resource Economics and Sciences (https://data.gov.au/dataset/impacts-of-xylella-fastidiosa-on-australian-wine-grape-industries)

Priority actions

We aim to protect our nation's trees from the impacts of *Xylella* by:

Resistance	• Robust legislative protections, including continued movement requirements on high risk hosts such as *Polygala myrtifolia*, lavender, rosemary and *Prunus spp*. • Pre-notification requirements for imports of high risk hosts from the EU and targeted inspections of high risk consignments. • Continuous review of the risk situation, through the Plant Health Risk Group, and implementation of further measures as appropriate. • Strengthened leadership in the form of a *Xylella* Preparedness Board, chaired by the Chief Plant Health Officer, to strengthen protections and ensure that a swift and effective response should the disease enter the UK. • Working with industry and others to raise awareness, encourage the responsible sourcing of plants and adoption of enhanced biosecurity measures.
Response & Recovery	• Develop new tools and methodologies to increase diagnostic capability and capacity. • Publication of a comprehensive *Xylella* specific contingency plan. • Targeted wider environment surveillance to facilitate early detection.
Adaptation	• Participate in trans-national research projects focussed on preventing, managing and adapting to *Xylella*.