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Chalara in Ash Trees: A framework for assessing ecosystem impacts and appraising options

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Executive Summary

Purpose

This is an analytical discussion paper that has been produced by Defra's Plant Health Evidence and Analysis team. It develops a possible framework for assessing the economic, environmental and social risks and impacts of Chalara. Such a framework could be used for assessing the effects and value for money of the options set out in the Interim Control Plan and subsequently the Chalara Management Plan. This paper was developed in parallel with the Chalara Management Plan and key evidence synthesised here informed the development of the Management Plan. However, it is not intended to provide a detailed policy appraisal, but rather to highlight the values at stake and to identify some of the analytical issues raised in appraising and developing response options. It also offers a broader framework for assessing other potential tree and plant diseases which can be developed in response to the work of the Tree Health and Plant Biosecurity Expert Taskforce.

Background

Chalara dieback of ash is a disease of ash trees caused by the fungus *Chalara fraxinea*. The incursion of Chalara into Great Britain poses a threat to ash trees. The disease causes leaf loss and crown dieback in affected trees and usually leads to tree death, although it is likely to take mature ash trees many years to succumb to the disease.

The nature and anticipated spread of Chalara has implications for the environment, society and the economy. The Government has outlined its approach to managing the disease in the Chalara Management Plan. This recognises the wide range of potential values at stake, and the importance of taking a proportionate approach to managing the disease in a cost-effective way, particularly in view of our evolving scientific understanding of the disease and its impact.

This paper helps to provide a framework in which optimal policy design can be developed, that considers both the additional economic, environmental and social benefits alongside any additional costs. By employing a framework that assesses the additional costs and benefits of alternative future policy options, to the extent such information can be quantified or described qualitatively, this can help inform decisions about which options safeguard the most benefit within a defined budget. The framework presented here explores and quantifies the benefits safeguarded for two scenarios, alongside a qualitative discussion of costs (presented in Section 2.7).

Method

Overview

The quantification and valuation assessments within this paper draw upon a variety of existing frameworks and data sources. Confidence ratings are used to indicate the reliability of the data sources used.

The paper describes a structured approach, using a series of logical and transparent steps to arrive at estimates of the value of the economic, environmental and social benefits delivered by ash trees and, therefore, the total values that would be at stake under a theoretical scenario of uncontrolled spread.

It illustrates the value of social and environmental benefits of reduced losses under certain scenarios of spread: removal of some trees and the slowing of the spread by two years.

Step 1 – Physical data on trees, woodlands and ash

This step brought together data on the extent, number and spatial distribution of trees and woodlands in the UK. It considered the composition of these woodlands to recognise the specific contribution from ash trees.

Step 2 – Commercial value of ash

The ash supply chain is complex but estimates were made of the total value of ash to the economy.

Step 3 – Identifying the value of social and environmental benefits delivered by woodlands

The ecosystems services approach provides a framework for categorising and valuing the wider social and environmental benefits delivered by woodlands and ash trees specifically.

This approach identified use and non-use values to society from provisioning, regulating and cultural ecosystems services which include biodiversity, landscapes and recreation.

Step 4 - Values for the societal use and non-use benefits of all woodlands

Unit values for the different societal benefits were applied to the area data to give an estimate of the total value of the social and environmental benefits from all woodlands. This was necessarily based on specific studies with known limitations. The values were based on willingness to pay for marginal changes in environmental goods and services and should therefore only be used to value marginal level change.

It is important to acknowledge that there are also significant indirect non-use benefits that are not quantified, for example, changes in public attitude to woodlands.

Step 5 – Estimating the proportion of total benefits attributable to ash trees

The method presented for estimating the proportion of the total benefits that can be attributed specifically to ash trees was kept simple and transparent out of necessity and was based on the proportion of ash by area compared to the total area of woodland. It used a proportion weighted by area at a country (England, Scotland, Wales) level.

However, it is important to acknowledge that these aggregations are a simplification and do not reflect spatial and distributional issues. Woodlands and their species composition are spatially heterogeneous. As a result, the value of ash in delivering certain ecosystems services will vary significantly across the country. Finally, the value of societal benefits depends directly on population distribution and therefore woodlands and ash trees close to large population centres will have higher use-values than more remotely located woodlands.

Step 6 – Valuing the loss of benefits under scenarios of disease spread

The spread of Chalara was forecast as part of a modelling project led by a team from the University of Cambridge. The model predicted a sinusoidal (s-shaped) curve reflecting the accelerating rate of spread in the earlier stages followed by a slowing down in the latter stages. This curve takes into account the spatial variation of the presence of ash within the country which in turn influences the rate of spread.

Step 7 – Valuing the benefits captured by delaying the spread

Two hypothetical scenarios were considered to illustrate the scale of benefits possible through delaying the spread. The first was based on the removal of a percentage of infected trees and thus reducing the number of sites acting as initial sources of infection. The second scenario is based on there being an intervention which would slow the spread of Chalara by delaying any initial spread for a period of two years.

Results Summary

Step	Description	Result
1	Physical data on trees, woodlands and ash (‘000 ha)	All woodland: 2,634 Broadleaved: 1,277 Ash: 142 % Ash: 5.4
2	Commercial value of ash (per annum)	£22 m
3	Identifying and classifying the value of social and environmental benefits delivered by woodlands	• Ecosystems services • Biodiversity • Use and non-use values • Non-monetised values
4	Total value of the societal use and non-use benefits of all woodlands (per annum)	£1.8 billion
5	Total value social and environmental benefits attributable to ash trees (per annum)	£150 m
6	Value of social and environmental benefits lost due to disease spread:	

	Net present value over 20 years (loss in £m) Annualised values	£347m – £763m £17.3m – £38.2m
7	Scenario 1: Value of benefits retained by the removal of trees (net present value over 20 years (£m)) Scenario 2: Value of benefits retained by delaying the spread by two years (net present value over 20 years (£m))	£42m –£93m £67m – £148m

Conclusions

Allowing for the relatively high levels of uncertainty, the values of the socio-economic benefits lost as a result of Chalara are significant. The social and environmental losses are several times higher than the commercial value of ash to the economy.

The benefits from reducing or slowing spread of the disease will be longer term, whereas the costs associated with attempting to slow Chalara are likely to be shorter term.

High-level benefit-cost analysis does not provide a single “answer”, but helps to inform decision-making under uncertainty. This quantitative approach could be backed-up by use of a qualitative approach such as multi-criteria analysis. It is important not to ignore costs and risks which cannot easily be monetised.

Background

Purpose of this paper

This is an analytical discussion paper that has been produced by Defra's Plant Health Evidence and Analysis team. It develops a possible framework for assessing the economic, environmental and social risks and impacts of Chalara. Such a framework could be used for assessing the effects and value for money of the options set out in the Interim Control Plan and subsequently the Chalara Management Plan. This paper was developed in parallel with the Chalara Management Plan and key evidence synthesised here informed the development of the Management Plan. However, it is not intended to provide a detailed policy appraisal, but rather to highlight the values at stake and to identify some of the analytical issues raised in appraising and developing response options. It also offers a broader framework for assessing other potential tree and plant diseases which can be developed in response to the work of the Tree Health and Plant Biosecurity Expert Taskforce.

The assessment draws upon a variety of existing sources of evidence including:

- scientific evidence on the potential spread;
- evidence from stakeholders and experts on commercial and environmental impacts;
- woodland data collected within the National Forest Inventory and other sources; and
- valuation evidence of the ecosystems benefits of woodland.

Confidence ratings for the evidence (see Annex 1) are indicated throughout the text.

This paper helps to provide a framework in which optimal policy design can be developed, that considers both the additional economic, environmental and social benefits alongside any additional costs. By employing a framework that assesses the additional costs and benefits of alternative future policy options, to the extent such information can be quantified or described qualitatively, this can help inform decisions about which options safeguard the most benefit within a defined budget. The framework presented here explores and quantifies the benefits safeguarded for two scenarios, alongside a qualitative discussion of costs (presented in Section 2.7).

Geographical Scope

Most of the evidence and analysis relates to Great Britain, but some evidence is England only. A separate assessment has been carried out for Scotland[1].

[1] http://www.forestry.gov.uk/pdf/WorrellReport-ChalaraImpacts.pdf/$FILE/WorrellReport-ChalaraImpacts.pdf

Rationale and objectives for a response to the outbreak

Chalara fraxinea

Chalara dieback of ash is a disease of ash trees caused by a fungus called *Chalara fraxinea (C. fraxinea),* including its sexual stage, *Hymenoscyphus pseudoalbidus (H. pseudoalbidus).* The disease causes leaf loss and crown dieback in affected trees and usually leads to their eventual death, although it is likely to take mature ash trees many years to succumb to the disease. It was discovered for the first time in Great Britain in a nursery in Buckinghamshire in February 2012. In October 2012, it was also discovered in the wider environment in woodland in Norfolk.

Rationale for Government Intervention

The nature and anticipated spread of Chalara has implications for the environment, society and the economy. The case for Government intervention is based on:

- Disease investigation and protection has public good characteristics, i.e. it benefits society at large. Government can regulate tree and plant movements where necessary and also has a role in convening various interested parties together and facilitating action to report, manage and adapt to the disease. It is unlikely that any of this will be currently achieved through the actions of private individuals or business interests.
- The benefits of healthy woodlands and trees have other public good characteristics which go beyond the incentives for private tree owners and managers. This is the case due to the widely-recognised amenity, biodiversity and recreational and cultural values attached to woodlands[2]. There are strong shared social values associated with trees and there is growing recognition of trees as an important component of "natural capital", a set of assets from which society and economy derives a wide range of benefits. This importance has long been recognised in landscape protection through land-use planning controls for example as well as in tree preservation controls.
- Provision of authoritative and effective advice to enable tree owners and managers to manage and adapt to the disease effectively and efficiently.

The Government's Chalara Management Plan sets out science-based and proportionate action that will be taken in order to minimise the impact of the disease on the environment, economy and society. Its four objectives are:

- Objective 1 – Reducing the rate of spread
- Objective 2 – Developing resistance to the disease in the ash population

[2] UK National Ecosystem Assessment, 2011 http://uknea.unep-wcmc.org/

- Objective 3 – encouraging citizen, landowner and industry engagement in surveillance, monitoring and action in tackling the problem

- Objective 4 – building resilience in woodland and associated industries

Therefore, the Government's approach to managing the disease recognises the wide range of potential values at stake, and the importance of taking a proportionate approach to managing the disease in a cost-effective way, particularly in view of substantial scientific uncertainty.

Section 1 – Framework for valuing ash and best estimates based on current data

1.1 Extent of ash and ecosystems services delivered

This section sets out a range of evidence relating to the commercial, social and environmental values provided by ash trees and woodland. The analysis uses existing frameworks and data sources rather than carrying out any primary research. It adopts the ecosystem services approach to ensure the full ranges of benefits are covered.

1.1.1 Areas and numbers of ash trees

Table 1 - **Areas of Ash in Great Britain** ('000 ha unless otherwise stated)

Country	England	Wales	Scotland	Great Britain
Woodland areas greater than 0.5 ha *Forestry Commission - National Forest Inventory 2012*[a]				
Total area of woodland	1,206	257	1,171	2,634
Area of broadleaved woodland	886	126	265	1,277
Area of ash woodland	110	18	14	142
Area ash as % of total	9.2%	6.8%	1.2%	5.4%
Area ash as % of broadleaved	12.5%	13.9%	5.1%	11.1%
Total number of woodland ash trees (million)	98.7	16.5	10.7	125.9
Woodland areas less than 0.5 ha *Centre for Ecology and Hydrology - Countryside Survey 2007*[b]				
Area of ash woodland	32.1	2.0	4.4	38.5
Total number of non woodland ash trees (million)	1.8	0.2	0.1	2.2
Total length of woody linear features (hedgerows lines and belts of trees) composed of ash ('000 km)	86.1	9.1	3.7	98.9
Total area of all woodland ash (CR Medium)	143	20	18	180

a (CR High) Forestry Commission figures are derived from the National Forest Inventory. This covers Forestry commission and private sector woodland, with a minimum area of 0.5 hectares and minimum width of 20 metres. Figures relate to the actual stocked area. This is a combination of net area for private woodland, which is the area actually covered by the trees (around 98% of the area shown), and gross area for Forestry commission woodland which includes small open spaces within the forest boundary such as ponds, rides and glades.
These figures are presented in the stats release at:-
http://www.forestry.gov.uk/pdf/NFI_Prelim_BL_Ash_Estimates.pdf/$FILE/NFI_Prelim_BL_Ash_Estimates.pdf
b (CR Medium) Figures from the countryside survey relate to areas less than 0.5 hectares, and are based on the actual area of land cover. Estimates for number of non woodland ash trees includes those in small clumps less than the minimum that could be mapped unit of the countryside survey of 20m x 20m.
These figures are presented in the stats release at:-
http://www.cs2007.ceh.ac.uk/sites/default/files/pdfs/Distribution%20of%20Ash%20trees%20in%20CS_9thJan2013.pdf

Summary of key facts about woodlands and ash

- Forestry Commission estimate (for woodlands over 0.5 hectares in size) that **woodland ash trees**[3] **cover 141,600 hectares in Great Britain** (5.4% of total woodland) and 110,400 hectares in England (9.2% of total woodland).[4] (CR High)
- In addition, figures produced from Countryside Survey data by the Centre for Ecology and Hydrology estimate a further **38,500 hectares of ash in GB in woodland of less than 0.5 hectares** (32,100 in England), and around **2.2 million individual ash trees in GB** (1.8 million of which in England). (CR medium)
- The number of ash trees is estimated to be **98.7 million for England and 125.9 million for GB**. (CR High)
- Ash coverage is more prevalent in **southern England** (in particular, West Sussex, Hampshire and Hereford and Worcester). The highest percentage of ash in broadleaved woodland is in a belt through the **midlands** from Gloucestershire to Lincolnshire. (Forestry Commission, 2012). (CR high)
- 17% of veteran trees recorded in the Countryside Survey 2007 were ash.[5] (CR Medium)
- Ash is found in many different landscape contexts, in fields and field boundaries, alongside rivers and streams and particularly in hedgerows. Assessment of the Countryside Survey 2007 sample vegetation plot types can give an indication of its importance in different non-woodland components (see Table 2), and indicates that ash is particularly important as a component of hedgerows (30% of plots) and stream sides (13% of plots). (CR Medium).
- The geographic distribution, species composition of woodlands, proximity to human populations and other distribution issues play a key part in the contribution of ash to the environment and associated societal benefits. These are covered in detail in the valuation section.

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[3] According to the Forestry Commission, "Woodland is defined in UK forestry statistics as land under stands of trees with a canopy cover of at least 20% (25% in Northern Ireland), or having the potential to achieve this. The definition relates to land use, rather than land cover, so integral open space and felled areas that are awaiting restocking are included as woodland". Estimated areas of ash have been derived broadly to exclude other species.

[4] FC, December 2012: NFI preliminary estimates of quantities of broadleaved species in British woodlands, with special focus on ash (linked above).

[5] However, it should be noted that the Countryside survey collects data on up to 10 veteran trees per surveyed square with a maximum of two from each species, hence this percentage estimate might not be an absolute estimate.
CEH, January 2013: Distribution of Ash trees (*Fraxinus excelsior*) in Countryside Survey data (linked above).

Table 2 - Frequency and cover of ash trees within Countryside Survey 2007 vegetation plots in Great Britain

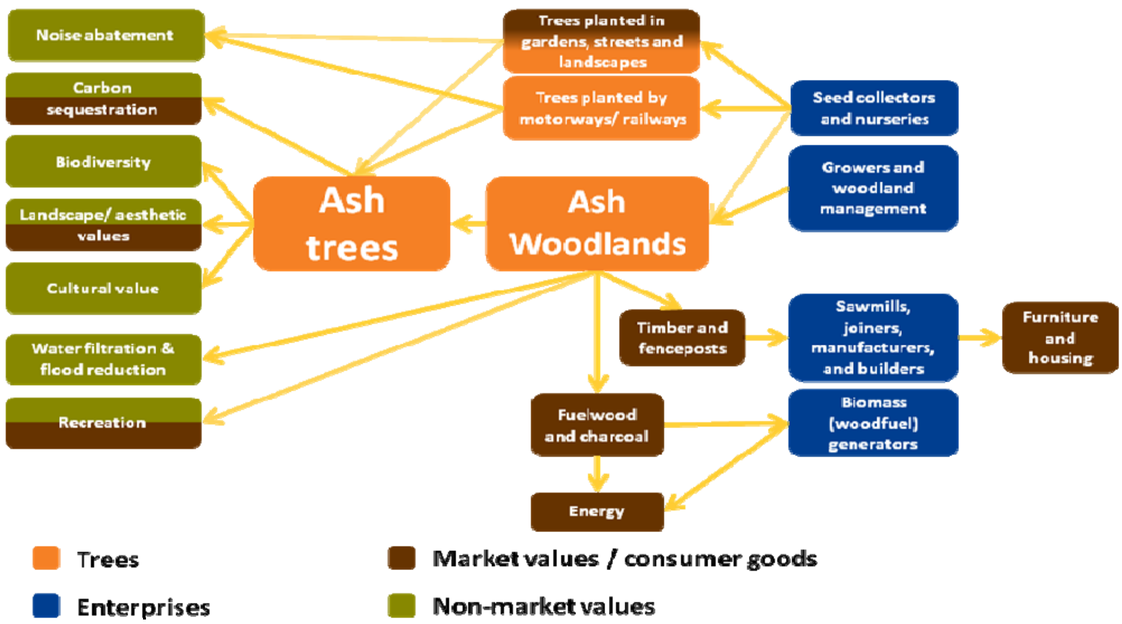
Plot types	Number of plots in which ash occurs	Percentage of total plots surveyed %	Mean cover of ash canopy within plots
Boundary	216	11	24
D (Hedge diversity plots)	720	30	18
H (Hedge plots)	121	20	21
M (Arable margins)	6	5	19
RV (Roadside)	211	10	20
SW (Streamside)	313	13	25
X (Field plots)	139	5	16
Y (Small habitat patches)	257	10	31

1.1.2 The significance of ash to the economy, environment and society

Ash trees represent a valuable commodity to the economy, deliver environmental benefits and contribute to societal well-being.

Their uses and values are summarised in Figure 1

Figure 1 – The Uses and Values of Ash Trees



1.1.3 The commercial role of ash

Estimating the commercial value of ash is difficult because there are no direct official figures and the supply chain is complex. Overall, forestry figures say little about how much is dependent upon ash particularly. For instance, in 2004, the last year for which species specific data is available, ash accounted for 8% of all hardwood going to UK sawmills: approximately 10,000 green tonnes. However, this represented only 0.13% of the total volume of wood sawn in 2011. (CR high)[6]

- Of 2.634 million hectares of forest land 5.4% comprises ash (CR High) and, according to FC estimates, 70-80% of ash woodland is not actively managed for timber (CR medium).
- Ash is estimated to be 15% of the standing UK hardwood resource stock, which is estimated to be equivalent to 22 million tonnes. (Confor, CR medium).
- Total hardwood harvest/production in 2011 was 541,000 green tonnes of which: (CR Medium unless otherwise stated)
    - Sawmills: 81,000 tonnes, of which around 8% is ash (CR low – this % based on species data from the 2004 Sawmill Survey, Forestry Commission). This represents less than 0.2% of total sawmill input (i.e. including softwood).
    - Fuel wood: 400,000
    - Other: 60,000 (mainly fencing, some charcoal)

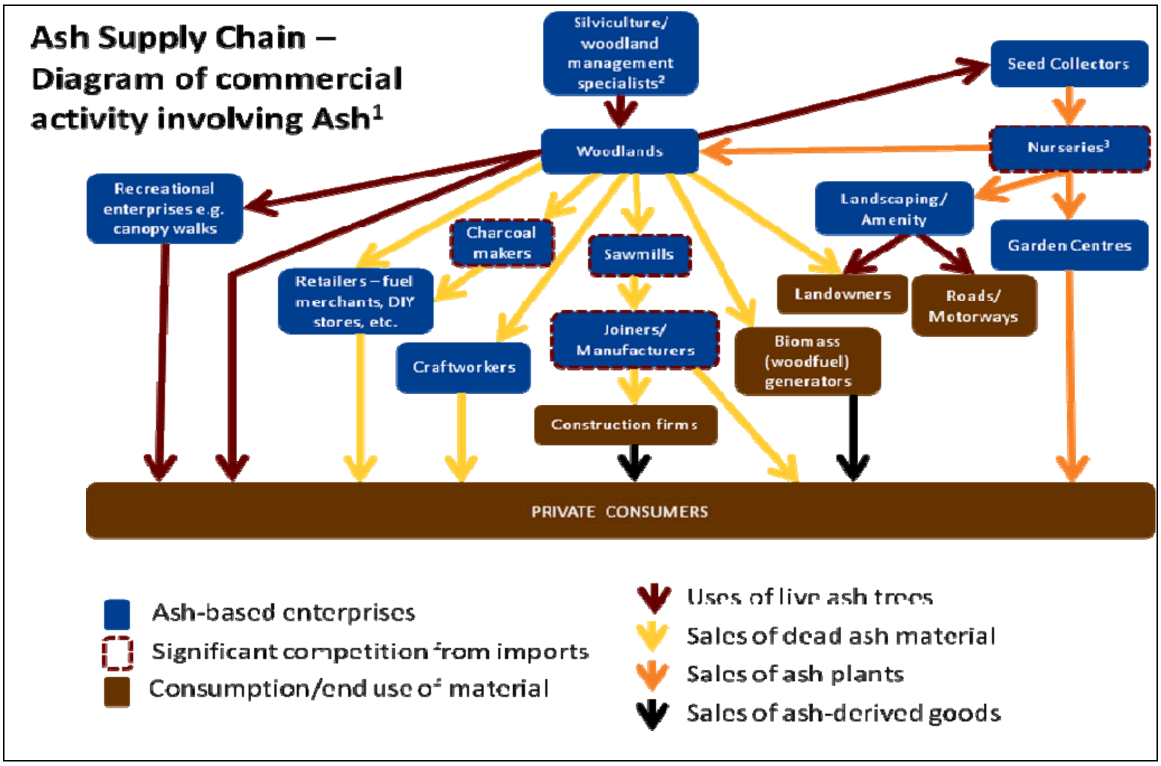
    (Forestry Commission, 2011 Sawmill Survey; CR medium)
- Ash has always been the hardwood most prized for firewood, as it burns readily when green (CR medium).

The total UK forestry and logging sector, including support services, directly employed around 14,000 people in 2010, in more than 3,000 separate enterprises. Gross Value Added (the standard measure of economic activity) for this sector was £385 million in 2011 and GVA for sawmilling £433m. (CR high)[7]

Figure 2 attempts to sketch a picture of the various commercial activities, uses and services related to ash trees, wood and woodlands generally. A first approximation based on the probable shares of ash in each sector suggests a provisional estimate of annual **Gross Value Added of the ash component of tree-related activity (nurseries, timber, firewood) of £22m**. (CR medium).

[6] Forestry Commission Sawmill Survey, 2004 http://www.forestry.gov.uk/forestry/infd-94pgy5
[7] ONS, Annual Business Survey, 2012 http://www.ons.gov.uk/ons/rel/abs/annual-business-survey/2011-provisional-results/index.html

Figure 2 – The Ash Supply Chain



[1] I.e. activities involving transactions with or between private enterprises based on Ash material
[2] This sector includes loggers.
[3] The nursery sector can be sub-divided into wholesalers growing from seed in the UK, wholesalers growing from imported saplings, and retail nurseries who may compete with garden centres.

Key features of the ash supply chain are:

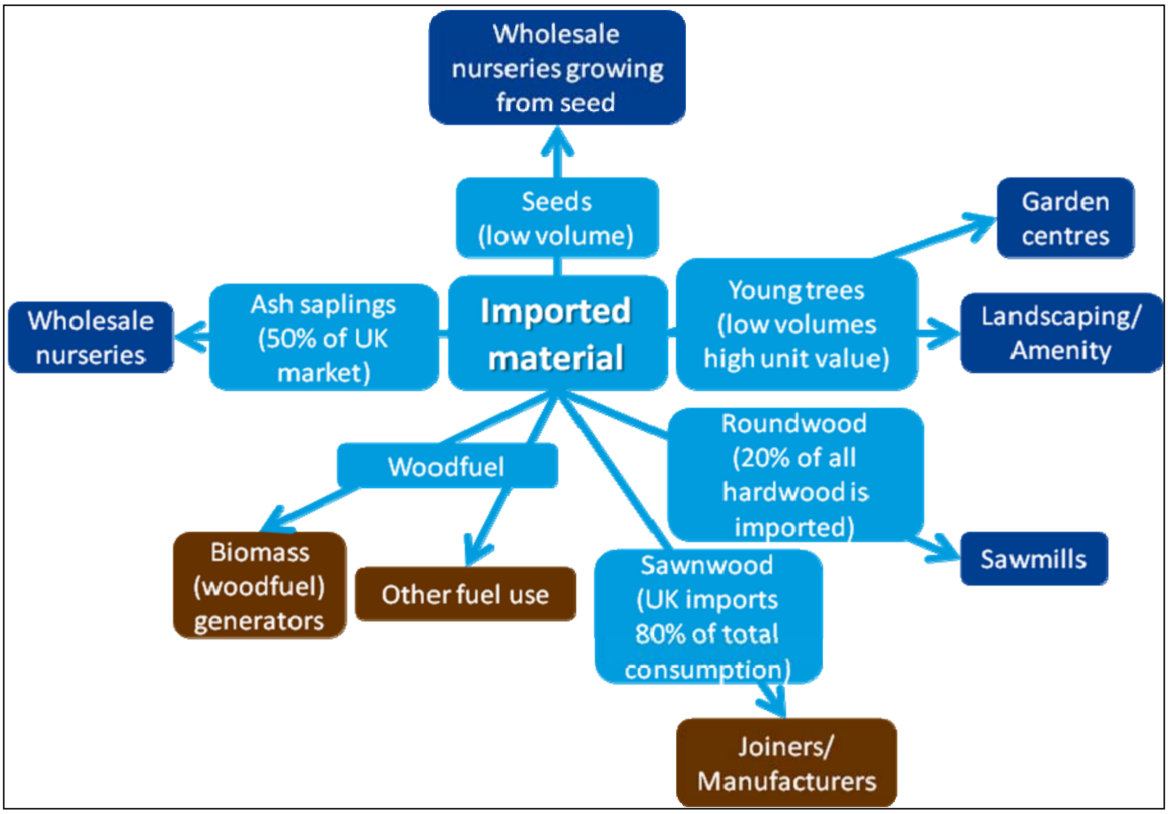
- Only 20-30% of standing ash woodland is commercially managed for timber, representing 1-2% of total UK woodland. (Forestry Commission, CR medium).
- There are estimated to be 60-80 enterprises in the nursery sector dealing in ash (Horticultural Trade Association; CR medium).
- This current stock of ash trees held by these nurseries has an estimated total value (in previous prices) of £2 - 2.5 million (source: Horticultural Trade Association survey; CR low). The majority of this stock, by volume, is 1-2 year seedlings (CR medium)

The role of **imports** is clearly important in various stages of the supply chain, as Figure 3 shows. In particular:

- Approximately half of ash saplings and young trees planted commercially in the UK are imported: on average approx. 580,000 plants p.a. (the vast majority of which are saplings), although figures vary considerably year-on-year (source: Forestry Commission, Forest Reproductive Materials database; CR medium). On the other hand, a recent survey of nurseries by the HTA estimated around 1.5 million ash trees are imported annually (CR medium)

- Between 2008 and 2011, the UK imported 15,000-20,000m^3 of ash sawn wood and exported 500m^3 (HMRC; CR medium)
- Overall, the total commercial value of ash trees and its wood products represents a relatively small part of the UK economy.

Figure 3 - Flowchart of commercial ash



The proportions above are calculated from Forestry Commission data and carry a medium confidence rating

1.1.4 The wider value of ash: an ecosystem services framework

Studies such as the **UK National Ecosystem Assessment** (NEA) present an ecosystems approach to assessing the wide range of benefits we derive from nature. The NEA considers woodland as one of eight “broad habitats” which provide many “services”, many or all of which apply to ash trees. This section describes these using the standard classifications of “provisioning”, “regulating”, “cultural services” and “supporting services” which underpin the other services. Not all benefits can easily be assigned to a single category, but broadly speaking, these include market values and non-market values such as environmental goods and services and societal benefits.

There are also less direct benefits to society that can be difficult to quantify and value.

a) Provisioning services

These are closely related to the commercial role of primary production of ash which has been covered above.

b) Regulating services

As with some of the other services, the benefits of ash may not be unique given that they can be provided or substituted by other species over time.

> Forestry Commission estimate that ash trees in GB sequester between 0.7-1.0m tonnes of CO_2 per year, valued **at £41-58m per year** using the DECC central non-traded carbon value for 2012 (CR Medium). This range gives a central estimate of **£49m per year**.

- Forestry Commission estimate the carbon stock for ash is approximately 52-78 MtCO2e (CR Medium). Any carbon loss from this stock after infection is expected to be very slow.
- There is good evidence for the role of urban trees and woods in contributing to air quality, shading, wind control, pollution reduction, noise absorption, abatement, water quality and flood alleviation. For example:
    - Belts of trees between residences and transport routes can absorb sound[8]. (CR High)
    - Belts of trees and shrubs can be effective at reducing noise pollution — a 33 m-wide tree buffer may reduce noise levels by 6-8 dB[9]. (CR High)
    - Forests can dampen temperatures in the soil and beneath the canopy, and in providing shade and shelter for animals and human visitors. Woodland cover can provide shade, reducing overheating and the need for air conditioning, and shelter from strong winds, reducing heat loss and soil erosion[10]. (CR High)
    - The benefits of absorbing air pollution by all trees have been estimated by FC[11] at around £0.5m p.a. (2012 prices), but the limited nature of the modelling meant that this will be a significant underestimate. Based on the proportion of ash by area, this gives an estimate of the value for ash of £0.04m p.a. (CR Low)
    - Increasing temperatures will increase the shade and shelter value of trees in towns[12], and also for livestock in the country. Shading of streams can aid thermal regulation and fish survival[13]. (CR High)

[8] Huddart, L. (1990). The Use of Vegetation for Traffic Noise Screening. Research Report 238, Transport and Road Research Laboratory. Department of Transport. Berkshire, England.
[9] LEONARD, R. E. AND PARR, S. B. (1970). Woodland trees as a sound barrier. *Journal of Forestry* 68, 282-283.
[10] Gardiner, B., Palmer, H and Hislop, M, 2006. The Principles of Using Woods for Shelter, Available at: www.forestry.gov.uk/pdf/fcin081.pdf/$FILE/fcin081.pdf
[11] Willis, K. G., Garrod, G., Scarpa, R., Powe, N., Lovett, A., Bateman, I. J., Hanley, N. and Macmillan, D. C. (2003). The Social and Environmental Benefits of Forests in Great Britain. Report to Forestry Commission. Centre for Environmental Appraisal and Management, University of Newcastle upon Tyne.
[12] Handley, N. & Gill, S. (2009). Woodlands helping society to adapt in combating climate change - a role for UK forests. An assessment of the potential of the UK's trees and woodlands to mitigate and adapt to climate change (eds. Read, D.J., Freer-Smith, P.H., Morison, J.I.L., Hanley, N., West, C.C. and Snowdon, P).
[13] Quine, C.P., Cahalan, C., Hester, A., Humphrey, J., Kirby, K., Moffat, A. and Valatin, G. (2011) National Ecosystem Assessment – Woodlands chapter.

However, these services can be provided by many other species of tree if diseased ash is replaced.

c) Biodiversity[14]

Ash is a fundamental structural component of native broadleaved woodland and is widely distributed across the UK but is most frequent in southern England. Ash dominated woodlands, and other woods where ash is a component, support a very wide range of native biodiversity. The relatively open canopy is often associated with rich woodland ground flora.

Draft reviews of the potential implications of Chalara on biodiversity and conservation put the importance of ash into perspective.

Broome *et al.*[15] listed UK 'priority species' whose survival is highly dependent upon ash:

Lower plants (mosses, lichens and liverworts)

- 130 lower plants are associated with ash woodland in GB
- 60/130 use ash trees as a habitat; bark is the substrate
- 40 of the 60 species require old trees with rough bark
- <10 of the 60 species have alternatives such as rock
- 15 of the 60 have only 1 other host species listed for GB, mainly oak or hazel
- 45 of the 60 use more than 2 tree species
- 3 species only use ash trees which are mainly growing in the open

Invertebrates

- 6 species are specifically dependent upon ash
- 3 species are strongly associated with ash wood as a habitat but are not ash-dependent

Fungi

- 2 species are specifically associated with ash trees, one of which uses dead wood and so it can use other trees as a substrate

Vascular plants

- 20 vascular plants are associated with broadleaved woodlands; some orchids are dependent through mycorrhizal associations but ash is not key to this

Birds, mammals, herptiles (reptiles and amphibians)

- None are dependent on ash but some species use ash, e.g. bats using cavities for roosting

Kirby (2012)[16] provides details of ash distribution and woodland types as well as the organisms which are dependent on or associated with ash. Ash is important in many

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[14] Further discussion of the ecological significance of ash and the likely impacts on biodiversity of ash dieback disease can be found in: An assessment of the potential impacts of ash dieback in Scotland http://www.forestry.gov.uk/pdf/WorrellReport-ChalaraImpacts.pdf/$FILE/WorrellReport-ChalaraImpacts.pdf

[15] Broome A, Harmer R, Bailey S (2012, unpublished draft). Biodiversity and conservation implications of ash dieback. Forestry Commission and Forest Research internal report dated 22 November 2012. 7pp.

respects not least because it produces abundant seed and can establish under a wide range of conditions. Consequently, it has filled gaps left by tree losses incurred through major events (e.g. Dutch elm disease and the devastating storm which occurred in the autumn of 1987). Kirby reported that at least 536 species of lichen grow on ash trees along with a 'suite of bryophytes'. The mixed ash woods in northern and western Britain and non-woodland veteran trees are of particular importance in hosting lichens. At least 27 species of invertebrate were described as using ash as a sole food plant. These figures are significantly higher than quoted by Broome *et al*. However, both represent high diversity value for ash.

Key features of ash include:

- Ash is the second most common species of individual non-woodland tree (after oak) and the most frequent hedgerow tree species. This specifically refers to individual trees occurring within the hedgerow, not ash forming a regularly trimmed component of the managed hedgerow itself. (CR medium)
- A rapid analysis by Joint Nature Conservation Committee of the Database of Insect Food-plants (DBIF) lists 111 insect species that are partly or completely dependent on ash (this compares with 274 for oak, 197 for hawthorn and 251 for hazel. Of these 111, 27 of them appear to be completely dependent upon trees in the genus *Fraxinus* (24% only list *Fraxinus* as a food plant). (CR medium)
- The importance of ash trees in hedgerows, boundaries and field margins may have specific importance for bird species. To the extent that these formations exist predominantly in an agricultural landscape, these trees could be of particular importance for farmland birds which are in decline. Little is known about the significance of the role of the ash as host species for life forms other than birds and insects, but it appears that ash has become far more significant for lichens following the widespread loss of elms.

However, incomplete understanding of the distinctive role of the ash tree, below as well as above ground, makes it very difficult to assess its ecological contribution in the habitats within which it exists.

Economic welfare value estimates do exist for forest biodiversity, but not for ash specifically. Forestry Commission estimate the non-use value of biodiversity benefits provided by woodland in GB to be around **£490m p.a**. (2012 prices, using Willis *et al.* 2003).[17] Whilst this monetary value highlights the significance of biodiversity, there are significant uncertainties around the estimate in particular:

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[16] Kirby, K (2012). Potential conservation implications of ash dieback (Chalara fraxinea) in Britain. 15pp. http://dps.plants.ox.ac.uk/plants/Content/KeithKirby/PotentialConservationImplicationsOfAshDieback_11_16.pdf

[17] The 2003 study used a "tokens" exercise with 8 focus groups of 6-8 people in England, Scotland and Wales to establish willingness-to-pay (wtp) for marginal increases in 'biodiversity' through new planting or conservation of different types of woodland – conifer forest, ancient native (natural and semi-natural) broadleaf forest and new native broadleaf forest, in both uplands and lowlands. The willingness to pay measures generated were multiplied by the number of households in the country in which the group was held, to provide a total figure.

- The method used to divide woodland by type relied on several different data sources, resulting in a significant area of woodland (2.2. million hectares) being assigned no biodiversity value.
- The original estimates are almost a decade old, and though adjusted to current prices, would fail to reflect any change in public attitudes towards nature and conservation over the past decade.

Apportioning the total value by ash's share of GB woodland within each country provides a first approximation of the biodiversity benefits of ash, estimated at £43 m p.a. (CR low).

A linear approximation based on area may overstate the marginal biodiversity contribution of ash, for instance where the loss of low density ash in a mixed broadleaved woodland may have negligible impact on biodiversity other than a few specialist species. Further adaptation over time would help to mitigate the losses to biodiversity from ash tree death.

In conclusion, new work would be needed to produce a more reliable estimate of the non-market value of biodiversity net losses associated with a given loss of ash woodland.

d) Cultural services and other values

People engage with trees and woodland in many ways not only through visits but also via TV, computers, social media, books; memories; enjoying views from house, school, work, car; active 'hands on' engagement via volunteering. These different types of engagement include both "use values" (direct, indirect) and "non-use values" (existence, altruism, bequest) values.

(i) Use values

These include use of woodlands, and green spaces with trees, such as parks, paths, and the countryside. However, it is not clear to what extent these might be affected by the gradual loss of ash which forms just one component of woodland.

Recreation

In England **358 million visits** were made to woodlands in 2011[18] (CR High). A further 65 million visits were made in Scotland (based on Scottish Recreation Survey and 86 million in Wales (based on Welsh Outdoor Recreation Survey – CR medium)[19]

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[18] Natural England. 2011. Monitor of Engagement with the Natural Environment: The national survey on people and the natural environment - Annual Report from the 2011-12 survey (NECR094) http://publications.naturalengland.org.uk/file/1755933

[19]http://www.forestry.gov.uk/website/forstats2012.nsf/LUContents/3D8CC6BE52653C8C8025734E003B75BF The three different estimates are not directly comparable as they are based on different surveys with different methodologies.

55% of the adult population visit the natural environment at least once a week. Forestry Commission and the National Ecosystem Assessment estimate the economic welfare value of woodland recreation at **£500** million p.a. [20] (CR Medium).

A first approximation of the ash component of the value of woodland recreation is **£43m p.a**. (CR Low – see next section).

This approximation is likely to be particularly uncertain, because recreation values will vary with (a) woodland type and ash density (b) location – both proximity to population densities and availability of substitute sites.

Landscape and amenity

Various methods have been used to assess the positive effect of trees and woods on property prices in urban areas (referenced in Stewart and O'Brien, 2011).[21] The 2003 study for the Forestry Commission on the social and economic benefits of woodlands estimated the value of landscape benefits provided by urban fringe woodland using survey-based estimation methods to be **£190 m p.a**. in GB (2012 prices) (CR Medium).

A first area-based approximation of the Ash component of this is estimated at **£15m p.a.**

It should be noted that there may well be overlaps between property values and recreation values (see next section) (CR Low).

- In addition to monetised benefits, social research shows that the public and landowners assign a value to trees and their contribution to the UK landscape. For instance, the 42,000 responses to England's **Independent Panel on Forestry consultation** illustrate the value people place on being able to access and enjoy woodlands. (CR High)
- **Volunteering and community woodland groups** - 11% of people in the UK undertook some form of voluntary activity connected to woodlands in 2011. (Forestry Commission, 2011). Diverse woodland-related activities are delivered by a broad range of charities, public bodies, volunteer groups, social enterprises. There are approximately 700 community woodland groups in the UK. Woodland and

[20] The highest proportion of woodland users comes from those aged 45-64, ABC1 social class, ethnically white and in employment. Under-represented groups include those age 16-24, C2DE social class, Black and Minority ethnic groups and the disabled. Morris, J., O'Brien, E., Ambrose-Oji, B., Lawrence, A., Carter, C., Peace, A. (2011). *Access for all? Barriers to accessing woodlands and forests in Britain*. Local Environment, 16:4, 375-396. Some evidence suggests there are cultural attitudinal barriers for ethnic groups travelling outside of familiar urban areas, but which can be overcome by assisting large groups to access national parks and woodlands.

[21] In addition to actual views from properties, the pervasive virtual presence of tree types in the *naming* of suburban streets across the country is further historic evidence of their cultural and economic value.

woodland/non woodland based interventions such as this can help build a strong sense of belonging, improve social cohesion and enhance social capital.[22] (CR Medium)

- **Education and learning** - There are over 150 Forest Schools in Britain.[23] The Forest Education Initiative has been running in Britain for 20 years. In 2010, 80 groups operated in Britain with the aim of increasing understanding and awareness of the environmental, social and economic potential of trees and woodlands. (CR Low). However, it is not clear if any of these are in woodlands dominated by ash.
- Current research points to a wide range of **wellbeing benefits** that people can potentially derive from engaging with trees and woodland, including mental health benefits (part of which will be reflected in recreation values), connection with nature and landscape[24], and symbolic[25] and spiritual meaning, expression and reflection. Trees are important markers of time providing a link between the past and the future and offer a rich sensory 3-dimensional experience.[26] (CR Medium)

(ii) Other non-use values of trees and woodlands

- Trees and woods are an important part of **cultural identity and cultural heritage** in Britain, and these values can have significant influence on stakeholder behaviour. (CR High)
- Choice experiment studies of landscape features in both England and Scotland (e.g. Hanley *et al.,* 2007[27]; Colombo and Hanley, 2008[28]) consistently show that woodland is one of the most highly valued features of landscapes when measured using willingness to pay.
- **Heritage, ancient and champion trees** are those that are of importance biologically, aesthetically or culturally due to their age and are a legacy of some of Britain's most

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[22] Independent Panel on Forestry. 2012. Final report. http://www.defra.gov.uk/forestrypanel/files/Independent-Panel-on-Forestry-Final-Report1.pdf Stewart, A. and O'Brien, L. (2010). Inventory of social evidence and practical programmes relating to trees, woods and forests and urban/peri-urban regeneration, place-making and place-shaping. Forest Research, Edinburgh; Lawrence, A. and Molteno, S. (2012). Community forest governance: a rapid evidence review. Report by Forest Research on behalf of the Independent Panel on Forestry.

[23] Knight, S. (2009). Forest School and outdoor learning in the early years. Sage Publications, London.

[24] The size of trees is significant for providing complexity to a landscape, and a contrast to the urban environment (i.e street trees symbolising 'nature' in the city).

O'Brien, L. Morris, J and Stewart, A. (2012). Exploring relationships between peri-urban woodlands and people's health and well-being. Forest Research http://www.forestry.gov.uk/fr/INFD-8RPCTE

O'Brien, L (2004). A sort of magical place: people's experience of woodlands in northwest and southeast England. Forest Research, Farnham http://www.forestry.gov.uk/FR/INFD-5Z5CDR

Carter, C. Lawrence, A. Lovell, R and O'Brien, L. (2009). The Forestry Commission public forest estate in England: social use, value and expectations. Forest Research. http://www.forestry.gov.uk/fr/INFD-82LDHU

[25] O'Brien, L and Morris, J (in press) The social distribution of well-being benefits gained from trees and woodlands in Britain. Local Environment. Hanley N, Ready R, Colombo S, Watson F, Stewart M and Bergmann EA (2008) "The impacts of knowledge of the past on preferences for future landscape change" *Journal of Environmental Management,* Volume 90, Issue 3, March 2009, Pages 1404-1412. O'Brien, E. (2005) Public and woodlands in England: well-being, local identity, social learning, conflict and management. Forestry, 78(4), 321-336.

[26] Same reference as footnote above

[27] Hanley N., Sergio Colombo , Pamela Mason and Helen Johns (2007) The reform of support mechanisms for upland farming: paying for public goods in the Severely Disadvantaged Areas of England. *Journal of Agricultural Economics*, 58 (3), 433-453.

[28] Colombo S and Hanley, N. (2008). How can we reduce the errors from benefits transfer? An investigation using the Choice Experiment method. *Land Economics*, 84 (1), 128-147.

historic landscapes. Britain has more veteran trees than most countries in Europe and their conservation is considered internationally important. (CR Medium)

- Historically, the political and symbolic meaning of trees and woodlands can influence current attitudes to the ownership of and access to woodlands. (CR Medium)

1.1.5 Summary of valuation estimates of woodlands in GB

Trees and woodlands provide benefits that are economic, social, and environmental. Apart from carbon sequestration values, overall GB woodland figures for the non-market benefits of ash as noted above come from the 2003 study on social and environmental benefits commissioned by Forestry Commission and updated to current prices. The relevant values are summarised in Table 3.

Table 3 - Summary of estimates of the social and environmental benefits of woodland (GB)

Type of benefit	Annual value 2012 prices (£m)	% of GB benefits		
		E	S	W
Social Active Use: Recreation	500	90%	6%	4%
Social Passive Use: Landscape	191	82%	13%	5%
Social Non-use: Biodiversity	491	94%	5%	1%
Environmental: Carbon sequestration	614	-	-	-
Environmental: Air Pollution absorption	0.5	-	-	-
Total	£1.8 bn			

Source: Willis (2003) in 2012 prices
(CR medium)

In order to derive the first approximation of the value of ash regional ash proportions were applied to regional non-market benefit estimates (given in the 2003 study) and then aggregated up to GB (e.g. Ash in England accounts for 9.2% of all woodland, so this percentage is applied to the estimate of each non-market benefit for England). This makes better use of the original data (highlighting the importance of human population density to the recreational and landscape values).[29]

Table 4 summarises these ranges together with our estimate of the market value (Gross Value Added) of ash activities. (CR low)

[29] However, there may be some "double discounting" in the case of Scotland - which has a very low estimate - where the low proportion of ash (0.4%) may be partly already captured in the low proportion of overall woodland non-market benefits attributed to Scotland (where conifer woodlands, which have relatively lower amenity value than broadleaves, dominate).

Table 4 - UK aggregated values of ash

Type of benefit	Value (£m per annum)
Social Active Use: Recreation	43
Social Passive Use: Landscape	15
Social Non-use: Biodiversity	43
Environmental: Carbon sequestration	49
Environmental: Air Pollution absorption	0.04
Total social + environmental	150
Total commercial value	22

These social and environmental estimates are not only inherently uncertain but they also exclude some values for which monetised estimates are not currently available. They do, however, provide an indication of the scale of the benefits that can be useful in social cost-benefit analysis of the management of Chalara. They also demonstrate that the **social and environmental values are significantly greater than market values**.

This section has developed an aggregate estimate of the socio-economic values at stake and therefore the total annual costs to society under the **theoretical scenario** that, over many years, Chalara continues to spread and that all infected ash trees eventually die as a result. In practice however the total valuation estimates are based on valuing marginal changes and should only be used to estimate the values associated with marginal losses of ash trees. As the scale of loss increases from marginal levels to that of most or all ash trees, the monetised values significantly underestimate the true value as a result of the scarcity value of the few ash trees that remain.

1.1.6 Distribution of impacts and values at a sub-national level

The valuation estimates have necessarily been based on aggregated data on areas of woodlands, proportion of ash trees and values of environmental and societal benefits. However, it is important to acknowledge that these aggregations are a simplification and fail to reflect spatial and distributional issues. Woodlands and their species composition are spatially heterogeneous. As a result, the value of ash in delivering certain ecosystems services will vary significantly across the country. In a mixed woodland used for recreation, the loss of ash trees may have relatively little impact and substitution by other species could offset losses. By contrast, the loss of ash trees in an established hedgerow could result in complete loss of the hedgerow as a landscape feature, a valuable habitat and a source of habitat connectivity. Finally, the value of societal benefits depends directly on population distribution and therefore woodlands and ash trees close to large population centres will have higher use-values than more remotely located woodlands.

Even at a country level, England has a disproportionately high share of recreational and amenity benefits from GB's trees generally (based on the 2003 study) and a disproportionately high share of GB's ash trees.

Alongside the high spatial variation in the abundance of ash across the UK, there will also be extensive spatial variation in the total economic value (market and non-market) of ash woodland, since non-market values depend on the characteristics of the population and population density in areas where ash is found.

The non-uniform value of certain woodlands and ash trees is perhaps best illustrated by environmentally sensitive areas and other areas designated as having a high environmental value.

Ash locations can be considered to be ecologically important where ash is a significant and hard to replace or re-create semi-natural feature with a strong role in ecosystem functioning. These locations include:

- Special Areas of Conservation (SACs) where ash is a significant component of a habitat feature notified under the EU Habitats Directive.
- Sites of Special Scientific Interest (SSSIs) where ash is a significant component of the site including sites where it is a notified feature. According to JNCC, there are 665 SSSIs in England where ash forms a major species component. (CR medium)
- Ancient woodland (continuously wooded since at least 1600) where ash is a significant component.
- Veteran ash trees (trees in middle or late stages of life providing a diversity of habitat related to their structure and rot status) which can occur within woods but also in agricultural, park and urban landscapes where they provide connectivity.
- Ash supporting a high proportion of the species that exclusively depend on it as a host, substrate or food source.

More generally:

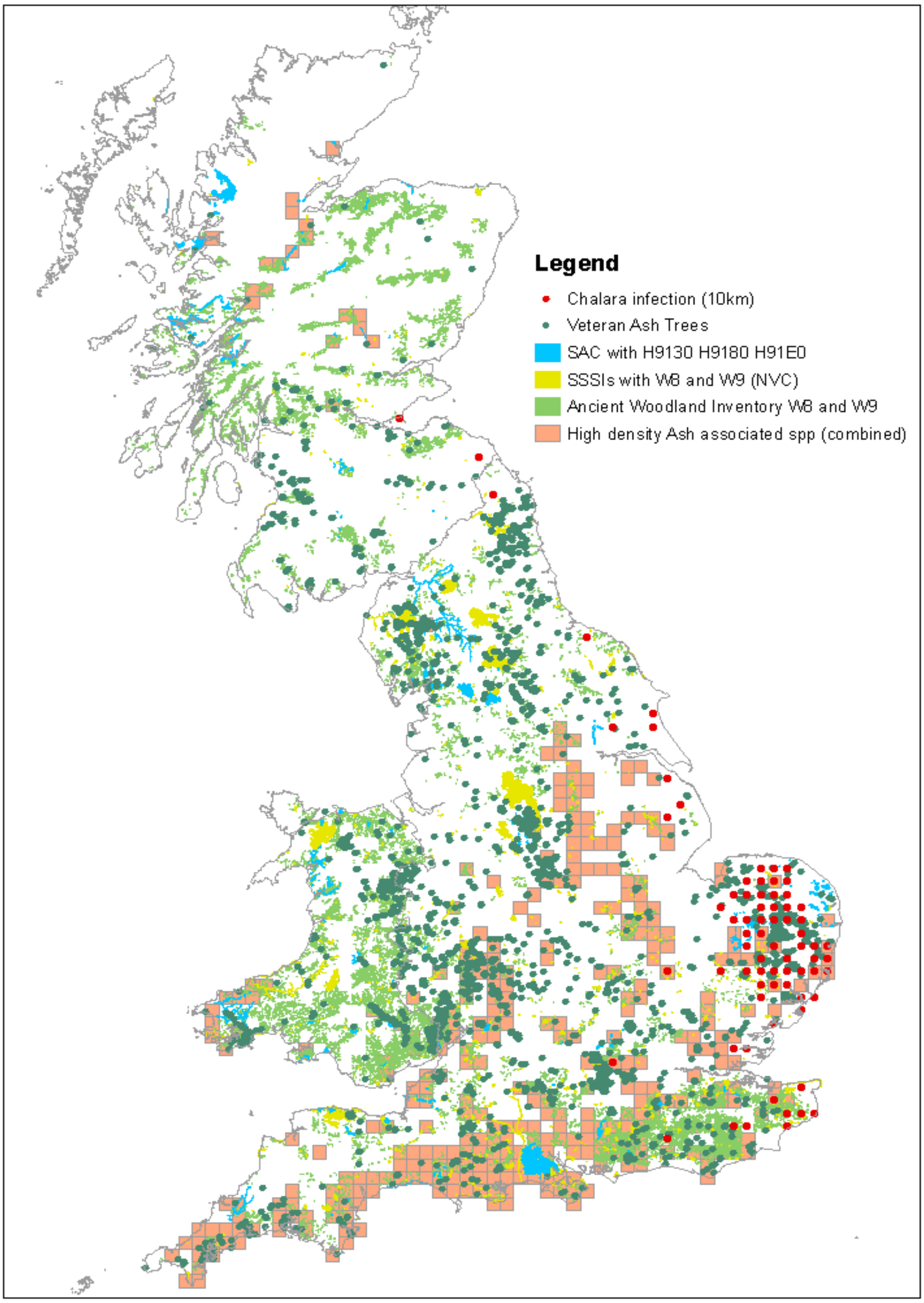
- SACs are a key EU conservation priority, but much of GB's mixed woodland does not meet the criteria to be classified as a habitat of European community interest.
- SSSIs address an important sample of semi-natural mixed woodland but the bulk falls outside designation. Mapping of ancient woodland picks up much of this undesignated resource which is the subject of restoration and ecosystem services targets in country biodiversity strategies.
- Large ash in hedgerows, fields and parkland is shown by sampling to be a major component of trees in landscape which collectively have a role in connectivity, but there are no currently available data sets to map it effectively. The veteran trees database is a significant start.

- Mapping species dependant on ash provides an alternative to the mapping of woods and trees for locating and identifying important ash.

Some provisional implications of the mapping:

- Important ash occurs in pockets of woodland, as part of major landscape areas such as the Forest of Dean, and as trees in the landscape, across much of GB. The density of locations is quite high.
- There are no strategic gaps in the distribution of important ash locations that suggest they can be isolated at a regional scale. Ash locations are, however, relatively more isolated in Scotland.
- There is no pre-existing, validated map of important ash locations and the data used provide only an approximate guide to inform any management approach to Chalara.

Figure 4– Map of important ash (JNCC[30])



[30] The Distribution of Important Ash in Great Britain http://jncc.defra.gov.uk/pdf/important_ash.pdf

1.2 Estimating the loss of benefits associated with the spread of Chalara

This section attempts to assess the costs (including loss of benefits) of Chalara under given patterns of spread of the disease under the theoretical scenario of no effective intervention. It provides a baseline for evaluating the potential benefits from interventions to manage or delay its spread.

1.2.1 Availability of existing valuation data

There is relatively limited evidence from previous tree diseases to draw on in directly assessing the loss of benefits as a result of specific pests or pathogens. We undertook a review of several papers[31] where economic valuation has been considered, and summarise relevant points below.

Previous UK studies have focused on landscape, recreation, biodiversity, air quality, carbon sequestration and any human health impacts as the non-market costs of tree disease. This may be due to the higher availability of previous studies and quantitative data on these benefits compared to other areas such as water quality or management.

- Recreation values for regions were based on local populations.
- One study by Price[32] gave separate valuations for landscape benefits in urban and rural environments.
- Price also estimates the reduction in the release of carbon from fossil fuels in addition to that captured as biomass (so that permanent carbon benefits are equal to the mass of carbon in the tree plus 0.5 times the mass of large dimension material).
- Price constructs a less valuable "replacement stock mix" for each disease scenario considered.

Valuation studies of tree pests from the United States were limited in scope due to the lack of data on non-market tree values.

- Studies focused on expenditure on mitigation, the lost value to residential properties as a result of mature tree death and the lost value to commercial timber growers.
- While spending on treating or replacing trees was recognised as a rational response, it was also considered sub-optimal spending. The resultant opportunity costs were referred to but not valued.

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[31] Aukema JE, Leung B, Kovacs K, Chivers C, Britton KO, et al. (2011), *Economic Impacts of Non-Native Forest Insects in the Continental United States*, PLoS ONE; Haw R (unpublished draft), *Impact assessment: Control options for London outbreak of Oak Processionary Moth (OPM)*, Forestry Commission; Price C (2010), *Appraising the economic impact of tree diseases in Britain: several shots in the dark, and possibly also in the wrong ball-park?*, Bangor; Sunderland T, Rogers K, Coish N (undated), *What proportion of the costs of urban trees can be justified by the carbon sequestration and air-quality benefits they provide?*, Natural England, Hi-line Consultancy, Torbay Council; Vannatta AR, Hauer RH, Schuettpelz NM (2012), *Economic Analysis of Emerald Ash Borer (Coleoptera: Buprestidae) Management Options*, Journal of Economic Entomology 105(1):196-206; Willis K, Garrod G, Hanley N, Scarpa R, Powe N, Lovett A, Bateman IJ (2003), *The social and environmental benefits of forests in Great Britain*, Forestry Commission.

[32] Price, C. (2010) Valuing landscapes with trees: subjectivity versus objectivity, holistic versus components-based approaches. *Scandinavian Forest Economics* 43: 80-99.

- The replacement costs of dead trees in an urban landscape were not counted: as replanting is a reasonable response to the lost value of dead trees (as providers of a stream of benefits), the cost must be less than the lost value reclaimed. Therefore, costs are counted twice if both the value of the lost tree and the cost of its replacement are included in an assessment.
- One study based the value of a small sample of trees on their existing condition, i.e. allowing for pre-existing health problems in the population.

1.2.2 Predicting the spread of Chalara

The Cambridge University modelling project[33] was able to predict the likely future spread of Chalara within the UK over a twenty-year timescale. A time period of this length was chosen to reflect the long-term nature of the benefits delivered by woodlands. A baseline scenario of the spread of the disease without any management intervention was presented. For this baseline a number of simplifying assumptions were made:

- no mortality of hosts,
- no aging of the host population,
- no difference in susceptibility and infectivity of different ages of ash trees

The Cambridge model can also be used to estimate the pattern of spread of Chalara under different hypothetical scenarios, which can represent different management options.

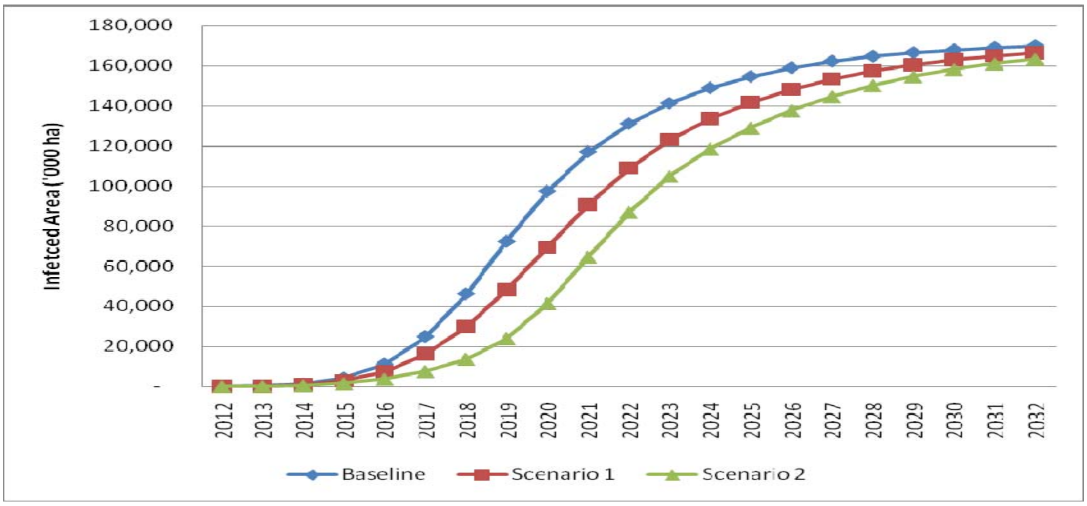
The first of these scenarios assumes that the number of initial infection sites is reduced, so that the initial area infected is reduced from 48 hectares to 35 hectares, a reduction of approximately 30%. The second scenario is based on a theoretical intervention that prevents any spread of the disease for two years. It should be noted that currently there is no known form of management that can achieve this.

[33] University of Cambridge: Chalara Modelling Report: Incursion, Risk and Sampling Modelling, due to be published May 2013

Table 5 – Area of infected ash under different hypothetical intervention scenarios

Year	Area infected with no intervention (ha)	Area infected under scenario 1 (ha)	Area infected under scenario 2 (ha)
2012	48	35	48
2013	345	239	48
2014	1,374	957	48
2015	4,300	2,919	345
2016	11,318	7,487	1,374
2017	25,012	16,285	4,300
2018	46,331	30,036	11,318
2019	72,430	48,206	25,012
2020	97,484	69,468	46,331
2021	117,116	90,882	72,430
2022	131,191	109,132	97,484
2023	141,373	123,152	117,116
2024	148,964	133,717	131,191
2025	154,708	141,898	141,373
2026	159,049	148,357	148,964
2027	162,307	153,463	154,708
2028	164,745	157,485	159,049
2029	166,580	160,639	162,307
2030	167,983	163,109	164,745
2031	169,073	165,053	166,580
2032	169,935	166,589	167,983

Chart 1 – Area of infected ash under different spread scenarios



1.2.3 Loss of benefits resulting from Chalara spread

The monetised social and environmental benefit estimates presented in section 1.1.4 can be applied to data on the physical extent of Chalara in ash trees to derive a high-level, aggregate estimate of the monetised losses to society from the impact of Chalara spread. Applying these monetised estimates to the different scenarios of spread can provide an estimate of the benefits that could potentially be captured by slowing the spread.

There is some uncertainty about how quickly infection leads to a decline in living stocks and the extent to which such declines from infection impacts upon non-market benefits. Carbon sequestration, for example, will cease on the death of a tree whereas the biodiversity benefits may change as the dead tree provides a habitat for insects. In the absence of clear scientific evidence about the links between infection and death it has been assumed that a certain proportion of the benefits from ash trees are lost on infection, and that this proportion varies depending on the specific benefit. To allow for the uncertainties, upper value and lower values have been used to generate a range of values. Details of the proportions used are in Table 6.

Table 6 – Proportion of benefits lost as a result of Chalara infection

Benefit	Proportion of benefits lost (Lower)	Proportion of benefits lost (Upper)
Recreation	20%	50%
Landscape	20%	50%
Biodiversity	20%	50%
Carbon sequestration	50%	100%
Air quality	50%	100%

Note that the impacts gradually increase over time as infection spreads, and that lost future benefits need to be discounted to a present value. The benefits of action will therefore be longer-term, particularly if the speed of spread increases in later years. Estimated losses are given in net present value terms over 20 years (i.e. measured from the perspective of now, in capital value terms) and also in average annual terms.

As before, these calculations are based upon partial estimates with associated uncertainties and should be treated as indicative.

Table 7 – Loss of societal benefits from predicted spread of Chalara over 20 years

Loss (£m)	Lower estimate	Upper estimate
Net present value	347	763
Annualised average	17.3	38.2

1.2.4 Other non-monetised social impacts

The strong public and media reaction to the discovery of Chalara is indicative of the deeply held and diverse **cultural values** that people and society attach to native trees such as ash (c.f. cultural services discussion). Spread of Chalara could potentially influence public perceptions and attitudes to tree disease and subsequently to trees and woodlands themselves. In the long term this could influence the number of visits to woodlands (currently estimated at over 350 million in England) and ultimately the value the public places on them.

There are potentially **intergenerational issues**, as most of the losses will occur in future decades.

1.2.5 Summary

Approximated non-market valuations of ash trees can provide the basis for a preliminary assessment of the socio-economic costs of Chalara spread. These will depend heavily upon the actual speed and pattern of the spread of infection as well as the underlying estimated unit values.

There is limited literature on economic analysis of tree diseases, and no single existing methodology which can be applied in the case of Chalara.

It is important to recognise the potential for economic and ecological adaptation to mitigate the longer term impacts of Chalara.

1.3 Estimating the benefits of slowing the spread of Chalara

The losses of benefits have been estimated under different hypothetical scenarios. By directly comparing these losses we can derive an estimate of the societal benefits that could be captured by slowing the spread of Chalara under these scenarios.

As before, these calculations are based upon partial and uncertain benefit estimates and so should be treated as indicative only (CR low). These are based upon 20-year appraisal periods to capture the long-term nature of the impacts.

Table 8 – Societal benefits captured by slowing the spread of Chalara

Scenario	**Net present value over 20 years (benefit, £m)**	**Annualised average over 20 years (benefit, £m)**
1. Reducing number of initial infected sites	42 - 93	2.1 - 4.7
2. Delaying the spread by two years	67 - 148	3.3 - 7.4

A shorter appraisal period is likely to reduce overall net benefit insofar as the benefits of deferred loss of amenity are likely to extend into the future. On the other hand, the costs of intervening are likely to be shorter term. However, mitigating factors are likely to mean that longer term losses are reduced due to the possibilities for adaptation to the disease.

Whilst several uncertainties are built into the estimates, further **sensitivity analysis** could be carried out around key assumptions, including the period of appraisal.

As noted above, the benefits to ecologically sensitive areas are not fully captured in this framework, nor are some social non-use values such as the cultural and historic importance of woodlands and trees, and any economic benefits from intervention. However, these excluded benefits could all be taken account of through the use of the broader multi-criteria analysis[34] framework to establish priority areas of intervention.

[34] Defra Evidence and Analysis Series, Paper 5 - Social Impacts and Wellbeing: multi-criteria analysis techniques for integrating nonmonetary evidence in valuation and appraisal https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69481/pb13695-paper5-socialimpacts-wellbeing.pdf

Section 2 – Options for Managing Disease: Chalara as a Case Study

The socio-economic impacts estimated in section 1 support the case for management of Chalara, although the potential for economic and ecological adaptation should also be recognised. The impacts of Chalara and its management are complex and need to be carefully assessed in a logical framework. This section offers a preliminary attempt for thinking about what this might involve. As there is little previous experience in analysing and appraising the impacts of plant and tree diseases, Chalara offers an important and valuable case study.

2.1 Mitigation and Adaptation

The latest scientific evidence and modelling show that there are broadly two types of direct action available in responding to Chalara:

i. **Slowing the rate of** spread.

ii. **Adapting** to the impact of Chalara. This is starting to happen already and its effect on socio-economic values and benefits will depend in part on other impacts of the management process.

The balance between these two approaches will depend upon:

- the likelihood of actions successfully slowing overall spread; and
- the variation in geographic distribution of ash trees and their contribution to the delivery of ecosystem services (e.g. woodland typologies).

These will have different impacts and risks, and there are similarities with the twin strategies of mitigating and adapting to climate change. The two are closely related, as mitigation allows time for adaptation, and certain actions may have benefits both in terms of mitigation and adaptation. Adaptation is further explored in Section 2.6.

2.2 Mitigating factors

As well as loss of benefits and additional costs, there will be mitigating factors and ecological and economic adaptation. This is particularly likely where spread is slow and incremental responses can be made:

- Over time, many of the losses of ash-related recreational and landscape benefits and regulating services could be partly offset by **early re-planting with, or natural growth** of, other species (as previously noted). However, the time lag involved in delivering offsetting service flows would reduce the present value of these off-setting investments.

- The loss of ash in the landscape whether as a direct result of Chalara or from managed replacement will allow compensation by **creating opportunities for other species** and the species that depend on them. For instance, in a mixed species woodland the loss of ash may create new niches for insect species and allow time for populations and communities to adjust to new conditions. Moreover, dead and diseased trees if left *in situ* may well be a benefit for wildlife. Dead and decaying trees are vital components of a properly functioning forest ecosystem and play a role in sustaining biodiversity, soil fertility and energy flows such as hydrological processes in streams and rivers. Opening of dense canopies can also be beneficial.[35] Much of this will depend upon prudent woodland management.
- Woods with **low frequency of ash** are likely to have greater ecological resilience – i.e. gaps can be filled without loss of ecosystem services (with potential benefits for biodiversity of deadwood and increased structural diversity in some situations).
- Impacts on **woodland tourism** may be limited where ash is low density and woodland management allows continued access. Any adverse impacts are in any case likely to be offset by increased tourism elsewhere e.g. in other forms of outdoor recreations.
- Increased costs to some agents will also mean **increased business opportunities** for others (e.g. silvicultural and logging firms). However this “additional business” would only represent a positive economic impact if those resources would otherwise have been unutilised.

2.3 Spatial scale of appraisal

When considering the management options there were two broad approaches available which were to some extent complementary:

i. A broad-brush / national appraisal can show the overall value for money of a given package of actions (their costs and effectiveness), but it is unlikely to be well aligned to a targeted approach to control.

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[35]Impacts on biodiversity will be greatly influenced by how diseased and dead trees are managed. Until the late 20th century, deadwood in managed forests was removed due to a misconception of the need to sanitise woodland to secure forest health – or simply to keep a wood looking ‘tidy’. Over time this has led to the widespread impoverishment of woodland biodiversity. Allowing some *in situ* decay and natural regeneration/planting (of genetically resistant ash or other native species) could be an appropriate management strategy, as in the case of the ‘Great Storm’ of 1987. Conversely removal of trees (healthy, diseased or dead) could have comparably greater impacts on biodiversity. Humphrey, J. and Bailey, S. (2012)., *Managing deadwood in forests and woodlands - Practice guide* 2012 http://www.forestry.gov.uk/pdf/FCPG020.pdf/$FILE/FCPG020.pdf

ii. A spatially targeted set of appraisals would be more sensitive and accurate (e.g. at county level) but challenging and would need to be closely integrated with the Chalara modelling. Deriving regional benefit estimates would involve some crude assumptions unless original empirical work is undertaken. It could also become more complex.

A decision needed to be made about the most appropriate spatial level for the appraisal, with trade-offs between precision and complexity. Depending on the size of the region, the numbers involved may be relatively small, and benefits will not necessarily occur in the same place (e.g. an early intervention in the midlands might deliver benefits later in time to the North West) and some form of aggregation would be necessary.

The impact of intervention and the links between infection, death and loss of benefits will vary with the situation of ash trees and the prevalence of other stresses and diseases. This suggests a valuable role for **sensitivity analysis**.

Estimated monetary values by region could be derived for recreation and amenity, for example, making use of some of the details of the 2003 non-market benefits study and applying unit willingness to pay values to population numbers in any given area; recreation models from the UK NEA could also be adapted, but biodiversity values may be more problematic unless new work is undertaken, and non-monetary values could also be ignored. There is also a complex and uncertain relationship between loss of trees and loss of use / non-use values, and there may be further policy-relevant considerations which are not captured. This suggests a multi-criteria analysis approach may add value and could also produce a ranking of spatial priorities.

It may be possible only to estimate an average figure across sites, and indirect costs e.g. those incurred outside central government, may not be readily monetised.

2.4 Spatially-targeted Management

The Cambridge University modelling work concluded that a spatially-targeted approach provides the most effective form of management.

The model predicted that by 2017 there will continue to be regional differences in both the probability of disease presence and the extent of infection across the UK. The East and the South-East of England are predicted to experience the highest levels of infection with lower disease presence predicted in other regions.

The model showed the probability of infection at any given location within the UK. In addition to the likelihood of individual locations becoming infected the modelling work can also predict the "hazard value" for a particular location. This is a measure of the importance of each site in terms of its impact on a future epidemic. The value of hazard at any location is a measure of the amount and value of ash that would become infected if that site were the focus of a new local epidemic. This means that each site in the UK can be categorised in terms of both its hazard and its risk and these two measures can be used to direct intervention efforts:

- Intervention would be more cost-effective at a site with a high hazard value but which has a low risk of becoming infected. Tackling an infection here would have a large impact due to the high hazard value with a low probability of additional infections occurring.

- Intervention would be less cost-effective at a site with a low hazard value and a high risk of becoming infected since any attempt to tackle new or existing infections would be rapidly outweighed by the continual infection pressure from elsewhere.

If recently planted sites are a major contributor to further disease spread then removal of these sites will delay the progress of the epidemic by up to three years nationally. There is considerable regional variation in this figure, with the Eastern and South-East regions experiencing delays of less than one year whereas the South-West and Scotland could experience delays of over three years.

2.5 Adapting to Chalara

Adaptation will become an important consideration given that current evidence shows that it will not be possible to eradicate the disease. Specifically, while successful mitigation may delay the need for adaptation and so such delayed adaptation expenditure can be seen as one of the benefits of successful intervention to slow the spread, if the intervention options are of only limited success, then pursuing adaptation strategies cannot be delayed for long.

Adaptation involves purposely adjusting woodland management plans, conservation objectives and landscape strategies in the anticipation that ash trees may have Chalara in 5-20 years, for instance by:

- bringing forward harvesting and re-planting;
- selective thinning and re-stocking;
- developing resistant varieties;
- improving natural regeneration (deer management); and
- encouraging some retention of diseased and deadwood for biodiversity.

These adaptation responses would need to vary depending upon the type and situation of ash trees and be considered alongside any other standard or shorter-term responses that might be expected in the absence of Government advice or intervention.

The potential impacts, costs and benefits of adaptation responses can potentially be incorporated into a multi-criteria analysis alongside control options.

2.6 Appraisal methods

2.6.1 Cost Benefit Analysis

Some means of assessing risks and outcomes and prioritising actions needs to be made. **Cost-benefit analysis** - in which all costs and benefits of specific actions and options are identified, monetised, discounted and compared (and subjected to sensitivity analysis as appropriate) – is a clear and attractive method of assessing value for money of different options. But there are a number of challenges and drawbacks:

- it depends upon reasonably clear quantified evidence of expected impacts and is limited in how much uncertainty it can deal with;
- crude and potentially unrealistic assumptions on benefits may need to be made, particularly at finer spatial scales (although new work could deal with this problem if commissioned now);
- not all benefits and risks of action can be readily monetised (such as social acceptability); and
- it limits stakeholder engagement

Multi-criteria analysis (a technique which can rank options according to scores across several criteria explicitly weighted by consensus) can be a more encompassing and inclusive form of appraisal but also has risks.

2.6.2 Multi-Criteria Analysis

The cost-benefit analysis as outlined previously provides an assessment of the net benefits from management of Chalara. Whereas a carefully constructed **multi-criteria analysis** (weighting and scoring options by various key criteria) can provide a transparent and comprehensive means of incorporating all impacts, including both monetised and non-monetised social, economic and environmental impacts. Because of the value judgements involved, multi-criteria analysis needs to be developed with key stakeholders / decision-makers and care needs to be taken to ensure consensus, appropriate challenge and to avoid biases. However, it has the potential to provide a more comprehensive ranking of priority interventions.

2.7 Costs and income foregone

This paper has deliberately focussed on estimating the value of socio-economic benefits forecast to be lost or at risk as a result of Chalara. However, it is acknowledged that any form of management response will incur costs. There are different types of costs and income foregone associated with different management options including income foregone, implementation costs (usually capital costs), maintenance/operating costs and other costs such as social and environmental spill-over costs.

In practice the main costs are likely to be:

- Costs of surveillance, detection, inspection.
- Costs of removal and disposal of recently-planted infected trees and replacement with other species
- Costs of further research, including on developing resistance in ash trees.
- Additional treatment and disposal costs to local authorities.

Whilst part of the rationale for slowing the spread of Chalara is for environmental benefit, there may be environmental spill-over costs associated with interventions to remove infected trees, including:

- Use of chemicals to treat the disease.
- Removal of trees where ash forms a dominant part may carry a number of environmental risks, including soil run-off leading to sedimentation and water pollution; increased flood risk from lack of water retention in previously wooded areas and dead tree blockages; loss of integrity of river/flood banks .
- Damage to adjacent habitats (and trees) and disturbance of wildlife.

As before, these considerations will have to be made at a relatively fine spatial scale and will depend upon different types and situations of ash woodland and non-woodland. To facilitate an analysis of environmental benefits, costs and risks, it can be helpful to use the **ecosystems services checklist** recommended by HM Treasury Green Book supplementary guidance to ensure all potential impacts and risks are considered[36]

[36] http://www.hm-treasury.gov.uk/d/accounting_environmental_impacts.pdf

2.8 Preliminary Conclusions

There are high levels of uncertainty, but the scale of commercial and societal benefits from ash and the diversity and depth of cultural services and sensitivity to woodlands suggests there is scope for targeted and proportionate action.

However, there are significant uncertainties in the spread and impact of Chalara so the success of management measures and achieving value for money may depend on the extent to which intervention can be targeted on a regional basis.

The benefits from slowing spread of the disease will be longer term, whereas the costs associated with attempting to slow Chalara are likely to be shorter term.

A high-level benefit-cost analysis would not provide a single "answer", but would help to inform decision-making under uncertainty. It is important not to ignore costs and risks which cannot easily be monetised.

High levels of uncertainty suggest that review and evaluation are necessary as understanding improves of disease spread and potential management costs.

There is a role for engaging with the public using approaches such as citizen science. Success in this area will provide many benefits including increased levels of surveillance and greater public awareness.

The importance of adaptation should be fully acknowledged, including substitution of ash with other tree species that provide similar benefits. There may be a case for research to inform and assist this process.

Annex 1 – Use of confidence ratings

Data in this paper has been sourced from different organisations / publications. In order to help the reader understand the data presented a confidence rating has been applied where appropriate.

1. CR *High: B*ased on significant evidence (e.g. recent survey, statistically sound using up to date methods, HMRC data, current industry practices; published in peer reviewed papers; recent qualitative research (interviews, focus groups etc) with sound methodology that includes results from a number of studies in different locations with different types of people that report similar findings).

2. CR *Medium:* Based on incomplete or dated evidence (e.g. an estimate based on old survey data, trade association estimates, a survey result which may not be entirely representative of the whole; qualitative research from one or two case studies; published in only one or two peer reviewed papers; published in grey literature).

3. CR *Low:* Based on speculative or incomplete evidence (e.g. rough estimate from a single expert, or industry body lacking supporting analysis, or early result based on fast developing situation on ground, not published in peer reviewed papers, qualitative research that involves a single case or does not provide details of the sample studied or method used.

Annex 2 – A Multi-Criteria Analysis Case Study

Decision-making in response to tree disease

The final report of the SMURF (Strategic Management of the *Uredo Rangelli* Fungus) project of the Australian Department for Agriculture, Fisheries and Forestry provides a case study of decision making in response to tree disease.[37] This used a Structured Decision Making process to choose a course of intervention in the 2010 outbreak of myrtle rust in Australia. This process started from a less-developed natural science base.

A mixed group of expert and non-expert stakeholders was used to identify the criteria (objectives) for evaluation of interventions and to determine the preferred course of intervention.

The objectives/criteria used for comparing options and the options themselves could be revised and redesigned during this process.

Agreed scores were used where quantitative data was lacking.

Alternative policies were explicitly defined. A range of specific intervention activities (e.g. "surveillance") was drawn up and the level of effort expended on each activity under each policy alternative decided. This ensured that group members evaluated each policy alternative under a common interpretation of costs and using a common understanding of objectives/criteria.

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[37] Liu S, Cook D, Walshe T, Long G (undated), *Strategic management of the* Uredo rangelii *fungus (SMURF) final report*, Department for Agriculture, Fisheries and Forestry (Australia)

Annex 3 – Summary of costs and benefits of intervention options

Values		No intervention		Intervention to slow spread		Encourage adaptation	
	Baseline ash value (p.a.)	Cost / risk	mitigating factors	Benefit	Cost / risk	Benefit	Cost
Nurseries / planters	£19m (with forestry)	collapse of demand; loss of stock; loss of value added	substitution to other plants		Import / movt ban - loss of stock value		
Forestry	£19m (with nurseries)	collapse of demand; inspection costs; loss of timber to woodfuel	replant with other species		Replanting after early removal; failure of owners to meet grant conditions?		Replanting after death (would come later)
Forestry support	£2m		unlikely to be affected - may involve increased pest control				
Saw milling	£0.1m	lost value added	substitution to other timbers				
Recreation	£43m	gradual loss, depends on ash density and pop proximity; health & safety concerns	alternative outdoor recreational opportunities	Deferred benefit loss		Minimise woodland closures and fears of accessing	
Biodiversity	£43m	General loss from decline of ash can be monetised. Threat to sensitive areas	Release of other species	Deferred benefit loss	Habitat damage, wildlife disturbance; Loss of ash that would still have performed ecological functions		
Landscape	£15m	loss of visual screening; general loss from decline of ash trees can be monetized		Deferred benefit loss			

Carbon	£49m	Loss of carbon absorption, can be monetised according to decline of ash		Deferred benefit loss			
Wider environment							
Wider cultural	Various use and non-use values				Public concern at widespread tree felling	Renewed appreciation of woodland	
Local authorities	landscaping	Inspection and removal of young street trees;		May involve less tree management than faster spread			
Rail and road	Screening etc (see landscape); 3m trees on road	removal of mature infected trees if there is a safety risk; possible road closures	£100 / tree estimated removal costs (inc transport and H&S)	May involve less tree management than faster spread	Inspection and removal of young infected trees in order to slow spread through the network.		
Forestry Commission, Forest Research		Possible surveillance costs			Surveillance, site inspections, removals		Silviculture guidance
Defra / FERA					Research, sampling		