Tree Species Guide for UK Agroforestry Systems

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Forest Research

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Introduction

This tree species guide provides an overview of the physical characteristics, environmental tolerances, silvicultural characteristics, and ecosystem services and disservices for a selection of 33 species of trees and shrubs that could be planted in UK agroforestry systems.

This guide has been produced following a rapid review of existing literature and databases, together with consultation with a stakeholder group. This guide comes with some important caveats, limitations and assumptions, which are discussed in these introductory sections.

This guide has been developed through the Defra Nature for Climate Fund (NCF) England Tree Planting Programme (ETPP) Expanding Agroforestry project.

Who is this guide for?

This guide aims to provide a simple and accessible overview of the key attributes (whether beneficial or detrimental) of tree species in UK agroforestry systems. As such, it is suitable for farmers interested in agroforestry, and other interested parties including farm advisers, foresters, and policy makers. This guide is intended for use in the early stages of the agroforestry design process to develop initial ideas about which tree species to plant. Following this, it may be advisable for those designing an agroforestry system to seek further specialist advice appropriate to the local context.

What is agroforestry?

Agroforestry is essentially 'farming with trees' and is a land management approach that integrates cultivated trees and agriculture. It includes either the introduction of trees or shrubs into farmland, or the introduction of crops or livestock into treed habitats such as woodland and orchards (Raskin and Osborn, 2019).

Agroforestry can be implemented at a field scale, integrating trees or shrubs within fields as lines of trees or scattered trees. The resultant agroforestry system could take the form of a silvopastoral system such as a grazed woodland, a wood pasture, an orchard, or where the fields are cropped, a silvoarable system. At the landscape scale, agroforestry can be implemented around or between-fields, through the cultivation of hedgerows, shelterbelts or riparian buffers. Taking areas out of agricultural production and planting them with trees for forestry is not considered as agroforestry within this guide.

Trees within agroforestry systems can have a wide range of functions and benefits, from protection of natural resources such as soil, to product diversification such as timber, woodfuel, fruits and nuts. In many cases, agroforestry systems are designed to deliver multiple benefits simultaneously. This guide aims to inform decision-making as to tree species selection according to the identified needs in a local context.

Of the tree species covered in this guide, no one species provides universal benefits of ecosystem services and resilience. There are clear trade-offs between the attributes of the different species. At the farm level, decisions need to be made as to which attributes to prioritise when selecting which species to plant. At a national level, including a diverse range of species to deliver multifunctional, resilient agroforestry systems is recommended.

Evidence base and sources of further information

An accompanying database provides transparency as to the evidential basis for the species guide. The database provides a more detailed assessment of the characteristics of each species covered in this guide, and is accompanied by numbered references where appropriate. References were sourced from the UK or north-west Europe where possible. The database has been designed so that it can be continually updated.

Further information on tree species selection:

- The Silviculture of Trees used in British Forestry (Savill, 2019)
- The Agroforestry Handbook (Raskin and Osborn, 2019)
- The Woodland Trust's Tree Species Handbook (Hotchkiss and Herbert, 2022)
- The Essential Tree Selection Guide (Sjoman and Anderson, 2023)
- CABI Compendium (www.cabidigitallibrary.org/journal/cabicompendium)

A number of freely accessible online interactive tools are available to assist with site-level decision-making for species selection.

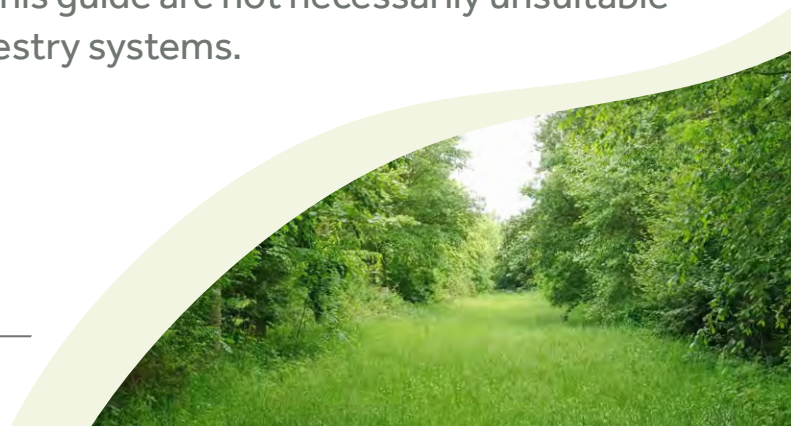
These include:

- Ecological Site Classification (www.forestdss.org.uk/geoforestdss), which is used to assess suitability of forestry species for a specified site, and also contains projected distributions and productivity of some species under future climate scenarios.
- Climate matching tool (climatematch.org.uk), which can inform selection of climate-resilient species.
- Ammonia reduction calculator (farmtreestoair.ceh.ac.uk/ammonia-reduction-calculator), used to guide the design of shelterbelts for ammonia mitigation.

How were the species selected?

The agroforestry tree species guide focuses on a priority list of 33 tree and shrub species. The species were selected through a combination of stakeholder engagement over species from the England Woodland Creation Offer (EWCO) list and consultation of the species list within the Agroforestry Handbook (Table 18, Briggs and Knight, 2019).

Species included in this guide do not necessarily represent a 'green list' of approved or recommended species, and polices and regulations may differ between UK nations and are subject to change. When considering what species to plant, please follow national and local regulations. For example, in Scotland, a licence would be required to plant certain tree species contained in this guide if the land is to be taken out of agricultural production and the purpose of the planting is for forestry. However, the species included in this guide are expected to be exempt when planted within systems this guide defines as agroforestry. Similarly, the species list is not exhaustive, and species omitted from this guide are not necessarily unsuitable for UK agroforestry systems.



Using this guide

For each tree species, the first page focuses on physical characteristics and silvicultural properties of the trees.
The second page focuses on tolerances and attributes (such as ecosystem services) where tree species choice is likely to influence the productivity, environmental impacts, and resilience of the agroforestry system.

The attributes were selected based on engagement with the stakeholder group.
It is also recognised that agroforestry systems provide general benefits for which tree species choice is likely less relevant.
One example is the extension of grazing season observed in agroforestry systems compared with treeless pastures (McAdam *et al.*, 2018), which is likely a general benefit of integrating trees within pasture where there is no clear evidence of a role of tree species choice.

The assessment of species attributes (such as ecosystem services) draws on direct evidence for species, in addition to inference based on the physical characteristics of species, such as maximum root depth, maximum height, and canopy spread. The approach to assessing attributes is discussed in the following sections, including attributes that were considered for inclusion in this guide, but ultimately could not be included due to a lack of species-specific evidence.

Colour scheme and confidence level

Attributes are colour-coded using a traffic-light system according to whether they provide a benefit or disbenefit, as follows:

Benefits (e.g. nutrient and organic matter accumulation) ▲ High ◆ Moderate ▼ Low

Disbenefits (e.g. acidification) ▲ High ◆ Moderate ▼ Low

In addition, where appropriate, for each attribute value a confidence level is displayed in this guide, as follows:

High confidence ●:
direct well-replicated evidence or information from reputable sources, for the species in question.

Moderate confidence ◐:
evidence for the species, but less reliable, e.g. limited expert opinion or a limited number of studies / limited replication.

Low confidence ○:
no (or very limited) direct evidence for the species, assessment primarily inferred from other tree characteristics.

Carbon sequestration

Benefit, categorised as very low, relatively low, moderate, high, or very high

Carbon sequestration in agroforestry systems is a complex topic which depends on a range of variables, such as planting density, tree management, vigour of tree growth, and site characteristics including climate (Soil Association, 2023). As such, the approach taken in this guide is to provide the maximum likely achievable carbon sequestration for each tree species using the Woodland Carbon Code,[1] assuming that trees are planted at 3 m spacing (2 m for Scots Pine). A maximum possible yield class for the UK (according to the Ecological Site Classification) was assumed for each species, to provide a consistent and comparable approach accounting for differences in productivity by

[1] woodlandcarboncode.org.uk

species. For small non-timber species such as Apple *Malus domestica*, carbon sequestration was assumed to be 'relatively low' in the short-term, and 'very low' in the medium- and long-term.

Soil carbon sequestration was not considered in the assessment, because of the lack of species-specific evidence from agroforestry systems. Other factors such as agricultural management practices, previous land use, and soil type are likely to be more relevant. However, evidence from forestry planting indicates that deciduous broadleaved species sequester significantly more soil carbon than coniferous species, with broadleaved nitrogen-fixing species having the strongest effect (Laganière *et al*., 2010).

The carbon sequestration values provided in the database represent tonnes of CO_2 equivalent within 1 hectare of trees. As such, these figures should be multiplied by tree percentage in an agroforestry system, however, the values provided are not intended to be a realistic assessment of carbon sequestration in agroforestry systems (given that maximum yield classes were selected), but rather provide a benchmark with which to make comparisons between species.

Three timeframes for carbon sequestration are presented in this guide: short-term (20 years), medium-term (40 years), and long-term (60 years). These refer to time after tree planting, assuming no coppicing, pollarding, thinning, or felling. As such, the medium-term and long-term categories are not applicable for trees managed on a coppice rotation of less than 20 years.

For each of the three timeframes, carbon sequestration is categorised by benchmarking the sequestration values described above against the wider tree species list. This means that, for example, Field Maple *Acer campestre* delivers very low carbon sequestration relative to other tree species in this guide, but could still increase carbon sequestration relative to a non-tree scenario.

Native status

Categorised as native, long-established introduction, or recent introduction

Native status is adapted from Stace's New Flora (2019), based on the following categories and sub-categories:

- **Native:** a species that colonised the British Isles naturally, typically long ago, from other native areas.
- **Long-established (archaeophyte):** a species typically associated with human activities or suspected to be introduced by humans, and present in the British Isles since at least 1500 AD. It is often uncertain whether the species is native or introduced. This category is further divided into the following sub-categories:
    - **Denizen:** behaves like a native species but suspected to be a possible human introduction (either intentionally or accidentally).
    - **Cultivated:** introduced by humans as crops, now persisting in the wild.
- **Recent introduction (neophyte):** a non-native species that arrived in the British Isles after 1500 AD, sub-categorised as:
    - **Naturalised:** established in the wild and not reliant on replanting.
    - **Survivor:** not naturalised, but persists without spreading, usually a relic of planting.

Native status sometimes varies across the UK, and in these cases, the 'highest' status is given (e.g. a species which is native to part of the UK but introduced elsewhere is categorised as 'native' for simplicity).

Value to wildlife

Benefit, categorised as negligible, relatively low, moderate, high, or very high

The value of tree species for native wildlife is derived from an article published in British Wildlife (Alexander *et al*., 2006). In the article, the authors estimate the value of tree species for nine different categories of species assemblages, such as 'mycorrhizal fungi', 'foliage invertebrates', 'blossom for pollen and nectar' and 'epiphyte communities', using a scoring system of 1 to 5. The values were estimated based on the opinions of a selection of established and published experts. A number of assumptions were made, including that the trees are maidens (i.e. no coppicing or pollarding) with no constraints associated with commercial operations such as inputs or other ecologically harmful management.

In this species guide, the values in the article are summarised by firstly providing an overall value of the tree species for wildlife by averaging the values (1-5) across all nine assemblage categories, which are then categorised as relatively low (average value <2.5), moderate (average value >2.5 and ≤3), and high (average value >3), with a very high category used for native oak (*Quercus* spp.*)* because these were substantially higher than any other species. Secondly, the assemblage(s) for which the tree species had the highest score is stated.

For species not included in the above article, their value is inferred based on their native status and similarity to species that are included in the article. For example, Italian alder (*Alnus cordata)* is predicted to have low to moderate wildlife value, based on the 'moderate' score for common alder (*A. glutinosa)*, but accounting for the introduced status of Italian versus the native common alder.

As for the carbon values, it should be noted that tree species' value for wildlife scores are benchmarked against the wider tree species list, not relative to non-tree scenarios. For example, planting a tree

species of 'relatively low' biodiversity value in an otherwise monoculture of arable or pasture could lead to substantial and significant biodiversity benefits. The extent of these benefits are likely to depend on a range of variables including management of the tree and its understorey vegetation, tree density, habitat connectivity, and management of the adjacent crop / pasture (reviewed in Kletty *et al*., 2023).

Other environmental impacts

Limited number of tree species covered

This section includes wider environmental impacts which were considered for inclusion as separate categories in this guide, but for which limited species-specific evidence is available, as described below.

Nutrient removal and deacidification

Trees can play an important role in mitigating nutrient leaching and acidification into nearby habitats, including watercourses and terrestrial plant communities adapted to low nutrient conditions. However, tree species selection is likely to play a relatively minor role, compared with hydrogeological properties including soil type and depth and water table height (Hill, 2019), in addition to tree management (T. Nisbet pers. comm.). Indeed, a meta-analysis found no significant difference in nutrient uptake among buffer strips comprising different vegetation types, including trees versus herbaceous buffers (Mayer *et al*., 2007).

Nevertheless, some evidence suggests that poplars (*Populus* spp.) and willows (*Salix* spp.) are particularly efficient at removing nitrate from water (Nisbet *et al*., 2011; Regni *et al*., 2021), while poplar is also particularly effective at removing atmospheric ammonia[2] (Tang *et al*., 2022). These species are additionally able to increase nitrate uptake when present at higher concentrations (Regni *et al*., 2021). To at least some extent, this is due to the rapid growth of these species and will therefore be strongly influenced by tree management (T. Nisbet pers. comm.).

[2] farmtreestoair.ceh.ac.uk/ammonia-reduction-calculator

It has also been hypothesised that root architecture plays a role in nutrient accumulation, with deeper-rooting species such as walnut (*Juglans* spp.). potentially more effective at reducing nitrogen leaching because of a greater 'safety net' effect (Andrianarisoa *et al.*, 2016). This hypothesis warrants further research, but there is insufficient evidence at present to include in this guide.

In some cases, trees can worsen leaching of nutrients into watercourses, and contribute to surface water acidification (Nisbet and Evans, 2014). This includes nitrogen-fixing alder *Alnus* species, where nitrogen levels are already high, and species which consume high quantities of water coupled with limited nutrient uptake, such as Scots pine (*Pinus sylvestris)*.

In terms of atmospheric nutrient removal, an online ammonia reduction tool provides advice on the design of shelterbelts for ammonia mitigation, including species selection.[3] Although the effect of species on ammonia recapture depends on location and soil type, aspen (*Populus tremula)* is generally the best-performing species of those included in the tool. However, other factors such as buffer dimensions are more important than species selection.

Given the apparently limited role of species selection for nutrient removal and deacidification, except in some cases, no specific category is included in the species guide, and key species (whether beneficial or detrimental) such as alder, poplars and willows are referred to within the 'other environmental impacts' category.

Water consumption

High water use by trees can either be beneficial in areas of excess water, such as those which are prone to flooding, or detrimental where water is in short supply and there is a risk of drought. Trees typically use more water than herbaceous vegetation such as pasture or arable crops. Comparable species-specific information

[3] farmtreestoair.ceh.ac.uk/ammonia-reduction-calculator

on water use is scarce, and plays a secondary role to climatic and soil factors, in addition to tree management (given that growing trees generally use more water than mature trees) (Nisbet, 2005; T. Nisbet pers. comm.). Therefore, water consumption by species is not included as a separate category in this guide.

Broadly speaking however, evergreen coniferous species have higher water consumption than broadleaved species, and of the broadleaved species, high-growth trees managed on a short rotation coppice have the highest consumption (Nisbet, 2005; T. Nisbet pers. comm.). In particular, willow and poplar have very high transpiration rates in wet soil conditions (Nisbet, 2005), but less so in drier soils (Hall *et al*., 1996; T. Nisbet pers. comm.). Similarly, there is evidence of high water use of common alder *Alnus glutinosa* when soil water content is high (Herbst *et al*., 1999). As such, the potential for high water consumption is noted for these species under 'other environmental impacts'.

Spray-drift reduction

Trees can also help to reduce spray-drift of agrochemicals onto nearby habitats. Traits such as timing of leaf emergence (Wenneker and Van de Zande, 2008) and leaf structure, hairiness and coarseness (Ucar and Hall, 2001; Ucar *et al*., 2003; Bentrup *et al*., 2019) appear to be important in determining the effect of a species, although other characteristics such as the height, width and porosity of a tree row or hedgerow are possibly more important (reviewed in Bentrup *et al*., 2019; Ucar and Hall, 2001). As such, given the limited evidence at present, this category is not included in this guide.

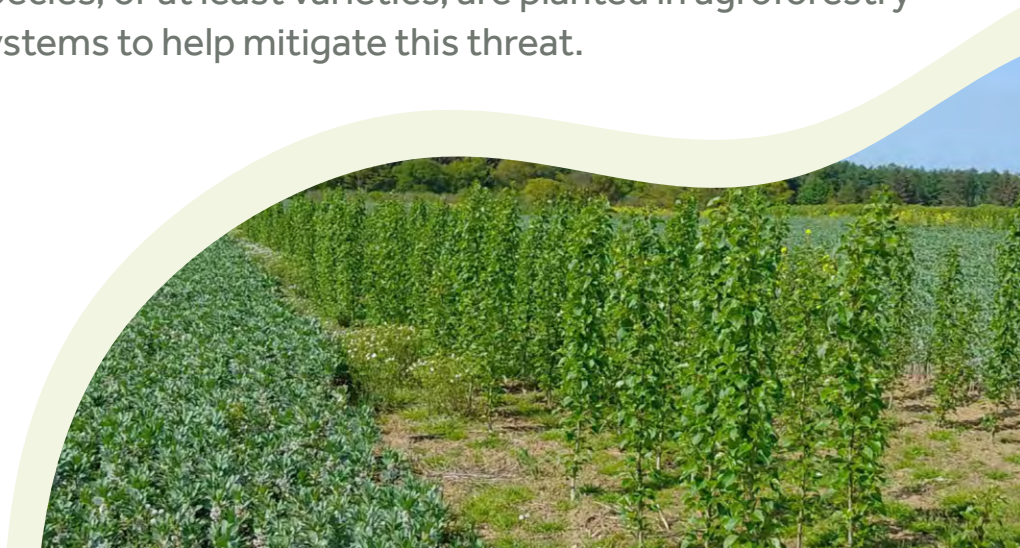
Susceptibility to pests and disease

Disbenefit, categorised under three subcategories as low, moderate, or high

Three categories are assessed, namely susceptibility to (i) disease, (ii) invertebrate pests (e.g. insects), and (iii) vertebrate pests (e.g. mammals and birds). The vertebrate pest assessment refers to damage to the whole tree. Damage to crops (e.g. squirrel damage to nuts) is included separately under 'Risks to farming operations'. For each category, a broad classification is made as follows:

- **High susceptibility:** the species is commonly affected by a pest or disease which causes serious damage (e.g. major loss of crop or tree mortality).
- **Moderate susceptibility:** the species is commonly affected by a pest or disease which causes less serious damage, i.e. trees can often make a full recovery, or are less commonly affected by a serious pest / disease.
- **Low susceptibility:** major pest or disease issues are rare.

The above categories are generalised for the UK at the time of writing. In reality, pest and disease issues are complex and depend on numerous factors such as climate, the presence of the pest or disease in the local area either currently or in the recent past, the composition of habitats and plant species locally and in the wider landscape, and tree stress (e.g. caused by unfavourable environmental conditions). In addition, populations of tree pests and diseases are rapidly changing and there is a constant threat of new pests and diseases colonising the UK, primarily due to climate change and global trade. It is advisable that a mixture of species, or at least varieties, are planted in agroforestry systems to help mitigate this threat.



Climate resilience

Benefit, categorised as low, moderate or high

The resilience of each tree species to projected climate change was assessed by undertaking a rapid review of the literature for each species, e.g. using the search terms "Juglans regia climate change UK", in addition to reviewing grey literature. The identified studies typically assess climate resilience by modelling species' environmental tolerances, such as temperature requirements and drought tolerance, against projected 2050 climate change scenarios, and do not typically account for any changes in community dynamics, for example from pest pressure or competition from other tree species. Where species-specific evidence was not found in the literature, a prediction is made based on the environmental tolerances of the species and its native distribution. The resilience of each species is evaluated according to three categories based on the available evidence:

- **High:** UK climate likely to generally become more suitable for the species, which is projected to expand its range within the UK with very limited areas of reduced suitability.
- **Moderate:** mixed effects of projected climate change in the UK, e.g. projected expansion in the north, but with reduced suitability in a comparable area in the south.
- **Low:** projected climate change likely to result in substantially reduced suitability for the species in the UK, with limited range expansion.

For example, sycamore (*Acer pseudoplatanus)* is categorised as 'moderate' because the species is likely to become less suited to the south-east, east and midlands of England, but more suited to northern England and south-east Scotland, such that its overall range would cover a similar area.

Note that each species is broadly assessed across the UK. In reality, the effect of climate change on species' suitability is often strongly dependent on the region of the UK.

Main products

Tree species can contribute to the following key commercial areas:

- **Food**, especially fruit or nut production.
- **Wood**, especially high-quality timber.
- **Biomass**, especially for woodfuel.
- **Speciality products**, which are typically targeted towards a local niche market.

All tree species fulfil at least one of these categories and, in many cases, more than one. The list of products focuses on those which are commonly marketed, for conciseness. However, trees often bring opportunities for numerous other speciality products, such as medicinal products, edible leaves, and dyes, depending on local market opportunities.

Fruit trees: rootstocks

Fruit trees, such as apple, pear, plum and cherry, are typically grown on rootstocks to control their vigour in addition to other benefits such as disease resistance. A summary of recommended rootstocks is provided in Table 1 on the right. Further guidance is readily available elsewhere.[4] Similarly, many cultivars are available for these species, both traditional and modern, offering different marketable products (e.g. dessert or culinary apples), taste, visual appearance, disease resistance, and harvesting times. Careful consideration should be given to cultivar selection in agroforestry systems to ensure suitable market opportunities and to fit in with seasonal labour demands (e.g. selecting late-ripening apple varieties to avoid conflicts with arable harvest[5]).

Table 1. Recommended rootstocks for fruit trees in agroforestry systems (adapted from information provided by Frank P Matthews).

Fruit tree	Rootstock	Size	Notes
Apple	M25	Vigorous	Vigorous planting schemes or very poor soil
	MM111	Vigorous	Vigorous planting schemes or very poor soil. Can be temperamental, generally less preferable to M25.
	MM106	Semi-vigorous	Appropriate for most schemes
	M116	Semi-vigorous	Appropriate for most schemes, similar to MM106 but with 'wet feet' resistance
Pear	Pyrus communis	Vigorous	-
	Pyrus kirchensaller	Vigorous	A more uniform rootstock from seed than *P. communis*
	Pyrodwarf	Semi-vigorous	Clonally produced and less suckers than *P. communis* or kirchensaller. The name is deceptive.
Pear / quince	Quince A	Semi-vigorous	Delayed compatibility issues, only appropriate in some circumstances
Cherry	Colt	Semi-vigorous	Appropriate for most schemes
	F.12.1 / avium	Vigorous	Vigorous planting schemes or very poor soil
Plum family*	Brompton	Vigorous	Vigorous planting schemes or very poor soil. Limited supply.
	St Julien A	Semi-vigorous	Appropriate for most schemes
	Wavit / Weiwa	Semi-vigorous	Appropriate for most schemes
	Myrobalan B	Vigorous	Vigorous planting schemes or very poor soil

* Plum family includes plums, damsons, gages, peaches, nectarines and interspecific *Prunus* crosses.

[4] For example: www.frankpmatthews.com/advice/fruit_rootstocks/, www.rhs.org.uk/fruit/fruit-trees/rootstocks

[5] agroforestrynet.eu/afinet/whitehall-farm-an-innovative-silvoarable-orchard-system-in-the-uk

Timber production

For high quality hardwood and timber in agroforestry systems it is essential to choose plants that are from an improved tree breeding programme. The system's effectiveness greatly depends on both using plants with the best genetic quality and utilising the correct provenance of the tree seedlings. Additionally, it is important to plant only healthy, high-quality saplings straight from the nursery; these are saplings that have a good ratio of shoot to root mass, are free from disease or injuries and do not have forks. For some species, hybrids or 'genetically improved' varieties are available, which offer improved vigour and disease resistance. Further information on the design and management of timber agroforestry systems is available in the Management Guidelines for Valuable Wood Production in Agroforestry Systems (Morhart *et al*., 2019).

To provide an indication of timber productivity in the species guide, maximum yield classes are stated from the Ecological Site Classification as cubic metres per hectare of equivalent single-species stand. These are maximum values achievable under optimal site conditions and management. In reality, yields are likely to be substantially lower in almost all cases, but the values aim to allow a comparison of productivity between species. Average yield classes are also stated where known.

Impact on local soil quality

The impact of tree species on soil quality is assessed according to two sub-categories: (i) nutrient accumulation, including nutrient cycling, nitrogen fixation and other soil improving characteristics, and (ii) effects on soil pH. Soil erosion control was also considered for inclusion in this guide, as described below, but is not currently included.

Nutrient and organic matter accumulation

Benefit, categorised as low, moderate, or high

Trees can help to return nutrients and organic matter to the upper soil layers by accessing nutrients at deeper soil layers than crop roots, which are subsequently released back into the topsoil, e.g. via litterfall and root breakdown (Isaac and Borden, 2019; Kim and Isaac, 2022). Although nutrient cycling is a complex topic, the most relevant traits include tree rooting depth, on the premise that deeper roots can access nutrients at greater depth, and canopy height and canopy spread which increases the distribution of leaf litter (Isaac and Borden, 2019; Casals *et al*., 2014; Pardon *et al*., 2017; Kassa *et al*., 2022). As such, these three traits were primarily used to assess the nutrient accumulation potential of tree species.

The nutrient content (e.g. NPK ratio) of leaf litter, and its impact on soil nutrients, also depends on tree species (e.g. Purahong *et al*., 2014), which is another layer of complexity beyond the remit of this guide.

Some trees can also increase soil nutrients through nitrogen fixation. Research into nitrogen-fixing trees is surprisingly uncommon in European agroforestry systems. The organic matter accumulation potential of tree species is broadly categorised as high, moderate, or low, based on rooting depth and canopy area, determined by tree height and canopy spread (see Table 2). Nitrogen fixation is noted separately where relevant.

Table 2. Decision matrix for predicting nutrient and organic matter accumulation of tree species.

	Small canopy area (height x width <250 m²)	Moderate canopy area (height x width <400 m²)	High canopy area (height x width >400 m²)
Deep roots	◆ Moderate	▲ High	▲ High
Moderate root depth	▼ Low	◆ Moderate	▲ High
Shallow roots	▼ Low	▼ Low	◆ Moderate

Acidification: effects on soil pH

Disbenefit, categorised as low, moderate, or high

Tree planting on agricultural land typically increases soil acidification, i.e. decreases pH (Hagen-Thorn *et*

al., 2004; De Schrijver *et al*., 2012; Jug *et al*., 1999). However, this effect appears to strongly depend on tree species, because of the differing chemical composition and decomposability of leaf litter (Hagen-Thorn *et al*., 2004). Tree species with slower litter decomposition rates and lower quantities of nutrients, such as Beech (*Fagus sylvatica)*, are associated with the greatest acidification effects, compared with species with rapidly decomposing litter, such as Lime (*Tilia* spp.), in forest plantations on former agricultural land (Hagen-Thorn *et al*., 2004; De Schrijver *et al*., 2012).

In this guide, tree species are classified as having high, moderate or low impacts, with 'high' species having the greatest effect on soil acidification (decrease in pH). Species categorised as 'low' would typically still have an acidifying effect, but less pronounced than in 'high' species. The categorisation was undertaken by benchmarking against relatively well-studied species included in multiple studies (see Table 3). Some species are categorised as 'unknown' where it was not possible to benchmark their acidification effect against other species, but in some of these species there is still evidence for an acidification effect after planting.

Table 3. Overview of acidification effects of relatively well studied tree species following the rapid literature review (see accompanying database for references).

Species	Acidification effect	Comments
Fagus syvatica	▲ High	Typically associated with highest acidification effects of broadleaved species
Quercus robur	▲ High	Similar, or slightly less, acidification effects as *F. sylvatica*
Alnus glutinosa	▲ High	Typically similar effects to native *Quercus*
Acer pseudoplatanus	◆ Moderate	Intermediate between *Quercus* and *Tilia*
Tilia spp.	▼ Low	Typically lowest acidification effects of broadleaved species

Soil erosion control

Not included in this guide

Control of soil erosion is often cited as one of the primary benefits of planting trees on agricultural land (Sollen-Norrlin *et al*., 2020; Torralba *et al*., 2016). Soil erosion can occur through water or wind. Erosion

from wind can be controlled by planting an effective windbreak, which depends more on planting density and tree height than on species choice (Böhm *et al*., 2014).

Research on the effectiveness of different tree species to control soil erosion by water is very limited. Willow (*Salix* spp.) and poplar (*Populus* spp.) are commonly recommended because of their rapid growth, extensive lateral root systems, and tolerance of wet soil conditions (Stokes *et al*., 2014). Their extensive root systems are also likely to help stabilise soils. Trees with deep root systems as well as an extensive root mass are likely to be most effective at stabilising soil (Ola *et al*., 2015; Reubens *et al*., 2007), while leaf litter production also helps to protect soil (Castro-Díez *et al*., 2019). However, the situation is complicated by the possibility of soil type interacting with root architecture to determine the benefit of trees on controlling soil erosion (Vannoppen *et al*., 2017).

Although careful consideration was given to the inclusion of this attribute in this guide, especially given the significant benefits of agroforestry systems on soil erosion control (Torralba *et al*., 2016), at this stage soil erosion control has not been included in this guide due to a lack of evidence as to the importance of root architecture, tree growth rates, and their interaction with soil types. Further research of the effects of tree root architecture on soil erosion in different soil types is therefore needed (Stokes *et al*., 2014).

Shade cover impacts

Benefit or disbenefit depending on system; categorised under three subcategories

Tree shade can be a desirable property in terms of livestock welfare and growth, or an undesirable property in most arable or horticultural systems in the UK. The effect of trees on spatial and temporal shading patterns is complex and depends on planting arrangement (particularly in an alley cropping system) and tree management. In this guide, the impact of shade is reported using the following three sub-categories:

- **Size of shadow**, categorised as 'low', 'moderate'

or 'high'. This is determined by the canopy volume, estimated from the maximum tree height, width, and canopy shape. Based on these variables, the area of the shadow cast by the tree is estimated, and then categorised by benchmarking against the wider species list.

- **Canopy density**, categorised as open, moderately open, moderately dense, or dense.
- **Leaf emergence**, categorised as 'early' (in April), 'late' (in May), or evergreen.

Livestock fodder benefits

Benefit, categorised as low, moderate, high, or (potentially) toxic

This category assesses the potential of each species to be used as supplementary fodder for livestock. The value of tree fodder for livestock varies according to site, season, and the part of the plant, in addition to tree and livestock species. Some nutrients, such as zinc and cobalt, strongly vary among different tree species, while others (such as selenium) appear to be more dependent on site conditions, with only minor differences between species (Kendall *et al*., 2021).

Given the importance of variables such as site and season, this guide does not include numeric values for the concentration of nutrients per species, but instead reports any nutrients or minerals shown to be present at high concentrations relative to other tree species and pasture forage. Potential disbenefits from low concentrations of particular nutrients or minerals in a species are not reported, on the assumption that any individual tree species will only be a minor supplementary component of the diet, such that any shortfalls are unlikely to be problematic in the context of a wider balanced diet. However, negative aspects are stated where the literature indicates a species has palatability or toxicity concerns.

A broad assessment of the species' benefit to livestock is evaluated as high, moderate, or low, based on evidence of nutritional value, including crude

protein, condensed tannins, micronutrient levels, and palatability. For example, Italian alder (*Alnus cordata)* is categorised as 'moderate' value because of its high crude protein and condensed tannin content, balanced against its low palatability. Where there is significant risk of toxicity (e.g. wild cherry *Prunus avium* and bird cherry *P. padus*), this is stated instead of the high-low nutritional value. Otherwise, a more specific or limited risk of toxicity is added as a note following the assessment of nutritional value (e.g. for sessile oak *Quercus petraea*, where there is some toxicity risk in certain plant parts / livestock types).

Risks to farming operations

This is a broad category which includes any other risks to productivity and farming operations that were encountered during the review. Particular attention was given to any tendency to readily spread, for example through suckering roots or prolific production of seeds that easily germinate. Other risks include allelopathy (toxicity to other plant species), risks to agricultural production other than pests and diseases, secondary hosts for pests of agricultural crops, and flammability.

Tree species list

Common name	*Latin name*
Field maple	*Acer campestre*
Sycamore	*Acer pseudoplatanus*
Italian alder	*Alnus cordata*
Common alder	*Alnus glutinosa*
Red alder	*Alnus rubra*
Paper-bark birch	*Betula papyrifera*
Silver birch	*Betula pendula*
Downy birch	*Betula pubescens*
Hornbeam	*Carpinus betulus*
Sweet chestnut	*Castanea sativa*
Hazel	*Corylus avellana*
Cider gum	*Eucalyptus gunnii*
Beech	*Fagus sylvatica*
Black walnut	*Juglans nigra*
Walnut	*Juglans regia*
Apple	*Malus domestica / cultivars*
Scots pine	*Pinus sylvestris*

Common name	*Latin name*
Black poplar	*Populus nigra ssp. betulifolia*
Hybrid poplars (timber)	*Populus* spp.
Aspen	*Populus tremula*
Wild cherry	*Prunus avium*
Plum	*Prunus domestica ssp. domestica*
Bird cherry	*Prunus padus*
Pear	*Pyrus communis*
Sessile oak	*Quercus petraea*
Pedunculate oak	*Quercus robur*
Red oak	*Quercus rubra*
White willow	*Salix alba*
Goat willow	*Salix caprea*
Grey willow	*Salix cinerea*
Willow varieties	*Salix* spp.
Rowan	*Sorbus aucuparia*
Small-leaved lime	*Tilia cordata*

Please note this list is not exhaustive and other species may be considered for planting

Species guide

Field maple *Acer campestre*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Typically up to **15 m**, exceptionally 25 m

Canopy cover
Rounded, **4–8 m** wide

Canopy density
Dense

Root architecture
Very shallow

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
10–20 years to maximum height

Establishment req.
Protection from browsing

Management req.
Minimal to no pruning

Longevity
Usually up to **120** years, potentially 200+ years

Rotation length
Typically **8–15** years, up to 30 years

Approach to silviculture
Coppices well

Field maple *Acer campestre*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy

Wind
▲ Tolerant

Drought
◆ Moderately tolerant

Waterlogging
◆ Moderately sensitive to ▼ Sensitive

Soil types
Neutral to calcerous, moist but well-drained

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Native ●

Value to wildlife
▼ Relatively low value, highest value for pollen and nectar ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▼ Low ●
Invertebrates	◆ Moderate risk ●
Vertebrates	◆ Moderate risk ● esp. rabbits ●

Climate resilience
▲ High resilience ◐

Productivity

Main products

Food	-
Wood	Timber ▼ Low yielding
Biomass	Woodfuel
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Dense ●
Leaf emergence	Early ●

Livestock fodder benefits
▼ Low to ◆ Moderate benefit ◐ (▼ Low crude protein, ◆ Moderate nutritional value)

Risks to farming operations
Could inhibit growth of nearby plants

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

●= high confidence, ◐= moderate confidence, ○= low confidence

Sycamore *Acer pseudoplatanus*

Physical

Typical systems
Arable, pasture, lowland and upland

Max. height
Typically up to **35 m**, exceptionally 40 m

Canopy cover
Broad, domed to ovoid >**8 m** wide

Canopy density
Moderate when young, otherwise Dense

Root architecture
Shallow to moderate, extensive

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
>50 years to maximum height

Establishment req.
Protection from browsing
Benefits from weed control

Management req.
Minimal to no pruning, self prunes well

Longevity
Potentially **400–500** years

Rotation length
Typically **65–75** year timber rotation, up to 100 years

Approach to silviculture
Can be coppiced up to **80–100** years
Can be pollarded

Sycamore *Acer pseudoplatanus*

Tolerances

High temperatures
◆ Moderately sensitive

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant, but benefits from shelter

Drought
◆ Moderately sensitive

Waterlogging
◆ Moderately sensitive to ▼ Sensitive

Soil types
Wide range, prefers deep, well-drained soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
Recent introduction
(Neophyte – naturalised) ●

Value to wildlife
▲ High value, esp. foliage invertebrates, leaf litter and epiphytes ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk, esp. squirrels ●

Climate resilience
◆ Moderate resilience ●

Productivity

Main products

Food	-
Wood	Timber ▲ Moderately high yielding
Biomass	Woodfuel
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	Moderate ○
Acidification	◆ Moderate acidification ◐

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Dense ●
Leaf emergence	Late ●

Livestock fodder benefits
▼ Low to ◆ Moderate benefit ◐
(Conflicting evidence for crude protein, ▼ Low digestability)
Risk of toxicity in horses

Risks to farming operations
Self sows freely, potential weed

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable .

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Italian alder *Alnus cordata*

Physical

Typical systems
Arable and lowland

Max. height
20–29 m

Canopy cover
Conical **4–8 m** wide

Canopy density
Moderately dense

Root architecture
Shallow

Growth rate
▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Minimal

Management req.
Minimal to no pruning

Longevity
60–100 years

Rotation length
At least **20–30** year timber rotation

Approach to silviculture
Variable coppicing ability, rotation **15–30** years

Italian alder *Alnus cordata*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲ Hardy

Wind
▲ Tolerant

Drought
▲ Tolerant, but reduces growth in drought

Waterlogging
◆ Moderately tolerant

Soil types
Prefers deep chalky soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
Recent introduction
(Neophyte - naturalised) ●

Value to wildlife
▼ Low to ◆ Moderate value ○

Other impacts
Risk of increased nitrate leaching and acidification

Resilience

Pest / disease susceptibility

Diseases ----	◆ Moderate risk ●
Invertebrates	▼ Low risk ●
Vertebrates --	▼ Low risk ○

Climate resilience
▲ High resilence ○

Productivity

Main products

Food	-
Wood	Timber, pulpwood ▲ Moderately high yielding
Biomass	Firewood
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▲ Nitrogen fixing ● Otherwise ▼ Low ○
Acidification	▲ High acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Moderately dense ●
Leaf emergence	Late ●

Livestock fodder benefits
◆ Moderate benefit ◐
(▲ High protein content,
▼ Low palatability)

Risks to farming operations
None known

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Common alder *Alnus glutinosa*

Physical

Typical systems
Arable, pasture, lowland and semi-upland

Max. height
Typically **12–25 m**, exceptionally 40 m

Canopy cover
Broad, conical to ovoid, **4–10 m** wide

Canopy density
Open

Root architecture
Moderate, to very shallow in wet soils

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Minimal
Risk of poor growth in tubes

Management req.
Minimal to no pruning

Longevity
Typically **100** years, potentially >250 years, only 20–25 years on poor soils

Rotation length
Maximum rotation **60–70** years

Approach to silviculture
Coppices well when young
Can be pollarded

Common alder *Alnus glutinosa*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant, but shelter required for straight stems

Drought
◆ Moderately sensitive to ▼ Sensitive, esp. when young

Waterlogging
▲ Tolerant

Soil types
Requires moist soils, otherwise undemanding

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
▲ Native ●

Value to wildlife
◆ Moderate value, highest value for foliage invertebrates, fruits and seeds ◐

Other impacts
Risk of increased nitrate leaching and acidification
High water consumption in wet conditions

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	▼ Low risk ●
Vertebrates	▼ Low to ◆ Moderate risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	-
Wood	Low quality timber ▲ Moderately high yielding
Biomass	Biomass, charcoal
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▲ Nitrogen fixing ● Otherwise ▼ Low ○
Acidification	▲ High acidification ◐

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate benefit ●
(▲ High crude protein, ◆ Moderate digestibility, ▼ Low palatability)

Risks to farming operations
Potential weed, readily self-sows

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Red alder *Alnus rubra*

Physical

Typical systems
Pasture and lowland

Max. height
Typically to **15 m**, exceptionally 25 m

Canopy cover
Narrow, pyramidal, **4–8 m** wide

Canopy density
Moderately open

Root architecture
Moderate, extensive

Growth rate
▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Minimal

Management req.
Minimal to no pruning

Longevity
60–100 years, but typically begins to die back after 15 years

Rotation length
Pulpwood **10–12** years,
sawlog **30–32** years

Approach to silviculture
Coppices well on short cycles when young

Photo courtesy of Paul Burgess

Red alder *Alnus rubra*

Tolerances

High temperatures
▼ Sensitive

Low temperatures
▲▲▲ Very hardy, but susceptible to spring frosts

Wind
▲ Tolerant

Drought
▲ Tolerant when established

Waterlogging
Unknown

Soil types
Moist but well drained

Slope and aspect
Avoid north-facing

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
Recent introduction
(Neophyte - naturalised) ●

Value to wildlife
▼ Low to ◆ Moderate value ○

Other impacts
Risk of increased nitrate leaching and acidification

Resilience

Pest / disease susceptibility

Diseases	▼ Low risk ●
Invertebrates	▼ Low risk ●
Vertebrates	▼ Low risk ○

Climate resilience
▲ High resilence ○

Productivity

Main products

Food	-
Wood	Timber and pulpwood ▲ Moderately high yielding
Biomass	-
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▲ Nitrogen fixing ● Otherwise ▼ Low ○
Acidification	▲ High acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Moderately open ●
Leaf emergence	Early ●

Livestock fodder benefits
Poorly understood, likely ▼ Low palatability ◐

Risks to farming operations
▼ Poor growth in most UK trials

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Paper-bark birch *Betula papyrifera*

Physical

Typical systems
Lowland

Max. height
Typically **23–25 m**, exceptionally 30 m

Canopy cover
Ovoid, spreading **>8 m** wide

Canopy density
Open

Root architecture
Shallow

Growth rate
▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Regular mulching / weed control
Risk of poor growth in tubes

Management req.
Minimal to no pruning

Longevity
Up to **200** years

Rotation length
Likely **30–40** year timber rotation

Approach to silviculture
Coppices weakly
Pollards weakly

Paper-bark birch *Betula papyrifera*

Tolerances

High temperatures
▼ Sensitive

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
▼ Sensitive

Waterlogging
▼ Sensitive

Soil types
Wide range, favours deep, fertile and well aerated soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	◆ Moderate
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	▼ Relatively low

Native status
Recent introduction
(Neophyte - survivor) ●

Value to wildlife
◆ Moderate to ▲ High value ○

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	▼ Low risk (▲ High future risk) ●
Vertebrates	▼ Low to ◆ Moderate risk ○

Climate resilience
▲ High resilence ○

Productivity

Main products

Food	-
Wood	Pulpwood
Biomass	-
Speciality	Tree sap

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	Conflicting evidence

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
Poorly understood ○

Risks to farming operations
Highly flammable bark

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Silver birch *Betula pendula*

Physical

Typical systems
Pasture, arable, lowland and semi-upland

Max. height
Typically up to **15–20 m**, exceptionally 30 m

Canopy cover
Columnar, tapering, **4–8+ m** wide

Canopy density
Open

Root architecture
Shallow, but deeper on dry sites

Growth rate
▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Regular mulching / weed control
Protection from browsing
Risk of poor growth in tubes

Management req.
Minimal to no pruning

Longevity
Up to **100** years, exceptionally 200 years

Rotation length
30–40 year timber rotation

Approach to silviculture
Coppices weakly

Silver birch *Betula pendula*

Tolerances

High temperatures
▼ Sensitive

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
▼ Sensitive

Waterlogging
▼ Sensitive

Soil types
Favours light, well-drained, acid soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
Native ●

Value to wildlife
▲ High value, esp. mycorrhizal fungi and foliage invertebrates ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	▼ Low risk (▲ High future risk) ●
Vertebrates	▼ Low to ◆ Moderate risk ●

Climate resilience
◆ Moderate resilience ●

Productivity

Main products

Food	-
Wood	Usually pulpwood ◆ Moderate to ▼ Low yielding
Biomass	-
Speciality	Tree sap

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Generally low ○ Useful for restoration of acid soils ●
Acidification	Conflicting evidence

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
▼ Low to ◆ Moderate benefit ○

Risks to farming operations
None known

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Downy birch *Betula pubescens*

Physical

Typical systems
Pasture, lowland and upland

Max. height
Typically up to **20 m**, exceptionally 30 m

Canopy cover
Irregular, **6–8 m** wide

Canopy density
Open

Root architecture
Shallow to moderate

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Regular mulching / weed control
Protection from browsing
Risk of poor growth in tubes

Management req.
Minimal to no pruning

Longevity
Up to **100** years, exceptionally 200 years

Rotation length
30–40 year timber rotation

Approach to silviculture
Coppices weakly, long rotation

Downy birch *Betula pubescens*

Tolerances

High temperatures
▼ Sensitive

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
▼ Sensitive

Waterlogging
◆ Moderately tolerant

Soil types
Wide range, favours more acidic, wet, peaty soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration
Short-term (20 yrs)	◆ Moderate
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	▼ Relatively low

Native status
Native ●

Value to wildlife
▲ High value, esp. mycorrhizal fungi and foliage invertebrates ◐

Other impacts
None known

Resilience

Pest / disease susceptibility
Diseases	▲ High risk ●
Invertebrates	▼ Low risk (▲ High future risk) ●
Vertebrates	▼ Low to ◆ Moderate risk ●

Climate resilience
▼ Low resilience ●

Productivity

Main products
Food	-
Wood	Timber and pulpwood ▼ Relatively low yielding
Biomass	Woodfuel
Speciality	Tree sap

Impact on local soil quality
Nutrients and organic matter accumulation	▼ Generally low ○ Useful for restoration of acid soils ●
Acidification	Conflicting evidence

Shade cover impacts*
Size of shadow (full grown)	▼ Low ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
▼ Low to ◆ Moderate benefit ○

Risks to farming operations
None known

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Hornbeam *Carpinus betulus*

Physical

Typical systems
Arable, pasture, and lowland

Max. height
Typically up to **25 m**, exceptionally 32 m

Canopy cover
Ovoid to globular, **>8 m** wide

Canopy density
Dense

Root architecture
Shallow to moderate

Growth rate
▼ Low to ◆ Moderate

Silviculture

Establishment time
>50 years to maximum height

Establishment req.
Protection from squirrel damage

Management req.
Minimal to no pruning

Longevity
Potentially **400+** years

Rotation length
15–25 year to **30–40** year coppice rotation

Approach to silviculture
Coppices well
Can be pollarded

Hornbeam *Carpinus betulus*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
◆ Moderately tolerant

Waterlogging
▼ Sensitive

Soil types
Wide range, favours fertile, damp soils

Slope and aspect
Any

Shade tolerances
Full sun to at least partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	◆ Moderate

Native status
Native ●

Value to wildlife
▼ Relatively low value, highest value for mycorrhizal fungi, leaf litter and seeds ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	▼ Low risk ●
Vertebrates	◆ Moderate to ▲ High risk esp. squirrels ●

Climate resilience
▲ High resilience ◐

Productivity

Main products

Food	-
Wood	Specialised timber ◆ Moderate yielding
Biomass	Woodfuel, charcoal
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low to ◆ Moderate ○
Acidification	▲ High acidification ◐

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Dense ●
Leaf emergence	Early ●

Livestock fodder benefits
▼ Low benefit ◐
(◆ Moderate crude protein,
▼ Low nutritional value)

Risks to farming operations
None known

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Sweet chestnut *Castanea sativa*

Physical

Typical systems
Arable, pasture, lowland to semi-upland

Max. height
30–35 m

Canopy cover
Ovoid to irregular, **>8 m** wide

Canopy density
Dense

Root architecture
Moderate to deep, extensive

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
20–50 years to maximum height, full nut production in 10-15 years

Establishment req.
Minimal

Management req.
Minimal to no pruning

Longevity
Potentially **300–1000** years

Rotation length
12–16 years coppice
25–30 years pulpwood

Approach to silviculture
Coppices well

Sweet chestnut *Castanea sativa*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy (but cultivars can be frost sensitive)

Wind
Potentially ▼ Sensitive

Drought
◆ Moderately sensitive to ▲ Tolerant (cultivars typically more sensitive)

Waterlogging
▼ Sensitive

Soil types
Wide range, favours acid to neutral, moist but well-drained soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	◆ Moderate

Native status
Long-established ●
(Archaeotype - cultivated)

Value to wildlife
▼ Relatively low value ◐
Highest value for seeds

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate to ▲ High risk ●
Invertebrates	▼ Low to ◆ Moderate risk ●
Vertebrates	▼ Low to ◆ Moderate risk ●

Climate resilience
◆ Moderate to ▲ High resilience ●

Productivity

Main products

Food	Nuts, typically using hybrid cultivars
Wood	Timber, pulpwood, poles ◆ Moderately high yielding
Biomass	Woodfuel (low quality)
Speciality	Tannins for leather etc., mushroom cultivation

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High ○ Useful soil improver on light soils ●
Acidification	Unknown

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Dense ●
Leaf emergence	Late ●

Livestock fodder benefits
Conflicting evidence
Nuts used for pig feed

Risks to farming operations
Timber can be affected by ring shake

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

●= high confidence, ◐= moderate confidence, ○= low confidence

Hazel *Corylus avellana*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Typically up to **6 m**, potentially 10 m

Canopy cover
Globular, spreading, **4–8 m** wide

Canopy density
Moderately dense

Root architecture
Shallow, limited extent

Growth rate
◆ Moderate

Silviculture

Establishment time
5–10 years to maximum height, full nut production from c. 10 years

Establishment req.
Protection from browsing

Management req.
Minimal to no pruning

Longevity
Typically **70–80** years, potentially 200+ years

Rotation length
6–9 years coppice, or **14–16** years with standard trees

Approach to silviculture
Coppices well

Hazel *Corylus avellana*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲ Hardy

Wind
▲ Tolerant

Drought
◆ Moderately sensitive

Waterlogging
▼ Sensitive

Soil types
Wide range, favours base-rich, damp but well drained soils

Slope and aspect
Avoid north facing

Shade tolerances
Favours full sun, but shade tolerant

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Native ●

Value to wildlife
◆ Moderate value, highest value for leaf litter and epiphytes ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▼ Low risk ●
Invertebrates	▼ Low risk ●
Vertebrates	◆ Moderate risk, esp. squirrels ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	Nuts
Wood	Fencing poles
Biomass	Woodfuel
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	Unknown

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Moderately dense ●
Leaf emergence	Early ●

Livestock fodder benefits
▼ Low benefit ◐
(▼ Low crude protein, ▼ Low digestibility)

Risks to farming operations
Suckering roots (rootstocks can mitigate this)
Nuts are susceptible to squirrel damage

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Cider gum *Eucalyptus gunnii*

Physical

Typical systems
Lowland

Max. height
25–34 m

Canopy cover
Ovoid, **>8 m** wide

Canopy density
Open

Root architecture
Poorly understood, potentially extensive

Growth rate
▲ High to ▲▲ Very high

Silviculture

Establishment time
10–20 years to maximum height

Establishment req.
Weed control

Management req.
Minimal to no pruning

Longevity
Unknown

Rotation length
Typically **12** year rotation

Approach to silviculture
Can be coppiced
Can be pollarded

Cider gum *Eucalyptus gunnii*

Tolerances

High temperatures
▼ Sensitive

Low temperatures
▲▲ Hardy in most of UK, but susceptible to early frosts

Wind
▼ Sensitive

Drought
Likely ◆ Moderately sensitive

Waterlogging
◆ Moderately sensitive to
◆ Moderately tolerant

Soil types
Favours slighly acidic

Slope and aspect
Avoid exposed locations

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲▲ Very high
Med-term (40 yrs)	▲▲ Very high
Long-term (60 yrs)	▲▲ Very high

Native status
Recent introduction
(Neophyte - survivor) ●

Value to wildlife
Negligible value, but some value for bees and other pollinators ◐

Other impacts
High water consumption

Resilience

Pest / disease susceptibility

Diseases	▼ Low risk ●
Invertebrates	▼ Low risk ●
Vertebrates	▼ Low to ◆ Moderate risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	-
Wood	Timber, pulpwood, potentially ▲▲ Very high yielding
Biomass	Woodfuel
Speciality	Oil

Impact on local soil quality

Nutrients and organic matter accumulation	◆ Moderate ○
Acidification	◆ Moderate ○

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Open ●
Leaf emergence	Evergreen ●

Livestock fodder benefits
Limited evidence

Risks to farming operations
High risk of failure from wind-chill and frosts
Highly flammable

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Beech *Fagus sylvatica*

Physical

Typical systems
Pasture, arable, lowland and upland

Max. height
Typically up to **35 m**, exceptionally 43 m

Canopy cover
Globular to broad ovoid, **>8 m** wide

Canopy density
Dense

Root architecture
Shallow to moderate, extensive

Growth rate
◆ Moderate

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Weed control
Risk of poor growth in tubes

Management req.
Minimal to no pruning

Longevity
Typically up to **150–300** years, exceptionally 900 years

Rotation length
Typically **70–80** year timber rotation, exceptionally 100-140 years

Approach to silviculture
Coppices weakly
Can be pollarded

Beech *Fagus sylvatica*

Tolerances

High temperatures
▼ Sensitive

Low temperatures
▲▲ Hardy, but susceptible to early and late frosts

Wind
▲ Tolerant, but benefits from shelter when young

Drought
◆ Moderately sensitive

Waterlogging
▼ Sensitive

Soil types
Wide range, but requires moderate moisture levels

Slope and aspect
Any

Shade tolerances
Full sun to at least partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	◆ Moderate

Native status
Native ●

Value to wildlife
▲ High value, especially for mycorrhizal fungi, wood-decay fungi and invertebrates, seeds and epiphytes ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk ●

Climate resilience
▼ Low to ◆ Moderate resilience ●

Productivity

Main products

Food	-
Wood	Timber ◆ Moderate yielding
Biomass	Woodfuel
Speciality	Oil from nuts

Impact on local soil quality

Nutrients and organic matter accumulation	◆ Moderate ○
Acidification	▲ High acidification ●

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Dense ●
Leaf emergence	Early ●

Livestock fodder benefits
▼ Low to ◆ Moderate benefit ●
(◆ Moderate crude protein and micronutrients)

Risks to farming operations
Potentially very large trees

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Black walnut *Juglans nigra*

Physical

Typical systems
Pasture, arable and lowland

Max. height
Typically up to **30 m**, exceptionally 50 m

Canopy cover
Globular, domed, **>8 m** wide

Canopy density
Moderate

Root architecture
Deep

Growth rate
◆ Moderate

Silviculture

Establishment time
>50 years to maximum height, 10 years for commercial nut yields

Establishment req.
Formative pruning
Weed control

Management req.
High pruning for timber

Longevity
Unknown

Rotation length
Typically **60** year timber rotation

Approach to silviculture
Can be coppiced
Can be pollarded

Black walnut *Juglans nigra*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy, but susceptible to late frosts

Wind
▼▼ Highly sensitive

Drought
◆ Moderately sensitive

Waterlogging
▼ Sensitive

Soil types
Somewhat demanding, favours deep, well drained, fertile soils

Slope and aspect
Favours south / south-west, sheltered locations.
Avoid north facing

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	◆ Moderate
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	▼ Relatively low

Native status
Recent introduction
(Neophyte - naturalised) ●

Value to wildlife
▼ Relatively low value, highest value for mycorrhizal fungi and leaf litter ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk, esp. from squirrels ●

Climate resilience
▲ High resilience ◐

Productivity

Main products

Food	Nuts, more difficult to de-shell than *J. regia*
Wood	High value timber, ◆ Moderately high yielding Vigorous hybrids available (likely lower value)
Biomass	-
Speciality	Dye and oil

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High ○
Acidification	▼ Low acidification ○

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Moderate ●
Leaf emergence	Late ●

Livestock fodder benefits
◆ Moderate to ▲ High benefit ◐
(▲ High crude protein, ◆ Moderate digestibility)
Risk of toxicity in horses from wood shavings, and all animals from mouldy walnuts

Risks to farming operations
Allelopathic toxicity to other plants, particularly affecting tomatoes and apples
Limited climatic suitability at present

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

●= high confidence, ◐= moderate confidence, ○= low confidence

Walnut *Juglans regia*

Physical

Typical systems
Pasture, arable and lowland

Max. height
20–30 m

Canopy cover
Globular to ovoid or domed (conical when young), up to **15 m** wide

Canopy density
Moderate

Root architecture
Very deep

Growth rate
◆ Moderate

Silviculture

Establishment time
20–50 years to maximum height, nut yields after 5-6 years

Establishment req.
Staking, irrigation, formative pruning for timber, weed control

Management req.
High pruning for timber

Longevity
150–280 years

Rotation length
Typically **60** years, exceptionally 30 years

Approach to silviculture
Can be pollarded

Walnut *Juglans regia*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy, but sensitive to unseasonable frosts (some varieties have improved frost resistance)

Wind
▼ Sensitive (flowers and foliage)

Drought
◆ Moderately sensitive

Waterlogging
▼ Sensitive

Soil types
Demanding; favours well drained, deep, fertile, alkaline loam

Slope and aspect
Avoid exposed locations

Shade tolerances
Full sun, light shade tolerated in early development

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	◆ Moderate
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	▼ Relatively low

Native status
Long-established
(Archaeotype - cultivated) ●

Value to wildlife
▼ Relatively low value, highest value for mycorrhizal fungi and leaf litter ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	▼ Low risk, although nuts susceptible to pest damage ●
Vertebrates	◆ Moderate risk, esp. from squirrels ●

Climate resilience
▲ High resilience ◐

Productivity

Main products

Food	Nuts (typically using specific varieties)
	High value timber or sawn wood
Wood	▼ Relatively low yielding
	Vigorous hybrids available (likely lower value)
Biomass	-
Speciality	Dye and oil

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High ○
Acidification	▼ Low acidfication ○

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Moderate ●
Leaf emergence	Late ●

Livestock fodder benefits
◆ Moderate to ▲ High benefit ◐
(▲ High protein, ◆ Moderate digestibility)
Risk of toxicity in horses from wood shavings, and all animals from mouldy walnuts

Risks to farming operations
Allelopathic toxicity to other plants, particularly affecting tomatoes and apples
Limited climatic suitability at present
Nut crop susceptible to squirrel damage

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Apple *Malus domestica*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Depends on cultivar and rootstock

Canopy cover
Ovoid to irregular crown
Spread depends on cultivar / rootstock

Canopy density
Moderate

Root architecture
Depends on cultivar and rootstock, generally very deep for its size

Growth rate
◆ Generally moderate (depends on cultivar and rootstock)

Silviculture

Establishment time
Full cropping in **3–9** years (depends on cultivar and rootstock)

Establishment req.
Staking, formative pruning, water during drought, protection from browsing

Management req.
Annual pruning

Longevity
Depends on cultivar and rootstock

Rotation length
12–45 years, depending on cultivar and rootstock

Approach to silviculture
Orchard tree

Apple *Malus domestica*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▼ Sensitive to frost pockets

Wind
▼ Sensitive

Drought
◆ Moderately sensitive

Waterlogging
▼ Sensitive

Soil types
Wide range, avoid poorly drained or shallow soils

Slope and aspect
Sunny and sheltered

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Long-established
(Archaeotype - denizen or cultivated) ●

Value to wildlife
▲ High value, especially for foilage invertebrates, leaf litter, pollen and nectar, fruits ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate to ▲ high risk ● (varies according to variety and rootstock)
Invertebrates	▲ Generally high risk ● (varies according to variety and rootstock)
Vertebrates	◆ Moderate risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	Fruits (inc. eating, cooking, cider)
Wood	Speciality timber
Biomass	Limited woodfuel from pruning
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	◆ Moderate ○
Acidification	Unknown

Shade cover impacts*

Size of shadow (full grown)	▼ Low but depends on rootstock / variety
Canopy density	Moderate ●
Leaf emergence	Early ●

Livestock fodder benefits
▲ High benefit ◐
(especially fruits and pomace)

Risks to farming operations
None known

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Scots pine *Pinus sylvestris*

Physical

Typical systems
Arable, pasture, lowland to upland

Max. height
35–40 m

Canopy cover
Conical, broadening with age, **>8 m** wide

Canopy density
Dense

Root architecture
Deep

Growth rate
▼ Low

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Protection from browsing
Risk of poor growth in tubes

Management req.
Regular pruning for timber

Longevity
Potentially **250–400** years

Rotation length
Typically **50–60** year timber rotation, up to 100 years

Approach to silviculture
High forest tree

Scots pine *Pinus sylvestris*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
▲ Tolerant

Waterlogging
◆ Moderately sensitive to
◆ Moderately tolerant

Soil types
Favours well-drained, non-calcareous soils, tolerant of poor fertility

Slope and aspect
Any

Shade tolerances
Favours full sun, esp. when young

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼ Relatively low
Long-term (60 yrs)	◆ Moderate

Native status
Native (in Scotland) ●

Value to wildlife
◆ Moderate value, highest value for mycorrhizal fungi ◐

Other impacts
High water consumption
Can increase acidification of nearby watercourses, especially in dry areas

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	◆ Moderate to ▲ High risk ●

Climate resilience
◆ Moderate resilience ●

Productivity

Main products

Food	Nuts
Wood	Diverse timber uses ▲ High yielding
Biomass	-
Speciality	Resin, pine oil, Christmas trees

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	▲ High acidification ◐

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Dense ●
Leaf emergence	Evergreen ●

Livestock fodder benefits
◆ Moderate benefit ◐

Risks to farming operations
Capable of becoming very large
Can aggressively regenerate from seeds
Flammable

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Black poplar *Populus nigra* ssp. *betulifolia*

Physical

Typical systems
Pasture, arable and lowland

Max. height
30–40 m

Canopy cover
Spreading, ovoid to irregular, **>8 m** wide

Canopy density
Moderately dense

Root architecture
Moderate to deep, vigorously suckering

Growth rate
▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Protection from browsing

Management req.
Regular pruning for timber, sucker removal in autumn / winter

Longevity
Potentially **200–300+** years

Rotation length
Typically **6–20** years

Approach to silviculture
Can be coppiced
Can be pollarded

Black poplar *Populus nigra* ssp. *betulifolia*

Tolerances

High temperatures
◆ Moderately tolerant to
▲ Tolerant

Low temperatures
▲▲ Hardy

Wind
▲ Tolerant

Drought
▲ Sensitive to
◆ Moderately sensitive

Waterlogging
◆ Moderately tolerant to
▲ Tolerant

Soil types
Favours lowland floodplains, especially loam, chalk or sand

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲▲ Very high
Med-term (40 yrs)	▲▲ Very high
Long-term (60 yrs)	▲▲ Very high

Native status
Native ●

Value to wildlife
▼ Relatively low value ◐,
but of high value as an endangered native tree, highest value for foliage invertebrates

Other impacts
High water consumption in wet conditions
High potential to reduce nutrient leaching

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	-
Wood	Low quality timber ▲ High yielding
Biomass	Charcoal
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High ○
Acidification	▼ Low to ◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Moderately dense ●
Leaf emergence	Early ●

Livestock fodder benefits
Likely ◆ Moderate benefit ○
(◆ Moderately high crude protein content)

Risks to farming operations
Vigorous, suckering roots
Risk of overwintering aphid pests of vegetables

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Hybrid poplars (timber) *Populus* spp.

Physical

Typical systems
Pasture, arable and lowland

Max. height
Depends on variety

Canopy cover
Depends on variety

Canopy density
Depends on variety

Root architecture
Moderate to deep, extensive surface

Growth rate
▲▲ Very high

Silviculture

Establishment time
Depends on variety

Establishment req.
Weed control

Management req.
Regular pruning

Longevity
N/A, harvested on rapid rotation

Rotation length
Typically **30–40** years, exceptionally 22 years

Approach to silviculture
High forest tree

Hybrid poplars (timber) *Populus* spp. *gra* ssp. *betulifolia*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
Susceptible to late frosts

Wind
◆ Moderately tolerant but benefits from shelter

Drought
▼ Sensitive (in terms of reducing growth rate)

Waterlogging
▼ Sensitive (in terms of reducing growth rate)

Soil types
Demanding in terms of rapid growth, requiring highly fertile base-rich, well-drained and
aerated soils

Slope and aspect
Any

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲▲ Very high
Med-term (40 yrs)	▲▲ Very high
Long-term (60 yrs)	▲▲ Very high

Native status
Hybrids typically derived from non-native species ●

Value to wildlife
▼ Relatively low value, highest value for foliage invertebrates ◐

Other impacts
High water consumption in wet conditions
High potential to reduce nutrient leaching

Resilience

Pest / disease susceptibility

Diseases	▲ High risk (but depends on variety) ●
Invertebrates	▲ High risk (but depends on variety) ●
Vertebrates	▲ High risk ●

Climate resilience
◆ Moderate to ▲ High resilience ○

Productivity

Main products

Food	-
Wood	Timber, potentially ▲▲ Very high yielding
Biomass	Bioenergy
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High ○
Acidification	▼ Low to ◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate to ▲ High (depends on variety) ●
Canopy density	Depends on variety ●
Leaf emergence	Early ●

Livestock fodder benefits
Likely ◆ Moderate benefit ○

Risks to farming operations
Risk of overwintering aphid pests of vegetables

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Aspen *Populus tremula*

Physical

Typical systems
Arable, pasture, lowland to upland

Max. height
18–40 m

Canopy cover
Ovoid to globular, slightly conical, **>8 m** wide

Canopy density
Light to moderately dense

Root architecture
Moderate to deep, abundant suckers

Growth rate
▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Protection from browsing

Management req.
Minimal to no pruning, self-prunes well

Longevity
Up to **100** years

Rotation length
Coppice rotation of **20** years for pulpwood

Approach to silviculture
Coppices well within first 5 years

Aspen *Populus tremula*

Tolerances

High temperatures
▼ Sensitive

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
◆ Moderately sensitive

Waterlogging
◆ Moderately tolerant to ▲ Tolerant

Soil types
Wide range, favours free-draining mineral soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
Native ●

Value to wildlife
▼ Relatively low value, highest value for foliage invertebrates ◐

Other impacts
High water consumption in wet conditions
High potential to reduce nutrient leaching

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate to ▲ High risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk ●

Climate resilience
◆ Moderate to ▲ High resilience ◐

Productivity

Main products

Food	-
Wood	Timber veneers, pulp, charcoal, potentially ▲ High yielding
Biomass	Potential for biomass where growth is rapid
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	◆ Moderate ○
Acidification	▼ Low to ◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Light to moderately dense ●
Leaf emergence	Late ●

Livestock fodder benefits
◆ Moderate benefit ○

Risks to farming operations
Abundant root suckers, can damage drains and buildings

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Wild cherry *Prunus avium*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Typically up to **25 m**, exceptionally 32 m

Canopy cover
Domed, globular to broad ovoid, **c. 8 m** wide or more

Canopy density
Moderately dense

Root architecture
Moderate, becoming shallow with age, suckering

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
20–50 years to maximum height, fruit yields within 5-6 years

Establishment req.
Weed control

Management req.
High pruning for timber

Longevity
Up to **100** years or more

Rotation length
40–80 years for timber

Approach to silviculture
Coppices poorly

Wild cherry *Prunus avium*

Tolerances

High temperatures
◆ Moderately sensitive

Low temperatures
▲▲ Hardy, but flowers can be damaged by late frosts

Wind
Conflicting information

Drought
◆ Moderately sensitive

Waterlogging
▲ Sensitive

Soil types
Well-drained, favouring deep fertile soils

Slope and aspect
Avoid exposed locations

Shade tolerances
Full sun, shade tolerant when young

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
Native ●

Value to wildlife
◆ Moderate value, highest value for fruits and seeds ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	◆ Moderate risk ●

Climate resilience
◆ Moderate resilience ●

Productivity

Main products

Food	Fruits
Wood	High-value timber ▲ High yielding
Biomass	-
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	◆ Moderate ○
Acidification	▼ Low acidification ○

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy density	Moderately dense ●
Leaf emergence	Early ●

Livestock fodder benefits
▼ Risk of toxicity ◐

Risks to farming operations
Root suckers
Risk of toxicity to other plants, including potatoes, wheat, plum
Liable to windthrow and heartrot, especially >60 years
Fruits vulnerable to damage from bullfinches

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Plum *Prunus domestica* spp. *domestica*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Depends on variety and rootstock

Canopy cover
Globular, depends on variety and rootstock

Canopy density
Moderately dense

Root architecture
Shallow and suckering, depending on root-stock

Growth rate
◆ Moderate

Silviculture

Establishment time
5–10 years to maximum height, fruit yields within 4–5 years, full production 7–9 years

Establishment req.
Formative pruning, shelter, irrigation

Management req.
Annual pruning in spring to early summer

Longevity
Unknown

Rotation length
25–35 years

Approach to silviculture
Orchard tree

Photo courtesy of App4Future

Plum *Prunus domestica* spp. *domestica*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy in most of the UK

Wind
▼ Sensitive

Drought
▲ Tolerant

Waterlogging
▼ Sensitive

Soil types
Favours sand or clay, acid to neutral, well drained soils

Slope and aspect
South or west facing

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Long established
(Archaeotype - denizen or cultivated) ●

Value to wildlife
◆ Moderate value, highest value for leaf litter, pollen and nectar and fruits ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▲ High ●
Invertebrates	▲ High ●
Vertebrates	▼ Low risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	Fruits (inc. fresh, dehydrated, canned and processed)
Wood	Speciality timber
Biomass	Limited woodfuel from pruning
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	▲ High acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Moderately dense ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate benefit ◐
(undersized fruits used for feed)
▼ Risk of toxicity in other plant parts

Risks to farming operations
Root suckers (can be mitigated through appropriate rootstocks)
Fruits vulnerable to damage from bullfinches

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Bird cherry *Prunus padus*

Physical

Typical systems
Arable, lowland to semi-upland

Max. height
15–21 m

Canopy cover
Spreading, domed and ovoid (conical when young), **4–8 m** wide

Canopy density
Light to moderately dense

Root architecture
Shallow and suckering

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Minimal

Management req.
Prune in mid-summer if silver leaf a problem

Longevity
60–100+ years

Rotation length
No typical rotation

Approach to silviculture
Can be coppiced
Can be pollarded

Bird cherry *Prunus padus*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy

Wind
Conflicting information

Drought
◆ Moderately sensitive

Waterlogging
◆ Moderately tolerant

Soil types
Wide range, favours well-drained damp soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Native ●

Value to wildlife
◆ Moderate value, highest value for fruits and seeds ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk (▲ High future risk) ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▼ Low to ◆ Moderate risk ●

Climate resilience
▼ Low resilience ◐

Productivity

Main products

Food	Fruits (inc. for jams and liqueur)
Wood	Speciality timber
Biomass	-
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	▼ Low acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Light to mod. dense ●
Leaf emergence	Early ●

Livestock fodder benefits
Risk of toxicity ◐

Risks to farming operations
Root suckers
Fruits vulnerable to damage from bullfinches

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Pear *Pyrus communis*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Depends on variety and rootstock

Canopy cover
Upright and slender to ovoid, spread depends on variety and rootstock

Canopy density
Dense

Root architecture
Generally deep, depending on variety and rootstock

Growth rate
▼ Low to ◆ Moderate

Silviculture

Establishment time
Full cropping in **3–9** years (depending on cultivar and rootstock)

Establishment req.
Staking, formative pruning, water during drought

Management req.
Annual pruning recommended

Longevity
Potentially **200–300** years, depending on cultivar and rootstock

Rotation length
15–40 years, depending on cultivar and rootstock

Approach to silviculture
Orchard tree

Pear *Pyrus communis*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy

Wind
▼ Sensitive

Drought
◆ Moderately sensitive
to ◆ Moderately tolerant

Waterlogging
▼ Sensitive

Soil types
Wide range, favours
well-drained with at least
moderate fertility, avoid very acidic soils

Slope and aspect
South or west facing, sheltered

Shade tolerances
Full sun, especially when young

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Long established
(Archaeotype - cultivated) ●

Value to wildlife
▲ High value, highest value
for invertebrates, leaf litter and
pollen and nectar ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	▲ High risk ●
Vertebrates	◆ Moderate risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	Fruits (inc. fresh, canned, dried, juiced)
Wood	Speciality timber
Biomass	Limited woodfuel from pruning
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	◆ Moderate ○
Acidification	Unknown

Shade cover impacts*

Size of shadow (full grown)	▼ Low, but depends on rootstock / variety ●
Canopy density	Dense ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate benefit ○

Risks to farming operations
None known

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Sessile oak *Quercus petraea*

Physical

Typical systems
Arable, pasture, lowland to upland

Max. height
Typically up to **27 m**, exceptionally 40 m

Canopy cover
Globular to broad ovoid, domed, **>8 m** wide, potentially very wide

Canopy density
Moderately dense

Root architecture
Deep

Growth rate
▼ Low to ◆ Moderate

Silviculture

Establishment time
>50 years to maximum height

Establishment req.
Weed control, protection from browsing, formative pruning

Management req.
High pruning for good quality timber

Longevity
Typically up to **400–500** years, potentially 600–1000+ years

Rotation length
15–25 years coppice, 120–160 years sawn-wood or veneer

Approach to silviculture
Can be coppiced
Can be pollarded

Sessile oak *Quercus petraea*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲▲ Very hardy but occasionally damaged by late frosts

Wind
▲ Tolerant

Drought
◆ Moderately tolerant

Waterlogging
▼ Sensitive

Soil types
Wide range, favours well-drained some-what acidic soils

Slope and aspect
Any

Shade tolerances
Full sun to at least partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	◆ Moderate
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	▼ Low

Native status
Native ●

Value to wildlife
▲▲ Very high, esp. for mycorrhizal fungi, wood-decay fungi and invertebrates, foliage invertebrates, seeds and epiphytes ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk ●

Climate resilience
▼ Low to ◆ Moderate resilience ●

Productivity

Main products

Food	-
Wood	High value timber (inc. sawnwood, veneers, plywood) ▼ Relatively low yielding
Biomass	Woodfuel
Speciality	Acorn flour, various medicinal products

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High ○
Acidification	▲ High acidification ◐

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Moderately dense ●
Leaf emergence	Late ●

Livestock fodder benefits
◆ Moderate benefit ◐
(◆ Moderate crude protein, ▼ Low minerals)
Risk of toxicity from buds, young leaves and acorns

Risks to farming operations
Capable of becoming very large tree
Timber very prone to defects

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Pedunculate oak *Quercus robur*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Typically up to **27 m**, exceptionally 40 m

Canopy cover
Globular to broad ovoid, domed, **>8 m** wide, potentially very wide

Canopy density
Moderate to moderately dense

Root architecture
Deep to very deep, more lateral roots on shallow soils

Growth rate
▼ Low

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Weed control, protection from browsing, formative pruning

Management req.
High pruning for good quality timber

Longevity
Typically up to **400–500** years, potentially 600-1000+ years

Rotation length
15–25 years coppice, 120 or more years sawnwood or veneer

Approach to silviculture
Can be coppiced (esp. in south)
Can be pollarded

Pedunculate oak *Quercus robur*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲ Hardy, but occasionally damaged by late frosts

Wind
▲ Tolerant, when established

Drought
◆ Moderately sensitive to
▼ Sensitive

Waterlogging
◆ Moderately sensitive to
◆ Moderately tolerant

Soil types
Wide range, favours well-drained but heavy, somewhat base-rich soils

Slope and aspect
Any

Shade tolerances
Full sun (especially when young)to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	◆ Moderate
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	▼ Low

Native status
Native ●

Value to wildlife
▲▲ Very high, esp. for mycorrhizal fungi, wood decay fungi and invertebrates, foliage invertebrates, seeds, and epiphytes ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	-
Wood	High value timber (inc. sawnwood, veneers, plywood) ▼ Rel. low yielding
Biomass	Woodfuel
Speciality	Acorn flour, various medicinal products

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High ◐
Acidification	▲ High acidification ◐

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Moderate to moderately dense ●
Leaf emergence	Late ●

Livestock fodder benefits
◆ Moderate benefit ◐
(◆ Moderate crude protein, ▼ Low minerals)
Acorns historically important for pig forage
Risk of toxicity from buds, young leaves and acorns

Risks to farming operations
Capable of becoming very large tree
Timber very prone to defects

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Red oak *Quercus rubra*

Physical

Typical systems
Arable, pasture and lowland

Max. height
Typically up to **20 m**, exceptionally 35 m

Canopy cover
Globular to broad ovoid, **>8 m** wide, potentially > 10 m

Canopy density
Moderately dense

Root architecture
Likely deep

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Minimal

Management req.
High pruning

Longevity
Typically **100** years, potentially 200 years

Rotation length
Typically **70–120** years

Approach to silviculture
Coppices well

Red oak *Quercus rubra*

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲▲ Very hardy, but occasionally damaged by late frosts

Wind
▲ Tolerant

Drought
◆ Moderately sensitive to ▲ Tolerant; Drought likely to damage timber

Waterlogging
▼ Sensitive

Soil types
Well-drained chalks, sand or clay, favours acidic sandy loams

Slope and aspect
Avoid north facing

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼ Relatively low
Long-term (60 yrs)	▼ Relatively low

Native status
Recent introduction (Neophyte - naturalised) ●

Value to wildlife
◆ Moderate to ▲ High value ○

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Inverte-brates	▼ Low to ◆ Moderate risk ●
Vertebrates	▲ High risk ○

Climate resilience
▲ High resilience ◐

Productivity

Main products

Food	-
Wood	Timber, lower value than native oaks ▼ Relatively low yield-ing
Biomass	Woodfuel
Speciality	-

Impact on local soil quality

Nutrients and organic mat-ter - accumulation	▲ High ○
Acidification ---	▲ High acidification ○

Shade cover impacts*

Size of shadow (full grown)	◆ Moderate ●
Canopy den-sity	Moderately dense ●
Leaf emer-gence	Late ●

Livestock fodder benefits
▼ Low benefit ○
Risk of toxicity from buds, young leaves and acorns

Risks to farming operations
Capable of becoming very large tree
Timber very prone to defects

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

White willow *Salix alba*

Physical

Typical systems
Arable, pasture and lowland

Max. height
25–33 m

Canopy cover
Irregular, broadly columnar, **>8 m** wide

Canopy density
Open

Root architecture
Extensive, shallow to deep, shallower in wet soils

Growth rate
▲ High
Risk of outcompeting slower-growing species

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Protection from browsing, weed control

Management req.
Strict pruning requirements for timber

Longevity
Typically **20–30** years, exceptionally 200+ years

Rotation length
Timber rotation of **12–15** years for subspecies *caerulea*

Approach to silviculture
Can be coppiced
Can be pollarded

White willow *Salix alba*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲ Hardy

Wind
▲ Tolerant

Drought
▼ Sensitive

Waterlogging
▲ Tolerant

Soil types
Wide range of damp soils, favours fertile and base-rich

Slope and aspect
Any

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	◆ Moderate
Med-term (40 yrs)	◆ Moderate
Long-term (60 yrs)	▼ Relatively low

Native status
Long established
(Archaeotype - denizen) ●

Value to wildlife
◆ Moderate value, highest value for pollen and nectar ◐

Other impacts
High water consumption in wet conditions
High potential to reduce nutrient leaching

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	▲ High risk ●
Vertebrates	◆ Moderate to ▲ High risk ●

Climate resilience
◆ Moderate resilience ○

Productivity

Main products

Food	-
Wood	Timber – usually subspecies *caerulea* (inc. plywood, pulpwood, posts) ▼ Relatively low yielding
Biomass	Fuelwood
Speciality	Tannins, edible truffles

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low to ◆ Moderate ○
Acidification	▼ Low to ◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate to ▲ High benefit ◐
(▲ High protein content, ◆ Moderate digestibility)

Risks to farming operations
Risk of blocking drains
Winter host of carrot aphid

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Goat willow *Salix caprea*

Physical

Typical systems
Arable, pasture, lowland and upland

Max. height
Typically up to **10 m**, exceptionally 20 m

Canopy cover
Irregular, bushy, **4–8 m** wide

Canopy density
Open

Root architecture
Extensive, moderate depth

Growth rate
◆ Moderate to ▲ High
Risk of outcompeting slower-growing species

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Protection from browsing, weed control

Management req.
Minimal to no pruning

Longevity
60–100+ years

Rotation length
5–12 years

Approach to silviculture
Coppices well

Goat willow *Salix caprea*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲ Hardy

Wind
▲ Tolerant

Drought
◆ Moderately sensitive

Waterlogging
◆ Moderately sensitive

Soil types
Deep, moist, well-drained

Slope and aspect
Any

Shade tolerances
Full sun to partial shade

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Native ●

Value to wildlife
▲ High value, highest value for foliage invertebrates, pollen and nectar ◐

Other impacts
High water consumption in wet conditions
High potential to reduce nutrient leaching

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	▲ High risk ●
Vertebrates	◆ Moderate to ▲ High risk ●

Climate resilience
◆ Moderate to ▲ High resilience ○

Productivity

Main products

Food	-
Wood	Speciality timber
Biomass	Fuelwood, charcoal
Speciality	Tannins and dye from bark

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	▼ Low to ◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate to ▲ High benefit ◐
(▲ High protein content, ◆ Moderate digestibility)

Risks to farming operations
Risk of blocking drains

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Grey willow *Salix cinerea*

Physical

Typical systems
Arable, pasture, lowland or upland

Max. height
Typically up to **8 m**, exceptionally 17 m

Canopy cover
Irregular, bushy, **2.5–4 m** wide

Canopy density
Open

Root architecture
Extensive, moderate depth

Growth rate
▲ High
Risk of outcompeting slower-growing species

Silviculture

Establishment time
5–10 years to maximum height

Establishment req.
Protection from browsing, weed control

Management req.
Minimal to no pruning

Longevity
Up to **100** years

Rotation length
12–15 years, or short rotation of 2-3 years

Approach to silviculture
Can be coppiced

Grey willow *Salix cinerea*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
▼ Sensitive

Waterlogging
▲ Tolerant

Soil types
Wet and damp soils, favours well-drained chalk, sandy or clay

Slope and aspect
Avoid north facing

Shade tolerances
Full sun, more shade tolerant in water-logged sites

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Native ●

Value to wildlife
▲ High value, highest value for foliage invertebrates, pollen and nectar ◐

Other impacts
High water consumption in wet conditions
High potential to reduce nutrient leaching

Resilience

Pest / disease susceptibility

Diseases	▲ High risk ●
Invertebrates	▲ High risk ●
Vertebrates	◆ Moderate to ▲ High risk ●

Climate resilience
◆ Moderate resilience ○

Productivity

Main products

Food	-
Wood	-
Biomass	Fuelwood
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	▼ Low to ◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate to ▲ High benefit ○

Risks to farming operations
Risk of blocking drains

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Willow varieties for SRC *Salix* spp.

Physical

Typical systems
Arable, pasture, lowland or upland (depends on variety)

Max. height
Depends on variety

Canopy cover
Irregular, bushy, **<4 m** wide

Canopy density
Open

Root architecture
Extensive, moderate depth

Growth rate
▲ High
Risk of outcompeting slower-growing species

Silviculture

Establishment time
First-year growth typically coppiced

Establishment req.
Protection from browsing, weed control

Management req.
Good yields may require high inputs of fertiliser, herbicides and pesticides

Longevity
22–30 years

Rotation length
2–5 years, typically 3 years

Approach to silviculture
Short-rotation coppiced

Willow varieties for SRC *Salix* spp.

Tolerances

High temperatures
▲ Tolerant

Low temperatures
▲▲ Hardy

Wind
▼ Potentially sensitive

Drought
▼ Sensitive

Waterlogging
▼ Sensitive to frequent waterlogging

Soil types
Wide range, but avoid free-draining sandy soils and high organic peaty soils (due to weed competition)

Slope and aspect
Any

Shade tolerances
Full sun

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	N/A
Long-term (60 yrs)	N/A

Native status
Hybrids, typically derived from non-native species ●

Value to wildlife
◆ Moderate value, highest value for pollen and nectar ○

Other impacts
High water consumption in wet conditions
High potential to reduce nutrient leaching

Resilience

Pest / disease susceptibility

Diseases	▲ High risk (but depends on variety) ●
Invertebrates	▲ High risk (but depends on variety) ●
Vertebrates	◆ Moderate to ▲ High risk ●

Climate resilience
◆ Moderate resilience ◐

Productivity

Main products

Food	-
Wood	-
Biomass	Bioenergy ▲ High yielding
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	▼ Low to ◆ Moderate acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Open ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate to ▲ High benefit ○

Risks to farming operations
Risk of blocking drains

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Rowan *Sorbus aucuparia*

Physical

Typical systems
Arable, pasture, lowland or upland

Max. height
Typically up to **15 m**, exceptionally 22 m

Canopy cover
Ovoid to domed, **4–8 m** wide

Canopy density
Open to moderately dense

Root architecture
Branching

Growth rate
◆ Moderate

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Protection from browsing, weed control

Management req.
Minimal to no pruning

Longevity
Usually up to **200+** years

Rotation length
Not typically grown on rotation

Approach to silviculture
Coppices well

Rowan *Sorbus aucuparia*

Tolerances

High temperatures
◆ Moderately sensitive

Low temperatures
▲▲ Hardy to ▲▲▲ Very hardy

Wind
▲ Tolerant

Drought
◆ Moderately sensitive

Waterlogging
▼ Sensitive

Soil types
Wide range, favours moderately fertile, humus-rich uncompacted soils

Slope and aspect
Any

Shade tolerances
Full sun to partial shade, more shade tolerant when young

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▼ Relatively low
Med-term (40 yrs)	▼▼ Very low
Long-term (60 yrs)	▼▼ Very low

Native status
Native ●

Value to wildlife
◆ Moderate value, highest value for leaf litter, blossom and seeds ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	◆ Moderate risk ●
Invertebrates	◆ Moderate to ▲ High risk ●
Vertebrates	▲ High risk, esp. deer ●

Climate resilience
▼ Low resilience ◐

Productivity

Main products

Food	Berries (inc. juicing, jelly and jams)
Wood	Turnery and speciality timber ▼ Low yielding
Biomass	Limited woodfuel
Specialty	-

Impact on local soil quality

Nutrients and organic matter accumulation	▼ Low ○
Acidification	▼ Low acidification ○

Shade cover impacts*

Size of shadow (full grown)	▼ Low ●
Canopy density	Open to moderately dense ●
Leaf emergence	Early ●

Livestock fodder benefits
◆ Moderate benefit to ▲ High benefit ◐
(▼ Low crude protein, ▲ High digestibility)

Risks to farming operations
Winter host for cereal aphids

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

● = high confidence, ◐ = moderate confidence, ○ = low confidence

Small-leaved lime *Tilia cordata*

Physical

Typical systems
Arable, pasture and lowland

Max. height
20–37 m

Canopy cover
Broad ovoid to globular, more conical when young, **>8 m** wide, potentially > 15 m

Canopy density
Dense to moderately dense

Root architecture
Conflicting information

Growth rate
◆ Moderate to ▲ High

Silviculture

Establishment time
20–50 years to maximum height

Establishment req.
Protection from browsing, and rodents

Management req.
Minimal to no pruning

Longevity
Potentially **800+** years and exceeding 1000 years if coppiced

Rotation length
10–20 years coppice, 100-140 years timber

Approach to silviculture
Coppices well
Can be pollarded

Small-leaved lime *Tilia cordata*

Tolerances

High temperatures
◆ Moderately tolerant

Low temperatures
▲▲ Hardy to ▲▲▲ Very hardy

Wind
▼ Sensitive

Drought
◆ Moderately sensitive
considerably reduced growth

Waterlogging
▼ Sensitive

Soil types
Wide range, favours neutral to slightly alkaline, moist and fertile soils

Slope and aspect
Favours valley bottoms with moist air, avoid exposed locations

Shade tolerances
Full sun to partial shade or greater

Environmental impacts

Carbon sequestration

Short-term (20 yrs)	▲ High
Med-term (40 yrs)	▲ High
Long-term (60 yrs)	▲ High

Native status
Native ●

Value to wildlife
◆ Moderate value, highest value for mycorrhizal fungi, leaf litter, pollen and nectar ◐

Other impacts
None known

Resilience

Pest / disease susceptibility

Diseases	▼ Low risk ●
Invertebrates	◆ Moderate risk ●
Vertebrates	▲ High risk (esp. browsing mammals) ●

Climate resilience
▲ High resilience ●

Productivity

Main products

Food	-
Wood	Timber ◆ Moderate yielding
Biomass	-
Speciality	-

Impact on local soil quality

Nutrients and organic matter accumulation	▲ High (often planted as soil improver) ◐
Acidification	▼ Low acidification ◐

Shade cover impacts*

Size of shadow (full grown)	▲ High ●
Canopy density	Dense to moderately dense ●
Leaf emergence	Late ●

Livestock fodder benefits
▲ High benefit ◐
(▲ High nutritional value and digestibility)

Risks to farming operations
None known

* Effect depends on system, likely benefits of shade in livestock systems but disbenefit in arable.

●= high confidence, ◐= moderate confidence, ○= low confidence

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This report reflects our current knowledge, and the authors accept no liability for any actions taken based on the information provided.

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