Forest Research

Future productive species for Scotland

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Commissioned by Dr Helen Sellars and Tim Gordon-Roberts, Scottish Forestry, with the cross-sector Adaptation and Resilience Steering Group.

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Executive Summary

Background

This report describes work led by Forest Research (FR), and commissioned by Scottish Forestry (SF), to support the selection of a shortlist of productive tree species for Scotland. Production of the shortlist delivers a primary action in Scottish Forestry's Routemap to Resilience. The work was overseen by the Adaptation and Resilience Steering Group established by Scottish Forestry with cross-sector representation from organisations including Confor, Environment LINK, Forest Research, NatureScot, Forestry and Land Scotland, industry groups, and independent forest management experts.

The purpose of the shortlist is to provide a focus for strategic actions, coordinated across the forestry sector, to diversify the range of tree species used for productive forestry. The shortlist will act as a tool to increase the resilience of Scottish forests to the risks associated with climate change and pests and diseases while maintaining the delivery of ecosystem services. It will allow joined up investment for tree improvement for resistance to pests and diseases, ecosystem health, productivity and carbon sequestration. It will give direction and guidance on future species selection for seed collectors, nurseries, foresters, and processors to increase their availability and use, and support silvicultural diversification.

The shortlist will also support delivery of the Routemap to Resilience actions such as enabling 'smart silviculture' using remote sensing, artificial intelligence and machine learning for example, and provide a focus for understanding the economics, processing, and high value products of a more diverse palette of species. The shortlist will support the UKFS 5th edition change to 65% single species maximum in any forest management unit and is aligned with the Forestry Grant Scheme.

Exclusion from the shortlist does not mean that the species should not be grown, which remains the decision of land managers. All species on the list can be legally planted in Scotland under the Wildlife and Natural Environment (Scotland) Act 2011.

The evidence framework assembled for this project is believed to be the most comprehensive assessment of its kind conducted in UK to date. Over 35 researchers assembled over 100 datasets to conduct the assessment, with inputs from over 40 external experts and feedback from many other stakeholders as part of two workshops and several presentations. The assessment is based on what we know now and helps to identify priorities for future research and development. It shows that no single species is suitable for planting in all locations. Therefore, careful site and species selection and forest management is required in line with the UK Forestry Standard and specific country guidance.

Approach

The report describes the methods and process used to select the shortlist from a longlist of 64 species, which were assessed against eight criteria: 1) tree improvement, 2) plant and seed supply, 3) silviculture, 4) site and climate suitability, 5) productivity, 6) tree health, 7) biodiversity and environmental impacts, and 8) wood properties and end use.

Each criterion was represented by one or more 'definitive attributes'. Ten were chosen, reflecting characteristics of species which could be quantified and scored, allowing the 64 species to be ranked using multi-criteria analysis. Data for 12 'supporting attributes' were also assembled, which helped to ensure the shortlist contained species suited to a range of site types and silvicultural systems. The data was derived from the existing literature and active research, supplemented with expert judgement.

A sensitivity analysis was carried out to explore the effects on the ranking of the longlisted species by applying 14 different sets of weightings to the definitive attributes, including weightings derived from a stakeholder workshop. A Monte Carlo approach was chosen, which was felt to produce a reasonable ranking, and this acted as the starting point for consultation.

A consultation comprising a series of meetings with different groups of stakeholders was conducted in the first half of 2025. Through a facilitated discussion, participants shared their judgements on each species to help identify any significant constraints or opportunities with the Monte Carlo ranked species and collectively produced a provisional shortlist. Nine species were ruled out due to their tree health risks. A short narrative was prepared for each species, which provided the rationale for inclusion in the shortlist. In subsequent meetings, the shortlist and narratives were revised through an iterative process until a stable consensus was reached. The changes resulting from each meeting were recorded.

Shortlist of productive species for Scotland (listed alphabetically)

Conifers	Broadleaves
Coast redwood *(Sequoia sempervirens)*	Aspen *(Populus tremula)* and Hybrid aspen *(Populus tremula x tremuloides)*
Douglas-fir *(Pseudotsuga menziesii)*	Beech (*Fagus sylvatica*)
European silver fir (*Abies alba*)	Common alder *(Alnus glutinosa)*
Grand fir (*Abies grandis)*	Downy birch (*Betula pubescens*)
Japanese cedar (*Cryptomeria japonica*)	Gean (*Prunus avium*)
Lodgepole pine [Alaskan] *(Pinus contorta var. latifolia)*	Hornbeam (*Carpinus betulus*)
Macedonian pine *(Pinus peuce)*	Norway maple (*Acer platanoides*)
Noble fir *(Abies procera)*	Pedunculate oak (*Quercus robur*)
Norway *spruce (Picea abies)*	Red oak (*Quercus rubra*)
Pacific silver fir *(Abies amabilis)*	Sessile oak (*Quercus petraea*)
Scots pine *(Pinus sylvestris)*	Silver birch (B*etula pendula*)
Sitka spruce *(Picea sitchensis)*	Small-leaved lime (*Tilia cordata*)
Western hemlock *(Tsuga heterophylla)*	Sweet chestnut (*Castanea sativa*)
Western red-cedar *(Thuja plicata)*	Sycamore (*Acer pseudoplatanus*)

Outcomes

The resulting shortlist has a total of 28 species: 14 conifers and 14 broadleaves (see table). A key objective was to ensure the shortlist comprised a palette of species suited to a range of silvicultural systems, climatic regions and site types at different altitudes across east and west Scotland and provides wood suitable for a range of relevant markets. The shortlist achieves this goal as far as possible given the current level of knowledge and experience of tree species performance, the limitations posed by Scotland's climate and land available for forestry and the species composition of the existing forest resource.

The evidence framework assembled for this project is believed to be the most comprehensive assessment of its kind conducted in the UK to date. There are plans to develop the framework further into an accessible resource to support strategic and operational decisions around species choice across UK, and as a platform for research integration, knowledge exchange, education and training. There are also plans to develop detailed guidance on the silviculture and appropriate deployment of each species.

1 Introduction

1.1 Aims

This report describes work led by Forest Research (FR) between January 2024 and May 2025, commissioned by Scottish Forestry (SF), to support the selection of a shortlist of productive tree species for Scotland. The purpose of the shortlist is to provide a focus for strategic actions, coordinated across the forestry sector, to diversify the range of tree species used for productive forestry, and increase the resilience of Scottish forests to the risks associated with climate change and pests and diseases. The shortlist will allow joined up investment for tree breeding and product development and give direction and guidance on future species selection for seed collectors, nurseries, foresters, and processors. This work supports the UKFS 5th edition change to 65% single species maximum in any forest management unit, and is aligned with the Forestry Grant Scheme.

Exclusion from the shortlist does not mean that the species should not be grown, which remains the land managers' decision. All species on the list can be legally planted in Scotland under the Wildlife and Natural Environment (Scotland) Act 2011.

The objective was to select the best performing tree species when evaluated against a wide range of criteria, including tree improvement potential, plant and seed supply, silviculture, productivity, tree health, biodiversity and environmental impacts, and wood properties and end use. The shortlist should also include species suited to a range of silvicultural systems, climates, both now and in the future, and site types at different altitudes across east and west Scotland, and provide wood suitable for a range of markets.

The resulting shortlist is given in Section 4 (Table 2) and has 14 conifers and 14 broadleaves: a total of 28 species. The report describes the methods and process used to select these species from a longlist of 64 species: the criteria and attributes used to assess each species; the weighting of attributes and ranking of species; and engagement with experts and stakeholders to elicit additional knowledge, sense check findings, and reach a consensus on the final shortlist. The appendices include a description of the methodology used to assess each attribute; a list of the experts involved; and tables summarising the data, outcomes of the sensitivity analysis, and a brief narrative for each species giving the rationale for inclusion on the shortlist.

1.2 Background

In November 2022, Scottish Forestry submitted a paper on 'Building resilient future forests' to the Scottish National Forestry Stakeholder Group, which led to recommendations to develop A Routemap to Resilience for Scotland's Forests and Woodlands (Scottish Forestry, 2025). A Steering Group was formed, which identified three priorities: planning; species choice and silviculture; and knowledge exchange. A priority action was to select a shortlist of productive tree species for Scotland, which will be used to broaden the species choice availability for productive forestry to support diversification of the resource and enhance its resilience to the effects of climate change and pests and diseases. Increasing species diversity is identified as a key measure to enhance forest resilience at a range of spatial scales in the UKFS Practice Guide 'Adapting forest and woodland management to the changing climate' (Atkinson *et al.*, 2022).

A workshop was organised by SF in collaboration with FR in Edinburgh in September 2023, involving around 50 industry stakeholders, which generated feedback on barriers and enablers for species diversification, the criteria to select a shortlist of productive species, and suggestions for which tree species should be included in the shortlist. FR was asked by SF to analyse the feedback, and the findings were presented to the Steering Group in December 2023. SF then commissioned FR to prepare the evidence to select the shortlist, starting in January 2024.

A large team of FR subject matter experts assembled the necessary data and converted these into scores for each longlisted species, provided commentary to interpret them, explored the effect of weightings for different criteria, proposed a shortlist and provided a narrative for each species to justify its prioritisation. Throughout, a diverse range of external experts were consulted to help assemble data, sense check the findings and offer feedback (see Appendix F). In May 2024, a second workshop was jointly organised by SF and FR to present the methodology and initial findings, again to an audience of around 50 stakeholders (Section 3.1). A provisional shortlist was presented to the Steering Group in December 2024 and following this there was a further round of stakeholder engagement. The shortlist was signed off by the Steering Group in September 2025.

2 Compiling the data

2.1 Species longlist

A tree species longlist was created and agreed comprising 64 species selected from the FR Strategy for Research on Tree Species (Kerr and Reynolds, 2020) (see Appendix B). Strictly speaking, two of the entries are varieties or sub-species (*Pinus contorta var. latifolia* and *Pinus nigra subsp. laricio*); three are hybrids, and one is a group of *Populus* species and hybrids (black, grey, white poplar and hybrids, and hybrid aspen).[1]

The 64 species were organised according to the categories used by FR to underpin the Strategy, i.e. principal, secondary, plot-stage and specimen-stage. The longlist comprises 23 principal species, 25 secondary species, 4 additional species native to GB[2], which were not already among the principal and secondary species, and 12 plot-stage species. No specimen-stage species were included. These categories were developed by Kerr and Jinks (2015) following an assessment of the knowledge of 240 temperate tree species in the United Kingdom (see Appendix A3). The general aim of the Strategy is to increase knowledge and awareness, with a focus on the emerging species (secondary and plot-stage) so that they can be promoted between successive stages, e.g. from plot-stage to secondary, and from secondary to principal, to make a wider range of species available for operational forestry.

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[1] For the Populus group, the data, scores and rankings in Appendix C and D provide an overall assessment for the whole group. In the later stages of the project, hybrid aspen was identified as being the best candidate from this group and included alongside native aspen in the shortlist. The other Populus species and hybrids were not shortlisted.

[2] Three of these species are considered non-native in Scotland: white willow, osier willow and whitebeam (Forestry Commission, 2020).

2.2 Criteria and attributes

The workshop in September 2023 generated a list of 47 attributes. These were grouped into eight criteria and ordered according to their approximate position along the forestry wood chain: 1) tree improvement, 2) plant and seed supply, 3) silviculture, 4) site and climate suitability, 5) productivity, 6) tree health, 7) biodiversity and environmental impacts, and 8) wood properties and end use.

Each criterion was represented by one or more 'definitive attributes', and in most cases also by one or more 'supporting attributes' (see Table 1). Ten definitive attributes were chosen, reflecting characteristics of species which could be quantified and scored. The set of scores for each definitive attribute allowed the 64 longlisted tree species to be ranked. Multi-criteria analysis was used to explore the effects of changing the weighting of each attribute on the overall ranking, and to derive a ranked longlist to act as the starting point for consultation with experts and stakeholders (see Section 3.2).

Table 1 Criteria, definitive attributes and supporting attributes

Criteria (8)	Definitive attributes	Supporting attributes
1. Tree improvement	• Tree improvement potential	
2. Plant and seed supply	• Plant and seed supply	
3. Silviculture	• Silvicultural knowledge • Establishment rate	• Shade tolerance • Natural regeneration • Palatability to deer • Grey squirrel damage
4. Site and climate suitability	• Suitability area – current • Suitability area – future	• Frost susceptibility • Drought susceptibility • Wind damage susceptibility • Fire susceptibility
5. Productivity	• Yield class category	• On-site carbon* • Off-site carbon and GHG potential*
6. Tree health	• Pest and pathogen risks	
7. Biodiversity and environmental impacts	• Contribution to Woodland Ecological Condition (WEC)	• Environmental impacts
8. Wood properties and end uses	• Wood technical potential	• Compatibility with Scotland's current wood value chain

*Data incomplete by time of publication and not included in this report.

Data for 12 supporting attributes were also assembled. Supporting attributes tended to be descriptive rather than evaluative, e.g. 'natural regeneration potential' and 'shade tolerance', where the value attached to a species does not necessarily imply that it is better or worse; just different or similar, because its value is dependent on the context. These attributes were important to consider in the later stages of the project to ensure the shortlist contained species suited to a range of site types and silvicultural systems. Another reason for designating an attribute as 'supporting' rather than 'definitive' was in cases where the dataset was incomplete (e.g. palatability to deer, squirrel damage susceptibility, and certain environmental impacts) and hence could not be included in the multi-criteria analysis, which required a near-complete dataset.

2.3 Data, scores and commentary

Data was assembled for both the definitive and supporting attributes for each longlisted species. For the definitive attributes, a score on a common scale from 1 (low performance) to 4 (high performance) was used. The one exception was tree health, which was scored using a three-point scale, but made to fit the four-point scale by using the three scores '0', '2' and '4'. The score of '0' was assigned to tree species with severe pest or pathogen risks, which we recommended should not be included in the shortlist (see Appendix A6).

The data was derived from the existing literature and active research and supplemented with expert judgement where necessary to refine the available data for a given species, fill data gaps, and convert the data into scores on the normalised scale.

For some attributes, indices were developed which aggregated scores for multiple factors, typically using an algorithmic scale. This was the case for tree improvement potential, plant and seed supply, pest and pathogen risks, contribution to WEC, wood technical potential, and compatibility with wood value chain, as described in Appendix A. The indices were calculated in separate spreadsheets (not included in this report).

The final scores were brought together in a matrix for the definitive attributes and another for the supporting attributes (see Appendix C). For several attributes, commentary was provided for each species to help interpret the data and scores (not included in this report).

2.4 Assumptions, confidence levels and data gaps

Silvicultural assumptions
The assessments were based on performance in single species stands, since the availability of data for different species mixes and silvicultural systems was very limited. Similarly, it was assumed that species were grown on suitable or very suitable sites and managed in accordance with the requirements in the UK Forestry Standard (UKFS) (Forest Research, 2023). These caveats were especially relevant to the silviculture, site and climate suitability, productivity, and tree health criteria. If there were significant known risks or benefits associated with how the species is managed, these were highlighted in the commentary.

Changes in the future

The shortlist of productive species for Scotland is intended to provide a focus for species diversification and investment throughout the sector, and as such its composition needs to remain stable over the longer term. However, improvements due to research and development, or outbreaks of novel pests or diseases and extreme weather events, or changes to policy or the economy, or the acquisition of new data from experience or research, could all change the balance of benefits, risks and uncertainties for different tree species and justify the addition of new species to the shortlist or removal of existing ones. These developments are difficult to predict, and hence most attributes were assessed for the current situation rather than for any future scenario.

For example, this was the case for compatibility with the wood value chain. While it is hoped that increases in the scale of planting, and investments in strength grading and processing and new product development, will, over time, increase the compatibility of shortlisted species, this was considered too uncertain to predict and score in the assessment. Similarly, for tree health, tree breeding programmes for ash and larch could produce disease resistant planting stock in the future, but this is unlikely to happen soon, so including these species on the shortlist at present was not considered appropriate. Once these improvements are realised, additions to the shortlist can be made.

The two exceptions, where assessments for the future have been provided, were site and climate suitability and pest and pathogen risks, although it should be highlighted that in both cases there are uncertainties around the direction and scale of change (see Appendix A4 and A6).

Confidence levels

Confidence in the data varied between attributes and between species. For several attributes (including those where multiple factors were aggregated to create an index) confidence scores were provided for each longlisted species, describing the current knowledge level. This was the case for tree improvement potential, plant and seed supply, site and climate suitability, and the wood properties and end use criterion. These scores were not included in the multi-criteria analysis, and have not been reported here, although they helped to inform the final species shortlist.

The definitive attribute 'silvicultural knowledge' (see Appendix A3) can be seen as a proxy for confidence in the data for several of the attributes, since more is known about the principal species, for example, than plot-stage species.

Data gaps

For some attributes, data was only available or reliable for better-known species. (The proportion of data gaps for a given attribute, or for a given species, was another indication of the confidence level.) For the definitive attributes, where it was desirable to create a complete set of scores, data gaps were addressed as follows:

In a few cases, the scores for closely related tree species were used as proxies, where these were considered sufficiently reliable, e.g. some silvicultural attributes.

If no credible proxy was available, a score of '1' (out of 4) was given to fill data gaps (these are coloured dark grey in Appendix C, Table 10). This was a conservative approach, but it also reflected the possibility that, for some attributes, a lack of data indicated poor performance for a given species. This was arguably the case for tree improvement potential, seed supply, silvicultural knowledge, and yield class.

An exception was made for tree health, where there was generally some knowledge to provide a tentative assessment for every longlisted species (albeit with varying levels of confidence). For this attribute, the available scores were '0', '2', and '4' (see Appendix A6) and the lower score of '0' was judged to be too conservative and restrictive as a value to fill data gaps since a decision had been made to use this score to justify ruling out species from the shortlist.

For the supporting attributes, no attempt was made to fill data gaps (apart from use of a few credible proxies), since their purpose was to complement the scores for the definitive attributes and they were not required for the multi-criteria analysis. The numerous gaps demonstrate the low level of silvicultural knowledge available for many emerging species and help inform future priorities for research.

3 Selecting the shortlist

3.1 Deriving a ranked longlist

Sensitivity analysis

The data for the 10 definitive attributes, normalised on a four-point scale, were assembled in a matrix showing the performance of each longlisted species against each attribute (Appendix C, Table 10). The weightings for each attribute can be manipulated through a form of multi-criteria analysis, which has the effect of adjusting the species ranking. After selecting a preferred weighting scenario, the user can generate a ranked longlist of species.

A sensitivity analysis was carried out to explore the effects of applying 14 different sets of weightings on the ranking in the longlist as follows:

1. Equal weightings for all 10 definitive attributes.
2. Weightings derived from a stakeholder workshop (see below).
3. Maximum weightings (i.e. a weighting of 100) applied to the top four attributes derived from the stakeholder workshop, and a minimum weighting (i.e. a weighting of 1) applied to the remaining six attributes.
4. A set of 10 further weighting scenarios, each of which maximised the weighting (i.e. a weighting of 100) for a single attribute in turn, with the minimum weighting (i.e. a weighting of 1) applied to the other nine attributes (see below).
5. Monte Carlo simulation, which uses a sample of all possible weighting scenarios across all 10 attributes (see below).

Stakeholder workshop

A workshop was held on 30 May 2024 with around 50 stakeholders invited from across the Scottish forestry sector to present and discuss the criteria and assessment methodology. Participants were then divided into six groups and, following a short period of deliberation, each group was asked to reach a consensus on what they felt the 10 weightings should be for each attribute on a scale from 1-10. The six sets of weightings are shown in Figure 1. This reveals the wide variation in the weighting assigned by each group to a given attribute. The averages (normalised) are shown in Figure 2.

The top four attributes were yield class category, pest and disease risks, future suitability area, and wood technical potential (current suitability area, and establishment rate, were very close in joint sixth place). As noted above, the weightings for these four attributes were maximised in one of the scenarios used in the sensitivity analysis.

This approach might appear better than use of equal weightings, but it raises issues that would need to be considered before using it as the basis for creating a prioritised longlist. First, the workshop participants were not likely to be representative of all the different interest groups across the sector. In fact, it would be hard to reach consensus on what a representative sample of the sector would look like. Secondly, it is difficult in a workshop setting with limited time to appreciate how different weightings influence the ranked list of species. For some attributes it is necessary to change the weighting by a factor of 10 to make a noticeable difference to the species rankings. Instead, we used the workshop to explore and demonstrate the sensitivity of different weightings to the ranking of species, rather than to derive the final shortlist.

Figure 1 Relative weights for each attribute for eight groups of stakeholders

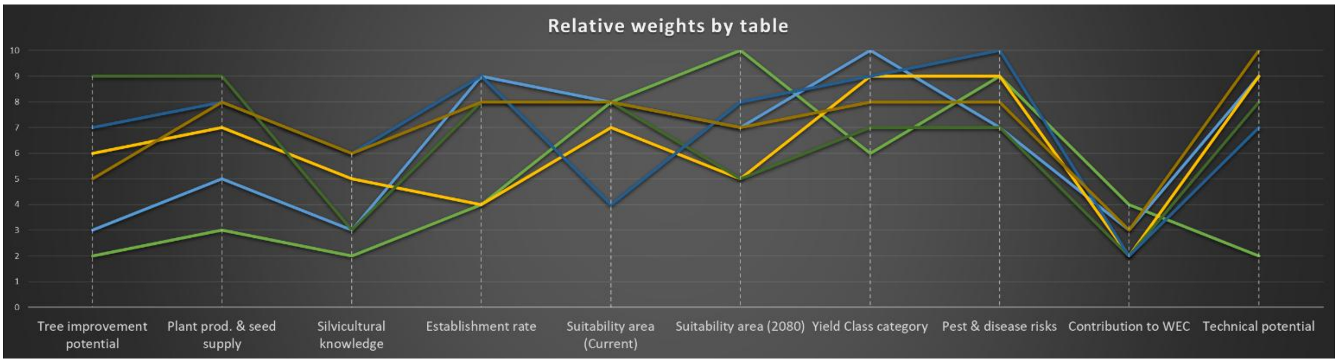
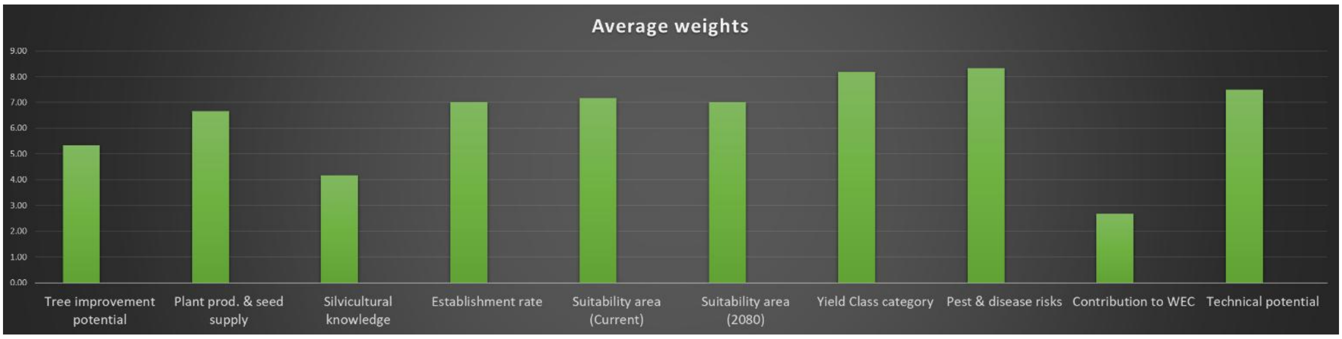


Figure 2 Average weights for each attribute derived from stakeholders



Maximum weightings scenarios

The group of 10 scenarios, where the maximum weighting of 100 was applied in turn to each of the 10 definitive attributes, attempted to show what would happen to the rankings when one attribute was favoured (see Appendix D). For a given scenario, this approach produced a unique ranking for each species (rather than ranking two or more of them as equal). However, these rankings are not the same as scores for the performance of each species for that attribute. For example, for the scenario that maximised tree improvement potential, the top performing species was silver birch, but, as can be seen in Appendix C, Table 10, the tree improvement potential was scored equally (4/4) for the top seven species for that scenario: silver birch, Sitka spruce, Scots pine, lodgepole pine, Douglas-fir, Corsican pine and ash. Silver birch ranked first under this scenario not because it has the best tree improvement potential, but because it scored 4/4 for tree improvement potential *and* performed marginally better across the other attributes.

Monte Carlo simulation

Another method used for weighting attributes was to run a Monte Carlo simulation. This approach took a random sample from a uniform distribution of weightings (1 to 100) for each of the 10 attributes over 10,000 iterations for each of the 64 longlisted species. Each iteration represents a possible weighting scenario. The simulation yielded a distribution of

10,000 final scores for each species. The choice of 10,000 simulations aligns with standard statistical practices and provides sufficiently stable outcomes to perform further analysis. The results were summarised with a median final score, which was used as the primary ranking metric for each species, ensuring robustness against outliers. Boxplots and density plots were also prepared to visualise the spread, skewness, and central tendency of the final scores, allowing for comparisons between species (not included in this report). The upper and lower quartile for a given species provided a visual representation of the extent to which its overall performance overlaps with that of other species that were ranked similarly.

Outcomes of the sensitivity analysis

The results of the sensitivity analysis are shown in Appendix D. This revealed three key points. Firstly, the ranking of the top performing species was largely consistent across most scenarios (see Table 15). Secondly, it was necessary to change the weighting of any one attribute substantially to change the overall ranking of species, due to the dilution effect of having 10 attributes. Thirdly, while some of the weighting scenarios appeared to produce outcomes that were slightly ‘better’ than others, none of them produced a ranked shortlist that felt exactly right when sense-checked with stakeholders. Whichever weighting scenario was chosen, it proved necessary to refine and finalise the ranked list it produced through expert and stakeholder consultation.

In collaboration with Scottish Forestry, the Monte Carlo approach was chosen, which was felt to produce a reasonable ranking of the longlist of species (arguably as good as most other scenarios), which acted as the starting point for consultation (see Section 3.2). The Monte Carlo rankings were almost identical to those derived from equal weightings of attributes, except that the Monte Carlo approach ensured each species had its own unique ranking (use of equal weighting produced several groups of species with equal rankings). The Monte Carlo approach also allowed the statistical analyses outlined above to be carried out.

3.2 Finalising the shortlist

Consultation

A consultation comprising a series of meetings was conducted between January and July 2025 with different groups of researchers, forestry policymakers, forest managers, regulators, nursery managers, sawmillers and processors, conservationists, and other interest groups, many of whom had attended the workshop in May 2024 (see Appendix F).

The first of these meetings brought together a group of FR researchers and took as its starting point the ranked list generated by the Monte Carlo simulation (see Appendix E, Table 15). Through a facilitated discussion, which considered the data, scores and commentary, plus expert knowledge and experience, participants shared their judgements on each species and collectively produced a provisional shortlist.

Nine species were ruled out from the start, because they scored ‘0’ for tree health and hence were judged to be unsuitable for promotion at present.

A short narrative was then prepared for each of the shortlisted species, which sought to interpret and summarise the data and provide the rationale for whether it should be included in the shortlist (Appendix E, Tables 16-19).

In subsequent meetings with different groups of FR researchers and external experts and stakeholders, the shortlist and narratives were revised through an iterative process until a stable consensus was reached. At each meeting, the focus of the discussion alternated between the ranked list of species, the data and narratives, and the evolving shortlist. Each species was discussed in turn, starting with the highest-ranking ones, to decide whether its inclusion on the shortlist was warranted and for what reasons. The changes resulting from each meeting were recorded.

Table 15 shows the Monte Carlo ranking alongside the final decision made on whether each species should be shortlisted. The species are divided into conifer and broadleaves to enable easier comparison; the species ruled out on tree health grounds are listed at the end. For both conifers and broadleaves, 14 species were selected. Overall, there was a good correspondence between the Monte Carlo ranking and the final shortlist of species. One exception, for example, was Leyland cypress, which was ranked relatively highly by the Monte Carlo simulation due to its good performance across most definitive attributes but was excluded from the shortlist. Despite its status as a relatively well understood secondary species, it is mostly known as a hedge tree, with poor form due to multiple stems. There are no known stands in Scotland, and it is an infertile hybrid, and therefore difficult to improve.

4 Shortlist of productive species for Scotland

The shortlist of productive species for Scotland is shown in Table 2. The list is intended for strategic purposes, providing a focus for investment, including research and development, at national level. Site-level species selection should continue to be informed by management objectives, site conditions and other contextual factors. Exclusion from the shortlist does not mean a species should not be planted, which remains the land managers' decision.

As noted in Section 1.1, a key objective of the project was to ensure the shortlist comprised a palette of species suited to a range of silvicultural systems, climatic regions and site types at different altitudes across east and west Scotland, with a low or medium tree health risk profile, and provided wood suitable for a range of markets. The shortlist achieves this goal as far as possible given the current level of knowledge and experience of tree species performance, the limitations posed by Scotland's climate and land available for forestry, and the species composition of the existing forest resource.

For the 14 shortlisted conifers, eight are suited to open planting and 12 for continuous cover forestry; eight are suited to the drier conditions in the east, and all 14 are suited to the west of Scotland. Six species are suited to upland sites (Sitka spruce, Scots pine, lodgepole pine (Alaskan provenance), Macedonian pine, noble fir, and Pacific silver fir (on sheltered upland sites) and 11 are mid-slope or lowland species. Seven species can supply the whitewood market, while the other seven require alternative redwood markets.

For the 14 shortlisted broadleaved species, all are suitable for open planting, while 11 can be managed with CCF. Almost all can be grown in both the east and west and in mid-slope and lowland sites, with one species, downy birch, suited to upland sites.

Table 2 Shortlist of productive species for Scotland (listed alphabetically)

Conifers	Broadleaves
Coast redwood *(Sequoia sempervirens)*	Aspen *(Populus tremula)* and Hybrid aspen *(Populus tremula x tremuloides)*
Douglas-fir *(Pseudotsuga menziesii)*	Beech (*Fagus sylvatica*)
European silver fir (*Abies alba*)	Common alder *(Alnus glutinosa)*
Grand fir (*Abies grandis)*	Downy birch (*Betula pubescens*)
Japanese cedar (*Cryptomeria japonica*)	Gean (*Prunus avium*)
Lodgepole pine [Alaskan] *(Pinus contorta var. latifolia)*	Hornbeam (*Carpinus betulus*)
Macedonian pine *(Pinus peuce)*	Norway maple (*Acer platanoides*)
Noble fir *(Abies procera)*	Pedunculate oak (*Quercus robur*)
Norway *spruce (Picea abies)*	Red oak (*Quercus rubra*)
Pacific silver fir *(Abies amabilis)*	Sessile oak (*Quercus petraea*)
Scots pine *(Pinus sylvestris)*	Silver birch (B*etula pendula*)
Sitka spruce *(Picea sitchensis)*	Small-leaved lime (*Tilia cordata*)
Western hemlock *(Tsuga heterophylla)*	Sweet chestnut (*Castanea sativa*)
Western red-cedar *(Thuja plicata)*	Sycamore (*Acer pseudoplatanus*)

All the species on the shortlist can be planted in mixtures. When choosing species for mixtures it is important to consider the predicted growth rates for that site, their shade tolerance and the timber they will produce. The more closely these factors are matched or are compatible for the species chosen the more intimate the mixture can be. Otherwise, they are better planted in discreet groups to avoid negative impacts on each other's establishment, growth and management. FR's Forest Development Types provide a tool to support planting and managing of mixed forest stands (Haufe *et al*., 2024).

5 Concluding remarks

The shortlist of productive species for Scotland derived from this project should provide a stable focus for actions by all parts of the forestry sector to diversify the forest estate and enhance its resilience to climate change and pests and diseases, while seeking to maintain productivity and other ecosystem services. However, the composition of the shortlist should not be seen as permanent and should be subject to review, to allow revisions in response to changing circumstances.

The evidence framework assembled for this project is believed to be the most comprehensive assessment of its kind conducted in UK to date. It would not have been possible without the collaboration of numerous researchers and external stakeholders, and the cross sectoral support from the Steering Group and subject matter experts. It was commissioned by Scottish Forestry, who initiated the project and ensured that the overall scope and detail met their needs and enabled the selection of the shortlist. Production of this shortlist delivers a primary action in the Routemap to Resilience (Scottish Forestry, 2025) and gives a focus for several of the follow up actions.

Future work

Similar work has now been commissioned for England by Defra and may also be carried out in Wales on behalf of the Welsh Government. Many of the actions that follow would benefit from dialogue and collaboration at UK level, including tree improvement programmes, developments to seed supply and plant production, research, knowledge exchange and training. There are also plans to develop the evidence framework further into an accessible resource to support strategic and operational decisions around species choice across the UK, and as a platform for research integration, knowledge exchange, education and training.

Acknowledgements

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Appendix A: Methodology used for assessment

The approaches used to assess each definitive and supporting attribute are described below for each of the eight criteria (see also Section 2.2, Table 1).

A1 Tree improvement

Definitive attribute: Tree improvement potential

A score for tree improvement potential was derived on a four-point scale by combining values for each of the following factors:

- *Provenance information*: quality of relevant information about natural patterns of variation among populations.
- *Selection* (feasibility of selection phase): size of domestic resource, availability of obvious foreign resource, amenability to grafting.
- *Testing* (feasibility of testing phase): cost, ease and practicalities of testing; timing of selection.
- *Breeding* (feasibility of mating, etc.): feasibility of controlled crosses; technicalities related to sexual reproductive biology (precocity, fecundity, physical characters).
- *Deployment*: ability to mass produce improved material from seed orchards, or through vegetative propagation; technicalities related to sexual and asexual reproductive biology.

Tree improvement was considered broadly, and encompassed population level (‘extensive’) improvement and individual-level tree breeding (‘intensive’). The five factors listed above were scored separately and aggregated to derive a total score for each species for both an ‘intensive’ and ‘extensive’ approach to tree improvement. The weightings used for each factor are given in Table 3.

Table 3 Factors and weightings used to derive the tree improvement score

Factor	Extensive weight	Intensive weight	Rationale
Provenance information	1.2	0.8	Only meaningful opportunity to generate gains with extensive approach. Limitations can be overcome under intensive
Selection	1.3	0.7	As above
Testing	0.7	1.3	Testing less important for extensive
Breeding	0.5	1.5	Breeding less important for extensive where it is not anticipated
Deployment	1	1	

The intensive and extensive values across species were centred and scaled and regressed against one another, with the sign (positive or negative) of regression residuals used to determine whether the better score for a species was extensive or intensive. The higher of the two scores was taken as an overall score. In many cases, species had very similar scores for intensive and extensive, and some borderline species were manually adjusted using common sense. For example, hybrid larch ranked as 'extensive' because provenance information is irrelevant but could only realistically be developed under an intensive programme. The distribution of the better scores was then explored visually, with three cuts made to group the species into scores 1 (less potential) to 4 (more potential).

The two approaches to tree improvement are outlined below:

Intensive tree breeding refers to tree improvement proper where hundreds (>200) of plus trees form a base population and testing takes place so that demonstrable genetic gains can be delivered recurrently through selection, testing, breeding and production of improved material. This tends to be justifiable only for important species planted out over large hectarages and, in these cases, the direct economic impact can be very large, permanent, and continues to grow as the programme progresses.

Extensive improvement refers to extensive activities where seed stands are identified, where the best seed sources are explored, or where a small founding population of plus trees is identified and brought together into a collection such as a clone bank or a qualified seed orchard. In general, scope is limited by small numbers (<80) of founding trees, meaning that opportunities for testing and further selection to deliver demonstrable genetic gains are limited. The approach could be delivered over a project timescale and can be used as a first step, opportunistically (e.g. where an interesting stand is at risk), or for native species where there is an interest in developing 'true to type' unimproved seed. It might result in a traceable/characterised seed resource that has some improvement, demonstrable or otherwise. As it is typically applied for minor species, the direct economic impact on a national scale is not very large. The main difference from intensive breeding is that it is not expected, from the outset, to proceed beyond a first phase of population improvement.

Commentary was provided on the prospects for tree improvement and recommended approach to take. A confidence rating was also provided. Data was also collated on Forest Genetic Resources (FGR) available in the UK for each species, drawn largely from Whittet (2022). Also, data on the total area planted for each species in GB, and number of single species stands over 5 ha, were assembled using the National Forest Inventory, and Sub-compartment Database for the Public Forest Estate, which provided an indication of the genetic resource available for tree improvement.

A2 Plant and seed supply

Definitive attribute: Plant and seed supply

Scores were derived for nine different factors relating to plant and seed supply, and then weighted and aggregated, using the expert judgement of an external consultant and two tree nursery managers. The factors were as follows:

1. *Seed supply* – Ease of access to commercial seed volume from the UK and overseas
2. *Seed quality* – In relation to seed borne pathogens, germination etc
3. *Seed storage* – Storage at nursery premises of own seed or bought-in seed
4. *Seed treatments* – Dormancy break, pelleting or hydration
5. *Weed control* – Weed competition of seed grown crops in soil and containers

6. *Economy/financials* – Cost of seed and production vs value of finished stock
7. *Crop cycle length* – Growth rate to produce finished stock for planting out
8. *Substrate/soil issues* – pH, raw materials, container size, planting densities
9. *Crop protection issues* – Pests, diseases and nutritional aspect of production

The first four factors relate to seed; the remaining five factors relate to nursery production and were assigned separate scores for bare root and cell grown plants. A weighted average for all attributes was calculated. A weighting of 50% was given to 'seed supply' which was seen as the most important attribute; the remaining eight attributes were aggregated to account for the remaining 50%. A confidence score and commentary were provided for each species.

A3 Silviculture

This criterion comprises two definitive attributes, 'silvicultural knowledge' and 'establishment rate', and four supporting attributes, 'natural regeneration potential', 'shade tolerance', 'palatability to deer', and 'squirrel damage susceptibility'. Two other criteria, 'productivity', and 'site and climate suitability', are closely related.

Definitive attribute: Silvicultural knowledge

The level of silvicultural knowledge for each species was scored on a four-point scale using the typology developed by Kerr and Jinks (2015): principal, secondary, plot-stage, and specimen-stage (see Table 4).

Table 4 Levels of silvicultural knowledge

Score	Category	Knowledge	Description
4	Principal	Excellent	Strong evidence base supported by an extensive body of research and experience over a wide range of environmental and silvicultural conditions. A detailed understanding of the factors.
3	Secondary	Good	Sound evidence base that includes experimental and operational evidence across a wide range of environmental and silvicultural conditions. A good understanding of the factors.
2	Plot-stage	Moderate	Reasonable experimental and/or operational evidence in Britain; not fully tested under all environmental or silvicultural conditions. Factors may be only partially understood.
1	Specimen-stage*	Low/Poor	Very limited experimental or operational evidence in Britain. Poor understanding of factors involved.

*No specimen-stage species were included in the longlist and no species was given a score of 1.

To help assign species to the four categories, Kerr and Jinks (2015) developed a knowledge score based on the following criteria:

- *Amount of research that has been carried out*: assessed using as a proxy the number of experiments recorded in the FR Register of Experiments, which holds information on all silviculture and genetics experiments set up since the 1920s.

- *Extent of current use in forestry:* categorised on a five-point scale derived from summaries of stocked area in the National Forest Inventory (Forestry Commission 2011).
- *Potential for producing wood products:* assessed on a five-point scale using either known information for widely used species, or information extracted from the CABI Forest Compendium (CAB International, 2005) for lesser-known species, specifically number and variety of wood products recorded and number of geographic regions where it has been planted, as a measure of potential.
- *Level of knowledge available for objective advice and recommendations*: the number of published reports and practice about the silviculture of species was rated on a three-point scale corresponding to low, medium or high categories.

Of the four attributes listed above and used by Kerr and Jinks (2015), the third item, 'potential for producing wood products', is already assessed in this study under the 'wood properties and end use' criterion. It was not feasible to revisit the analysis by Kerr and Jinks and remove this attribute to avoid double counting, although the effect on the scores is likely to have been insignificant.

Definitive attribute: Establishment rate

Speed of establishment is an important factor when planting any species as it will indicate the likely timescale for any maintenance and period of protection against browsing. For this study, various sources of quantifiable data were used, and some expert judgement, including the selection of an analogue species where there was little research data available (e.g. *Picea rubens* was equated to *Picea orientalis*). Growth rate during the first five years of establishment was used based on a classification developed by Reynolds *et al.* (2021). The categories shown in Table 5 are a judgement on the speed of establishment under standard silvicultural practices on a suitable site.

Table 5 Establishment rate categories

Tree size at 5 years	Description	Speed
0 to <100 cm	Not yet established	Slow
$\geq$ 100 to <150 cm	Established	Slow/Medium
$\geq$150 to <200 cm	Established	Medium/Fast
$\geq$ 200 cm	Well-established	Fast

Key data sources used were surveys carried out on the Public Forest Estate in England (Reynolds and Kerr, 2022) and the CABI Forestry Compendium (CAB International, 2005).

Supporting attributes

Four supporting attributes were recorded: natural regeneration potential, shade tolerance, palatability to deer, and susceptibility to grey squirrel damage.

Natural regeneration potential

Given the right environmental conditions, nearly all tree species will naturally regenerate through sexual or asexual means of reproduction. The ability to regenerate stands naturally can be cost-effective and allows trees to colonise suitable microsites, while natural regeneration can be more resilient to drought and browsing than planted stock. However, when this regeneration is unwanted it can interfere with management objectives and represent a significant risk. When this was the case, the risk was highlighted in the supporting attribute ‘environmental risk’ (see Appendix A7).

The natural regeneration potential for common conifers is categorised as frequent, occasional and rare in Nixon and Worrell (1999) and their findings have been used. The same set of categories has been used for broadleaves, and Evans (1988) has been used as a guide to which of the common species to assign to each category. For eucalypts, Booth’s (2012) review of invasiveness in cold climates was used and the two species of *Nothofagus* were considered similar to eucalypts in terms of natural regeneration.

Shade tolerance

Shade tolerance is a useful silvicultural attribute of tree species and often relates to their successional status. Light demanders tend to be pioneer trees with wide site tolerances, while shade tolerant trees are usually more site demanding, later successional species. Kerr *et al.* (2020) categorises the shade tolerance of common trees species into light-demanding, intermediate and shade tolerant. The following additional publications were used to fill gaps: Ellenberg and Leuschner (2010), Bögelein *et al.* (2019) and USDA (1990).

Palatability to deer

There are patterns in preference of deer for different tree species, for example a preference for oak over ash. However, the likelihood that a tree species or woodland area will be browsed is also dependent on a suite of landscape, woodland and stand variables including availability of alternative food sources, planting density, tree species richness, and presence of a shrub or understorey layer (Jarnemo *et al*. 2014; Ward *et al*., 2008; Ohse *et al.,* 2017; Spake *et al*., 2020). Several sources were used to compile a score for palatability to deer and other mammals including Ferris and Carter (2000), Hotchkiss and Herbert (2022), Leslie and Purse (2016), Rutgers (undated) and Scottish Forestry (undated). An estimate was possible for 57 of the 64 longlisted species, scored on a three-point scale: high, medium and low palatability.

Susceptibility to grey squirrel damage

Susceptibility to bark stripping by grey squirrels is variable from year to year and is influenced by landscape features such as proximity to large mature woodlands. Nevertheless, the most susceptible species are well known. These include beech and sycamore, followed by oak, other maple species, sweet chestnut and birch. Gean is one of the few broadleaved species with low susceptibility. Coniferous species such as Norway spruce, western hemlock and Scots pine can also be susceptible to damage, but less frequently than deciduous species. References used included Gill (1992), Haw (2025), Hotchkiss and Herbert (2022), Mabbett (undated), Mayle and Broome (2013), Peden (2020), Rowe and Gill (1985), and Shuttleworth and Gill (2019). An estimate was possible for 39 of the 64 longlisted species, scored on a three-point scale: high, medium, and low susceptibility.

A4 Site and climate suitability

Definitive attributes: Site and climate suitability, current and future

The two definitive attributes for this criterion are based on use of Ecological Site Classification (ESC) to derive areas in Scotland that are suitable or very suitable for each species for both current and future climates (i.e. 2080). This pair of attributes needs to be treated with caution given the limitations of the data and inherent uncertainty associated with climate change. They are used in this study to help inform selection of the shortlist but should not be used to guide species selection at an operational level.

The analysis used the UKCP09 A1b climate data from the Met Office, which is equivalent to the UKCP18 RCP6 scenario and reflects a mid-range projection of atmospheric GHG concentration.

Confidence scores were assigned for each species, based on a) confidence in the ESC model (e.g. whether the forest resource in GB is of sufficient size for the modelling to be accurate), and b) sensitivity of the species to the base data, especially soils data (pine and birch for example can grow on poor sites and are less sensitive to soils data, so a higher confidence rating can be given).

When interpreting the scores for this attribute it is important to note that the use of ESC to assess suitability for future climates is based on predicted average changes in temperature and rainfall and does not consider the effects of extreme weather events, or secondary effects, for example due to increased susceptibility to pests and diseases.

We recognise a precipitation gradient exists across Scotland, with 30 year mean values of over 3000mm a year on the west of Scotland to around 700mm in some parts of eastern Scotland. While such significant differences could lead to different tree species growth responses, localised effects relating soil, topography and proximity to the sea can all have mitigating impacts. Observations and modelling of the yield class of productive conifers across Scotland show that even within the drier regions the species can perform similarly to those in the wetter zones, *where localised factors compensate*. On this basis we considered that Scotland could be represented for strategic analysis purposes as a single biome, albeit with considerable localised heterogeneity in growing conditions at an individual site level.

It was noticed that ESC tends to overestimate the suitable area in Scotland for climate alone (both now and in the future) while it tends to underestimate the suitable area when soil types are integrated. A combination of the two provides a range of values, an upper and lower limit to the estimates. The underestimation is associated with the interpretation of national scale soil data, and their tendency to be pessimistic in relation to soil nutrient regime in some parts of the country.

In some cases, the suitability area for a given species in Scotland might be low, but the species has the potential to occupy an important niche and should still be considered for the shortlist. For example, use of ESC suggests the suitability area for noble fir will decline by 2080, but it was not ruled out because the species is one of the few alternatives to Sitka spruce on exposed upland sites (DAMS 16-20) and can still be viably planted with appropriate site selection.

Supporting attributes

The use of ESC to assess suitability for future climates was complemented with assessments of the following abiotic risks as supporting attributes: susceptibility to drought, frost, and wind damage, and wildfire risk. These data help compensate for the fact that ESC is based on predicted average changes and currently does not consider extreme events.

Drought susceptibility

There are many aspects to drought tolerance, including a species' resistance but also how rapidly it recovers, i.e. its resilience. A tree's response to drought is a combination of its genetics and the site characteristics, such as climate and soil texture. Where available, information from ESC on drought tolerance presented in Davies *et al.* (2020) for conifers was used. In other cases, Hill's (1999) list of Ellenberg site factors was used as a source, which describes conditions that are optimum for a wide variety of British plants. One Ellenberg factor describes plants' soil moisture preferences, and this was used to infer drought tolerance, with those showing preference to drier sites being assumed to be more drought tolerant.

Frost susceptibility

Frost tolerance is complex, being a combination of many environmental and genetic factors. Trees can be damaged by cold during early Autumn frosts, late spring frosts, periods of particularly low temperatures, and by rapid freezing and thawing. There are however broad differences between species in their ability to withstand cold and this is largely related to the coldness of their natural habitat (Kreyling *et al.*, 2015). Information from Cannell *et al.* (1987), Day and Peace (1946), Evans (1986), Kerr and Evans (1993), Leslie and Purse (2016), Murray *et al.* (1986) and Rogers *et al.* (2020) were interpreted to categorise tree species into whether they are susceptible to cold or frost damage. More detail on cold tolerance was provided for some species in the commentary.

Wind damage susceptibility

The DAMS windiness scoring system (Quine and White, 1994) was used to predict the probability of damage through the life of a forest stand based on tree dimensions and stand and site characteristics. In this study, wind damage susceptibility was assessed using the maximum DAMS score required for the species to be categorised as Suitable in ESC (i.e. DAMS scores above the given value would mean the species was Marginal or Unsuitable in ESC) (Quine and White, 1994; Pyatt *et al.*, 2001). The score could be defined as 'Maximum Suitable DAMS'. Note that wind damage susceptibility is also a function of growth rate, and hence for a given DAMS score, a stand with a higher yield class could be more vulnerable.

Wildfire risk

The risk of a wildfire occurring and the damage resulting depends on many factors associated with the local context, including the fuel characteristics, size, age and density of the stand, ground flora, dead material, weather conditions, forest design, topography and location, and public access. The assessment used in this study is based on the fuel characteristics only.

The fuel characteristics that are the main consideration here are those that determine the flammability of different tree species: ignitibility (measured time to ignition), sustainability (duration of combustion, effective heat of combustion, heat content, or total heat release), combustibility (mass loss rate, peak heat release rate), and consumability (proportion of fuel consumed by fire) (Varner *et al.*, 2022). The following characteristics were considered: leaf and bark resin (volatile production & content); leaf shape and size (e.g. broadleaf or needle); litter characteristics; dead branches; canopy density and shape; bark density (determines step vulnerability); and climate 'preference' (species suited to drier locations tend to be more at risk).

A recent review of tree species flammability characteristics (Popović *et al.*, 2021) was a source of information on individual species, and this was complemented with expert knowledge. An assessment was made for all 64 longlisted species on a five-point scale.

A5 Productivity

Definitive attribute: Yield class category

Given the lack of reliable data, the yield models in Forestry Yield (Matthews *et al.*, 2016) were used to determine an upper range of yield classes to estimate productivity on suitable and very suitable sites. As a validation, 'good' sites in Scotland were selected in ESC and the yield classes generated by ESC were compared with those presented in the yield models. These data were used to derive a score for productivity using a common four-point scale for both conifers and broadleaved species. In nearly all cases, conifers were assigned one of three scores: moderate, fast and very fast (except yew), and broadleaves were assigned one of two scores: slow and moderate (except Eucalyptus species, which scored very fast).

It was decided that Douglas-fir, western hemlock, and grand fir should be given the same 'very fast' classification as Sitka spruce. This judgement considered the view that Sitka will be uniquely productive on some sites (i.e. wetter sites) compared to other conifers, but there will also be situations where Sitka isn't the most suitable choice. Also, within their natural range, most of the Pacific Northwest conifers have similar maximum potential, and that subject to improvement programmes for Scotland these species could conceivably achieve similar yields to Sitka spruce.

Supporting attributes

On-site carbon and potential off-site carbon & GHG sequestration

Provisional estimates were generated for 'on-site' and 'potential off-site carbon and greenhouse gas sequestration', although the data was not finalised by the time of publication and has not been reported here. The estimates were derived from the productivity classes for each species described above, along with estimates for rotation length and wood density.

A6 Tree health

Definitive attribute: Pest and pathogen risks, current and future

Tree health risks were assessed for each species with four separate scores: pests and pathogen risks both current and future. The assessments of current and future risks were based on the expert judgement of FR's Tree Health staff with reference to the UK Plant Health Risk Register (PHRR) and other published sources.

Future risks were considered for pests and pathogens already present in Scotland, but also those judged to be of imminent risk of introduction to Scotland. This included those already established within other areas of the UK and those highlighted as high risk of introduction to the UK. Scores were based on the risk rating for entry/establishment of pests and pathogens provided by the UK PHRR and the European and Mediterranean Plant Protection Organisation (EPPO) databases (which only consider risks for the whole of the UK and are not specific to Scotland). In some cases, a decision was made to diverge from the UK PHRR and EPPO risk ratings based upon expert opinion, which was then justified within the commentary accompanying the scores. Scores were provided on a three-point scale using the definitions shown in Table 6.

Table 6 Scores for current and future pest and pathogen risks

Score	Definition of risk
0	Productivity of the tree species is at severe risk from known pest or pathogen threats, which cannot be mitigated.
2	Either a) productivity of the tree species might be at risk due to known threats that can be mitigated sufficiently, or which may result in sporadic cases of severe damage, or b) knowledge gaps do not allow a full risk assessment.
4	No apparent threats are known to severely risk the productivity of the species.

'Mitigations' were defined as any measures for managing and surveying a pest or pathogen, which would prevent its introduction and/or spread.

Tree species scoring '0' were not included in the shortlist, because the risks were considered too severe for them to be promoted now or in the foreseeable future. This was notably the case for exotic pines judged to be susceptible to Dothistroma, larch species due to Phytophthora, and ash due to Chalara.

Research into tree health and tree breeding programmes will continue for both larch and ash with the aim of developing resistant reproductive material, and once available these species could be reconsidered for inclusion in the shortlist. (This possibility underlines the need for the shortlist to be reviewed every few years, and that some species excluded from the shortlist in its current form will still be priorities for research investment.)

Scores for risks were not cumulative, i.e. where several pests or pathogens would each threaten a tree species if they were established, their risk ratings were not combined to change a rating from, say, '2' to '0'. It was decided that future scores should not be higher than the current score for a particular risk to any given tree species. When deriving an overall score for tree health to be included in the evaluation matrix (Appendix C, Table 11), the lowest score (highest risk) from across the four attributes (pest and pathogen risks, current and future) was selected.

There was always some information available to make an assessment for each tree species, and hence no data gaps were recorded. If there was insufficient knowledge for a full risk assessment, a score of '2' was given (and this was recorded in the commentary as '2b'). Assigning the lowest score of '0' was judged to be too conservative and would have ruled out tree species with potential. It is important to acknowledge that a high level of uncertainty applies across the whole tree health dataset (not just to those species scoring

2b). Novel pests and pathogens can appear unannounced, and the impact of known threats to a given tree species may not become apparent until it is deployed at scale.

Key references used in the tree health assessment included Bevan (1987), Drenkhan *et al*. (2016), Gonzalez *et al*. (2021), Tubby *et al*. (2023), Peace (1962), Phillips and Burdekin (1982), Savill (2019), Woodward *et al*. (1998) as well as the UK PHRR and EPPO databases, FR Tree Species Database, and numerous references for specific pests and pathogens.

A7 Biodiversity and environmental impacts

Definitive attribute: Contribution to Woodland Ecological Condition

The biodiversity value of each longlisted tree species was estimated using an index derived for this study, based on their contribution to Woodland Ecological Condition (WEC). WEC is an established measure of potential biodiversity value and forest condition that uses 15 stand level indicators, assessed through a field survey of the network of 1 ha National Forest Inventory sample squares across GB (Forestry Commission, 2022).

Five of the 15 WEC metrics were judged to be strongly influenced by species choice, and these formed the basis of the index. They were: occupancy of native trees; woodland regeneration (stand level); woodland regeneration (square level); vegetation and ground flora; and veteran trees. To avoid double counting, we aggregated the two measures of woodland regeneration, effectively reducing the number of WEC metrics included in the index to four. The use of WEC metrics to derive the index, taken out of the context of the NFI sample squares for which they were originally intended, suggested it was inappropriate to count natural regeneration at two spatial scales.

The remaining 10 WEC metrics were judged to be strongly influenced by management and local context rather than species choice per se and were not included in the index. These were: number of native tree species; age distribution of trees; herbivore damage; invasive plant species; open space within woodland; favourable land cover around woodland; tree health; vertical woodland structure; volume of deadwood; and size of woodland.

For the four WEC metrics included in the index, ecological traits were selected that could act as proxies, and for which there was sufficient data to cover most longlisted tree species. The traits are shown in Table 7. For each species, a value between 0-1 was assigned for each trait using the categories shown in the table. The categories used to derive values for each trait are outlined below.

Nativeness

The assessment of nativeness in Scotland was based on the National Forest Inventory (NFI) Woodland Ecological Condition (WEC) working group (Forestry Commission, 2020, page 79ff.) who used expert knowledge, FR's Tree Species Database, and the NWSS methodology for Scotland (Patterson *et al.*, 2014, Annex 1). Five longlisted species native to UK are not considered to be native in Scotland: beech, hornbeam, white willow, osier willow and whitebeam.

Table 7 Metrics and traits used to assess contribution to WEC

WEC metric	Trait used in this study	Category	Value
Occupancy of native trees	Nativeness	Non-native, Neophyte	0
		Near-native, Neophyte	0
		Near-native, Archaeophyte	0.5
		Close-relative, Neophyte	0.5
		Native	1
Woodland regeneration	Natural regeneration potential	Rare	0
		Occasional	0.5
		Frequent	1
Vegetation & ground flora	Shade casting	Shade tolerant	0
		Intermediate	0.5
		Light-demanding	1
	Phenology	Evergreen	0
		Deciduous	1
Veteran trees	Minimum age	0-99 years	0
		100-199 years	0.5
		200+ years	1

The distinction between native and non-native was subdivided further based on Reynolds and Kerr (2023), who built on Lemoine and Svenning (2022). The aim was to take a reasoned approach to European tree species that may have migrated to Britain after the last Ice Age if we were still physically joined to mainland Europe. The assessment considered factors including potential speed of migration, known refugia in northern Europe, and physical barriers to movement. From this analysis, species were divided into categories (Reynolds and Kerr, 2023). In addition, known information on the species introduction to Britain was taken from Stace (2019). The categories and descriptions are given in Table 8. The near-natives, non-natives, and close-relatives can all be split into two categories, archaeophytes and neophytes, depending on whether they arrived in the UK before or after AD 1550.

Natural regeneration potential

Natural regeneration potential is already a supporting attribute within the silviculture criterion (see Appendix A3). The values for each species were assigned as shown in Table 7. Within the WEC methodology, natural regeneration is regarded as being beneficial, because it enables the development of structural diversity within the stand, but it is also potentially a drawback (see Appendix A7 ‘Invasiveness’, below). In general, the problem was seen primarily to be a risk for exotic conifers with high or intermediate shade tolerance, and for beech. To adjust for this problem, for these tree species the values for natural regeneration potential were reduced to zero when calculating the index for contribution to WEC.

Table 8 Nativeness categories

Category	Description
Native	Arrived naturally in Britain and Ireland since the end of the last glaciation (i.e., without the assistance of humans) or was already present (i.e., it persisted during the last Ice Age). https://bsbi.org/definitions-wild-native-or-alien
Near-native	Originates in Europe and, had the English Channel once been shallower, these species could potentially have reached the UK naturally. https://growwild.kew.org/blog/uk-native-plants-and-fungi
Non-native	Introduced either deliberately or accidentally by humans. https://bsbi.org/definitions-wild-native-or-alien
Close-relative	A European tree species of the same genus as a UK native that may not have reached the UK naturally.
Archaeophyte	Long-established aliens introduced by humans, often early farmers, from the Neolithic era up to about AD 1500, and are now thoroughly naturalised. https://bsbi.org/definitions-wild-native-or-alien
Neophyte	First introduced to the UK after the discovery of the New World in c. 1550, a key turning point for our flora, after which plant species were imported from across the globe for commercial and ornamental purposes. https://bsbi.org/definitions-wild-native-or-alien

Shade casting

The logic for including shade casting as a trait is that tree species that cast substantial shade are likely to suppress vegetation and ground flora within the stand reducing the abundance and diversity of this important forest strata and associated biodiversity. The most relevant measure of shade casting available for the full longlist of species was shade tolerance, which is already a supporting attribute in the Silviculture criterion (see Appendix A3). In the future, a more direct measure of shade casting might be possible through assessments of leaf area index or modelling of light penetrating to ground level based on remote sensing data.

Phenology

In addition to shade casting, leaf phenology type is known to influence the composition and structure of ground flora, which we assessed by scoring evergreen species as '0' and deciduous species as '1'. The values for shade casting and phenology were each given a 50% weighting, so that together they provide a value for 'Vegetation and ground flora' in the index for contribution to WEC without double counting.

Maximum age

The maximum age attained by each tree species was the most relevant available proxy for the WEC metric 'veteran trees'. Long-lived tree species, including those capable of resprouting (e.g. willow), are likely to support a greater species richness of associated biodiversity due to stability of the tree as a habitat and resource. The age thresholds shown in Table 7 were selected so that the longlisted species were distributed roughly evenly between each age class.

Since this project is focusing on species to be managed primarily for production, an alternative approach could have been to use the rotation length. However, we took the view that the biodiversity value associated with maximum age would be realised in situations where shortlisted species are able to grow beyond rotation age and approached veteran status through long-term retention.

Aggregation

For each species, the values for each trait were then aggregated to form an index. As mentioned, 10 WEC metrics were judged to be a function of management and context rather than species per se. Excluding these metrics from the index gave the impression that the worst performing species were of considerably less biodiversity value than the highest performing species, yet all tree species have some biodiversity value and could potentially be grown and managed in ways that maximised the contribution of the 10 metrics to WEC. To reflect this view (that all species have some value), we structured the scores so that the lowest any species could score was '2' and the highest was '4'. Despite the simplicity of the index, the scores look credible, although they should only be seen as indicative.

Supporting attribute: Environmental impacts

Tree species can influence the environment in multiple ways, and it would be difficult to bring these effects into a single score. The data required for a full assessment of environmental risks and benefits is incomplete, even for principal tree species. Environmental risks are largely a consequence of the management regime rather than the species per se, so the value of a single score taken out of context would be limited. The approach taken was to highlight the small proportion of longlisted species which can pose a substantial risk in certain circumstances, while noting where the risks can be mitigated through proper site selection and management. The following environmental impacts were considered as part of this study.

Invasiveness

An invasive species is any animal or plant with the ability to spread and be detrimental to the environment, the economy, or our health and well-being. In the UKFS they are categorised separately from tree pests and diseases (defined as organisms which specifically harm trees, and which are dealt with in the General Forestry Practice section). Some invasive species are native (e.g. bracken) but most are non-native (e.g. grey squirrel and rhododendron). The effects of invasive species on the biodiversity of forests and their associated habitats are wide ranging. Those that pose the most significant risk are subject to control provisions under legislation (Forest Research, 2023).

In general, the potential invasiveness of non-native plants is more of a concern for non-woodland species. A few longlisted tree species with potential problems were flagged up in the dataset for environmental impacts (see Appendix C, Table 11). For example, Sitka spruce and western hemlock can regenerate freely, which is beneficial from a silvicultural perspective, but this can present challenges if the regeneration establishes on adjacent sites managed for other objectives. Mitigation should be effective if certain localities are avoided, and UKFS and other management guidelines are followed, for example 'Managing invasive and non-native species' (Forestry Commission Scotland, 2015). The risks need to be weighed against the benefits of both species from the perspective of productivity and other ecosystem services.

Water quantity

Trees are generally beneficial for flood risk reduction, but this can pose a potential disbenefit for water resources. The impact on water quantity arises from the ability of trees to evaporate more water, principally by canopy interception, than shorter types of vegetation. Conifers tend to evaporate more water than broadleaves because they have a canopy all year round. In general, interception loss of rainwater is 25-40% for conifers, and 10-25% for broadleaved species. These ranges primarily reflect site (e.g. rainfall, wind/exposure and altitude), rather than species differences, with the latter tending to be small, especially for conifers. Broadleaved species with lighter canopies such as birch, ash and rowan tend to have lower interception losses than species with dense canopies (e.g. beech and oak). Limited data are available for minor species and likely to be site specific.

Trees can also evaporate more water by transpiration, for which there can be greater differences between certain species. As with interception loss, species differences tend to be small for conifers and larger for broadleaves. Species that are adapted to wet environments, such as willows and poplars, can have a high transpiration loss, although this can quickly change when trees are water stressed, when their stomata close and productivity decreases. Eucalypts and some other species (e.g. Paulownia) can also have high water use, including where deep rooting can access ground water supplies.

While there is a good case for separating conifers from broadleaves in terms of a potential flood benefit, evidence is lacking to distinguish significant species differences. In addition, evaporation loss is only one aspect of the flood benefit provided by trees, with others derived from related soil and ‘hydraulic roughness’ factors that are largely unaffected by woodland type or species (more impacted by woodland design and management).

A similar case can be made for separating conifers from broadleaves regarding the potential disbenefit for water resources, with a stronger basis for distinguishing between some broadleaved species. However, the environmental impact of such ‘thirsty’ species depends on the scale of the woodland, with the risk increasing when larger areas, or proportions of the catchment, are established, e.g. with large-scale, short rotation forestry or short rotation coppice crops of poplar, willow or eucalypts. The UKFS provides guidance on managing this risk. An alternative perspective on the impact of thirsty species is that their ability to tolerate waterlogging in poorly draining areas can be an advantage.

Water quality

Overall, trees are good for water quality, and the potential negative effects of trees on water quality are primarily associated with woodland management rather than species choice, e.g. cultivation and drainage, road construction and timber harvesting. For this reason, productive forestry is more problematic than non-productive forestry, which causes much less disturbance. However, these risks have been shown to be effectively controlled by application of good management practices. Implementation of UKFS should ensure water quality protection, with no significant differences expected between conifers and broadleaved species, or productive and non-productive forestry, including for sensitive water supplies and fisheries.

There is one main caveat, which concerns the interaction between trees and air pollution. Trees enhance capture and removal of acid pollutants, which can then acidify soil and water. Tree type and species have a relatively small effect on pollutant scavenging, which is mainly determined by canopy height and structure. When air pollution was at its peak in the 1970s, the scavenging of sulphur and nitrogen pollutants by upland conifer forests contributed to increased surface water acidification. The issue is now much reduced following a 90% reduction in sulphur emissions, with acid sensitive streams slowly recovering in response.

Another exception concerns nitrogen fixing tree species such as alder, which can promote nitrate leaching from soils and increase surface water acidification. For this reason, the UKFS limits the planting of alder in riparian areas of acid vulnerable catchments to <10%.

Effects on soil

Tree species differ in the type of leaf litter they produce, although it is typically acidic unless the soil is underlain by calcareous rock. The regular enrichment of the soil with organic matter from annual leaf fall results in surface soil layers having a marginal acidity, regardless of tree type or species. The release of organic acids from these layers can reduce the pH of drainage waters but this natural organic acidity reflects normal soil processes and rarely leads to adverse effects on receiving stream waters.

Slope stability

Slope stability is affected by rooting habit. There are differences between species, and possibly similarities between species within a genus (see Forest Enterprise Scotland, 2015, pp. 13-14), and a partial dataset could be assembled using proxies to fill data gaps, although the general recommendation is to plant a mix of species, rather than use a particular species that on its own might improve slope stability.

Hybridisation

There are risks of hybridisation if grey alder is established close to native alder populations, and hybrid aspen is close to native aspen, although the risk is considered to be low due to lack of seed production. If there is concern over the genetic integrity of a native woodland, then geographical buffering or separation should help to mitigate the risk. The two native oaks also frequently hybridise (although not with red oak) although this is not considered a concern.

A8 Wood properties and end use

The ‘wood properties and end use’ criterion covers wood properties, processing and markets, from primary processing to end use. The information presented is based mostly on published sources, supplemented with unpublished research data for some species under active research. A degree of judgement and experience was necessary to ensure the data was as reliable as possible.

For many longlisted species there was very limited information that could be found in the time available. Information relating to properties and uses abroad may not apply to the UK, due to differences in growth conditions and the economics of the timber market. Wood sourced from its established range may have better properties and value chains that have had a long time to establish around it. However, in some cases, the wood produced in the

UK may be better if the established range is not used for wood products for some other reason, e.g. protected status. For this reason, data about UK-grown material was more highly weighted for relevance.

Scores over three axes were generated, inspired by the United Nations Framework Classification for Resources (UNFC):

- *Technical potential (T)* – the range of things that could be done with the wood if unrestricted by other factors (assuming you have a unit volume, so not accounting for forest productivity).
- *Compatibility with wood value chain (E)* – how well adapted the current wood chain in the UK is for this species. A high score means less adaptation is required and a low score means lots of changes would be necessary.
- *Knowledge state (K)* – a general level of certainty about the T and E scores. A low value means not much current knowledge, and the associated risk that the knowledge we think we have might be misleading.

Wood technical potential was included among the definitive attributes, while compatibility with the wood value chain was included among the supporting attributes to avoid over-emphasising current market preferences, which are primarily for spruce.

The data for the knowledge state or K score for each species has not been included in this report. A high K score represents a species about which we can be confident thanks to research and/or experience. A low K score represents a lack of information, or information that may not be transferable to the UK context. Lack of information for some criteria does, however, result in lower T and E scores.

The scores for wood technical potential, and compatibility for wood value chain, both on a scale from 0-7 were transferred to the four-point scale used in the overall evaluation matrix as follows: Scores of 0, 1, 2 and 3 were all converted to '1'; scores of 4 and 5 were converted to '2'; a score of 6 was converted to '3' and a score of 7 was converted to '4'. This approach retained the distinctions between the better performing species when transferring to the simpler four-point scoring system.

Definitive attribute: Wood technical potential

The wood technical potential (T) score expresses the potential inherent in the wood on a scale from 0-7. The score is weighted towards construction use but recognises that wood is needed for multiple markets, and that there needs to be a range of product types for components of the log breakdown. Some aspects of this score can be improved through tree breeding and silviculture.

Firstly, an initial score was assigned to each species through expert judgement, and then an algorithm was created and refined until it produced values that broadly matched, and the scores were recalculated. The T score was calculated as the sum of the following sub-factors, which was then divided by 3.5 and rounded to the nearest integer:

- Workability score (0 to 5 points)
- Durability score (0 to 5 points)
- 3 times the minimum Sitka index
- 5 points if there is documented use in construction
- 2 points if there is document use in furniture/joinery/flooring

- 1 point if there is documented use in pulp
- 2 points if there is documented use in utility items
- 1 point if there is documented use in peeled veneer products
- 2 points if there is documented use in external applications

The workability score describes the ease of working in secondary processing on a five-point scale from 'very difficult to work' to 'working well or easily', based mostly on Porter (2004) and similar sources.

The durability score attempts to summarise the information about the natural durability of the wood to fungi, and the treatability with preservatives of the heartwood and sapwood. Information about durability came from standard BS EN 350 (BSI 2016) if listed, although for several species more anecdotal sources had to be used.

The Sitka index reflected how similar the wood properties were to Sitka spruce, based on calculations of the density, stiffness and strength of each tree species compared to those of Sitka expressed as ratios. A set of Sitka indices close to 1 is an indication that the species will strength grade in a similar way to home-grown spruce. The lowest value indicates the likely limiting property for grading. If there are any values below 0.9 the species is unlikely to be graded economically to C16. Grading for density can be quite effective, although this is the least important of the indices (unless it is very low). Since, for stiffness, the mean value is the characteristic (and therefore harder to improve through grading), the Sitka index for stiffness is particularly important. Since strength is a more difficult property to predict, the Sitka index for strength can also be important.

Where data does not exist, or has not been found, the T score will be reduced in the calculation as a result. This means any species with a low knowledge state (K score), will also score low for technical potential. Many of these species are better regarded as unknown rather than known to be unsuitable. However, species that are not suited to timber production will also score low, and the reason for lack of information can be that the species is not worth the study.

The data for the T scores were taken from numerous sources, favouring more reliable sources where possible, but needing to use more anecdotal and less scientific sources where there was no alternative. Several of the elemental scores are also combinations of different sub-elements. The mechanical properties data that makes up the Sitka index came mostly from the records of Edinburgh Napier University, relatively recent scientific literature, and Lavers (1983). Data in Lavers is old, with much coming from the early work of the Forest Products Research Laboratory. This means much of the hardwood data is from before the 1950s and may not be a good representation of the current resource (Ridley-Ellis and Cramer, 2024). In some cases, data from timber outside the UK was the only option, for which similar countries and good quality studies where preferred, even if the data was old (e.g. Huber *et al.*, 2023). Sources like the internet wood database (Meier, 2024) were used for properties data as last resort.

Supporting attribute: Compatibility with wood value chain

The compatibility with wood value chain (E) score expresses the compatibility with the current wood value chain on a scale from 0-7. It describes the economic challenge to bring the resource to market. A high E score represents a species that can be adapted into the current wood value chain without major changes. A low score represents a species that would need significant changes for primary processing, manufacturing and end use.

Firstly, an initial score was assigned to each species through expert judgement, and then an algorithm was created and refined until it produced values that broadly matched, and the scores were recalculated. The E score is calculated as the sum of the following factors, which was then divided by 5 and rounded to the nearest integer:

- Workability score (0 to 5 points)
- Drying score (0 to 5 points)
- 2 times the UK market familiarity score (0 to 5 points)
- The genus score (0 to 5 points)
- The form score (0 to 2 points)
- 1 point if there is documented use in pulp
- 1 point if there is documented use in utility items
- 1 point if there is documented use in external applications
- 2 times the possibility rating for strength grading UK-grown (0 to 5 points)

The workability score describes the ease of working in secondary processing on a five-point scale from 'very difficult to work' to 'working well or easily' and is the same as used in the T score since this property affects processing.

The drying score attempts to summarise the information about wood drying. Three points are given if there is a listed kiln schedule similar to a main commercial species, and 2 points if the species is described as seasoning well or scores well in terms of ease of kilning.

The UK market familiarity score attempts to summarise the level of knowledge and acceptance in the modern UK market of this species and is scored on a scale from 0 (species that are very unfamiliar) to 5 (species is commonly used, either home-grown or imported). A low UK market familiarity score does not mean that the species is not a mainstream wood value chain species in other countries. It also does not imply that it is unsuitable for the UK market, or different to a familiar species. The genus score takes into account market familiarity at genus level when the exact species may not matter.

The form score denotes the general usefulness of the timber in terms of the size and amount of sawn wood that can be obtained from a tree. Softwoods score 2 and hardwoods score 1, with the exception that any species which is known not to produce much timber of any useful size and is generally regarded as not commercially important is given a score of 0.

The data for the E score were taken from numerous sources, favouring more well known and trusted publications, but also relying on expert knowledge and judgement. Several of the elemental scores are also combinations of different sub-elements. Information on kiln drying was obtained from Pratt *et al.* (1997). The information about strength grading possibility draws mostly from the record of approvals of standards committee CEN TC124 WG2 and Ridley-Ellis *et al.* (2022). Information on uses was drawn from numerous sources and collated, and for this purpose sources like the internet wood database (Meier, 2024) were taken as more reliable than they are for the quantitative wood properties data.

Appendix B: Longlist of species

Table 9 Tree species included in the assessment

Accepted name	Common name	Status	Wood type	Scotland native*	Code
Abies grandis (Douglas ex D.Don) Lindl., 1833	Grand fir	Principal	Softwood	Non-native	GF
Abies procera Rehder, 1940	Noble fir	Principal	Softwood	Non-native	NF
Acer pseudoplatanus L.	Sycamore	Principal	Hardwood	Non-native	SY
Alnus glutinosa (L.) Gaertn., 1790	Common alder	Principal	Hardwood	Native	CAR
Betula pendula Roth, 1788	Silver birch	Principal	Hardwood	Native	SBI
Betula pubescens Ehrh., 1791	Downy birch	Principal	Hardwood	Native	DBI
Castanea sativa Mill.	Sweet chestnut	Principal	Hardwood	Non-native	SC
Fagus sylvatica L.	Beech	Principal	Hardwood	Non-native	BE
Fraxinus excelsior L.	Ash	Principal	Hardwood	Native	AH
Larix × marschlinsii Coaz	Hybrid larch	Principal	Softwood	Non-native	HL
Larix decidua Mill.	European larch	Principal	Softwood	Non-native	EL
Larix kaempferi (Lamb) Carr.	Japanese larch	Principal	Softwood	Non-native	JL
Picea abies (L.) H.Karst	Norway spruce	Principal	Softwood	Non-native	NS
Picea sitchensis Trautv. & G.Mey.	Sitka spruce	Principal	Softwood	Non-native	SS
Pinus contorta var. *latifolia* Engelm., 1871	Lodgepole pine	Principal	Softwood	Non-native	LP
Pinus nigra subsp. *laricio* Maire	Corsican pine	Principal	Softwood	Non-native	CP
Pinus sylvestris L.	Scots pine	Principal	Softwood	Native	SP
Populus spp. L.	Poplar	Principal	Hardwood	Native/Non-native	POP
Pseudotsuga menziesii (Mirb.) Franco, 1950	Douglas-fir	Principal	Softwood	Non-native	DF
Quercus petraea (Matt.) Liebl.	Sessile oak	Principal	Hardwood	Native	SOK
Quercus robur L	Pedunculate oak	Principal	Hardwood	Native	POK
Thuja plicata Donn ex D.Don	Western red-cedar	Principal	Softwood	Non-native	RC
Tsuga heterophylla (Raf.) Sarg.	Western Hemlock	Principal	Softwood	Non-native	WH
Abies alba Mill.	European silver fir	Secondary	Softwood	Non-native	ESF
Abies amabilis Douglas ex J.Forbes	Pacific silver fir	Secondary	Softwood	Non-native	PSF

Acer platanoides L., 1753	Norway maple	Secondary	Hardwood	Non-native	NOM
Alnus cordata (Loisel.) Duby, 1828	Italian alder	Secondary	Hardwood	Non-native	IAR
Alnus incana Moench, 1794	Grey alder	Secondary	Hardwood	Non-native	GAR
Carpinus betulus L., 1753	Hornbeam	Secondary	Hardwood	Non-native	HBM
Chamaecyparis lawsoniana (A.Murray bis) Parl., 1864	Lawson's cypress	Secondary	Softwood	Non-native	LC
Cryptomeria japonica (Thunb. ex L.f.) D.Don	Japanese cedar	Secondary	Softwood	Non-native	JCR
Cupressus x *leylandii (*A.B.Jacks. & Dallim.) [Syn: × *Hesperotropsis leylandii* (A.B.Jacks. & Dallim.) Garland & Gerry Moore]	Leyland cypress	Secondary	Softwood	Non-native	LEC
Eucalyptus glaucescens Maiden & Blakely, 1929	Tingiringi gum	Secondary	Hardwood	Non-native	TRE
Eucalyptus gunnii Hook.f., 1844	Cider gum	Secondary	Hardwood	Non-native	EGU
Eucalyptus nitens (H. Deane & Maiden) Maiden	Shining gum	Secondary	Hardwood	Non-native	SHE
Juglans nigra L., 1753	Black walnut	Secondary	Hardwood	Non-native	BWA
Juglans regia L., 1753	Walnut	Secondary	Hardwood	Non-native	CWA
Nothofagus alpina (Poepp. & Endl.) Oerst., 1871 [Syn: *Nothofagus procera*]	Rauli	Secondary	Hardwood	Non-native	RAN
Nothofagus obliqua (Mirb.) Blume	Roble	Secondary	Hardwood	Non-native	RON
Picea omorika (Pančić) Purk., 1877	Serbian spruce	Secondary	Softwood	Non-native	OMS
Pinus pinaster Aiton	Maritime pine	Secondary	Softwood	Non-native	MAP
Pinus radiata D.Don	Monterey pine	Secondary	Softwood	Non-native	RAP
Populus tremula L., 1753	Aspen	Secondary	Hardwood	Native	ASP
Prunus avium (L.) L., 1755	Gean [Syn: Wild cherry]	Secondary	Hardwood	Native	WCH
Quercus rubra L.	Red oak	Secondary	Hardwood	Non-native	ROK
Sequoia sempervirens (D.Don) Endl., 1847	Coast redwood	Secondary	Softwood	Non-native	RSQ
Sequoiadendron giganteum (Lindl.) J.Buchholz, 1939	Giant Sequia / Redwood [Syn: Wellingtonia]	Secondary	Softwood	Non-native	WSQ
Tilia cordata Mill., 1768	Small-leaved lime	Secondary	Hardwood	Native	SLI

Salix alba L., 1753	White willow	Additional native	Hardwood	Non-native	WWI
Salix viminalis L., 1753	Osier	Additional native	Hardwood	Non-native	
Aria edulis (Willd.) M.Roem., 1847 [Syn: *Sorbus aria*]	Common whitebeam	Additional native	Hardwood	Non-native	WBM
Taxus baccata L., 1753	Yew	Additional native	Softwood	Native	YEW
Abies concolor (Gordon & Glend.) Lindl. ex Hildebr., 1861	White fir [Syn: Colorado white fir]	Plot-stage	Softwood	Non-native	
Abies nordmanniana (Steven) Spach	Nordmann fir [Syn: Caucasian fir]	Plot-stage	Softwood	Non-native	NMF
Alnus rubra Bong., 1833	Red alder	Plot-stage	Hardwood	Non-native	RAR
Cedrus atlantica (Endl.) Manetti ex Carrière, 1855	Atlas cedar	Plot-stage	Softwood	Non-native	ACR
Hesperocyparis macrocarpa (Hartw.) Bartel, 2009 [Syn: *Cupressus macrocarpa*]	Monterey cypress	Plot-stage	Softwood	Non-native	MC
Picea × lutzii Little	Lutz spruce	Plot-stage	Softwood	Non-native	
Picea engelmannii Parry ex Engelm.	Engelmann spruce	Plot-stage	Softwood	Non-native	ES
Picea orientalis (L.) Peterm.	Oriental spruce	Plot-stage	Softwood	Non-native	ORS
Picea rubens Sarg.	Red spruce	Plot-stage	Softwood	Non-native	RDS
Pinus peuce Griseb., 1846	Macedonian pine	Plot-stage	Softwood	Non-native	MCP
Pinus strobus L., 1753	Weymouth pine	Plot-stage	Softwood	Non-native	WEP
Pinus taeda L.	Loblolly pine	Plot-stage	Softwood	Non-native	LOP

*Source: Forestry Commission (2020)

Appendix C: Species performance

Table 10 Scores for definitive attributes

			1. Tree Improvement	2. Plant & seed	3. Silviculture		4. Site & climate suitability		5. Productivity	6. Tree health	7. Biodiversity & Environmental impacts	8. Wood properties & end use
Latin name	**Common name**	**Status**	**Tree improvement potential**	**Plant & seed supply**	**Silvicultural knowledge**	**Establishment rate**	**Suitability area (current)**	**Suitability area (2080)**	**Yield Class category**	**Pest & pathogen risks**	**Contribution to WEC**	**Technical potential**
		Weighting	**100**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Abies grandis	Grand fir	Principal	2	3	4	2	2	3	4	2	2	3
Abies procera	Noble fir	Principal	2	2	4	2	3	1	4	2	2	3
Acer pseudoplatanus	Sycamore	Principal	3	3	4	3	4	4	2	4	3	3
Alnus glutinosa	Common alder	Principal	3	4	4	3	3	4	1	2	4	2
Betula pendula	Silver birch	Principal	4	4	4	4	4	4	2	4	4	3
Betula pubescens	Downy birch	Principal	3	4	4	3	4	4	1	4	4	3
Castanea sativa	Sweet chestnut	Principal	2	3	4	2	1	3	1	2	3	4
Fagus sylvatica	Beech	Principal	2	3	4	2	3	3	2	2	3	3
Fraxinus excelsior	Ash	Principal	4	2	4	3	2	3	2	0	4	3
Larix × marschlinsii	Hybrid larch	Principal	3	3	4	4	4	3	3	0	4	4
Larix decidua	European larch	Principal	3	3	4	4	2	3	2	0	4	4
Larix kaempferi	Japanese larch	Principal	3	3	4	4	4	4	2	0	4	4
Picea abies	Norway spruce	Principal	2	4	4	3	3	3	3	2	2	4
Picea sitchensis	Sitka spruce	Principal	4	4	4	4	4	4	4	2	2	4
Pinus contorta var. latifolia	Lodgepole pine	Principal	4	3	4	3	4	4	2	2	3	4
Pinus nigra subsp. laricio	Corsican pine	Principal	4	3	4	3	2	4	3	0	3	3
Pinus sylvestris	Scots pine	Principal	4	4	4	3	4	4	2	2	4	4
Populus spp. and hybrids	Black, grey, white poplar	Principal	3	4	4	4	2	3	2	2	3	3
Pseudotsuga menziesii	Douglas-fir	Principal	4	3	4	4	2	2	4	2	2	4
Quercus petraea	Sessile oak	Principal	3	3	4	2	3	3	1	4	4	4
Quercus robur	Pedunculate oak	Principal	2	3	4	2	2	4	1	4	4	4
Thuja plicata	Western red-cedar	Principal	3	3	4	3	3	3	4	4	2	2
Tsuga heterophylla	Western hemlock	Principal	3	3	4	4	3	4	4	2	2	4
Abies alba	European silver fir	Secondary	2	3	3	2	2	3	3	2	2	4
Abies amabilis	Pacific silver fir	Secondary	2	2	3	1	4	4	3	2	2	2
Acer platanoides	Norway maple	Secondary	2	4	3	3	3	3	2	2	3	2
Alnus cordata	Italian alder	Secondary	2	3	3	4	1	1	2	2	3	1
Alnus incana	Grey alder	Secondary	2	3	3	4	4	4	2	2	3	1
Carpinus betulus	Hornbeam	Secondary	1	3	3	2	1	1	1	4	3	1
Chamaecyparis lawsoniana	Lawson cypress	Secondary	1	3	3	4	2	3	3	0	2	3
Cryptomeria japonica	Japanese cedar	Secondary	2	2	3	4	2	3	3	2	2	2
Cupressus × leylandii	Leyland cypress	Secondary	1	4	3	4	3	3	4	2	2	2
Eucalyptus glaucescens	Tingiringi gum	Secondary	2	1	3	4	1	4	4	2	2	1
Eucalyptus gunnii	Cider gum	Secondary	3	2	3	4	3	3	4	4	2	1
Eucalyptus nitens	Shinning gum	Secondary	3	1	3	4	3	1	4	2	2	3
Juglans nigra	Black walnut	Secondary	1	3	3	2	1	1	1	4	3	2
Juglans regia	Common walnut	Secondary	1	2	3	2	1	1	1	4	3	2
Nothofagus alpina	Rauli	Secondary	2	1	3	4	2	1	2	2	3	2
Nothofagus obliqua	Roble	Secondary	2	1	3	4	1	1	2	0	3	2
Picea omorika	Serbian spruce	Secondary	2	4	3	2	3	1	3	2	2	2
Pinus pinaster	Maritime pine	Secondary	2	3	3	4	1	1	3	2	3	4
Pinus radiata	Monterey pine	Secondary	2	3	3	4	1	1	3	0	3	4
Populus tremula	Aspen	Secondary	2	3	3	4	4	4	2	2	4	2
Prunus avium	Gean	Secondary	3	2	3	3	2	4	2	2	3	2
Quercus rubra	Red oak	Secondary	2	2	3	2	2	4	1	4	3	4
Sequoia sempervirens	Coast redwood	Secondary	1	2	3	3	2	3	4	4	2	2
Sequoiadendron giganteum	Giant redwood / Sequoia	Secondary	1	2	3	3	2	1	4	4	2	2
Tilia cordata	Small-leaved lime	Secondary	1	3	3	2	1	1	1	2	4	2
Salix alba	White willow	Native	1	3	1	4	4	4	1	2	3	2
Salix viminalis	Osier willow	Native	1	1	1	4	1	1	1	2	4	2
Sorbus aria	Whitebeam	Native	1	3	1	1	1	1	1	2	3	1
Taxus baccata	Yew	Native	1	3	1	1	1	1	1	2	3	2
Abies concolor	White fir	Plot stage	2	3	2	1	1	1	3	2	2	2
Abies nordmanniana	Nordmann fir	Plot stage	1	4	2	1	1	1	2	2	2	2
Alnus rubra	Red alder	Plot stage	2	3	2	4	1	1	3	2	3	3
Cedrus atlantica	Atlas cedar	Plot stage	1	3	2	2	1	1	2	2	3	2
Cupressus macrocarpa	Monterey cypress	Plot stage	1	2	2	4	1	1	3	2	3	3
Picea × lutzii	Lutz spruce	Plot stage	2	1	2	4	1	1	3	2	2	1
Picea engelmannii	Englemann spruce	Plot stage	1	1	2	2	1	1	2	2	2	2
Picea orientalis	Oriental spruce	Plot stage	1	1	2	1	2	2	3	2	2	3
Picea rubens	Red spruce	Plot stage	1	1	2	2	1	1	2	2	2	2
Pinus peuce	Macedonian pine	Plot stage	2	3	2	1	4	4	2	2	3	2
Pinus strobus	Weymouth pine	Plot stage	1	3	2	3	1	1	2	0	3	4
Pinus taeda	Loblolly pine	Plot stage	2	1	2	4	1	1	3	2	3	4

4 = high performance; 1 = low performance; 0 = not shortlisted due to tree health risk; dark grey = data gap

Table 11 Data for supporting attributes

			3. Silviculture				4. Site & climate suitability				7. Biodiversity & environmental impacts	8. Wood properties & end use
Latin name	Common name	Status	Shade tolerance	Natural regeneration	Palatability	Squirrel damage susceptibility	Frost susceptibility	Drought susceptibility	Wind damage susceptibility	Fire risk	Environmental impacts	Compatibility with wood value chain (7 = high; 1 = low)
Abies grandis	Grand fir	Principal	Shade tolerant	Occasional	High	Low	Y	Intolerant	16	High		4
Abies procera	Noble fir	Principal	Intermediate	Occasional	High	Low	Y	Intolerant	18	Hign		4
Acer	Sycamore	Principal	Shade tolerant	Frequent	Medium	Very high	N	Moderate	18	Low		3
Alnus glutinosa	Common alder	Principal	Light demanding		Low	Low / high	N	Moderate	16	Low		3
Betula pendula	Silver birch	Principal	Light demanding	Frequent	Low	High	N	Intolerant	16	Low		4
Betula pubescens	Downy birch	Principal	Light demanding	Frequent	Low	High	N	Intolerant	18	Low		4
Castanea sativa	Sweet chestnut	Principal	Light demanding	Rare?	Low	High	Y	Tolerant	16	Very low		4
Fagus sylvatica	Beech	Principal	Shade tolerant	Frequent	Low	Very high	Y (young)	Moderate	16	Very low	Prolific regeneration	4
Fraxinus excelsior	Ash	Principal	Intermediate	Frequent	High	Medium	Y	Moderate	14	Low		4
Larix × marschlinsii	Hybrid larch	Principal	Light demanding	Frequent	Medium	Medium	Y	Intolerant	16	Medium?		7
Larix decidua	European larch	Principal	Light demanding	Frequent	Medium	Medium	Y	Tolerant	16	Medium?		7
Larix kaempferi	Japanese larch	Principal	Light demanding	Frequent	Medium	Medium	Y	Intolerant	16	Medium?		7
Picea abies	Norway spruce	Principal	Shade tolerant	Occasional	Medium	Medium	Y	Intolerant	16	High		7
Picea sitchensis	Sitka spruce	Principal	Intermediate	Frequent	Low	Low	Y	Intolerant	18	High	Prolific regeneration	7
Pinus contorta var.	Lodgepole pine	Principal	Light demanding	Frequent	Medium	Medium	N	Moderate	18	High	Prolific regeneration	5
Pinus nigra subsp.	Corsican pine	Principal	Light demanding	Rare	Low	Low	Y	Very tolerant	18	Very high		6
Pinus sylvestris	Scots pine	Principal	Light demanding	Frequent	Medium	Medium	N	Very tolerant	18	High		7
Populus spp. and	Black, Grey, White	Principal	Light demanding		High	High	N	Intolerant	16	Low	Hybridises [hybrid aspen]	3
Pseudotsuga	Douglas-fir	Principal	Intermediate	Frequent	Medium	Low	Y	Intolerant	14	Medium?		7
Quercus petraea	Sessile oak	Principal	Intermediate	Occasional?	High	High	Y	Tolerant	16	Low		5
Quercus robur	Pedunculate oak	Principal	Intermediate	Occasional?	High	High	Y	Moderate	16	Low		5
Thuja plicata	Western red-cedar	Principal	Shade tolerant		High	Medium	N	Moderate	14	High		4
Tsuga heterophylla	Western hemlock	Principal	Shade tolerant	Frequent	Low	Medium	Y	Moderate	16	High	Prolific regeneration	5
Abies alba	European silver fir	Secondary	Shade tolerant		High		Y?	Intolerant	16	High		6
Abies amabilis	Pacific silver fir	Secondary	Shade tolerant		High		Y	Moderate	18	High		4
Acer platanoides	Norway maple	Secondary	Intermediate	Frequent	Medium	High	N	Moderate	14	Low		2
Alnus cordata	Italian alder	Secondary	Light demanding		Low	Low		Tolerant	14	Low		1
Alnus incana	Grey alder	Secondary	Light demanding		Low	Low	Y	Intolerant	22	Low	Hybridises	1
Carpinus betulus	Hornbeam	Secondary	Shade tolerant	Rare?	Medium	High	N	Moderate	16	Very low		1
Chamaecyparis	Lawson cypress	Secondary	Intermediate		Medium		Y	Moderate	14	High		3
Cryptomeria	Japanese cedar	Secondary	Shade tolerant		Medium			Intolerant	14	High		2
Cupressus ×	Leyland cypress	Secondary	Intermediate		Medium			Moderate	14	High		2
Eucalyptus	Tingiringi gum	Secondary	Light demanding	Rare?	Low	Low	Y	Moderate		Very high		0
Eucalyptus gunnii	Cider gum	Secondary	Light demanding	Rare?	High	Low	Y	Moderate	16	Very high		0
Eucalyptus nitens	Shinning gum	Secondary	Light demanding	Rare?	Low	Low	Y	Intolerant	16	Very high		2
Juglans nigra	Black walnut	Secondary	Light demanding		Low		Y	Intolerant	18	Low		2
Juglans regia	Common walnut	Secondary	Intermediate		Low	Medium	Y	Tolerant	14	Low		2
Nothofagus alpina	Rauli	Secondary	Light demanding		High	Medium	Y	Moderate	14			2
Nothofagus obliqua	Roble	Secondary	Light demanding	Rare?	High	Medium	Y	Moderate	16			1
Picea omorika	Serbian spruce	Secondary	Intermediate	Rare?	Low		N	Intolerant	16	High		3
Pinus pinaster	Maritime pine	Secondary	Light demanding		Low		N	Tolerant	14	High		4
Pinus radiata	Monterey pine	Secondary	Light demanding				Y?	Very tolerant	16	Very		4
Populus tremula	Aspen	Secondary	Light demanding	Frequent	Medium		N	Moderate	16	Low		2
Prunus avium	Gean	Secondary	Light demanding	Occasional?	Medium	Low	N	Moderate	14	Low		2
Quercus rubra	Red oak	Secondary	Intermediate		Medium	Medium	Y	Moderate	16	Low		3
Sequoia	Coast redwood	Secondary	Shade tolerant		Low	Low	Y	Moderate	16	Medium?		2
Sequoiadendron	Giant redwood /	Secondary	Intermediate		Low	Low	N	Intolerant	16	Medium?		2
Tilia cordata	Small-leaved lime	Secondary	Shade tolerant	Occasional	Low	Low	N	Moderate	16	Low		3
Salix alba	White willow	Native	Intermediate	Frequent	High		N	Intolerant	18	Low		3
Salix viminalis	Osier willow	Native	Light demanding	Frequent	High		N	Intolerant		Low		3
Sorbus aria	Whitebeam	Native	Intermediate		Medium			Tolerant		Low		0
Taxus baccata	Yew	Native	Shade tolerant		High		N	Tolerant		Low?		1
Abies concolor	White fir	Plot stage	Shade tolerant		High		Y	Moderate		High		3
Abies	Nordmann fir	Plot stage	Shade tolerant		High		Y	Moderate	16	High		3
Alnus rubra	Red alder	Plot stage	Light demanding		Medium	Low	Y		16	Low		2
Cedrus atlantica	Atlas cedar	Plot stage			Medium			Moderate		High?		2
Cupressus	Monterey cypress	Plot stage								High		2
Picea × lutzii	Lutz spruce	Plot stage	Intermediate		Medium		Y			High		2
Picea engelmannii	Englemann spruce	Plot stage	Intermediate				N			HIgh		4
Picea orientalis	Oriental spruce	Plot stage	Intermediate					Moderate	14	High		3
Picea rubens	Red spruce	Plot stage	Intermediate		Low		N			High		3
Pinus peuce	Macedonian pine	Plot stage	Intermediate				N	Moderate	18	High		2
Pinus strobus	Weymouth pine	Plot stage	Light demanding				N	Low	16	High		3
Pinus taeda	Loblolly pine	Plot stage	Light demanding							High		3

Appendix D: Sensitivity analysis

Table 12 Species rankings for 14 weighting scenarios

			Monte Carlo ranking	Equal weighting	Workshop	Top 4 attributes	Tree improvement potential	Plant & seed supply	Silvicultural knowledge	Establishment rate	Suitability area (current)	Suitability area (2080)	Yield class category	Pest & disease risk	Contribution to WEC	Technical potential
Abies grandis	Grand fir	Principal	25	23	22	20	25	25	19	44	31	28	7	25	48	24
Abies procera	Noble fir	Principal	34	33	35	15	31	49	22	48	24	41	10	32	52	28
Acer pseudoplatanus	Sycamore	Principal	7	5	6	3	9	12	5	30	5	5	31	3	14	21
Alnus glutinosa	Common alder	Principal	15	13	19	39	15	5	13	33	17	9	53	19	7	34
Betula pendula	Silver birch	Principal	1	1	2	2	1	1	1	1	1	1	29	1	1	19
Betula pubescens	Downy birch	Principal	4	4	5	7	8	4	4	29	4	4	51	2	3	20
Castanea sativa	Sweet chestnut	Principal	35	33	43	43	31	29	22	48	43	34	56	32	24	15
Fagus sylvatica	Beech	Principal	26	23	29	26	25	25	19	44	21	28	38	25	19	24
Fraxinus excelsior	Ash	Principal	23	23	38	51	7	45	19	36	31	28	38	60	11	24
Larix × marschlinsii	Hybrid larch	Principal	8	8	10	17	11	15	8	4	7	20	13	56	4	5
Larix decidua	European larch	Principal	18	18	24	40	17	22	17	9	29	25	36	58	10	11
Larix kaempferi	Japanese larch	Principal	9	8	11	24	11	15	8	4	7	8	33	56	4	5
Picea abies	Norway spruce	Principal	16	13	12	11	21	5	13	33	17	23	14	19	45	9
Picea sitchensis	Sitka spruce	Principal	2	2	1	1	2	2	2	2	2	2	1	14	41	1
Pinus contorta var. latif	Lodgepole pine	Principal	6	5	7	8	4	12	5	30	5	5	31	16	14	3
Pinus nigra subsp. larici	Corsican pine	Principal	19	18	21	40	6	22	17	35	29	12	15	58	17	23
Pinus sylvestris	Scots pine	Principal	3	3	3	6	3	3	3	28	3	3	30	15	2	2
Populus spp. and hybri	Black, grey, white poplar	Principal	13	13	16	32	15	5	13	7	27	23	34	19	16	22
Pseudotsuga menziesii	Douglas-fir	Principal	10	10	9	9	5	17	10	6	26	37	3	18	43	7
Quercus petraea	Sessile oak	Principal	12	10	13	9	13	17	10	42	15	21	52	4	6	7
Quercus robur	Pedunculate oak	Principal	17	13	17	18	21	20	13	43	27	9	53	6	7	9
Thuja plicata	Western red-cedar	Principal	11	10	8	5	13	17	10	32	15	21	3	4	43	33
Tsuga heterophylla	Western hemlock	Principal	5	5	4	3	9	12	5	3	14	5	2	16	42	3
Abies alba	European silver fir	Secondary	32	28	27	22	29	27	30	47	34	32	16	28	49	13
Abies amabilis	Pacific silver fir	Secondary	38	33	32	23	31	49	35	58	11	16	18	32	52	40
Acer platanoides	Norway maple	Secondary	24	23	26	34	25	9	28	36	21	28	38	25	19	37
Alnus cordata	Italian alder	Secondary	47	46	48	59	41	35	42	22	48	47	43	42	30	61
Alnus incana	Grey alder	Secondary	22	21	20	33	24	24	26	11	10	13	37	23	18	59
Carpinus betulus	Hornbeam	Secondary	53	50	53	52	53	37	45	52	51	51	59	12	34	62
Chamaecyparis lawsoni	Lawson cypress	Secondary	39	39	41	44	49	32	37	17	38	36	20	61	55	29
Cryptomeria japonica	Japanese cedar	Secondary	33	33	33	35	31	49	35	15	37	34	18	32	52	40
Cupressus × leylandii	Leyland cypress	Secondary	21	21	18	19	46	8	26	11	20	27	6	23	47	36
Eucalyptus glaucescens	Tingiringi gum	Secondary	42	39	39	44	36	56	37	17	44	19	11	38	55	60
Eucalyptus gunnii	Cider gum	Secondary	20	18	14	12	17	44	25	9	19	25	5	7	46	58
Eucalyptus nitens	Shinning gum	Secondary	30	28	28	13	19	55	30	13	23	39	8	28	49	27
Juglans nigra	Black walnut	Secondary	49	49	49	48	52	36	44	51	50	50	58	11	33	47
Juglans regia	Common walnut	Secondary	52	50	51	49	53	54	45	52	51	51	59	12	34	48
Nothofagus alpina	Rauli	Secondary	46	46	47	47	41	58	42	22	40	47	43	42	30	46
Nothofagus obliqua	Roble	Secondary	55	54	59	63	43	59	48	25	55	55	46	64	37	50
Picea omorika	Serbian spruce	Secondary	43	39	40	29	36	10	37	50	25	42	20	38	55	44
Pinus pinaster	Maritime pine	Secondary	29	28	30	27	29	27	30	13	42	39	16	28	22	13
Pinus radiata	Monterey pine	Secondary	40	39	44	44	36	32	37	17	44	42	20	61	27	16
Populus tremula	Aspen	Secondary	14	13	15	25	21	20	24	7	9	9	34	19	7	34
Prunus avium	Gean	Secondary	28	28	34	42	19	47	30	38	34	15	41	28	22	38
Quercus rubra	Red oak	Secondary	27	23	25	20	25	45	28	44	31	14	55	8	19	12
Sequoia sempervirens	Coast redwood	Secondary	31	28	23	13	47	47	30	38	34	32	8	9	49	38
Sequoiadendron gigant	Giant redwood / Sequoi	Secondary	41	39	36	16	49	52	37	40	38	42	11	10	55	44
Tilia cordata	Small-leaved lime	Secondary	51	50	57	60	53	37	45	52	51	51	59	45	12	48
Salix alba	White willow	Native	37	33	31	35	48	29	61	15	11	16	56	32	24	40
Salix viminalis	Osier willow	Native	59	59	60	61	59	62	62	27	59	59	62	50	13	53
Sorbus aria	Whitebeam	Native	64	64	64	64	64	43	64	64	64	64	64	55	40	64
Taxus baccata	Yew	Native	63	61	63	62	61	42	63	63	61	61	63	52	39	55
Abies concolor	White fir	Plot stage	57	54	55	50	43	40	54	60	55	55	26	46	59	50
Abies nordmanniana	Nordmann fir	Plot stage	60	59	58	56	59	11	58	62	59	59	48	50	62	53
Alnus rubra	Red alder	Plot stage	44	39	42	37	36	32	50	17	44	42	20	38	27	29
Cedrus atlantica	Atlas cedar	Plot stage	58	54	56	54	57	40	54	55	55	55	46	46	37	50
Cupressus macrocarpa	Monterey cypress	Plot stage	48	46	46	38	51	53	52	22	48	47	25	42	30	31
Picea × lutzii	Lutz spruce	Plot stage	56	54	54	54	43	59	54	25	55	55	26	46	59	63
Picea engelmannii	Englemann spruce	Plot stage	61	61	61	57	61	63	59	56	61	61	49	52	63	55
Picea orientalis	Oriental spruce	Plot stage	54	54	50	31	57	59	54	60	41	38	26	52	63	55
Picea rubens	Red spruce	Plot stage	62	61	61	57	61	63	59	56	61	61	49	46	59	32
Pinus peuce	Macedonian pine	Plot stage	36	33	37	28	31	29	49	58	11	16	42	32	24	40
Pinus strobus	Weymouth pine	Plot stage	50	50	52	52	53	37	53	41	51	51	45	63	34	18
Pinus taeda	Loblolly pine	Plot stage	45	45	45	30	40	57	51	21	47	46	24	41	29	17

Table 13 Species rankings for 14 weighting scenarios (reordered for each scenario)

Rank	Monte Carlo ranking	Equal weightings	Workshop	Top 4 attributes	Tree improvement potential	Plant & seed supply	Silvicultural knowledge	Establishment rate	Suitabilty area (now)	Suitability area (2080)	Yield Class category	Pest & disease risk	Contribution to WEC	Technical potential
1	Silver birch	Silver birch	Sitka spruce	Sitka spruce	Silver birch	Silver birch	Silver birch	Silver birch	Silver birch	Silver birch	Sitka spruce	Silver birch	Silver birch	Sitka spruce
2	Sitka spruce	Sitka spruce	Silver birch	Silver birch	Sitka spruce	Sitka spruce	Sitka spruce	Sitka spruce	Sitka spruce	Sitka spruce	Western hemlock	Downy birch	Scots pine	Scots pine
3	Scots pine	Scots pine	Scots pine	Sycamore	Scots pine	Scots pine	Scots pine	Western hemlock	Scots pine	Scots pine	Douglas-fir	Sycamore	Downy birch	Lodgepole pine
4	Downy birch	Downy birch	Western hemlock	Western hemlock	Lodgepole pine	Downy birch	Downy birch	Hybrid larch	Downy birch	Downy birch	Western red-cedar	Sessile oak	Hybrid larch	Western hemlock
5	Western hemlock	Sycamore	Downy birch	Western red-cedar	Douglas-fir	Common alder	Sycamore	Japanese larch	Sycamore	Sycamore	Cider gum	Western red-cedar	Japanese larch	Hybrid larch
6	Lodgepole pine	Lodgepole pine	Sycamore	Scots pine	Corsican pine	Norway spruce	Lodgepole pine	Douglas-fir	Lodgepole pine	Lodgepole pine	Leyland cypress	Pedunculate oak	Sessile oak	Japanese larch
7	Sycamore	Western hemlock	Lodgepole pine	Downy birch	Ash	Black, grey, white	Western hemlock	Black, grey, white	Hybrid larch	Western hemlock	Grand fir	Cider gum	Common alder	Douglas-fir
8	Hybrid larch	Hybrid larch	Western red-cedar	Lodgepole pine	Downy birch	Leyland cypress	Hybrid larch	Aspen	Japanese larch	Japanese larch	Shinning gum	Red oak	Pedunculate oak	Sessile oak
9	Japanese larch	Japanese larch	Douglas-fir	Douglas-fir	Sycamore	Norway maple	Japanese larch	European larch	Aspen	Common alder	Coast redwood	Coast redwood	Aspen	Norway spruce
10	Douglas-fir	Douglas-fir	Hybrid larch	Sessile oak	Western hemlock	Serbian spruce	Douglas-fir	Cider gum	Grey alder	Pedunculate oak	Noble fir	Giant redwood /	European larch	Pedunculate oak
11	Western red-cedar	Sessile oak	Japanese larch	Norway spruce	Hybrid larch	Nordmann fir	Sessile oak	Grey alder	Pacific silver fir	Aspen	Tingiringi gum	Black walnut	Ash	European larch
12	Sessile oak	Western red-cedar	Norway spruce	Cider gum	Japanese larch	Sycamore	Western red-cedar	Leyland cypress	White willow	Corsican pine	Giant redwood /	Hornbeam	Small-leaved lime	Red oak
13	Black, grey, white poplar	Common alder	Sessile oak	Shinning gum	Sessile oak	Lodgepole pine	Common alder	Shinning gum	Macedonian pine	Grey alder	Hybrid larch	Common walnut	Osier willow	European silver fir
14	Aspen	Norway spruce	Cider gum	Coast redwood	Western red-cedar	Western hemlock	Norway spruce	Maritime pine	Western hemlock	Red oak	Norway spruce	Sitka spruce	Sycamore	Maritime pine
15	Common alder	Black, grey, white	Aspen	Noble fir	Common alder	Hybrid larch	Black, grey, white	Japanese cedar	Sessile oak	Gean	Corsican pine	Scots pine	Lodgepole pine	Sweet chestnut
16	Norway spruce	Pedunculate oak	Black, grey, white	Giant redwood /	Black, grey, white	Japanese larch	Pedunculate oak	White willow	Western red-cedar	Pacific silver fir	European silver fir	Lodgepole pine	Black, grey, white	Monterey pine
17	Pedunculate oak	Aspen	Pedunculate oak	Hybrid larch	European larch	Douglas-fir	European larch	Lawson cypress	Common alder	White willow	Maritime pine	Western hemlock	Corsican pine	Loblolly pine
18	European larch	European larch	Leyland cypress	Pedunculate oak	Cider gum	Sessile oak	Corsican pine	Tingiringi gum	Norway spruce	Macedonian pine	Pacific silver fir	Douglas-fir	Grey alder	Weymouth pine
19	Corsican pine	Corsican pine	Common alder	Leyland cypress	Shinning gum	Western red-cedar	Grand fir	Monterey pine	Cider gum	Tingiringi gum	Japanese cedar	Common alder	Beech	Silver birch
20	Cider gum	Cider gum	Grey alder	Grand fir	Gean	Pedunculate oak	Beech	Red alder	Leyland cypress	Hybrid larch	Lawson cypress	Norway spruce	Norway maple	Downy birch
21	Leylandii cypress	Grey alder	Corsican pine	Red oak	Norway spruce	Aspen	Ash	Loblolly pine	Beech	Sessile oak	Serbian spruce	Black, grey, white	Red oak	Sycamore
22	Grey alder	Leyland cypress	Grand fir	European silver fir	Pedunculate oak	European larch	Noble fir	Italian alder	Norway maple	Western red-cedar	Monterey pine	Aspen	Maritime pine	Black, grey, white
23	Ash	Grand fir	Coast redwood	Pacific silver fir	Aspen	Corsican pine	Sweet chestnut	Rauli	Shinning gum	Norway spruce	Red alder	Grey alder	Gean	Corsican pine
24	Norway maple	Beech	European larch	Japanese larch	Grey alder	Grey alder	Aspen	Monterey cypress	Noble fir	Black, grey, white	Loblolly pine	Leyland cypress	Sweet chestnut	Grand fir
25	Grand fir	Ash	Red oak	Aspen	Grand fir	Grand fir	Cider gum	Roble	Serbian spruce	European larch	Monterey cypress	Grand fir	White willow	Beech
26	Beech	Norway maple	Norway maple	Beech	Beech	Beech	Grey alder	Lutz spruce	Douglas-fir	Cider gum	White fir	Beech	Macedonian pine	Ash
27	Red oak	Red oak	European silver fir	Maritime pine	Norway maple	European silver fir	Leyland cypress	Osier willow	Black, grey, white	Leyland cypress	Lutz spruce	Norway maple	Monterey pine	Shinning gum
28	Gean	European silver fir	Shinning gum	Macedonian pine	Red oak	Maritime pine	Norway maple	Scots pine	Pedunculate oak	Grand fir	Oriental spruce	European silver fir	Red alder	Noble fir
29	Maritime pine	Shinning gum	Beech	Serbian spruce	European silver fir	Sweet chestnut	Red oak	Downy birch	European larch	Beech	Silver birch	Shinning gum	Loblolly pine	Lawson cypress
30	Shinning gum	Maritime pine	Maritime pine	Loblolly pine	Maritime pine	White willow	European silver fir	Sycamore	Corsican pine	Ash	Scots pine	Maritime pine	Italian alder	Red alder
31	Coast redwood	Gean	White willow	Oriental spruce	Noble fir	Macedonian pine	Shinning gum	Lodgepole pine	Grand fir	Norway maple	Sycamore	Gean	Rauli	Monterey cypress
32	European silver fir	Coast redwood	Pacific silver fir	Black, grey, white	Sweet chestnut	Lawson cypress	Maritime pine	Western red-cedar	Ash	European silver fir	Lodgepole pine	Noble fir	Monterey cypress	Oriental spruce
33	Japanese cedar	Noble fir	Japanese cedar	Grey alder	Pacific silver fir	Monterey pine	Gean	Common alder	Red oak	Coast redwood	Japanese larch	Sweet chestnut	Black walnut	Western red-cedar
34	Noble fir	Sweet chestnut	Gean	Norway maple	Japanese cedar	Red alder	Coast redwood	Norway spruce	European silver fir	Sweet chestnut	Black, grey, white	Pacific silver fir	Hornbeam	Common alder
35	Sweet chestnut	Pacific silver fir	Noble fir	Japanese cedar	Macedonian pine	Italian alder	Pacific silver fir	Corsican pine	Gean	Japanese cedar	Aspen	Japanese cedar	Common walnut	Aspen
36	Macedonian pine	Japanese cedar	Giant redwood /	White willow	Tingiringi gum	Black walnut	Japanese cedar	Ash	Coast redwood	Lawson cypress	European larch	White willow	Weymouth pine	Leyland cypress
37	White willow	White willow	Macedonian pine	Red alder	Serbian spruce	Hornbeam	Lawson cypress	Norway maple	Japanese cedar	Douglas-fir	Grey alder	Macedonian pine	Roble	Norway maple
38	Pacific silver fir	Macedonian pine	Ash	Monterey cypress	Monterey pine	Small-leaved lime	Tingiringi gum	Gean	Lawson cypress	Oriental spruce	Beech	Tingiringi gum	Atlas cedar	Gean
39	Lawson cypress	Lawson cypress	Tingiringi gum	Common alder	Red alder	Weymouth pine	Serbian spruce	Coast redwood	Giant redwood /	Shinning gum	Ash	Serbian spruce	Yew	Coast redwood
40	Monterey pine	Tingiringi gum	Serbian spruce	European larch	Loblolly pine	White fir	Monterey pine	Giant redwood /	Rauli	Maritime pine	Norway maple	Red alder	Whitebeam	Pacific silver fir
41	Giant redwood / Sequoia	Serbian spruce	Lawson cypress	Corsican pine	Italian alder	Atlas cedar	Giant redwood /	Weymouth pine	Oriental spruce	Noble fir	Gean	Loblolly pine	Sitka spruce	Japanese cedar
42	Tingiringi gum	Monterey pine	Red alder	Gean	Rauli	Yew	Italian alder	Sessile oak	Maritime pine	Serbian spruce	Macedonian pine	Italian alder	Western hemlock	White willow
43	Serbian spruce	Giant redwood /	Sweet chestnut	Sweet chestnut	Roble	Whitebeam	Rauli	Pedunculate oak	Sweet chestnut	Monterey pine	Italian alder	Rauli	Douglas-fir	Macedonian pine
44	Red alder	Red alder	Monterey pine	Lawson cypress	White fir	Cider gum	Black walnut	Grand fir	Tingiringi gum	Giant redwood /	Rauli	Monterey cypress	Western red-cedar	Serbian spruce
45	Loblolly pine	Loblolly pine	Loblolly pine	Tingiringi gum	Lutz spruce	Ash	Hornbeam	Beech	Monterey pine	Red alder	Weymouth pine	Small-leaved lime	Norway spruce	Giant redwood /
46	Rauli	Italian alder	Monterey cypress	Monterey pine	Leyland cypress	Red oak	Common walnut	Red oak	Red alder	Loblolly pine	Roble	White fir	Cider gum	Rauli
47	Italian alder	Rauli	Rauli	Rauli	Coast redwood	Gean	Small-leaved lime	European silver fir	Loblolly pine	Italian alder	Atlas cedar	Atlas cedar	Leyland cypress	Black walnut
48	Monterey pine	Monterey cypress	Italian alder	Black walnut	White willow	Coast redwood	Roble	Noble fir	Italian alder	Rauli	Nordmann fir	Lutz spruce	Grand fir	Common walnut
49	Black walnut	Black walnut	Black walnut	Common walnut	Lawson cypress	Noble fir	Macedonian pine	Sweet chestnut	Monterey cypress	Monterey cypress	Englemann spruce	Oriental spruce	European silver fir	Small-leaved lime
50	Weymouth pine	Hornbeam	Oriental spruce	White fir	Giant redwood /	Pacific silver fir	Red alder	Serbian spruce	Black walnut	Black walnut	Red spruce	Osier willow	Shinning gum	Roble
51	Small-leaved lime	Common walnut	Common walnut	Ash	Monterey cypress	Japanese cedar	Loblolly pine	Black walnut	Hornbeam	Hornbeam	Downy birch	Nordmann fir	Coast redwood	White fir
52	Common walnut	Small-leaved lime	Weymouth pine	Hornbeam	Black walnut	Giant redwood /	Monterey cypress	Hornbeam	Common walnut	Common walnut	Sessile oak	Yew	Noble fir	Atlas cedar
53	Hornbeam	Weymouth pine	Hornbeam	Weymouth pine	Hornbeam	Monterey cypress	Weymouth pine	Common walnut	Small-leaved lime	Small-leaved lime	Common alder	Englemann spruce	Pacific silver fir	Osier willow
54	Oriental spruce	Roble	Lutz spruce	Atlas cedar	Common walnut	Common walnut	White fir	Small-leaved lime	Weymouth pine	Weymouth pine	Pedunculate oak	Red spruce	Japanese cedar	Nordmann fir
55	Roble	White fir	White fir	Lutz spruce	Small-leaved lime	Shinning gum	Atlas cedar	Atlas cedar	Roble	Roble	Red oak	Whitebeam	Lawson cypress	Yew
56	Lutz spruce	Atlas cedar	Atlas cedar	Nordmann fir	Weymouth pine	Tingiringi gum	Lutz spruce	Englemann spruce	White fir	White fir	Sweet chestnut	Hybrid larch	Tingiringi gum	Englemann spruce
57	White fir	Lutz spruce	Small-leaved lime	Englemann spruce	Atlas cedar	Loblolly pine	Oriental spruce	Red spruce	Atlas cedar	Atlas cedar	White willow	Japanese larch	Serbian spruce	Red spruce
58	Atlas cedar	Oriental spruce	Nordmann fir	Red spruce	Oriental spruce	Rauli	Nordmann fir	Pacific silver fir	Lutz spruce	Lutz spruce	Black walnut	European larch	Giant redwood /	Cider gum
59	Osier willow	Osier willow	Roble	Italian alder	Osier willow	Roble	Englemann spruce	Macedonian pine	Osier willow	Osier willow	Hornbeam	Corsican pine	White fir	Grey alder
60	Nordmann fir	Nordmann fir	Osier willow	Small-leaved lime	Nordmann fir	Lutz spruce	Red spruce	White fir	Nordmann fir	Nordmann fir	Common walnut	Ash	Lutz spruce	Tingiringi gum
61	Englemann spruce	Yew	Englemann spruce	Osier willow	Yew	Oriental spruce	White willow	Oriental spruce	Yew	Yew	Small-leaved lime	Lawson cypress	Oriental spruce	Italian alder
62	Red spruce	Englemann spruce	Red spruce	Yew	Englemann spruce	Osier willow	Osier willow	Nordmann fir	Englemann spruce	Englemann spruce	Osier willow	Monterey pine	Nordmann fir	Hornbeam
63	Yew	Red spruce	Yew	Roble	Red spruce	Englemann spruce	Yew	Yew	Red spruce	Red spruce	Yew	Weymouth pine	Englemann spruce	Lutz spruce
64	Whitebeam	Whitebeam	Whitebeam	Whitebeam	Whitebeam	Red spruce	Whitebeam	Whitebeam	Whitebeam	Whitebeam	Whitebeam	Roble	Red spruce	Whitebeam

Table 14 Species rankings for 14 weighting scenarios (reordered by Monte Carlo ranking)

			Monte Carlo ranking	Equal weighting	Workshop	Top 4 attributes	Tree improvement potential	Plant & seed supply	Silvicultural knowledge	Establishment rate	Suitability area (current)	Suitability area (2080)	Yield class category	Pest & disease risk	Contribution to WEC	Technical potential
Betula pendula	Silver birch	Principal	1	1	2	2	1	1	1	1	1	1	29	1	1	19
Picea sitchensis	Sitka spruce	Principal	2	2	1	1	2	2	2	2	2	2	1	14	41	1
Pinus sylvestris	Scots pine	Principal	3	3	3	6	3	3	3	28	3	3	30	15	2	2
Betula pubescens	Downy birch	Principal	4	4	5	7	8	4	4	29	4	4	51	2	3	20
Tsuga heterophylla	Western hemlock	Principal	5	5	4	3	9	12	5	3	14	5	2	16	42	3
Pinus contorta var. latif	Lodgepole pine	Principal	6	5	7	8	4	12	5	30	5	5	31	16	14	3
Acer pseudoplatanus	Sycamore	Principal	7	5	6	3	9	12	5	30	5	5	31	3	14	21
Larix × marschlinsii	Hybrid larch	Principal	8	8	10	17	11	15	8	4	7	20	13	56	4	5
Larix kaempferi	Japanese larch	Principal	9	8	11	24	11	15	8	4	7	8	33	56	4	5
Pseudotsuga menziesii	Douglas-fir	Principal	10	10	9	9	5	17	10	6	26	37	3	18	43	7
Thuja plicata	Western red-cedar	Principal	11	10	8	5	13	17	10	32	15	21	3	4	43	33
Quercus petraea	Sessile oak	Principal	12	10	13	9	13	17	10	42	15	21	52	4	6	7
Populus spp. and hybri	Black, grey, white poplar	Principal	13	13	16	32	15	5	13	7	27	23	34	19	16	22
Populus tremula	Aspen	Secondary	14	13	15	25	21	20	24	7	9	9	34	19	7	34
Alnus glutinosa	Common alder	Principal	15	13	19	39	15	5	13	33	17	9	53	19	7	34
Picea abies	Norway spruce	Principal	16	13	12	11	21	5	13	33	17	23	14	19	45	9
Quercus robur	Pedunculate oak	Principal	17	13	17	18	21	20	13	43	27	9	53	6	7	9
Larix decidua	European larch	Principal	18	18	24	40	17	22	17	9	29	25	36	58	10	11
Pinus nigra subsp. larici	Corsican pine	Principal	19	18	21	40	6	22	17	35	29	12	15	58	17	23
Eucalyptus gunnii	Cider gum	Secondary	20	18	14	12	17	44	25	9	19	25	5	7	46	58
Cupressus × leylandii	Leyland cypress	Secondary	21	21	18	19	46	8	26	11	20	27	6	23	47	36
Alnus incana	Grey alder	Secondary	22	21	20	33	24	24	26	11	10	13	37	23	18	59
Fraxinus excelsior	Ash	Principal	23	23	38	51	7	45	19	36	31	28	38	60	11	24
Acer platanoides	Norway maple	Secondary	24	23	26	34	25	9	28	36	21	28	38	25	19	37
Abies grandis	Grand fir	Principal	25	23	22	20	25	25	19	44	31	28	7	25	48	24
Fagus sylvatica	Beech	Principal	26	23	29	26	25	25	19	44	21	28	38	25	19	24
Quercus rubra	Red oak	Secondary	27	23	25	20	25	45	28	44	31	14	55	8	19	12
Prunus avium	Gean	Secondary	28	28	34	42	19	47	30	38	34	15	41	28	22	38
Pinus pinaster	Maritime pine	Secondary	29	28	30	27	29	27	30	13	42	39	16	28	22	13
Eucalyptus nitens	Shinning gum	Secondary	30	28	28	13	19	55	30	13	23	39	8	28	49	27
Sequoia sempervirens	Coast redwood	Secondary	31	28	23	13	47	47	30	38	34	32	8	9	49	38
Abies alba	European silver fir	Secondary	32	28	27	22	29	27	30	47	34	32	16	28	49	13
Cryptomeria japonica	Japanese cedar	Secondary	33	33	33	35	31	49	35	15	37	34	18	32	52	40
Abies procera	Noble fir	Principal	34	33	35	15	31	49	22	48	24	41	10	32	52	28
Castanea sativa	Sweet chestnut	Principal	35	33	43	43	31	29	22	48	43	34	56	32	24	15
Pinus peuce	Macedonian pine	Plot stage	36	33	37	28	31	29	49	58	11	16	42	32	24	40
Salix alba	White willow	Native	37	33	31	35	48	29	61	15	11	16	56	32	24	40
Abies amabilis	Pacific silver fir	Secondary	38	33	32	23	31	49	35	58	11	16	18	32	52	40
Chamaecyparis lawsoni	Lawson cypress	Secondary	39	39	41	44	49	32	37	17	38	36	20	61	55	29
Pinus radiata	Monterey pine	Secondary	40	39	44	44	36	32	37	17	44	42	20	61	27	16
Sequoiadendron gigant	Giant redwood / Sequoia	Secondary	41	39	36	16	49	52	37	40	38	42	11	10	55	44
Eucalyptus glaucescens	Tingiringi gum	Secondary	42	39	39	44	36	56	37	17	44	19	11	38	55	60
Picea omorika	Serbian spruce	Secondary	43	39	40	29	36	10	37	50	25	42	20	38	55	44
Alnus rubra	Red alder	Plot stage	44	39	42	37	36	32	50	17	44	42	20	38	27	29
Pinus taeda	Loblolly pine	Plot stage	45	45	45	30	40	57	51	21	47	46	24	41	29	17
Nothofagus alpina	Rauli	Secondary	46	46	47	47	41	58	42	22	40	47	43	42	30	46
Alnus cordata	Italian alder	Secondary	47	46	48	59	41	35	42	22	48	47	43	42	30	61
Cupressus macrocarpa	Monterey cypress	Plot stage	48	46	46	38	51	53	52	22	48	47	25	42	30	31
Juglans nigra	Black walnut	Secondary	49	49	49	48	52	36	44	51	50	50	58	11	33	47
Pinus strobus	Weymouth pine	Plot stage	50	50	52	52	53	37	53	41	51	51	45	63	34	18
Tilia cordata	Small-leaved lime	Secondary	51	50	57	60	53	37	45	52	51	51	59	45	12	48
Juglans regia	Common walnut	Secondary	52	50	51	49	53	54	45	52	51	51	59	12	34	48
Carpinus betulus	Hornbeam	Secondary	53	50	53	52	53	37	45	52	51	51	59	12	34	62
Picea orientalis	Oriental spruce	Plot stage	54	54	50	31	57	59	54	60	41	38	26	52	63	55
Nothofagus obliqua	Roble	Secondary	55	54	59	63	43	59	48	25	55	55	46	64	37	50
Picea × lutzii	Lutz spruce	Plot stage	56	54	54	54	43	59	54	25	55	55	26	46	59	63
Abies concolor	White fir	Plot stage	57	54	55	50	43	40	54	60	55	55	26	46	59	50
Cedrus atlantica	Atlas cedar	Plot stage	58	54	56	54	57	40	54	55	55	55	46	46	37	50
Salix viminalis	Osier willow	Native	59	59	60	61	59	62	62	27	59	59	62	50	13	53
Abies nordmanniana	Nordmann fir	Plot stage	60	59	58	56	59	11	58	62	59	59	48	50	62	53
Picea engelmannii	Englemann spruce	Plot stage	61	61	61	57	61	63	59	56	61	61	49	52	63	55
Picea rubens	Red spruce	Plot stage	62	61	61	57	61	63	59	56	61	61	49	46	59	32
Taxus baccata	Yew	Native	63	61	63	62	61	42	63	63	61	61	63	52	39	55
Sorbus aria	Whitebeam	Native	64	64	64	64	64	43	64	64	64	64	64	55	40	64

Appendix E: Productive species shortlist

Table 15 Shortlist for conifers and broadleaves (reordered by Monte Carlo ranking)

Monte Carlo ranking	CONIFERS			Shortlist
2	Picea sitchensis	Sitka spruce	Principal	**YES**
3	Pinus sylvestris	Scots pine	Principal	**YES**
5	Tsuga heterophylla	Western hemlock	Principal	**YES**
6	Pinus contorta var. latifolia	Lodgepole pine [Alaskan]	Principal	**YES**
10	Pseudotsuga menziesii	Douglas-fir	Principal	**YES**
11	Thuja plicata	Western red-cedar	Principal	**YES**
16	Picea abies	Norway spruce	Principal	**YES**
21	Cupressus × leylandii	Leyland cypress	Secondary	NO
25	Abies grandis	Grand fir	Principal	**YES**
29	Pinus pinaster	Maritime pine	Secondary	NO
31	Sequoia sempervirens	Coast redwood	Secondary	**YES**
32	Abies alba	European silver fir	Secondary	**YES**
33	Cryptomeria japonica	Japanese cedar	Secondary	**YES**
34	Abies procera	Noble fir	Principal	**YES**
36	Pinus peuce	Macedonian pine	Plot stage	**YES**
38	Abies amabilis	Pacific silver fir	Secondary	**YES**
41	Sequoiadendron giganteum	Giant redwood / Sequoia	Secondary	NO
43	Picea omorika	Serbian spruce	Secondary	NO
45	Pinus taeda	Loblolly pine	Plot stage	NO
48	Cupressus macrocarpa	Monterey cypress	Plot stage	NO
54	Picea orientalis	Oriental spruce	Plot stage	NO
56	Picea × lutzii	Lutz spruce	Plot stage	NO
57	Abies concolor	White fir	Plot stage	NO
58	Cedrus atlantica	Atlas cedar	Plot stage	NO
60	Abies nordmanniana	Nordmann fir	Plot stage	NO
61	Picea engelmannii	Englemann spruce	Plot stage	NO
62	Picea rubens	Red spruce	Plot stage	NO
8	Larix × marschlinsii	Hybrid larch	Principal	RULE OUT
9	Larix kaempferi	Japanese larch	Principal	RULE OUT
18	Larix decidua	European larch	Principal	RULE OUT
19	Pinus nigra subsp. laricio	Corsican pine	Principal	RULE OUT
39	Chamaecyparis lawsoniana	Lawson cypress	Secondary	RULE OUT
40	Pinus radiata	Monterey pine	Secondary	RULE OUT
50	Pinus strobus	Weymouth pine	Plot stage	RULE OUT

Monte Carlo ranking	BROADLEAVES			Shortlist
1	Betula pendula	Silver birch	Principal	**YES**
4	Betula pubescens	Downy birch	Principal	**YES**
7	Acer pseudoplatanus	Sycamore	Principal	**YES**
12	Quercus petraea	Sessile oak	Principal	**YES**
13	Populus spp. and hybrids	Black, grey, white poplar & hybrids,	Principal	NO
14	Populus tremula	Aspen	Secondary	**YES**
15	Alnus glutinosa	Common alder	Principal	**YES**
17	Quercus robur	Pedunculate oak	Principal	**YES**
20	Eucalyptus gunnii	Cider gum	Secondary	NO
22	Alnus incana	Grey alder	Secondary	NO
24	Acer platanoides	Norway maple	Secondary	**YES**
26	Fagus sylvatica	Beech	Principal	**YES**
27	Quercus rubra	Red oak	Secondary	**YES**
28	Prunus avium	Gean	Secondary	**YES**
30	Eucalyptus nitens	Shinning gum	Secondary	NO
35	Castanea sativa	Sweet chestnut	Principal	**YES**
37	Salix alba	White willow	Native	NO
42	Eucalyptus glaucescens	Tingiringi gum	Secondary	NO
44	Alnus rubra	Red alder	Plot stage	NO
46	Nothofagus alpina	Rauli	Secondary	NO
47	Alnus cordata	Italian alder	Secondary	NO
49	Juglans nigra	Black walnut	Secondary	NO
51	Tilia cordata	Small-leaved lime	Secondary	**YES**
52	Juglans regia	Common walnut	Secondary	NO
53	Carpinus betulus	Hornbeam	Secondary	**YES**
59	Salix viminalis	Osier willow	Native	NO
63	Taxus baccata	Yew	Native	NO
64	Sorbus aria	Whitebeam	Native	NO
23	Fraxinus excelsior	Ash	Principal	RULE OUT
55	Nothofagus obliqua	Roble	Secondary	RULE OUT

Table 16 Rationale for selection of conifer species (alphabetical order)

The reasons for shortlisting are grouped as follows: 1. Range of silvicultural systems, 2. Geographic range, 3. Tree improvement, 4. Wood properties and end use, 5. Other.

Key issues are grouped as follows: i. Tree health risks, ii. Site & climate suitability, iii. Biodiversity & environmental impacts, iv. Tree improvement & plant and seed supply, v. Wood properties & end use, vi. Other.

Conifer species	Rationale	Reasons for shortlisting	Key issues
Coast redwood	Highly productive secondary conifer species with currently no known major tree health risks. May not be fully cold hardy in Britain, is sensitive to late frosts, does not withstand exposure and is not drought tolerant. Shade tolerant and best suited to underplanting or enrichment interplanting. Seed supply unstable; seed quality also erratic. Likely to be challenging to work with in a tree improvement programme. Timber has low familiarity in Europe. Mechanical properties possibly similar to Sitka. No strength grading in the European system. Potentially a reasonably wide range of uses. Virtually no knowledge of UK-grown wood properties. Listed as endangered by IUCN. Adds another genus to the shortlist potentially increasing tree health resilience.	1. Primarily suitable for CCF. 2. Suitable for warm, moist sheltered sites across Scotland primarily in the west. 4. Compatibility with cladding and panelling markets due to its natural durability and attractive timber. Potential to develop structural market. 5. Adds another genus to the shortlist potentially increasing tree health resilience.	iv. Seed supply. Nursery practice needs support. Challenging tree improvement prosects due to limited parent material. v. Market development.
Douglas-fir	Highly productive principal conifer species, with attractive timber properties. Cold hardy but can suffer from exposure and hence best suited to more sheltered areas. Tolerant of the drier conditions in the east where it may offer an alternative to spruce and pine. Currently no known major tree health risks although potential future damage from Swiss needle cast and *Phytophthora pluvialis*. Very good tree breeding potential with strong rationale to improve domestic supply of improved material. Very well-established markets in the UK. Mechanical properties better than Sitka, but very variable strength. Can be strength graded in the UK with multiple options. Potential for CLT and glulam production. Wide range of uses. Drying and seasoning well known,	1. Suitable for CCF and open planting. 2. Best suited to more sheltered areas, both east and west. Tolerant to drier conditions. Better sites required. 3. Very good tree breeding potential. 4. Very well-established markets and good potential. for future development.	

	similar to spruce. Good level of knowledge of wood properties.		
European silver fir	Secondary conifer species with good productivity. Cold hardy throughout Britain but vulnerable to frost unless planted under shelter. Does not tolerate very poor soils or heather competition. Slow and very difficult to establish on clearfell sites; better suited to underplanting. High palatability to deer. Better understood silviculture than other firs. Can be severely attacked by *Dreyfusia* (syn. *Adelges*) *nordmannianae* which can cause death with high infestations; less problematic in mixed stands. Timber is familiar to the UK market, but mostly through imports. Blue stain might be an issue. Mechanical properties similar to Sitka. Strength grading exists in the European system but not for UK-grown. Potential for CLT and glulam production. Wide range of uses. Drying and seasoning known. Low level of knowledge of UK-grown wood properties.	1. Suitable primarily for CCF and mixtures. 2. Lowland to mid-slope species across west and east Scotland. 4. Suitable for white wood market, with properties similar to Sitka spruce.	i. *Dreyfusia* (syn. *Adelges*) *nordmannianae.* ii. Drought. iv. Nursery practice needs support.
Grand fir	Highly productive principal conifer species. Cannot tolerate exposure as well as noble fir. Slow establishment, although quicker than noble fir, and subsequent growth is rapid. Modest tree improvement potential due to low fecundity, but possible to build upon existing FR archive of 35 plus trees, and make new selections from provenance trials, or to register and manage new seed stands. Reportedly resistant to *Heterobasidion annosum s.s*. and *Armillaria* spp. Susceptible to *Adelges piceae* attack - linked to drought and exposure (less risk on west) as with many *Abies* spp. Timber not familiar on the UK market; mechanical properties likely similar to Sitka but could be lower. Strength grading exists in the European system but not for UK-grown. Potentially wide range of uses. Drying and seasoning known. Low level of knowledge of UK-grown wood properties.	1. Suitable primarily for CCF and mixtures. 2. Lowland to mid-slope species across west and east Scotland. 3. Modest tree improvement potential. 4. Currently suitable for non-construction grade white wood market. Has potential for market development.	i. *Adelges piceae*. ii. Drought. iv. Nursery practice needs support. v. High value market needs development.
Japanese cedar	Secondary conifer species with good productivity and currently no known major tree health risks. Prefers a warm maritime climate on deep, well-drained soils; does not respond well to exposure. Fast establishment rate, but not always easy to establish initially on clearfell sites. Tree improvement hindered by tiny domestic resource; potential to	1. Primarily suitable for CCF. 2. Suitable for warm, moist sheltered sites across Scotland	iv. Limited tree improvement potential. v. Timber mechanical properties much lower than Sitka

	develop a qualified orchard using selections from the currently limited provenance tests. Timber not familiar on the UK market. Mechanical properties much lower than Sitka. Potentially a reasonably wide range of uses. Low level of knowledge of UK-grown wood properties. The pollen can cause allergies. Unrelated to UK natives suggesting lower tree health risk but also lower biodiversity value.	primarily in the west. 4. Attractive timber, highly valued in Japan. 5. Adds another genus to the shortlist potentially increasing tree health resilience.	spruce. Market development.
Lodgepole pine [Alaskan]	Modest to slow growing principal conifer species with relatively well understood silviculture. Highly susceptible to Dothistroma needle blight, although Alaskan provenance would be used, which are less susceptible and widely grown as a nurse with Sitka spruce. Can regenerate profusely on adjacent forested and non-forested land. Timber has low familiarity in Europe. Mechanical properties potentially similar to Sitka. Strength grading exists in the European system but not for UK-grown. Wide range of uses. Drying and seasoning known, similar to spruce. Good treatability. Low level of knowledge of UK-grown wood properties.	1. Primarily suitable for open planting and mixed as a nurse with Sitka spruce. 2. Particularly useful for poor upland exposed sites. 4. Fits in with existing pine market. 5. DNB risk reduced by provenance selection.	iii. Planting adjacent to priority habitats due to potential for prolific regeneration. iv. Tree improvement not worthwhile due to limited role.
Macedonian pine	Conifer species with limited silvicultural knowledge in UK, but a large suitability area in Scotland and a potential alternative to Sitka spruce and lodgepole pine on very poor sites. Reputation for high wind stability. Can have higher productivity than Scots pine but harder to propagate and very slow to establish initially, similar to firs. Susceptibility to Dothistroma needle blight reportedly low. Timber is of low familiarity globally. Mechanical properties possibly similar to Sitka, but most likely lower. No strength grading in the European system. Potentially a reasonably wide range of uses. Very low level of knowledge of wood properties generally. Limited natural range; listed as near threatened by IUCN.	1. Suitable for open planting and use in mixtures. 2. Particularly useful for poor upland exposed sites across Scotland. 4. Suitable for non-construction grade pine market. 5. Resistant to DNB.	iv. Provenance choice. Nursery practice needs support.
Noble fir	Highly productive principal conifer species and one of the few alternatives to Sitka on poor upland sites. Can tolerate exposure better than Douglas-fir and grand fir and is comparably more windfirm and tolerant of	1. Suitable primarily for open planting.	v. High value market needs development.

	frosts. Often very slow to establish on clearfell sites, but subsequent growth can be rapid. Modest tree improvement potential due to low fecundity but possible to make new selections from provenance trials, or to register and manage new seed stands. Some plus trees have been archived. Susceptible to *Phytophthora ramorum*. Timber not familiar on the UK market, but mechanical properties likely very similar to Sitka. Strength grading exists in the European system but not for UK-grown but there is a partial dataset. Potentially wide range of uses. Drying and seasoning known. Reasonable level of knowledge of wood properties.	2. Particularly useful for poor upland exposed sites. 3. Modest tree improvement potential. 4. Currently suitable for non-construction grade white wood market. Has potential for market development.	
Norway spruce	Principal conifer species with good productivity. A viable alternative to Sitka, particularly sites which are drier than the classic Sitka sites, but not on poor, wet and exposed sites. Wide climatic tolerances but damaged by late spring frosts, although less so than Sitka. More sensitive to establishment conditions than Sitka and can take longer to close canopy. Susceptible to drought conditions and cracking. Defoliated by *Elatobium abietinum* but less severe than on Sitka. Some risks from *Dendroctonus micans*; effective control programme in place. *Ips typographus* regularly arriving in SE England, intercepted in Scotland in 2023; potential to cause extensive tree mortality, with high risk following storm damage and drought. Reliant on imports for improved material. 250 plus trees have recently been selected; grafted copies are being planted into qualified seed orchards. Very well-established markets in the UK; processed and sold with Sitka. Wide strength grading possibility in the UK. Small-scale commercial production of glulam and CLT in the UK. Wide range of uses. Drying and seasoning well known. Good level of knowledge of wood properties.	1. Suitable for CCF and open planting and mixtures. 2. Lowland to mid-slope species across west and east Scotland. 3. Tree improvement is underway in UK. 4. Suitable for construction grade white wood market, processed and sold with Sitka spruce.	i. *Ips typographus*. ii. Drought.
Pacific silver fir	Secondary conifer species with good productivity and currently no known major tree health risks. Large suitability area. Very slow early growth similar to other firs. Rapid later growth on suitable sites. Modest tree improvement potential due to low fecundity but possible to make new selections from provenance trials, or to register and manage	1. Suitable primarily for CCF and mixtures. 2. Mid-slope and sheltered upland sites across west and east Scotland.	iv. Nursery practice needs support. v. High value market needs development.

	new seed stands. Timber not familiar on the UK market; low level of knowledge but mechanical properties likely very similar to Sitka. Strength grading exists in the European system but not for UK-grown. Wide range of uses. Drying and seasoning known. Low level of knowledge of UK-grown wood properties.	3. Modest tree improvement potential. 4. Potentially suitable for white wood market, with properties very likely similar to Sitka spruce.	
Scots pine	Principal conifer species with moderate productivity; our only commercial native conifer. Increasingly valuable for drought prone sites in eastern Britain under climate change. Dothistroma needle blight generally causes low to moderate levels of damage. Abundant seed supply, although limited from domestic seed orchards. Strong public support for reopening breeding programme with excellent potential to improve form, disease tolerance, growth and timber properties. Well-established markets in the UK, but somewhat restricted by bluestain. Mechanical properties better than Sitka. Can be strength graded in the UK, but with limited options due to lack of modern data. Potential for glulam and CLT production. Wide range of uses. Drying and seasoning well known, similar to spruce. Some natural durability and good treatability. Reasonable level of knowledge of UK-grown wood properties. High biodiversity value.	1. Suitable for open planting and CCF. 2. Suitable for west and east Scotland on poorer soils. High drought tolerance. 3. Excellent tree breeding potential. 4. Very well-established markets and good potential for future development. 5. Native with very high biodiversity value.	
Sitka spruce	Main commercial conifer in the UK. Fast-growing and easy to establish due to good early growth and lower palatability to deer. Best suited to upland north and west. Suitability area expected to decrease in the drier east but increase in the west under predicted wetter and warming conditions. Can be grown in mixtures and irregular stands. Some risk from *Dendroctonus micans*; effective control programme in place. Defoliated by *Elatobium abietinum*. Host susceptibility to *Ips typographus* currently being investigated; potential to cause tree mortality, with high risk following storm damage and drought. Can regenerate profusely on adjacent forested and non-forested ground. Excellent advanced-generation tree improvement potential. Very well-established UK markets. Wide strength grading possibility in the UK. Small-scale	1. Suitable for open planting and CCF. 2. Suitable for west and east Scotland on most site types with sufficient moisture. 3. Excellent tree breeding potential. 4. The principal species for UK market.	i. *Ips typographus*. ii. Drought. iii. Planting adjacent to priority habitats due to potential for prolific regeneration.

	commercial production of glulam and CLT in the UK. Wide range of uses. Drying and seasoning well known. Very good level of knowledge of wood properties.		
Western hemlock	Highly productive principal conifer species with rapid establishment rate and currently no known major tree health risks although very susceptible to root and butt rot caused by *Heterobasidion annosum*. Cold hardy throughout Britain but sensitive to late frosts; less tolerant to exposure and less windfirm than Sitka, and drought sensitive. High shade tolerance and natural regeneration under canopy if deer numbers are low, making it ideal for CCF but on some sites uncontrolled natural regeneration may present challenges for adjoining woodlands. Tree improvement would be relatively easy, quick and efficient due to the species biology. Timber not widely familiar on the UK market, but mechanical properties likely very similar to Sitka. Strength grading exists in the European system but not for UK-grown but there is a partial dataset. Wide range of uses. Drying and seasoning well known, similar to spruce. Reasonable level of knowledge of wood properties.	1. Suitable for CCF and open planting and mixtures. 2. Suitable for sheltered sites across Scotland. 3. Good tree improvement potential. 4. Currently suitable for non-construction grade white wood market. Has potential for market development.	ii. Drought. iii. Planting adjacent to priority habitats due to potential for prolific regeneration. v. High value market needs development.
Western red-cedar	Highly productive principal conifer species, with currently no known major tree health risks, although very susceptible to root and butt rot caused by *Heterobasidion annosum*. Suitable for warm, moist climates in more sheltered sites in Western Scotland. Shade tolerance makes it suitable for a range of silvicultural systems, although sensitivity to exposure makes it more suited to mixed CCF stands than clearfell sites where it can be difficult and slow to establish. Tree improvement could build on an existing FR archive of 39 plus trees, and progress can be rapid due to some unique reproductive characteristics. Wood mechanical properties lower than Sitka. Cannot yet be strength graded but there is a partial dataset. Currently used for cladding but with potential for other uses. Drying and seasoning known. Some natural durability. Reasonable level of knowledge of wood properties.	1. Suitable primarily for CCF. Can be established on open sites with sufficient side shelter. 2. Suitable for the warm, moist climates in Western Scotland, and sheltered sites in the east. 3. Potentially rapid progress with tree improvement. 4. Growing demand for wood for cladding and internal panelling due to its natural durability, as a substitute for larch.	

Table 17 Rationale for selection of broadleaved species (alphabetical order)

The reasons for shortlisting are grouped as follows: 1. Range of silvicultural systems, 2. Geographic range, 3. Tree improvement, 4. Wood properties and end use, 5. Other.

Key issues are grouped as follows: i. Tree health risks, ii. Site & climate suitability, iii. Biodiversity & environmental impacts, iv. Tree improvement & plant and seed supply, v. Wood properties & end use, vi. Other.

Broadleaved species	Rationale	Reasons for shortlisting	Key issues
Aspen [Including Hybrid aspen]	Secondary broadleaved species, relatively productive. High suitability area in Scotland both now and predicted for the future. Important production tree in Scandinavia. Valued as a fast-growing broadleaved species grown on short rotations when afforesting agricultural land, or to increase biodiversity in planted conifer forests. A range of rust (*Melampsora*) can result in serious defoliation; repeated infections may lead to dieback and ultimately mortality. Some specialist markets. Mechanical properties potentially similar to Sitka. Blue stain might be an issue. No strength grading in the European system. Potentially a reasonably wide range of uses. Drying and seasoning known. Good treatability. Virtually no knowledge of UK-grown wood properties. High associated biodiversity. Spreads by suckers - potentially a problem or benefit. [Hybrid aspen: grows much more rapidly than native aspen. Risk of hybridisation considered to be low due to lack of seed production. Challenges around variability of clonal material.]	1. Suitable for open planting, CCF and mixes. 2. Lowland to mid-slope species across west and east Scotland. 3. Tree improvement could build on established clone bank. 5. Native with high biodiversity value. [5. Hybrid aspen: higher productivity than native aspen]	[iii. Hybrid aspen: can hybridise with native aspen] [iv. Hybrid aspen: issues with plant and seed supply] v. Market development.
Beech	Principal broadleaved species, relatively productive, with currently no known major tree health risks. Vulnerability to drought may limit use in southern and eastern Britain. Productivity (MAI) culminates later than other principal broadleaved species. Suitable for mixtures and CCF. Uncontrolled regeneration into neighbouring sites can be an issue. Problems with seed storage, and supply and quality in some years. Tree improvement could be technically difficult; good silviculture may be more effective; 50 plus trees identified. Familiar to the UK market, but mostly through imports. High mechanical properties. Strength grading exists in the European system but not for UK-grown. Has potential for products like	1. Suitable for open planting, CCF and mixes. 2. Lowland to mid-slope species across west and east Scotland.	i. Limited tree improvement. v. Market development. vi. Very susceptible to grey squirrel damage.

	glulam, LVL and furniture, but might struggle to compete commercially with established production in Europe. Wide range of uses. Drying and seasoning well known. Good treatability. Low level of knowledge of wood properties. Highly vulnerable to grey squirrel damage.		
Common alder	Principal broadleaved species, short-lived and relatively fast-growing with rapid early growth, valuable as a nurse rather than a pure crop. Thrives in the wetter areas and riparian zones of the north and west. Suffers damage along riparian corridors from *Phytophthora alni*. Cold hardy and frost resistant, but not tolerant of exposure: high suitability area. Has value for land reclamation. Very little previous tree improvement in Britain or elsewhere but could be an easy species to work with. Familiar in Europe for limited markets. Quite high mechanical properties. No strength grading in the European system. Potentially a reasonably wide range of uses. Drying and seasoning known, similar to spruce. Good treatability. Virtually no knowledge of UK-grown wood properties in UK. Only native nitrogen fixing tree in GB.	1. Suitable for open planting and mixes. 2. Lowland to mid-slope species across west and east Scotland. 3. Has tree improvement potential. 5. Native with high biodiversity value.	v. Market development.
Downy birch	Principal broadleaved species, relatively slow growing, with currently no known major tree health risks. Probably behaves the same as silver birch, but form is less good, slower growing. Potential in low-cost low return systems. One of the few suited to poor wet sites at higher elevations (where silver birch is not suited), even if just for biomass. Tree improvement is technically possible but complicated by rarity of trees with good stem form. Familiar to the UK market as imported plywood. High mechanical properties. Strength grading will soon exist in the European system but not for UK-grown. Wide range of uses. Drying and seasoning known. Low level of knowledge of UK-grown wood properties. Valued more ecologically than for its timber. Soil improver.	1. Suitable for open planting, CCF and mixes. 2. Upland and mid-slope species across west and east Scotland. Particularly useful for poor upland exposed sites, and buffer zone planting for priority habitats. 3. Initial tree improvement underway. 5. Native with high biodiversity value.	v. Market development.
Gean	Secondary broadleaved species, relatively productive. If managed for timber, with formative pruning, can produce high value logs. Prefers warm, sunny sites. Bacterial canker due to *Pseudomonas syringae* pv	1. Suitable for open planting, CCF and mixes.	iv. Seed supply. v. Market development.

	morsprunorum is widespread and common in GB, causing dieback in European plantations. Only shortlisted species with significant seed supply issues, which is always short. Timber familiar in Europe for limited markets. Quite high mechanical properties. No strength grading in the European system. Potential for some markets. Drying and seasoning known. Virtually no knowledge of UK-grown wood properties. Squirrel damage rarely reported. Native species currently planted for its high biodiversity value.	2. Lowland species across west and east Scotland. 3. Improved material available. 4. Potentially high value timber. 5. Native with high biodiversity value. Low susceptibility to grey squirrel damage.	
Hornbeam	Secondary broadleaved species, relatively slow growing, with currently no known major tree health risks. Prefers warm summers, but will tolerate cold winters, hence limited suitability area in Scotland. Wide soil tolerances but more nutrient demanding than beech. Better tolerates waterlogging than beech. Has value as an admix. Strongly shade bearing and used as a nurse on the continent. Tree improvement similar to beech and oak. 50 plus tree identified. Very dense timber, good firewood. Some small, very specialist markets. High mechanical properties. No strength grading in the European system. Limited range of uses. Drying and seasoning known. Good treatability. Very low level of knowledge of wood properties generally.	1. Suitable for open planting and mixes. 2. Lowland species across west and east Scotland.	iv. Limited tree improvement potential. v. Significant market development.
Norway maple	Secondary broadleaved species, relatively productive. Limited silvicultural knowledge in GB. Better suited to group mixtures, which also reduces squirrel damage. Timber requires heavy thinning and pruning. More tolerant of drier sites than sycamore, but less tolerant of exposure and hence better for lowland sites. *Phytophthora cactorum* (abundant in UK) a problem. Very susceptible to vascular wilt (*Verticillium dahliae*) when young. Familiar in Europe for limited markets. Quite high mechanical properties. No strength grading in the European system. Potentially a reasonably wide range of uses. Drying and seasoning known. Good treatability. Virtually no knowledge of UK-grown wood properties. Oak, beech and sycamore also available for similar sites.	1. Suitable for open planting, CCF and mixes. 2. Lowland species primarily for east Scotland. Useful for drier sites.	v. Market development.

Pedunculate oak	Principal broadleaved species, relatively slow growing, with currently no known major tree health risks. Pedunculate is found on heavier soils than sessile oak. Considered more light-demanding than sessile oak, and deep rooting which makes it very windfirm. Herbivore protection essential. Seed supply impacted by mast years and storage problems. Tree improvement underway but currently limited by low acorn yield per seed orchard. Familiar to the UK market; mostly through imports, but some home-grown. High mechanical properties. Can be visually strength graded in the UK. Some small-scale use in construction. Wide range of uses. Drying and seasoning well known. Some natural durability and good treatability. Moderate level of knowledge of UK-grown wood properties. Native with high biodiversity and cultural value. Grey squirrel damage.	1. Suitable for open planting, CCF and mixes. 2. Lowland to mid-slope species across west and east Scotland. 3. Tree improvement underway. 4. Wood familiar to UK market and in demand. 5. Native with very high biodiversity value.	v. Market development.
Red oak	Secondary broadleaved species, relatively slow growing, with currently no known major tree health risks. More productive than native oaks. Probably more suited to sessile than pedunculate oak sites. Potential increased role on drier soils as a result of climate warming. Next step in tree improvement would be to develop seed stands. Familiar as an import. Timber has high mechanical properties. Strength grading exists in the European system but not for UK-grown. Wide range of uses. Drying and seasoning known. Good treatability. Very low level of knowledge of UK-grown wood properties. Won't hybridise with native (white) oaks.	1. Suitable for open planting, CCF and mixes. 2. Lowland species across west and east Scotland.	v. Market development.
Sessile oak	Principal broadleaved species, relatively slow growing, with currently no known major tree health risks. More prominent than pedunculate oak in the west of Britain. Tolerant of exposure but will develop poor form; timber production requires sheltered sites. Herbivore protection essential. Seed supply impacted by mast years and storage problems. Tree improvement underway but currently limited by low acorn yield per seed orchard. Familiar to the UK market; mostly through imports, but some home-grown. High mechanical properties. Can be visually strength graded in the UK. Some small-scale use in construction. Wide range of uses. Drying and seasoning well known. Some	1. Suitable for open planting, CCF and mixes. 2. Lowland to mid-slope species across west and east Scotland. 3. Tree improvement underway. 4. Wood familiar to UK market and in demand.	v. Market development.

	natural durability and good treatability. Moderate level of knowledge of UK-grown wood properties. Native with high biodiversity and cultural value. Grey squirrel damage.	5. Native with very high biodiversity value.	
Silver birch	Principal broadleaved species, relatively productive, with currently no known major tree health risks. Frost resistant and windfirm with a large suitability area in Scotland, although drought sensitive. A pioneer species with fast early growth. Relatively short-lived. With thinning, can produce good sawlogs. Tree improvement programme underway; qualified seed widely available. Familiar to the UK market as imported plywood. High mechanical properties. Strength grading will soon exist in the European system but not for UK-grown. Wide range of uses. Drying and seasoning known. Good treatability. Low level of knowledge of UK-grown wood properties. Native with high biodiversity value. Grey squirrel damage.	1. Suitable for open planting, CCF and mixes. 2. Lowland to mid-slope species across west and east Scotland. 3. Improved material available. 4. Wood familiar to UK market. 5. Native with high biodiversity value.	v. Market development.
Small-leaved lime	Secondary broadleaved species, relatively slow growing. Distribution limited by climate, although numerous specimens established across Scotland. May become more suited to warmer, wetter areas of Scotland in the future. Too cool except in southern England for natural regeneration. Shade tolerant, traditionally managed as coppice. Used on the Continent as a nurse with oak. Can be affected by *Phytophthora* species causing root disease and bleeding cankers. Occasionally affected by Verticillium wilt, which can be fatal. Some specialist markets. Quite high mechanical properties. No strength grading in the European system. Potentially a reasonably wide range of uses. Drying and seasoning known and is similar to spruce. Good treatability. Virtually no knowledge of UK-grown wood properties.	1. Suitable for open planting, CCF and mixes. 2. Lowland species primarily in east Scotland. Some drought tolerance. 5. Native with high biodiversity value.	ii. Low climate suitability. vi. Limited knowledge and experience.
Sweet chestnut	Principal broadleaved species, with currently no known major tree health risks in Scotland, although there is a potential future risk from *Cryphonectria parasitica* now present in southern England. Managed traditionally by coppice where it is very productive for a broadleaved species. Better suited to hotter drier conditions, and low suitability area in Scotland although likely to increase with	1. Suitable for open planting and mixes. 2. Lowland species across west and east Scotland. Drought tolerant. Suitability expected	i. Potential future risk from *Cryphonectria parasitica*. v. Market development.

	increasing temperature due to climate change. Legacy breeding programme exists. Some small-scale existing markets for fencing in the UK, wider use in Europe and in the UK historically. Reasonable mechanical properties. Can be visually strength graded in the UK. Some small-scale use in construction. Wide range of uses. Drying and seasoning known. Some natural durability. Low level of knowledge of UK-grown wood properties. Introduced by Romans and naturalised in GB.	to increase under climate change. 3. Legacy tree improvement activities. 4. Favourable timber properties.	
Sycamore	Principal broadleaved species, relatively productive, with currently no known major tree health risks. Similar ecological tolerances (but wider) than ash. Tolerant of exposure and cold hardy with a large suitability area, although for quality timber needs sheltered sites. Less drought tolerant than other Acer species. Attributes of a pioneer but shade tolerant; very easy to establish. Tree improvement underway with good prospects. Some specialist markets. Quite high mechanical properties. Strength grading exists in the European system but not for UK-grown. Wide range of uses. Drying and seasoning known. Good treatability. Low level of knowledge of UK-grown wood properties. Marked preference by grey squirrels; crop can be damaged from early age. Non-native, with key role as replacement for ash.	1. Suitable for open planting, CCF and mixes. 2. Lowland to mid-slope species across west and east Scotland. 3. Tree improvement underway.	v. Market development. vi. Very susceptible to grey squirrel damage.

Table 18 Rationale for exclusion of conifer species (alphabetical order)

Conifer species	Rationale for exclusion
Atlas cedar	Climatically unsuitable.
Corsican pine	Highly susceptible to Dothistroma needle blight caused by *Dothistroma septosporum* resulting in severe defoliation, crown dieback, growth reduction and potential tree mortality. Fire risk.
Englemann spruce	Insufficient knowledge and experience.
European larch	Killed by *Phytophthora ramorum*. No mitigation to current risk appears likely in the short- to medium- term.
Giant redwood / Sequoia	Insufficient knowledge and experience.
Hybrid larch	Killed by *Phytophthora ramorum*. No mitigation to current risk appears likely in the short- to medium- term.
Japanese larch	Killed by *Phytophthora ramorum*. No mitigation to current risk appears likely in the short- to medium- term.
Lawson cypress	Killed by *Phytophthora lateralis* & *Phytophthora cinnamomi*.
Leyland cypress	No known stands in Scotland. Mostly known as a hedge tree with multiple stems. Infertile hybrid, therefore difficult to improve.
Loblolly pine	Insufficient knowledge and experience. Other better-known pines are on the list.
Lutz spruce	Lack of established clonal material. As a Sitka hybrid this tree is likely to have similar susceptibility to pests and pathogens.
Maritime pine	Significant tree health risk. Climatically unsuitable.
Monterey cypress	Potentially climatically unsuitable. Insufficient knowledge and experience.
Monterey pine	Highly susceptible to Dothistroma needle blight caused by *Dothistroma septosporum* resulting in severe defoliation, crown dieback, growth reduction and potential tree mortality. Fire risk.
Nordmann fir	Insufficient knowledge and experience as a forestry species. Other better-known firs are on the list.
Oriental spruce	Likely to have similar susceptibility to bark beetles as Sitka spruce. Very susceptible to *Dendroctonus micans*. Better performance and suitability from the other two spruces on the shortlist.
Red spruce	Insufficient knowledge and experience.
Serbian spruce	Declining suitability area. Likely to have similar susceptibility to bark beetles as Sitka spruce. Better performance and suitability from the other two spruces on the shortlist.
Weymouth pine	Highly susceptible to white pine blister rust caused by *Cronartium ribicola* which is very damaging on this species. Susceptibility to Dothistroma needle blight caused by Dothistroma septosporum reportedly 'low' to 'moderate'.
White fir	Insufficient knowledge and experience. Other better-known firs are on the list.

Yew	Very low productivity. Poor form.

Table 19 Rationale for exclusion of broadleaved species (alphabetical order)

Broadleaved species	Rationale for exclusion
Ash	Chalara dieback of ash due to the fungus *Hymenoscyphus fraxineus* is widespread and resulting in debilitation or death of a high proportion of trees of all ages. No mitigation to current risk appears likely in the short- to medium- term.
Black, grey, white poplar and hybrids	Black, grey, white and hybrid poplar were assessed as a group, along with hybrid aspen, but only hybrid aspen was judged to perform sufficiently well as a productive forestry species to be shortlisted, which was included alongside native aspen.
Black walnut	Climatically unsuitable.
Cider gum	Climatically unsuitable (cold damage).
Common walnut	Climatically unsuitable.
Grey alder	Hybridises with common alder. Potentially invasive. Comparable performance to preferred native alder. Limited product range.
Italian alder	Comparable performance to preferred native alder. Limited product range.
Osier willow	Short-lived, more suitable to SRF. Low knowledge and experience.
Rauli	Low climate suitability (frost sensitive). Susceptible to *Phytophthora pseudosyringae* (less than Roble).
Red alder	Climatically unsuitable (frost sensitive).
Roble	Highly susceptible to *Phytophthora pseudosyringae* causing sudden dieback & killing. No mitigation to current risk appears likely in the short- to medium- term.
Shinning gum	Climatically unsuitable (cold damage).
Tingiringi gum	Climatically unsuitable (cold damage).
Whitebeam	Low productivity. Low knowledge and experience.
White willow	Short-lived, more suitable to SRF.

Appendix F: Participants

Table 20 Researchers, experts and stakeholders involved in the study

Criteria	Forest Research	External
1. Tree improvement	Richard Whittet, Joan Cottrell	Jason Hubert (SF)
2. Plant and seed supply	Chris Hardy, Richard Whittet	Selchuk Kurtev (ICM), Sam Firkins (Forestart Ltd), Ben Goh (Maelor Forest Nurseries Ltd), Kenny Hay (FLS, Newton nursery), Lorenza Pozzi (FC), Dave Richardson (Forestart Ltd), Helen Richardson (Forestart Ltd), Imam Sayyed (Forestry England), Craig Turner (Alba Trees; Confor Nursery Producers' Group), Rodney Shearer (Elsoms Trees), Alice Snowden (Cheviot Trees)
3. Silviculture	Andrew Leslie, Bill Mason, Chris Reynolds, Victoria Stokes, Ian Willoughby	Andrew MacQueen (Independent forester), Martin Price (FLS), Gareth Waters (FLS)
4. Site/climate suitability	Stephen Bathgate, Andrew Leslie, Bill Mason, James Morison, Mike Perks, Chris Reynolds, Victoria Stokes, Megan Wilks, Ian Willoughby	Andrew MacQueen (Independent forester), Martin Price (FLS), Gareth Waters (FLS)
5. Productivity	Stephen Bathgate, Andrew Leslie, Ewan Mackie, Bill Mason, Robert Matthews, Chris Reynolds, Victoria Stokes, Ian Willoughby	Andrew MacQueen (Independent forester), Martin Price (FLS), Gareth Waters (FLS)
6. Tree health	Max Blake, Katy Dainton, Molly Davidson, Sarah Green, Steven Hendry, Daegan Inward, Liam Morton, Sonja Steinke, Joan Webber	Clarinda Burrell (SF), Flora Donald (SF), James Nott (SF)
7. Biodiversity and environmental impacts	Nadia Barsoum, Alice Broome, Mike Dunn, Robin Gill, Tom Nisbet	Stephen Cavers (CEH), Linsey Mason-McLean (SF), Alan McDonnell (Trees for Life), Beth Purse (CEH), Duncan Stone (NatureScot), Juli Titherington (SF), Andrew Weatherall (RSPB, Scottish Environment Link)
8. Wood properties and end use	Adam Ash, Elspeth Macdonald	Research led by Dan Ridley-Ellis (Edinburgh Napier University). Consultees: George Birrell (Kronospan), Philip Blake (Munro Sawmills), Mark Council (Logie Timber Ltd), Ellinor Dobbie (Abbey Timber), David V. Edwards (Tilhill), Caroline Gordon (Tulloch Timber), Jason Hubert (SF), Kieran Jamieson (UPM), Andrew Johnston (UPM), David Leslie (James Jones & Sons),

		Andy Leitch (Confor), Bryan McMurdo (UPM), Alex Murray (Glennon Bros.), John Paterson (Egger), Kevin Reid (SF), Harry Stevens (BSW)
Steering Group and cross cutting roles	David Edwards, Rob Grierson, Rob Hattersley, James Pendlebury, Chris Quine, Vadim Saraev	Steering Group: Alan Hampson (SF), Helen Sellars (SF), Tim Gordon-Roberts (SF), Chris Quine (FR), David Leslie (James Jones & Sons), Craig Turner (Alba Trees), Duncan Stone (NatureScot), Nathan Bryceland (SLE), Andrew MacQueen (Independent), Andrew Weatherall (RSPB, Scottish Environment Link), Alan McDonnell (Trees for Life), Jo Ellis (FLS), Barry Mulholland (Tilhill), Andy Leitch (Confor)

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