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Using alternative conifer species for productive forestry in Scotland

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Foreword

Bob McIntosh
Director, Forestry Commission Scotland

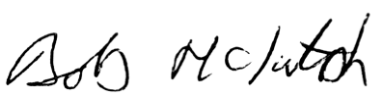
Foresters in Scotland have always had a fascination with conifers and the variety of conifers capable of being grown here, a legacy of our history as great 'improvers' of land and the interest in tree planting from the 'planting lairds' of the 18th century. Our predecessors introduced these new trees, firstly as specimens in arboreta or gardens, then as trial species and finally as forest trees grown to produce timber for the new sawmills and other timber processing facilities which have flourished in 21st century Scotland.

By the time the great push for afforestation had come after World War I we were lucky enough to have a wide selection of tree species to choose from and enough good advice derived from the experiments of people like Sir John Stirling Maxwell at Corrour and the subsequent publication of 'The Selection of Tree Species' by Mark Anderson in 1950 to consolidate our knowledge. Anyone looking at the early FC forests planted between the 2 World Wars, such as along the Great Glen or around Benmore and Glenbranter in the Cowal peninsula or the many fine estate woodlands such as Atholl, Darnaway or Drumlanrig, would readily appreciate how the principals of good site selection could translate into attractive and productive forests – forests of 'beauty, profit and effect' to quote from the 4th Duke of Atholl.

Somewhere after World War II forestry in Scotland came to rely more and more heavily on Sitka spruce, a tree which has served the forestry sector very well indeed, notwithstanding a degree of over-zealousness in the past in establishing new forests composed almost solely of Sitka. Those in the down-stream timber sector have much to thank those foresters for and many forestry jobs are, and will remain, dependent on Sitka spruce.

We all however recognise that it pays to diversify and that forests composed of a variety of species, whether native or introduced, conifer or broadleaved, will better deliver against both potential and as yet unknown future demands which these forests may have to meet and from the biological pests and diseases and abiotic threats which can strike any managed or natural forest. The current threats posed by red band needle blight and the various *Phytophthora* organisms bear testimony to that whilst the increasing interest in building with home-grown wood and the work done by places such as the Centre for Wood Science and Technology at Napier University in Edinburgh demonstrates the potential market demand for different types of timber.

Accordingly I commend to all practising foresters this new publication by Dr. Scott McG.Wilson, which in conjunction with additional new guidance being produced by Forest Research on Ecological Site Classification for these alternative species will give foresters a new tool to help them decide on the 'right tree in the right place'.



Introduction and objectives

Productive and visually attractive alternative conifer landscapes - Craigvinean Forest, Perthshire (left) and Achray Forest, Trossachs, Stirlingshire (above)

Current Scottish Government policy supports the expansion and sustainable management of our plantation forests, especially as a valuable source of timber for construction and of woodfuel for energy production. Their role in carbon sequestration, public amenity and biodiversity conservation is also increasingly valued. Introduced and native species, conifers and hardwoods, all have their own part to play. This guide offers information, inspiration and encouragement to landowners and foresters who wish to use a wider variety of conifer species for timber production in Scotland. While Scotland has a long and pioneering history of using many different conifer species in its plantation forests, recent decades have seen over-riding emphasis placed on a small number of species, particularly Sitka spruce and Scots pine (the latter in native pinewood schemes). Those species will continue to be key "planks" in the development of Scotland's forests. However there are good reasons to support maintaining a component of other productive conifer species that are well suited to Scotland's climatic conditions. Rising concerns about the risks from future climate change, and recent outbreaks of novel pests and diseases affecting pine species and Japanese larch, make it important to "spread the risk" by not putting all our forestry "eggs in any one basket". Fortunately, some of the available alternative conifer species, such as Douglas fir, larch and western red cedar, produce valuable timber that is naturally durable and hence suited to external construction uses. Growing a wider range of conifer species in our plantations, with an associated diversity of silvicultural systems, also serves to enhance the visual amenity of our forest landscapes.

This guide brings together existing information on site suitability, establishment, silviculture, harvesting, marketing and processing for quality crops of alternative conifer species. Some of the species require a different silvicultural approach from Sitka spruce, often more similar to that traditionally applied to quality hardwood stands. The emphasis here is placed on effective silviculture to produce quality final crops for identified markets, rather than on volume yield. The guide also presents detailed information about a selection of the potential alternative conifer species that are likely to be suitable for use within Scotland, dealing with their historic record, potential for adoption, standing resource, site suitability, provenance selection, establishment, silviculture, harvesting, marketing and processing for key end-uses. Many of these species have been used previously in Scottish plantation forests, albeit on a smaller scale, but a few have only been grown in forest gardens and trial plots to date. For each species there are details of some of the best stands, demonstrating their regional potential, and also short reports explaining how their timber has been utilised within Scotland and beyond.

Scotland has one of the world's longest historical records of creating new forests by tree planting, using a wide variety of species, both native and introduced. This should serve as a source of confidence and encouragement to develop and diversify our plantations during the 21st century. In the case of three European conifer species dealt with in this guide - Norway spruce, European larch and European silver fir - the record goes back up to 300 years to the late 1600's, when major private landowners in Perthshire, Argyll and the Borders began to establish tree plantations. These were the famous "planting dukes". A much wider range of new conifer species were introduced to Scotland during the mid-late 1800's, as a result of "plant hunting" expeditions to the Pacific Northwest of North America and to the Far East of Asia. These expeditions by the famous collectors such as Archibald Menzies and David Douglas were sponsored by major private landowners to bring back new species that would improve the landscape amenity and productive forestry potential of their estates. Species such as Douglas fir, grand fir, noble fir, western hemlock, western red cedar and coastal redwood were tried out in arboreta (tree collections) around the big country houses, and later in forest gardens where plots or stands of trees were compared using scientific methods. Many of these species were then adopted for wider-scale use in the more extensive new plantation forests, established from the late 1800's onwards (including after 1919 by the Forestry Commission).

Sitka spruce (*Picea sitchensis*) was identified early as a "very useful tree" and has come to play a major role in Scottish forestry, alongside the traditional Scots pine. However, earlier plantation forests created during the period 1890-1960 usually included at least a minor component of some of the alternative conifer species - Norway spruce, Douglas fir and larch were the most widely used, but grand fir, noble fir, western hemlock and western red cedar found a place. Selection of tree species for planting was guided by the expertise of estate foresters, accumulated in classic forestry texts, such as Mark Anderson's "*The Selection of Tree Species*". By contrast, from the early 1960's onwards, the emphasis changed to the use of intensive site preparation methods (cultivation, drainage and fertilisation) to prepare sites for establishment of Sitka spruce, often together with lodgepole pine on the peaty soils. As a result, the establishment of other conifers (with the exception of Scots pine within native pinewood schemes) has tended to decline, leaving an ageing resource in many cases. This process has been accompanied by a decline in experience of their silviculture and utilisation.

Species	1991 on	1981-90	1971-80	1961-70	1951-60	1941-50	1931-40	1921-30	1911-20	1901-10	1861-1900	to 1860	Total
	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha
Norway spruce	405	1542	3580	9401	9379	5172	1820	1252	276	32	109	0	**32968**
Hybrid larch	668	2326	1808	4107	3080	979	146	228	47	20	36	0	**13445**
Douglas fir	641	2303	925	1962	2587	662	259	382	228	49	59	12	**10069**
European larch	62	515	477	898	1791	1197	1342	831	534	121	660	22	**8450**
Mixed/ minor conifer	200	844	825	1023	2095	867	368	385	86	168	1111	26	**7998**
Western hemlock	19	115	104	382	446	128	140	125	0	0	8	0	**1467**
Noble fir	11	469	360	450	102	2	0	0	9	9	10	0	**1422**
Grand fir	4	129	386	300	126	39	9	0	0	0	0	0	**993**
Minor pines	16	0	29	10	34	0	78	91	0	0	41	0	**299**
Cypresses	0	0	6	41	65	13	0	0	0	0	16	0	**141**
Silver firs (other)	0	0	0	0	0	0	0	0	0	0	28	21	**49**
Western red cedar	0	0	0	0	19	9	0	0	0	0	9	0	**37**
Sequoia redwoods	0	0	0	0	0	0	9	0	0	0	4	0	**13**
Japanese cedar	0	0	0	0	0	5	0	0	0	0	0	0	**5**
Total	**2026**	**8243**	**8500**	**18574**	**19724**	**9073**	**4171**	**3294**	**1180**	**399**	**2091**	**81**	**77356**

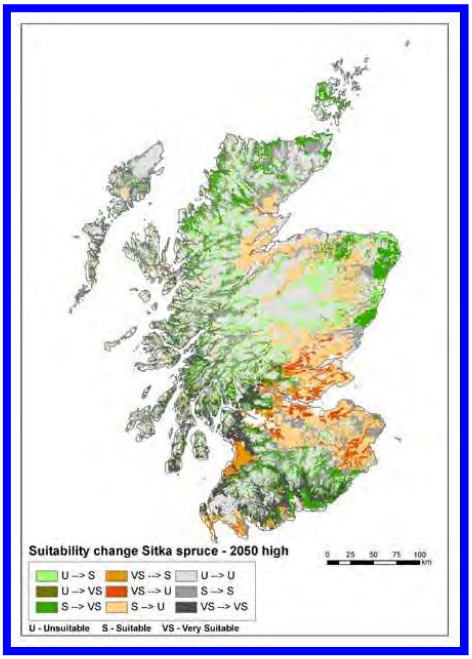
Inventory data on the standing crop of alternative conifer species in Scotland as at 1995 (FC-NIWT)

Record of arboreta, forest gardens and species trials

Arboreta and tree collections **-** there is a long record in Scotland of establishment of arboreta or tree collections around the major country houses, especially in Perthshire, Aberdeenshire and the Borders. The earliest recorded examples may go back to the 1500's, but many of the surviving tree collections date from the major plant-hunting expeditions of the early-mid 1800's. These collections were originally created mainly for the landscape amenity and botanical interest of their owners, but also provided an opportunity to compare the survival and growth rate of a range of tree species established on the same sites at much the same time. As individual specimens were used, comparisons were of a simple, non-statistical type. Also, many of the arboreta were established on fertile brown-earth soils in sheltered lowland or valley-bottom locations and so did not provide a reliable indication of likely performance of species on poor, exposed upland planting sites. Arboreta and tree collections now provide a growing focus for environmental tourism interest in Scotland.

Scone Palace Arboretum, Perthshire - testbed of the early Victorian plant hunting expeditions

Forest gardens and species trials- at the end of the 1800's and into the early 1900's it was realised that it was better to compare species growing in trial plots rather than as individual open-grown specimens. These more closely represented forestry growing conditions and allowed for better statistical comparisons. Forest gardens were laid out at a number of locations in Scotland such as Crarae in Argyll, Benmore and Kilmun in Cowal and Lael in Wester Ross, at which species in single plots were compared for their forestry potential. These locations were usually more typical of the growing conditions to be expected in upland conifer plantations. Both the newly-established Forestry Commission and private growers became involved in this work. Measures taken often included survival, height growth, volume increment, stem form and basal area, monitored over 50+ years in some cases. Later it became usual to establish species trials with replicated plots, allowing for greater statistical power in comparison of species and provenance performance. Many trials are still ongoing.



Above: lodgepole pine killed by red band needle blight - Clashindarroch Forest, Aberdeenshire
Left: assessment of climate change risk to Sitka spruce

Given the success achieved with Sitka spruce, it is natural for some woodland owners and foresters to ask "why the need to diversify", especially where this may well involve using species with which there is less recent experience and familiarity. However, while the proportion of the forest estate used for the alternative conifer species is likely to remain relatively small in the short-medium term, there are strong arguments for maintaining the diversity of our plantations and encouraging diversification in the wood processing industries.

Climate change - current predictions for climate change in Scotland over the next conifer rotation, while much less drastic than those for southern England, do suggest that some of our current species choices may be placed under challenge. In particular, Sitka spruce in the drier east of Scotland may become less productive and more risk-prone due to more frequent and severe summer droughts. Damage by stem-cracking has already been observed on mid-rotation Sitka spruce in Aberdeenshire, after the unusual 2003 summer drought. By contrast, some species that have traditionally been regarded as being too frost-sensitive for use in Scotland, such as western red cedar and coastal redwood, may become better suited. Other species may benefit from a warmer climate by displaying increased growth rates and timber yields. It is very difficult to predict exactly how climate will change and how individual tree species may respond. For that reason an approach based on maintaining species diversity in our plantations is likely to reduce the risk of any catastrophic reduction in their productivity.

Tree pests and diseases - the last ten years have seen a rapid increase in the number of new pests and diseases affecting tree species in Britain, particularly in more southern areas. While many have affected our hardwood species, such as oak and beech, there have been marked impacts on the Corsican and lodgepole pines from red-band needle blight and on the Japanese larch from *Phytophthora ramorum*, both introduced fungal diseases. It is likely that this increase in disease incidence is a combined effect of a warmer climate, fostering their reproduction and putting tree crops under initial stress, together with more frequent and extensive international movements of potentially-infected plant material and other vectors. The result has been that the worst affected tree species have had to be withdrawn from use in new woodland planting and restocking until the longer-term risks are better understood. While Sitka spruce has not been involved as yet, it would be unwise to assume that it will escape future pest and disease problems, which, given its current dominance in Scotland's forests, could cause major disruption to the forestry and wood-processing sector. Here again, encouragement of tree species diversity offers the opportunity to reduce resource risk levels.

Alongside the need to use species diversification as an approach to reducing our forest resource risk profile, there are additional positive benefits which wider use of a range of alternative conifer species could offer, as Scotland's plantation forests continue to mature.

Durable construction timber - the better quality "green log" material produced from Sitka spruce crops in Scotland is already being used for "small-section, short-span" construction timber in the form of kiln-dried carcassing and standard timber-framing. However, it is not ideally suited to use for "large-section, long-span" construction beamwork or for exposed construction applications such as cladding, decking and weather-boarding that require better durability in service. There is increased interest in Scotland in a range of architectural systems using timber both structurally and decoratively, inspired by aesthetic considerations and a wish to reduce the embodied energy and "carbon footprint" of building construction. Douglas fir, larch, slow-grown Norway spruce, Scots pine and high-quality western hemlock have inherent potential for future structural applications. While Sitka spruce whitewood can be chemically-treated to enhance its durability, the available range and effectiveness of chemicals used for that purpose has tended to reduce for health and safety reasons. The more naturally durable timbers such as Douglas fir heartwood, larch, western red cedar and *Sequoia* are increasingly being preferred for exterior exposed applications such as cladding. At present there is a mismatch between the demand for these more naturally durable timbers and the growing stock in Scottish forests, which has to be covered by imported material. That market opportunity could be addressed by future crops of alternative conifers grown within Scotland.

Silvicultural and landscape diversity - post-war plantation forests in Scotland, although productive, have often been criticised for a uniformity of appearance due to the use of single species conifer stands and regular, even-aged (clearfell and replant) silvicultural systems. However we all know of mixed conifer forests that are more varied and attractive, for example where there are a range of age-classes of trees present or where the golden colour of larch in autumn provides added interest. Some older conifer forests form part of wider historic designed landscapes, for example in Highland Perthshire. Encouragement of the use of a wider variety of conifer species is likely to improve the landscape amenity of our plantation forests as these mature into the second and subsequent rotations. Also, as a number of the alternative conifer species are more shade tolerant and can regenerate under a mature canopy, their use is likely to be accompanied by wider adoption of continuous-cover silvicultural systems. These factors will help to combine productivity with public support.

Below: attractive mixed coniferous landscape, Drumlanrig Estate, Dumfries-shire
Left: larch cladding on rural community centre, Highlands

When selecting alternative conifer species for establishment or restocking it is essential to ensure that they are well-suited to the site conditions and capable of productive growth. In order to make this assessment reliably, the following information must first be collected:-

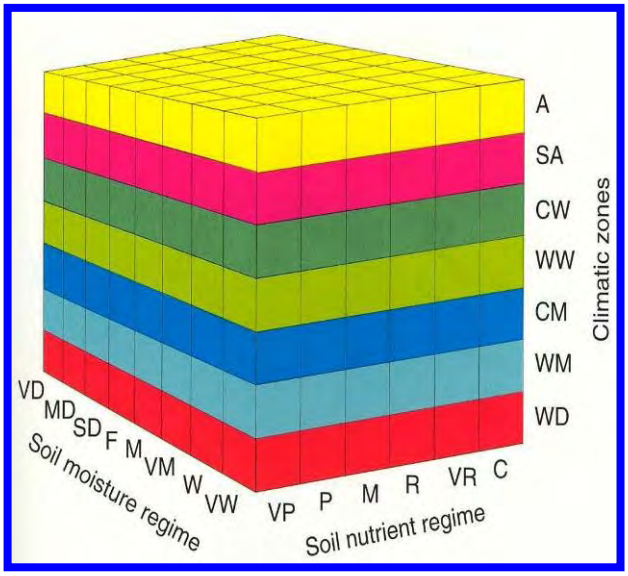
- What are the ecological site requirements of the conifer species of interest?
- What are the current ecological conditions applying on the planting/ restock site?
- How might those conditions change within the lifetime of the trees being grown?

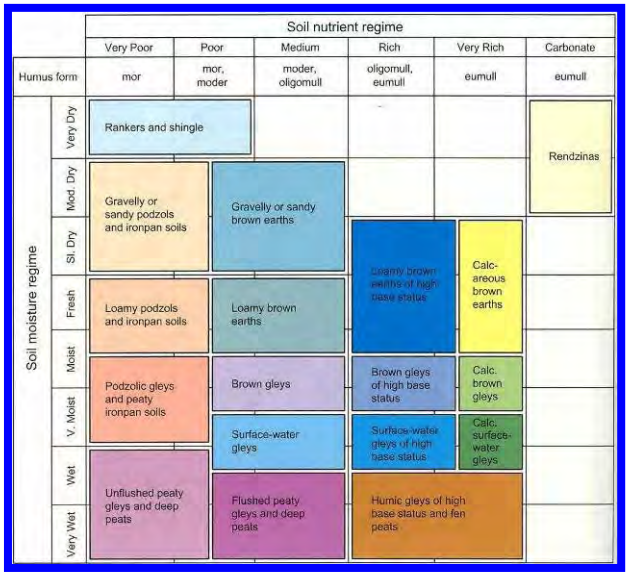
Although rather less research has been carried out on the ecological site requirements of alternative conifer species, as compared to Sitka spruce and Scots pine, a combination of evidence from their previous use in Britain and from their home territories does allow us to make reasonably accurate assessments, at least for the better known alternative species. Current climate data can be obtained for any site from meteorological records but soil information is best gathered from examination of soil maps and soil profiles in field test pits. A range of information about predictions of potential regional climatic change are now available on the UK Climate Impacts Programme (UKCIP) and Forest Research websites.

One of the best ways to assess the suitability of any tree species is its past record of growth on or near any particular site. Long-service estate foresters often had this knowledge "at their fingertips" for their own patch. A variety of traditional forestry texts drew together information about the performance of many of the alternative conifer species in different regions of Britain, based on experience of their use in the late 1800's and early 1900's. Of particular relevance to Scotland was Prof. Mark Anderson's book "*The Selection of Tree Species*", first published in 1950, and various editions of FC Bulletin 14 "*Forestry Practice*", which both present tabular information on species suitability in terms of climate and soils. Other texts by authors such as Charles Ackers and Peter Savill contain valuable insights. Anderson's book was the first to present a formal scheme for evaluating soil quality from ground vegetation in Britain, an approach that has been carried forward into the more recent FC Ecological Site Classification (ESC), discussed overleaf. When selecting tree species using these traditional methods, it is best to avoid using any that appear to be only marginally suitable for a given site, as they may later become vulnerable to climate changes or disease.

SOIL MOISTURE CLASS	DRY		MOIST		WET - MINERAL		WET - PEATY		
SOIL FERTILITY CLASS	*Hardy*	*Tender*	*Hardy*	*Tender*	*Hardy*	*Tender*	*Hardy*	*Tender*	
A	Austrian pine Corsican pine			Nordmann fir				Norway spruce	INCREASING SOIL FERTILITY
B	Japanese larch Corsican pine European larch		European larch Japanese larch Weymouth pine Western red cedar Lawson cypress	Douglas fir Silver fir spp Spruce spp Western hemlock	Western red cedar	Norway spruce		Norway spruce	
C	Japanese larch European larch Corsican pine Monterey pine		Western red cedar Lawson cypress	Spruce spp Western hemlock Silver fir spp		Spruce spp		Spruce spp	
D	European larch Japanese larch	Douglas fir		Spruce spp Western hemlock Noble fir					
E			European larch	Douglas fir Norway spruce					
F	Shore pine Mountain pine		Shore pine Mountain pine		Mountain pine Shore pine		Mountain pine Shore pine		

From M.L. Anderson (1961) - future species groupings - estimated site suitability of various conifers



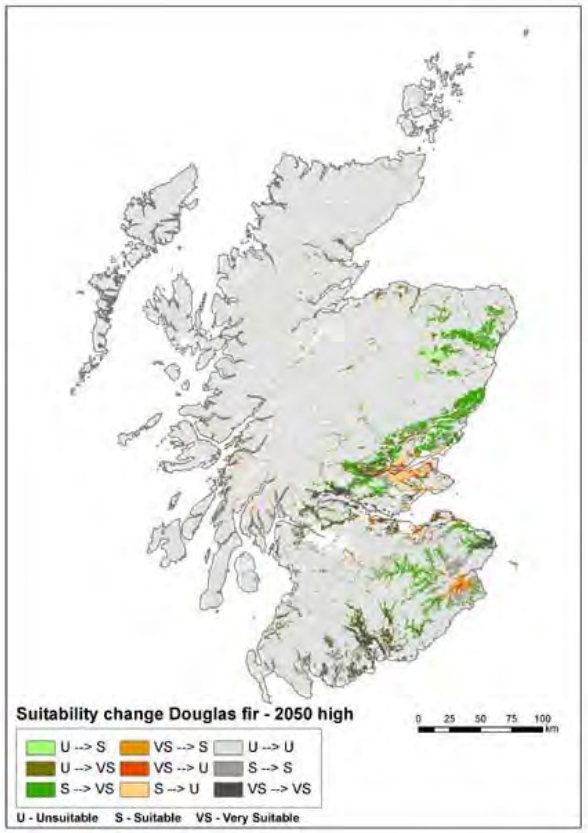


FC Ecological Site Classification - cube diagram of climate-soil quality space and soil quality grid

The Ecological Site Classification (ESC) is a relatively new system developed by the Forestry Commission since the early 1990's for use throughout Great Britain. While drawing on some experience from older British schemes such as Mark Anderson's, and those from European countries such as France and Finland, it was most strongly influenced by the equivalent Biogeoclimatic Ecosystem Classification (BEC) used in British Columbia, Canada. This is relevant to Scottish conditions due to the strong similarity of climate and the fact that many conifer species of interest were introduced from British Columbia, Washington and Oregon.

The ESC describes forest sites mainly in terms of their climate (warmth and wetness), soil moisture regime (SMR) and soil nutrient regime (SNR), with some account also taken of their continentality (seasonal temperature range) and windiness/ exposure (DAMS score). For each tree species, it is possible to estimate the range of site conditions where it will prove suitable for productive growth, and within this, where it will be a very suitable choice. This allows decisions to be made at the site level as to which tree species to consider and which to avoid. Information about the site requirements, pest and disease susceptibility and silvicultural characteristics of a range of tree species of potential interest for forestry in Scotland are now available from the Forest Research website [http://www.forestry.gov.uk/fr/treespecies] and is being added to. For some more minor species, such as Japanese red cedar, additional research is certainly still needed. Good quality information about the current ecological conditions applying on the site for which species are being chosen is also essential, and relies on effective field survey of the soil and ground vegetation. Where maps of climate and soil information are available, it becomes possible to produce forest and regional scale suitability maps for tree species of interest. The ESC is available for use either manually in the form of FC Bulletin 124 or in the form of the computer-aided ESC Decision-Support System (ESC-DSS) (see Forest Research website). At present the latter works at the individual site level, but a spatial (GIS-mapped) version is currently under development by Forest Research.

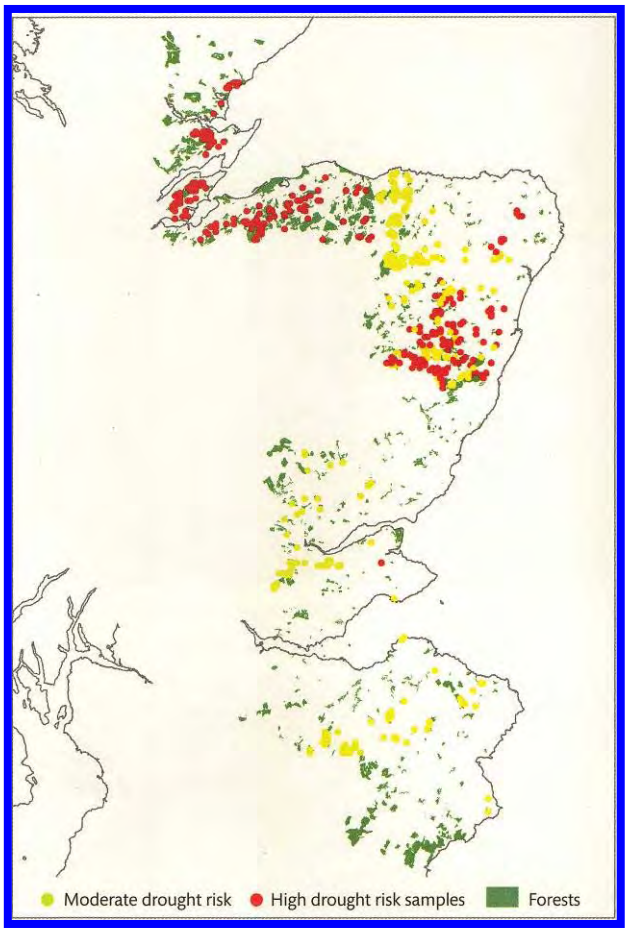
The ESC can also be used together with predictions of future climate change produced by the UK Climate Impacts Programme (UKCIP), adjusting the suitability assessments produced by the ESC to take account of expected climatic changes. Revised suitability (or "suitability change") maps can then be produced for each species. Forest Research have undertaken this work for some of the better known species such as Douglas fir, Norway spruce and larch, and are currently extending that work to include more minor species, based on the best available evidence as to their ecological site requirements. Further detail can be found on their website.



Suitability change mapping for Douglas fir in Scotland in 2050 high CO_2 (Forest Research)

Future species trials **-** due to the inherent uncertainty of the predictive-modelling approach, new series of species and provenance trials will certainly be required to provide more reliable guidance on the future selection of alternative tree species. Forest Research are currently planning such series of replicated trials under EU experimental programmes. Trials will be established at a wide range of sites, some of which will be in areas of England, Wales and France that currently have climates broadly similar to those expected for Scotland in 2050 and 2080 under climate change scenarios. Performance of species will be compared (including many species covered by this guide), but within-species provenance differences will also be examined. Early results can be expected within a few years, developing over the coming decades. This should provide further information in the future as to the selection of provenances of native and introduced tree species that should thrive in Scotland, within a changing climate.

Suitability modelling- in order to assess the potential future suitability of alternative species, one approach is to compare their known ecological site requirements with the predicted future growing conditions in areas of interest, such as eastern Scotland. The Forestry Commission Ecological Site Classification (ESC) provides a systematic framework for making these comparisons. Ecological site requirements of individual species can be estimated from their natural ranges and from their past performance in British trials and plantations. Future growing conditions can be predicted by computerised spatial analysis based on climate-change models, such as the recent UKCP09 outputs. Predicted future climates can be matched with areas that experience similar conditions at present. The elements of such work are subject to a considerable degree of uncertainty, both as to actual climatic outcomes and as to the ecological requirements of tree species that have been little studied in the past and for which there is limited British experience.



Assessing soil drought risk (Forest Research)

Above: advance regeneration of western red cedar, Darnaway
Left: natural regeneration of western hemlock, Novar

Crops of alternative conifer species can be established either by planting or natural regeneration. Where good quality mature stands of the desired species are growing on site or nearby, it may be more reliable and less expensive to accept natural regeneration. Shade-tolerant species such as western hemlock, western red cedar and grand fir often produce abundant natural regeneration during the rotation, whereas species that demand more light, such as Douglas fir and larch, will usually require deliberate regeneration thinnings. Norway spruce tends to regenerate only once stands reach 60-70 years old, later than for Sitka spruce.

There are three common situations for the planting of alternative conifer species:-

- New planting onto a bare-ground, unwooded site (e.g. moorland or grassland)
- Restocking of a felled plantation stand of Sitka spruce, Scots pine or another conifer.
- Enrichment under-planting in an existing conifer (or occasionally a hardwood) stand.

Species should be chosen to suit the site, based on application of ESC or an equivalent method. The following factors must then be considered to ensure successful establishment:-

Site preparation - the site must be in a suitable condition for the trees to establish well, and this may require cultivation, drainage, weed control and other preparatory works. Some of the alternative conifer species "make a slower start" than Sitka spruce and this may mean that more effort has to be put in to effective site preparation, as when planting quality hardwoods.

Frost and exposure tolerance - certain of the alternative conifers are late-successional species that are adapted to establish or regenerate within a sheltered forest microclimate - these include western red cedar, *Sequoia*, grand fir, silver firs and, to an extent, Douglas fir. Planting pure stands of these species onto an exposed bare-ground site is not advised. Ideally these species should be established by under-planting into old open stands of pine or larch which provide top shelter, or in some cases by use of mixtures with pine, larch or beech.

Provenance and stocking - provenances should be selected using the advice given for each species - normally from a British Registered Seed Stand or selected overseas sources. For the more minor species, plants may have to be ordered well in advance from a nursery under a contract-growing arrangement. Plants should be held on site before planting for as short a time as possible and carefully handled to avoid degrade. Initial stocking densities should comply with grant-scheme requirements for productive conifers - often 2000-2500 stems/ha.

Low intensity approaches to early stand tending typically applied to young Sitka spruce will often be inadequate to secure stands of an alternative conifer species of good timber potential. A "traditional forestry" approach, similar to that for quality hardwoods, is more suitable. Most careful attention needs to be given to the following aspects of early stand tending:-

Protection from browsing- many of the alternative conifer species are more palatable to deer and other herbivores than Sitka spruce or Scots pine, especially when planted. This applies particularly to grand and noble firs, silver firs, Douglas fir and western red cedar. Adequate attention must be given to protection by either fencing, deer control or both, for a sufficient period to allow the young stand to get away without leader damage that will affect stem form. New plantations will usually be deer-fenced, but extensive tracts of woodland managed under continuous-cover forestry with natural regeneration are more easily protected by stalking.

Weed control and cleaning - many of the alternative conifers require protection from weed competition for a period of time after establishment, especially on heathery or very fertile sites. In some cases it may take longer for these species to exert control over a site than would be the case for Sitka spruce and the weed control effort needs to be sustained during that time to ensure establishment of a successful crop. Where invasive natural regeneration of non-target species such as Sitka spruce, birch, *Rhododendron* or, in some cases, western hemlock arises, there may also be a need to control competition by cleaning young stands.

Disease, mortality and stocking - it is important to avoid reduction of effective stocking below the target levels, or patchy stocking, as a result of mortality from disease or other factors. Regular inspection of young plantations of alternative conifers, followed up by appropriate operations, including beating up, are an essential element of early tending. Where a particular species has suffered noticeable mortality, it may be sensible to beat-up with another, forming a mixed stand for management through the rotation to a final timber crop.

Respacing/ pruning - particularly where natural regeneration has been accepted, but in some cases where planted trees have been established at full stocking, it may be desirable to carry out selective respacing/ pre-commercial thinning operations. These have the objectives of improving the young stand by removing poorly formed individuals (e.g. where the leader has divided), allocating future increment to the target initial stocking of stems and adjusting the balance of growing space in mixed stands to favour desirable timber species. Some high-value crops of Douglas fir, Japanese red cedar etc can benefit from early pruning of selected final crop trees to 7-10m height.

Below: restocking with planted Douglas fir, Drumlanrig
Right: restocking with planted European silver fir, Drumlanrig

Alternative conifer species have been grown successfully in Britain in regular, even-aged stands, under both clearfell-replant systems and uniform shelterwood systems relying on natural regeneration. Many of the demonstration stands described for individual species later in this guide are even-aged, having been planted 1890-1960. Norway spruce, Douglas fir, European larch, western red cedar, *Sequoia*, Lawson cypress and Macedonian pine are well suited to even-aged silviculture. Rotation lengths for quality timber vary with the individual species, but are typically rather longer than for Sitka spruce, at 60-90 years. This reflects the fact that for many of these species, log length and stem value continue to increase as diameter approaches 100cm, with logs of 60-90cm dbh often valuable for specialist markets. There are arguments that the most shade-tolerant species such as grand fir, silver firs and western hemlock may display superior timber properties when established under top shade. Hence although they can form fine even-aged stands, they may be considered inherently more suitable for operation within irregular mixed-species forestry, relying on natural regeneration.

A number of the alternative conifers can form valuable components of mixed-species even-aged stands, either with Sitka spruce, Scots pine, other alternative conifers or hardwoods. Mixtures offer a number of advantages, including nursing more sensitive species in their early years and retention of options in terms of the final crop until later in the rotation. That can be particularly valuable where climate change or disease risks make it uncertain which species will perform best over the complete rotation. Some mixtures are established with the intention that all species included will be carried through to the final crop, whereas others are designed such that some components will be felled earlier, often as biomass thinnings. When combining species in mixtures, it is essential to consider their relative shade tolerance and habit. Well-matched pairings such as Douglas fir/ western red cedar and Grand fir/ western hemlock are easier to manage than contrasting pairings such as Grand fir/ European larch, although where well-managed, the latter can yield fine quality timber crops of both species.

Productive stands of alternative conifers should be progressively thinned throughout the rotation to remove inferior stems and to allocate increment to a sensible number of superior final crop stems. Final crops of poorly-thinned “beanpole” material attract lower prices, whereas the improved markets for woodfuel make early thinning operations more viable. Thinning intensity should be adjusted to the individual species and site - larch needs to be well thinned throughout the rotation, whereas grand fir will respond well to infrequent heavy thinning, as long as the wind regime remains moderate. Some species, such as Douglas fir and larch, require to be well thinned later in the rotation to promote their natural regeneration.

Below: larch in pure even-aged mature stand - Shambellie
Right: larch in selection stand with Douglas fir - Drumlanrig

Above: noble fir as an understorey to Scots pine - Glen Dye
Left: pure, even-aged mature noble fir - Glen Nevis

Some growers of alternative conifer species use irregular (non-clearfell) silvicultural systems (sometimes referred to as "continuous-cover forestry" or "selection forestry"). Many of the alternative conifer species are very well suited to use within these systems, as they are at least moderately shade tolerant and naturally regenerate rather easily under a mature canopy. Even larch, which is more light demanding, can be compatible with irregular forestry, with appropriate thinning regimes in place. Many long-established examples of irregular forestry have a mixed-species composition, but that is by no means essential - species such as Norway spruce, Douglas fir, western red cedar, hemlock and grand fir can be operated very successfully under irregular systems within single-species stands. While some examples of irregular forestry are planted from scratch as intimate mixtures, most arise from conversion of even-aged conifer plantations by progressive thinning and enrichment under-planting.

There are several variants of irregular forestry, including single-tree and group selection systems and group shelterwood systems. However, they have the following in common:-

- At least two, and preferably three or more, size-classes of trees present on any site.
- An avoidance of clear-felling, although smaller coupe fellings are used at times.
- Progressive harvesting of mature trees as these reach a "target diameter" for sale.
- Reliance on natural regeneration as the main (but not only) method of restocking.

The main advantages of irregular forestry from the point of view of the grower are:-

- Avoidance of periodic replanting costs through use of natural regeneration.
- Avoidance of landscape disturbance (e.g. visual amenity, sporting values, privacy)
- Retention of the forest microclimate, soil moisture and habitat protection.
- More natural growing conditions for some species, possibly producing better timber.
- More even production flow of timber of the marketable size classes (in small woods).

Irregular forestry is most easily applicable on sites that are accessible (well-roaded), have good deep soils and are naturally sheltered from strong winds. Success usually requires monitoring and fine-tuning of the operations necessary to achieve the desired outcomes and must be tailored to suit the characteristics of species being grown and timber markets served. Irregular forestry is often combined with the marketing of high value stems to specialist processors (e.g. Douglas fir, larch) or for local/ on-site processing (e.g. western red cedar).

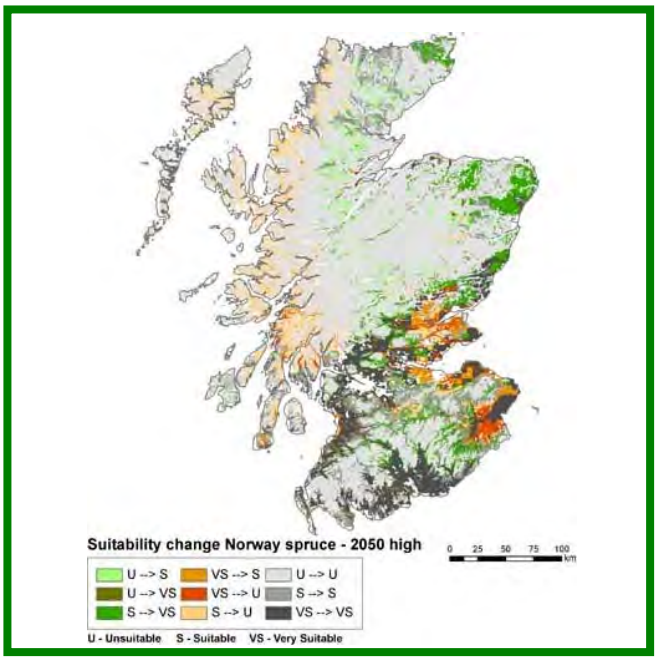
Norway spruce

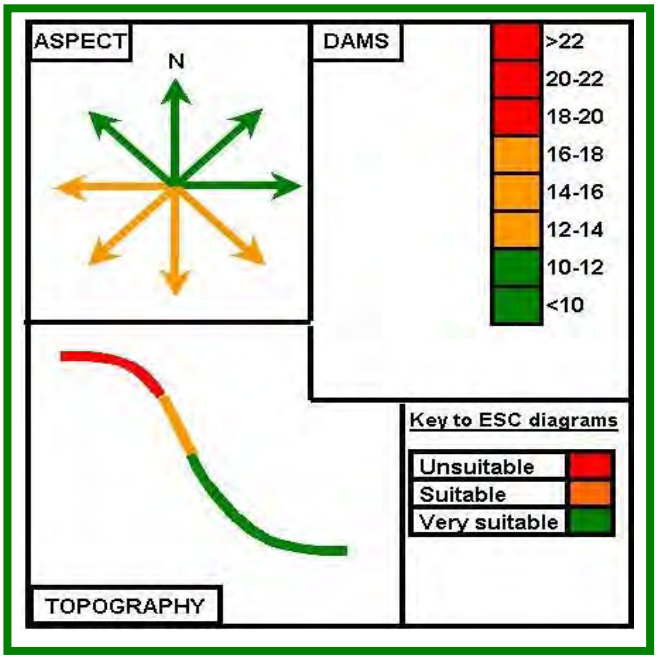
Potential for use in Scotland

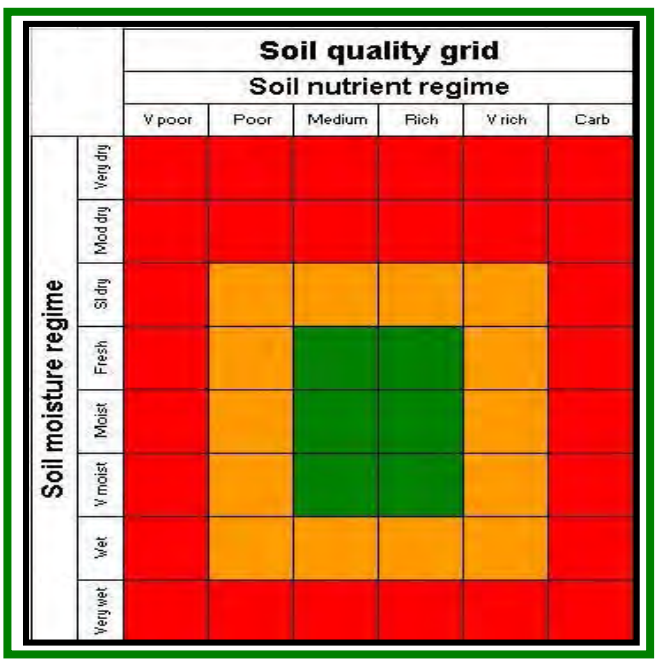
Record and potential - the Norway spruce (*Picea abies*) is native to large areas of mainland Europe, being a montane species in more southern parts, but extending onto the lowland plains of northern Europe, Scandinavia and European Russia. Along with the European silver fir, it contributed to the major historical European whitewood or "white deal" timber marketing category, and is still used today for the full range of construction, carpentry and packaging applications not requiring high natural durability. It was introduced to Scotland at some time between 1500 and 1700, and from the 1800's onwards has been extensively used as a principle timber producing species. Only since the Second World War, with more widespread plantings of Sitka spruce, has Norway spruce been displaced as the most commonly planted spruce. At times it was planted onto upland sites with unsuitable soils and excessive exposure, where it grew poorly. Where Sitka spruce is suitable for a site, it will normally produce a higher yield of comparable timber than Norway. However Norway spruce can safely use a range of sites in eastern Scotland that are likely to become too dry for Sitka spruce under climate change scenarios, and is likely to hold a steady, if not expanding, role in Scottish forestry. This is underpinned by its significance as a food source for the red squirrel. Norway spruce will serve equivalent markets to Sitka spruce, sometimes for the better grades.

Premier FC Scotland stands of Norway spruce - Glentress, Ae and Clashindarroch Forests

Existing resource - the National Inventory of Woodland and Trees recorded ~33,000ha of Norway spruce in Scotland in the mid-1990's. Of this about 25% would now be over 60 years old and coming due for harvest, so there is likely to have been some subsequent loss of extent. The mature standing crop tends to be concentrated in sheltered areas of Scotland that have used this species over a longer period, including Aberdeenshire, Angus, Perthshire, the Borders and Dumfries and Galloway. Crops in Argyll and the west Highlands have more often been felled and restocked with Sitka spruce, Scots pine or native hardwoods. Recently, many of the older surviving stands of Norway spruce that are potentially windfirm have been reserved as suitable habitat and food sources for the red squirrel (a protected species). The cones are larger than those of Sitka spruce and more nutritious for red squirrel. Very little Norway spruce has been planted over recent years other than for Christmas trees - the planting rate is now below that of Douglas fir and European/ hybrid larch, and of course far below that of Sitka spruce. Natural regeneration has been recruited in some suitably-managed stands. The timber of Norway spruce currently being harvested is accepted as equivalent to Sitka spruce and some older, slower-grown Norway timber from good sites is felt to be better.







Site suitability - Norway spruce is best suited to sites with a moist climate (>850mm) and soils with Fresh to Moist ESC-SMR. It will operate under regimes with 700-850mm of rainfall, that will be too dry for Sitka spruce, but here it should be kept to slope foot and valley bottom sites that are well supplied with moisture, even where these are slightly waterlogged. With predicted climate change in eastern Scotland, Norway spruce is likely to expand at the expense of Sitka spruce onto the drier site types, perhaps together with grand fir on the valley bottoms and Douglas fir on the free-draining slopes. Norway spruce is much less tolerant of wind-exposure than Sitka spruce and should not be pushed "up the hill" onto sites where it will be unstable, especially if rooting depth is limited. Norway spruce is less frost-sensitive than Sitka spruce, but only late-flushing provenances should be used on frost-prone sites. ESC-SNR should be between Poor and Rich. Norway spruce grows well on lush, rich, heavy sites, but will not withstand any heather competition. Dry shallow soils are unsuitable, resulting in crown die-back. Norway spruce is susceptible to butt-rot on old conifer sites and prior urea stump-treatment is essential when restocking.

Provenance - Norway spruce does not start to produce a good seed crop until 60-70 years and hence no seed stands in Britain have been registered. Some of the best older stands are starting to produce natural regeneration when suitably managed and there may be scope for future registration of seed stands, where cones are not reserved for red squirrel. Past provenance research has shown that sources from the eastern European (Polish and Romanian) part of the natural range perform best in Britain. Certain German sources from the Harz are also useful. High-elevation French and Swiss sources and high-latitude Scandinavian sources should be avoided as they tend to grow more slowly or to flush earlier, increasing the risks of late frost damage.

Establishment and early tending **-** most of the existing stands of Norway spruce in Scotland were established as pure even-aged crops by planting, either onto open land or by under-planting old hardwoods. Very few schemes of this type have been undertaken in recent years, but new planting should be at 2,000-2,500 stems/ha for quality timber production. Norway spruce has been regarded as more susceptible to deer damage and weed competition than Sitka spruce and good site preparation and protection are required. Recently, most attention has been focussed on retaining mature Norway spruce for forest diversity and the red squirrel, with promotion of natural regeneration. This does not start until 60-70 years, whereas for Sitka spruce it can often be at 40-50 years, so some growers and foresters become impatient. Regeneration thinning and scarification are not useful until there is a good seed-rain, and if carried out prematurely on fertile sites will foster the growth of highly competitive weeds, this being counter-productive. A few older stands are now regenerating well.

Norway spruce cones provide an important source of food for the red squirrel in Scotland

Natural regeneration - Norway spruce/ grand fir

Silviculture **-** even-aged crops of Norway spruce are generally grown on rotations some 15 years longer than for Sitka spruce on the equivalent sites, hence 55-70 years. Yield is usually slightly lower, with GYC of 6-22, typically 12. The site types where Norway spruce is likely to be used now will be at the upper end of this range. Thinning of regular stands should follow the yield-tables - due to the greater shade tolerance as compared with Sitka spruce, the response to later thinnings may be better. Norway spruce can also be used in mixed forestry with species such as beech, Douglas fir, grand fir and western red cedar which are of comparable shade-tolerance, but natural regeneration of grand fir and red cedar will come much earlier than that of Norway spruce. In pure stands that are retained past 70-80 years it should be possible to regulate the basal-area and regeneration more easily than for the medium-tolerant Sitka spruce. Pure Norway spruce may deplete soil fertility on some site types - mixtures with western red cedar or hardwood species can help this.

Stacking and de-barking large-section Norway spruce logs prior to sawing for construction timber at James Jones & Sons, Kirriemuir

Processing **-** the majority of Norway spruce timber from Scotland is processed along with equivalent diameters of Sitka spruce by major industrial scale processors. Small roundwood is taken by various woodfuel enterprises within Scotland and further afield. It is also in demand from the major particle board mills. Sawlog material up to 60cm dbh is normally sent to the major mills operated by James Jones & Sons and BSW/ Howie across Scotland, along with many other smaller sawmilling companies. For larger logs (>60cm dbh) both James Jones (at Kirriemuir) and BSW (at Petersmuir) have specialist lines that process this material for beams, purlins and sleepers. Norway spruce is processed along with Sitka spruce and Douglas fir of similar dimensions for agricultural purlins and similar applications. Very high grade spruce logs potentially meeting the C24 grade may be taken by the specialist beam mills normally preferring Douglas fir and larch, many south of the border. Some beams, planks and cladding are cut by mobile mills.

Marketing- there are few difficulties in selling good crops of Norway spruce, as the timber is accepted as the equivalent of Sitka spruce for almost all purposes and there is the added advantage that Christmas trees can be marketed from early thinnings (although not as valuable as the silver firs). Small roundwood will be saleable to regional-scale industrial processors for pulp, particle-board and woodfuel uses. Standard logs of 30-50cm can be sold under the normal C16 green and red log categories to the major industrial mills, producing dimension stock for carcassing, fencing, pallet, box-manufacture etc. Use of such sizes for load-bearing construction is growing, as is application of spruce for cladding. Norway spruce, if slow-grown, may be superior to Sitka for cladding work. Spruce timber can also be used in engineered timber systems. Pole-length Norway spruce logs above 60cm dbh may now attract specialist demand from national buyers for C24 large-section beams. While less favoured than Douglas fir, there appears more demand than for Sitka spruce.

Two-stage sawing of large-section Norway spruce logs prior for construction beams and planks at James Jones & Sons (Kirriemuir)

FC Craigvinean and Clashindarroch Forests **-** within those regions of Scotland where red squirrel remain frequent, measures are being taken to maintain areas of habitat that will favour them over introduced grey squirrels. Diverse conifer forestry, including species such as Scots pine, larch, Douglas fir and Norway spruce is generally more favourable than pure Sitka spruce plantations. The larger cone-size of Norway spruce makes it especially valuable. Where there are existing crops of mature Norway spruce, planted before 1950, these are being set aside as long-term retentions for management under continuous-cover forestry systems. Securing natural regeneration can be a challenge as seed rain does not reach the required levels until the crop is 60-70 years old, and if thinning has been inadequate during the earlier part of the rotation, crops can become unstable before they have properly regenerated. In older stands of Norway spruce at the FC Craigvinean Forest in Perthshire (NN 996456, 100-150m asl, east-facing, brown earth slope, p1940, GYC = 20), progressive regeneration thinnings are being implemented to improve the stability of the crops, extending their rotation and promoting Norway spruce natural regeneration. In less well thinned stands at higher elevations in the FC Clashindarroch Forest in Aberdeenshire (NN 450300, 300-350m asl, east-facing, gentle upland slope, p 1938, GYC = 10), an alternative approach is being considered where phased strip felling into the wind would be used to promote natural regeneration, retaining all age classes of Norway spruce on site to provide squirrel habitats.

Norway spruce stands being converted to irregular forestry - Craigvinean and Fearnoch Forests

FCS - Lochaber, Dumfries and Galloway **-** in some other parts of Scotland, red squirrel may not be quite such a major issue but there remains the intention to retain mature stands of Norway spruce as an element of diverse forestry. This is being approached by progressive thinning to promote natural regeneration. Some fine mature stands of Norway spruce are at:-

- Fearnoch Forest, Lorne (NM 970310) - planted on undulating brown soil site in 1938, this stand is scheduled for conversion to CCF by thinning from 50m^2/ha to around 35m^2/ha at which natural regeneration can be expected to start. A local population of red squirrel will benefit from retention of some Norway spruce, alongside Sitka spruce and other crops.

- Forest of Ae, Dumfries (NX 981915) - one of the best stands of Norway spruce in Scotland, running along the fertile alluvial flats of the Water of Ae (planted 1930, GYC =20). Has been well-thinned, but lush ground vegetation may impede future regeneration.

- Cairn Edward Forest, Castle Douglas (NX 647737) - very good stands of Norway spruce planted in 1926 on steep, east-facing brown-earth slopes and plateau. Very productive for this species with GYC of 18-22. Stands have been rather under-thinned to date. Natural regeneration has been initiated, but is more plentiful for Douglas fir at the present time.

- Glen Orchy, Argyll (NN 258348) - fine old stands of Norway spruce (planted 1880) on the alluvial flats of the River Orchy, another good example of its use of the moister sites.

Spruce timber dimension stock for construction (above) and Norway spruce applied to house cladding in Scotland (below, Alan Dickson)

Large-section timber elements - a rather smaller proportion of the home-grown spruce resource could potentially meet the C24 timber grading standard, allowing its use for heavy load-bearing applications that would normally require Douglas fir, larch or oak beams. Mature stands of slower-grown Norway spruce yield large-section logs that are currently used for agricultural purlins and other less highly-specified beam markets, but at present not for the more demanding architectural beam elements. Another way to approach this issue is to utilise smaller pieces of Norway spruce timber in engineered timber systems. Glue-laminated beam systems using Norway spruce timber have been used for many years in Europe and the species is widely preferred for use in cross-laminated massive timber panel elements, especially for the visible/ contact facings. Weaker/ moister timbers such as the *Abies* firs can be used for the internal/ non-contact layers. Wider use of these construction techniques is currently attracting attention in Scotland.

Timber framing and cladding - greater use of Scottish-grown timber in building construction will provide benefits in terms of both architectural design and climate-change mitigation, by substituting for alternative materials with higher embodied energy and by sequestering carbon from the atmosphere. While attention recently has focussed on the naturally durable timbers, such as Douglas fir, larch and western red cedar, spruce also has a major part to play. Good quality spruce logs meeting the C16 timber grading standard can be used in structural applications such as timber framing. Norway spruce crops, slow-grown on suitable sites, may produce a higher proportion of material of this type, as compared with Sitka spruce on exposed upland sites. In Scandinavia, Norway spruce timber is widely used for traditional cladding systems, and some Scottish architects, especially in the Highlands, are now adopting that approach. The lack of natural durability can be compensated for by treatment or careful technical detailing.

Whitewood for large-section applications - sleepers/ purlins - James Jones & Sons

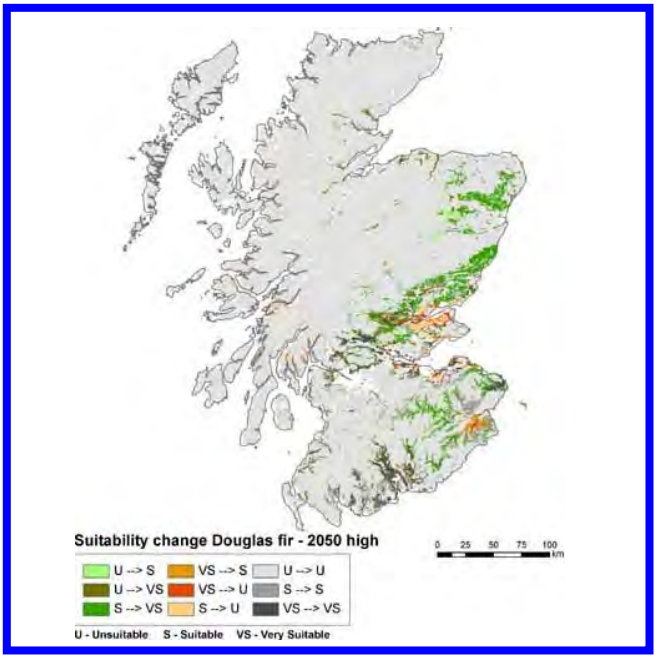
Douglas fir

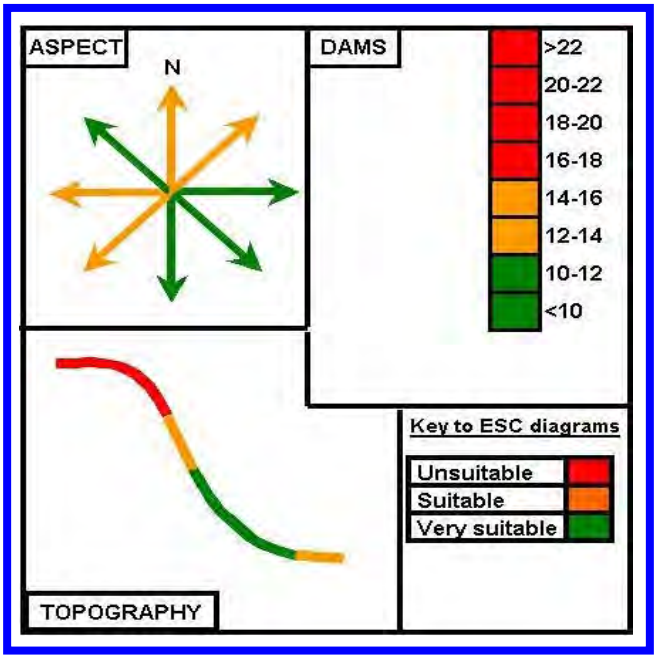
Potential for use in Scotland

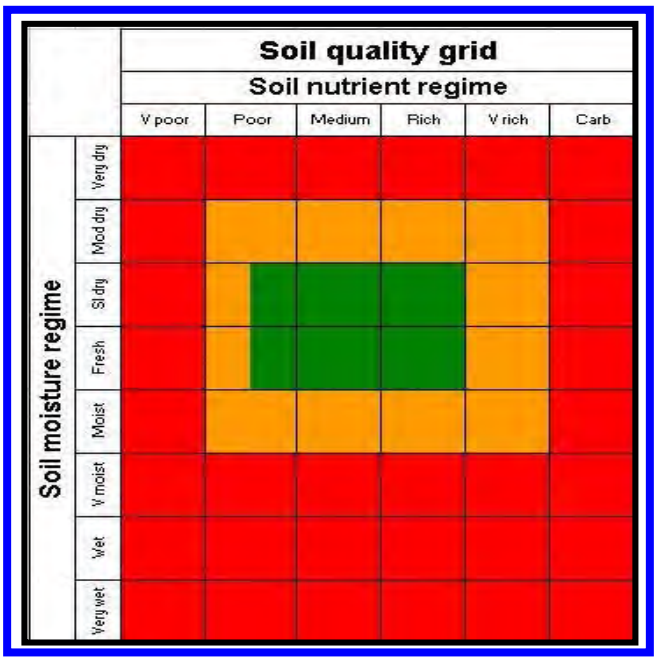
Record and potential **-** the Douglas fir (*Pseudotsuga menziesii*) is a highly valued timber tree from the Pacific Northwest, that is found in both coastal and much drier inland areas ranging from British Columbia southwards to Mexico. It was discovered by Archibald Menzies in 1792, and later introduced to Scotland by David Douglas in 1826-27. There were more extensive later introductions in the 1850's by William Lobb and John Jeffrey for the Oregon Association. The species was widely tried in the private Scottish arboreta such as those at Scone and Murthly, and later used in private plantations from the 1870's (e.g. at Taymount). Douglas fir of suitable, northern coastal, provenances was found to perform well on the more sheltered sites in Scotland. Despite the timber being valued for construction in America, with good natural durability in the heartwood of older trees, the areas established in Scotland were less than those for the spruces and pines, although comparable with larch. Some fine plantations were created between 1900 and 1940 on private estates such as Drumlanrig, Atholl and Darnaway, and more widely on sheltered Forestry Commission ground. Post-war plantings have tended to be on the poorer sites and less well established and tended. Home-grown timber took some time to compete with oak and larch in the major markets, but is now highly regarded for structural and marine beamwork, cladding and decking. With climate change, Douglas fir is likely to expand its growing area in eastern Scotland, as against spruce.

Premier Douglas fir around the Moray Firth - Monaughty Forest, Glenferness Estate and Reelig Glen

Existing resource **-** the National Inventory of Woodlands and Trees recorded some 10,000 ha of Douglas fir in Scotland in the mid-1990's. Of this, about 10% was the pre-1940 material that represents the premium timber resource for structural beams etc. This combines stands on private estates such as Drumlanrig, Atholl, Murthly and Glenferness with the best early Forestry Commission material planted out in the 1920-40 period at Port Clair, Glen Urquhart, Inchnacardoch, Monaughty, Craigvinean, Cairn Edward, Doach Wood etc. Due to its very high current capital value (£60-100/ m^3 at roadside), there has been a tendency for such stands to be liquidated, although many are now long-term retentions for continuous-cover silviculture, natural regeneration and landscape amenity. Nearly 70% of the standing resource recorded by NIWT was mid-rotation post-war plantations. While some of these are of good quality and can be promoted to join the future premium resource, a good deal consist of poorer plantations on more exposed upland sites that may be of less favourable provenance and have been inadequately tended. These stands are only suitable for more standard timber grades. Little Douglas fir has been planted recently due to a perception that it was more sensitive/ demanding than Sitka spruce - this needs to be addressed for future timber supply.







Site suitability - Douglas fir can be used on the sheltered lower valley slope sites across Scotland - although it will grow faster in the wetter western districts, it is tolerant of the drier conditions in the east and may offer an alternative to spruce and pine where these are affected by drought and disease respectively. It is largely intolerant of exposure and should not be used on high elevation or upper slope sites. Frost pockets should be avoided for Douglas fir as it is vulnerable to late frosts. The soil requirements of Douglas fir used to be regarded as fairly demanding, but in fact a range of soils can be suitable. Soil moisture regime should ideally be Fresh to Moist, but drier soils can also be used. Moist soils must remain well-aerated, so Douglas fir is not ideal for alluvial or valley bottom sites. ESC-SNR is ideally Medium to Rich, but Douglas fir can use rather poor sites, with heather control. Douglas fir has moderate susceptibility to butt-rot.

Provenance- by contrast with the other alternative conifers dealt with in this guide, a significant body of provenance research has been carried out on Douglas fir in Britain, leading to a recent set of recommentations from Forest Research (Fletcher and Samuel, 2010). Only the "green" or coastal Douglas fir should be used in Britain. Sources from the coastal Washington area of the native range are thought to offer the best combination of climate tolerance and growth rate for most Scottish conditions, with the more inland Washington Cascades material being useful in the drier eastern districts. Traditionally, material from coastal British Columbia (Vancouver Island and the Lower Fraser Valley) was used to establish some of the fine stands in Britain (p1920-30's). That material is still suitable, but has a more conservative growth rate, although possibly slightly better stem form. There are 15 Registered Seed Stands in Britain, 8 being in Scotland, which can be considered highly suitable sources, some of which are of British Columbia origin. There is also one qualified seed orchard in England.

Restocking with Douglas fir in south-west Scotland - natural regeneration at Doach Wood (above), planting at Drumlanrig (below)

Establishment and early tending- Douglas fir can be established successfully as a pure even-aged crop on open ground but this requires some care. It is inadvisable to plant Douglas fir on exposed sites or those with poorly drained or compacted soils. Some schemes on ex-arable or improved pasture land have failed due to instability, which may be a product of "lazy rooting" induced by excessive residual macro-nutrients. Good quality planting stock and careful plant handling are essential, as are effective deer protection and early weed-control, although Douglas fir should get away quite rapidly. Planting at 2,000-2,500 stems/ha is advised. Young crops should be respaced to remove coarse stems and pruning final crop trees to 7-10m can be beneficial. Mixtures with larch, spruce, red cedar, hemlock and silver firs are possible. Douglas fir seeds irregularly, but can naturally regenerate well, especially on the drier soils. Regeneration will not tolerate the same shade as red cedar, hemlock, grand fir etc. Progressive thinning is preferable to a late seed-tree felling that may induce instability.

Silviculture- even-aged crops of Douglas fir can be managed for standard green log assortments on rotations similar to spruce (50-60 years). GYC is 8-24, typically 14. Such material will be well suited to the major industrial mills. However premium beam material typically comes from stands of 60-90 years and 60-90+cm dbh. There is good evidence, at least from south-west England, that Douglas fir continues to put on height and value well past 100 years and 100cm dbh. Experienced growers typically apply target-diameter felling to their main Douglas fir crop, but leave a small proportion of elite stems for premium beams or transmission poles. Processors of such material very often have no effective size limit, taking 14m+ logs, >100cm dbh. Douglas fir should continue to be thinned throughout the rotation on a regular cycle, with the aim being selective improvement of the final crop. Over-stocking induces instability and tends to impede natural regeneration. Heavy thinnings of the type used with grand fir etc are better avoided.

Douglas fir - respacing promising natural regeneration; mid-rotation selective thinning

Marketing- Douglas fir gives a sound, moderately durable and very strong timber (530 kg/m^3) that is favoured for construction. As with redwood and red cedar, there is a marked distinction between heartwood and sapwood, with the former better for demanding/ durable applications. Marketing is best tackled in three phases:-

- Small roundwood - sale of thinnings up to 15cm dbh for woodfuel, pulp and particle board, usually to regional industrial plants or their timber buyers.
- Standard sawlogs - 20-60cm, currently mostly sold to the major industrial processors at the regional scale as spruce-equivalent logs for C16 carcassing, fencing and decking. Can be equally sold standing or from roadside.
- Premium logs - >60cm especially where straight and clear of knots, can be sold to specialist mills or their national buyers for C24 construction and marine beams or transmission poles. These purchasers will usually prefer to fell themselves with prices at £60-100/m^3

Extraction and presentation of Douglas fir logs for beamwork - United Utilities, Thirlmere (above); Port Clair Forest (below)

Haulage and two-stage beam sawing of pole-length Douglas fir - JB Timber Ltd, Hull (above) and SH Somerscales of Lincs (below)

Processing- small-roundwood of Douglas fir is processed for woodfuel, pulp and particle board by regional industrial-scale enterprises, along with equivalent spruce and pine. Processing of log material is divided between larger industrial mills that mainly saw spruce and the more specialist mills that saw Douglas fir, larch and quality hardwoods. Standard Douglas fir logs generally go to the former and are used for the less specialist structural applications requiring at most the C16 grade (e.g. carcassing), but increasingly for decking and cladding. There is debate over whether Douglas fir needs to be treated for cladding - sapwood probably should be. Larger logs (>70cm dbh and transmission poles >50cm dbh) are normally handled by the smaller more specialist mills. Beams meeting the C24 grade and above go for demanding architectural and marine uses. Small-industrial processors have recently been joined by architects and mobile-millers. Some specialist processors may “box-out” the durable heartwood for demanding uses.

Perthshire **-** one of the earliest areas in Britain where Douglas fir was cultivated was the Tay Valley in Perthshire, between Pitlochry and Perth. The sheltered climatic conditions and fertile brown-earth slope soils have been found to favour the species. From the 1830's onwards, Douglas fir was planted within arboreta and tree collections on the major private estates such Atholl, Murthly and Scone. Owners of those estates were particularly enthusiastic in their promotion of plant-hunting expeditions to the Pacific Northwest. Later, Douglas fir was used within Forestry Commission plantings at Craigvinean. Some key stands are at:-

- Craigvinean Forest and The Hermitage, Dunkeld (NO 010417, NO 005420) The Hermitage valley at the southern end of Craigvinean Forest was originally part of the Atholl Estate but is now owned and managed by the National Trust for Scotland. It contains one of the tallest Douglas fir in Britain at ~62m. Douglas fir was also included in post-war Forestry Commission plantings on the lower slopes of Craigvinean (p 1949, GYC=20) which are currently being converted to continuous-cover silviculture.
- Scone Palace Arboretum, Perth (NO 117267) and Murthly Arboretum, Dunkeld. Specimen trees on both of these private estates represent some of the earliest plantings of Douglas fir in Britain, dating from the period 1830-1860. The early success of the species here encouraged growers to plant it out more widely across Scotland.

Premier stands of Douglas fir in the Lakes - Wythop Wood (FC)/ Thirlmere (United Utilities)

Great Glen & Argyll **-** one of the most successful Douglas fir growing regions in Scotland is the Great Glen, running from Inverness south to West Argyll, together with some adjacent areas such as Glen Urquhart and Loch Awe. These areas provide the desirable combination of a relatively mild, moist climate, good topographical shelter (east-facing slopes) and brown forest soils. These were among the first areas to be planted by the Forestry Commission. Many of the better stands were felled in the 1970's and 1980's, but the best remaining are:-

- Port Clair, Inchnacardoch and Glen Urquhart (NH 379102, NH 346076, NH 392169, NH 398116, NH 455294) - excellent early plantings by the Forestry Commission on land acquired from the Frasers of Lovat, dating from 1923-34. Some are used as Registered Seed Stands, many thought to be of British Columbia/ Lower Fraser River provenances. Many remaining stands are on steep slopes, some with significant harvesting issues. GYC has been very impressive in many cases (20-26). These stands supply poles and beams.
- Sutherland's Grove, Barcaldine (NM 966425) and Mackenzie's Grove, Inverliever (NM 956099). Examples of early pre-Commission plantings from the period 1870-1920, showing the long-rotation timber potential of Douglas fir on sheltered brown-earth sites. The stand at Barcaldine is mainly of amenity benefit, but the Inverliever stand is a productive mixture (GYC = 16) with Sitka spruce of the same age, replicating stand types found in the Pacific Northwest and offering a potential model for "insurance mixtures" on sites where Sitka spruce may come under drought stress with predicted climate change.

Moray Firth **-** the mild, sheltered climatic conditions of the Moray Firth lowlands, with their sandy brown soils, have provided highly suitable growing conditions for Douglas fir in Scotland. Alongside Scots pine and larch, it provides a suitable species choice for sites that would prove rather too dry for spruce. A number of private estates have had considerable success with Douglas fir as an element of their productive forestry portfolio. It has also been grown to maturity at the Forestry Commission Monaughty Forest, since the late 1920's:-

- Monaughty Forest, Moray (NH 123570; NH 166591) Stands of British Columbia origin Douglas fir, planted in 1928 onto rather dry, south-facing acid brown-earth slopes at 50m asl. These have produced fine, straight timber, with GYC of 14-22, and demonstrate the potential of Douglas fir as a suitable species for dry planting sites in eastern Scotland.
- Darnaway and Glenferness Estates, Moray and Novar Estate, Easter Ross These estates have used Douglas fir as a major element of their forestry since the early-1900's, often on more upland sites at 150m asl, sometimes with considerably poorer soils. Stands are pure or even-aged mixtures with spruce, pine and larch.
- Reelig Glen, Beauly Firth (NH 558426). This Forestry Commission amenity woodland, originally acquired from the Lovat Estate, contains some of Scotland's tallest Douglas firs, ranging from 50-65m in height at the base of a very sheltered, steep-sided valley.

Pre-war FC elite stands of pure Douglas fir - Doach Wood, Kirkcudbright/ Monaughty Forest, Moray

South Scotland and North of England **-** this is one of the main regions identified recently for production of premium beam material of Douglas fir, and offers a number of contrasting examples of the long-rotation silviculture of the species. In most cases, growers are keen to bring on natural regeneration by thinning stands well into the later rotation, but if earlier thinning was deficient this can carry the increased risk of instability on the more wind-prone sites. Some of the most impressive stands are:-

- FCS Doach Wood and Cairn Edward Forest (NX 794577; NX 643744) - these are mature even-aged plantations of Douglas fir from the 1920-40 period, on relatively sheltered brown-earth slopes at ~50m asl. The have been "kept tight" throughout the rotation, producing fine stands of slow-grown (GYC = 20) pole-length timber. In order to recruit natural regeneration basal area has recently been reduced considerably, but this has had to be undertaken over several cycles to limit the risk of windthrow damage.
- FCS Glentress Forest (NT 285406), FCE Wythop Wood (NY 202306), Drumlanrig Estate (NX 877984), Kyloe Estate (Northumb) and Thirlmere (NY 308194). These are fine stands of pre-war Douglas fir that are further down the route to natural regeneration and future irregular silviculture via a progressive thinning approach. Material harvested has been used for premium beamwork applications of the type described below, attracting very high log prices. Douglas fir stands managed using this approach are equally, if not more attractive in terms of recreation/ landscape amenity as compared with regular stands.

Structural beams **-** the last few years have seen increased application of premium home-grown Douglas fir beams in high-profile architectural commissions. These have included shopping malls, sports arenas, educational and health buildings and museums/ heritage interpretation centres. Douglas fir timber beams in these situations, while being less expensive than more traditional oak-beams, are substituting for the use of steel or reinforced concrete members, which have higher embodied energy. Douglas fir can be machined off-site to allow for rapid erection. A good example is the recently opened National Trust for Scotland Robert Burns Birthplace Museum at Alloway, Ayrshire. This used a modern form of post-and-beam architecture with heavy-section Douglas fir members harvested in South Scotland, the Lakes etc, processed by SH Somerscales sawmill in Lincolnshire and assembled on and off-site by Carpenter Oak of Lintrathen, Angus. The architects on the Burns Birthplace Museum project were Simpson & Brown, Edinburgh.

Use of large Douglas fir beams for high-profile construction - beams sawn at SH Somerscales (above) for NTS Robert Burns Museum (below)

Scottish-grown Douglas fir roof-trusses in new Forestry Commission district offices at Huntly (below) and Smithton, Inverness (above)

Structural beams- throughout Britain the Forestry Commission have adopted an early-adopter/ demonstration role for the use of structural Douglas fir beams in public-sector office construction projects. Heavy-section Douglas fir beams have been used to provide wide-span (12-14m) roof trusses in new-build district offices for the Forestry Commission at Golspie, Inverness and Huntly. Material has been harvested from the Commission's own premier pre-war plantations at Port Clair Forest, near Fort Augustus and elsewhere. Preparation of the structural beams has been by specialist processors such as Gilmour & Aitken on Clydeside and Carpenter Oak at Lintrathen, Angus. Architects on these projects have included HRI of Inverness. Use of Douglas fir in this way is one of the most impressive demonstrations of the potential of the alternative conifers in Scotland, but there is a serious likelihood of exhaustion of supplies of pre-war Douglas fir with long beam potential. Establishment of new crops is then an urgent priority.

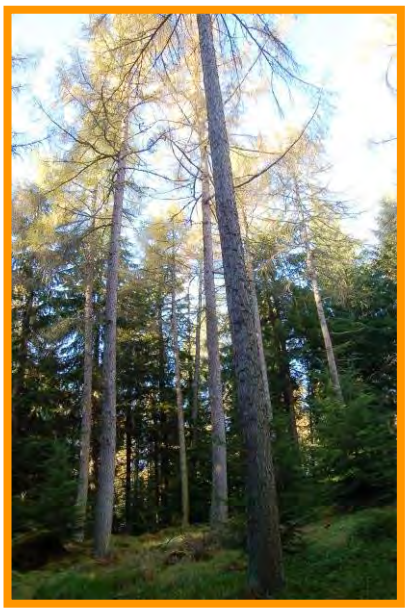
Douglas fir used for simple post-and-beam construction in Scotland - community forest cabin (above)/ David Douglas Pavilion, Scone

Marine, decking and signage- apart from structural beam applications, home-grown Douglas fir timber can be employed for a wider variety of external uses that require a combination of good strength and at least moderate durability. These uses include marine lock-gates and dockworks, cladding and decking, manufacture of garden and public recreation furniture and countryside signage. They have the potential to use a wider range of size and quality classes of Douglas fir timber as compared with the premium beam markets. Douglas fir is more often treated for cladding and decking uses as compared with larch or western red cedar, although the heartwood timber is moderately durable. Marine beams for lock-gates and harbour works are handled by specialist small-industrial firms (e.g. JB Timber of Humberside and Gilmour & Aitken of Clydeside) whereas cladding, decking, signs and outdoor furniture tend to be produced by small independent sawmills (e.g. Association of Scottish Hardwood Sawmillers members, Signs Workshop)

Post and beam construction- in recent years home-grown Douglas fir has been increasingly specified for smaller-scale post-and-beam construction projects. These include single private house constructions, social housing complexes, community centres, summer-houses etc. Many such projects also use timber for cladding, most commonly the European larch in Scotland. Scotland has tended to take the lead within the UK, with these construction methods seen as being both visually attractive and environmentally sustainable. A number of the Scottish-based architects (e.g. Neil Sutherland/ Makar of Inverness) have developed the capacity to process Douglas fir posts and beams "in house". Others will use supplies "sawn to order" by regional sawmills (e.g. Russwood at Newtonmore and James Jones at Kirriemuir). A prominent example of use of Douglas fir posts was for the David Douglas Pavilion within the Scone Palace Arboretum, commemorating the life and work of the famous plant-hunter and his introductions.

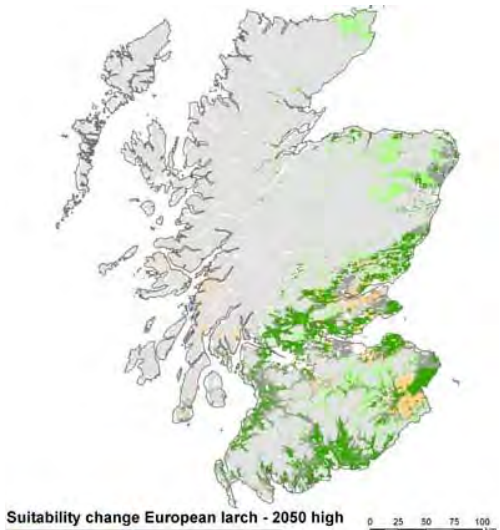
Douglas fir dimension stock for construction use and example of assembly into forest furniture (Signs Workshop, Dolgellau, Wales)

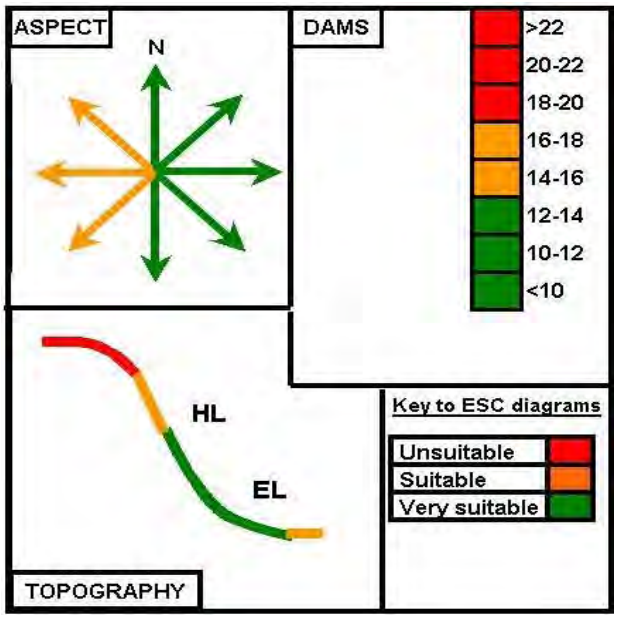
Record and potential- the European larch (*Larix decidua*) is native to the mountains of western and central Europe, and was introduced into Scotland at latest by the late 1600's. Apart from the native Scots pine, it is the conifer species with the longest record of use for timber production in Scotland, particularly in Perthshire, Dumfries-shire and the Moray Firth area. Its timber is strong and naturally durable and has been used for a variety of external applications such as cladding, fencing, boat-building and some post-and-beam construction. Fine long stems from older trees attract particularly high values for demanding applications. European larch is primarily a species for the more fertile and freely-drained site types. The Japanese larch (*Larix kaempferi*) was introduced in 1861 and has been used on more upland sites with infertile, often less well-drained soils, together with Sitka spruce and lodgepole pine. It grows better than European larch on those sites but usually has inferior timber. Japanese larch is susceptible at present to lethal *Phytophthora ramorum* infection and cannot be recommended for widespread planting until that risk is better understood. A hybrid between the two larch species (known as "hybrid" or "Dunkeld" larch) (*Larix x marschlinsii*) developed when they were planted together on the Atholl estate in Perthshire. Hybrid larch of reliable provenance produces similar timber to the European larch, and usually grows faster. Predicted climate change and strong timber demand may see wider use of larches in Scotland.

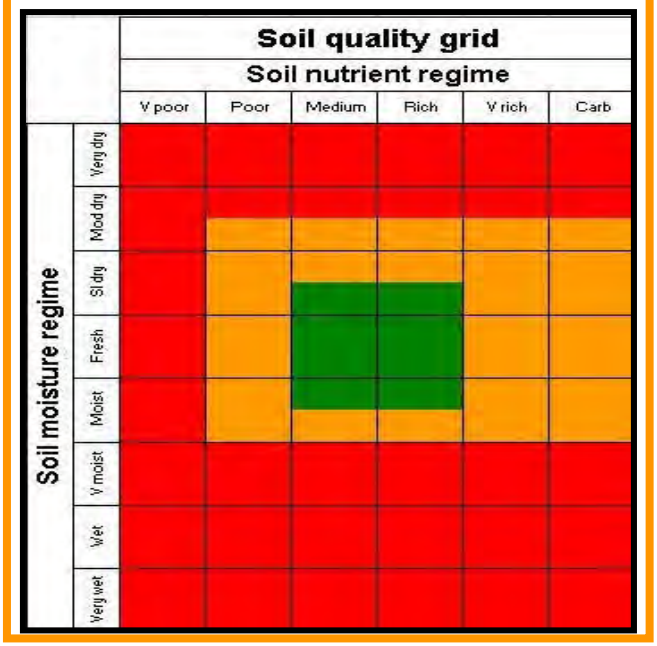


Premier stands of European larch in Scotland - Shambellie and Cawdor Estates, FCS Duror Forest

Existing resource **-** European and hybrid larches have been widely planted in many parts of Scotland and there is a significant standing resource by comparison with most of the alternative conifer species considered in this guide. The National Inventory of Woodlands and Trees records some 13,500 ha of hybrid larch and 8,500 ha of European larch. There is some 4,500 ha of pre-1940 material for the two species combined, the majority here being of European larch. As larch tends to be a longer-rotation species for high-value applications (typically 70-90+ years), this older stock represents the major premium timber resource. A small proportion of it is of very high quality, suitable for boat-building, but much of the remainder would be suitable for intermediate applications such as cladding and beamwork. Much of the best older larch is on the private estates such as Darnaway, Cawdor, Atholl, Novar, Bowhill, Drumlanrig and Shambellie that have a long record of growing it. The Forestry Commission have also grown larch in areas such as Aberdeenshire and Perthshire. Stands of European larch on exposed sites at high elevations are often much poorer. From the 1950's onwards, hybrid larch has tended to replace European larch for new plantings - in the 1990's the rate of planting was ten times greater for hybrid larch than for European. Some younger p1950-1970 larch of both species has now begun to be sold for fencing and cladding.







Site suitability - the diagrams opposite refer to European larch. Hybrid larch can use poorer, wetter sites, reflecting the genetic influence of the Japanese parent. High quality crops of either species can best be grown on sites with relatively sheltered climates and brown earth soils. Use of exposed or infertile sites will often imply poor growth rates and stem form. Current larch growing areas such as Perthshire, Angus, Aberdeenshire, Moray and Dumfries-shire are likely to remain suitable under climate change and there may well be expansion of optimal growing conditions within these areas. Larch may expand at the expense of spruce on some drier south-east facing slopes but will suffer on very dry sites. Sheltered lower and upper mid-slopes are the best sites, together with the slope foot where soils remain well-drained. Waterlogged soils are unsuitable. ESC SMR should be Slightly Dry-Moist, ideally with Poor-Rich ESC SNR. Both species suffer from spring frosts and butt-rot is an issue on old conifer sites. Larch bark beetle can occur in Scotland.

Provenance - getting the right provenance is essential to producing a good crop of larch, as inappropriate choice may lead to poor form and a high risk of canker. For the European larch, home-collected seed from one of 14 Registered Seed Stands (8 of these in Scotland) is the best option. There are many other stands potentially suitable for registration. There also five qualified seed orchards. If seed is being sought from the native range, Czech and Slovak material (including the famous Sudeten larch) should be used. High alpine sources have a higher risk of canker and are unsuitable. Obtaining good planting stock of hybrid larch is a long-standing problem that has restricted use of this species. Although there are two Registered Seed Stands in Scotland, seedling material from these should not be used, as only a proportion will breed true as hybrid larch. Planting stock should be sourced from controlled pollination or vegetative propagation programmes undertaken by the nurseries.

Establishment and early tending **-** as a light-demanding pioneer species, even-aged larch crops can be planted onto open land as long as exposure is moderate. Pure stands and mixtures with spruce, Douglas fir and hardwoods work well. Mixtures with shade species such as hemlock and grand fir can also be operated as larch makes more rapid early growth, but later thinning is critical. In mixture it is essential to ensure that larch does not suppress slower species. Planting density should be at ~2,000 stems/ ha, for good quality larch crops. Palatability to deer is average for the conifers and standard protection is required. Rapid early growth will allow escape from weed competition other than on over-fertile, lush sites. Low branches die early but may not self-prune and some brashing is beneficial to reduce the number of small occluded knots in timber. Respacing and early line thinning are especially important in larch. Natural regeneration will occur in larch stands only with careful thinning and bare mineral soil, as vegetation competition may suppress it.

Regeneration of larch in south-west Scotland - planting on cultivated restock site and natural regeneration under larch-grand fir mixture

Early thinning of promising young larch stands

Silviculture **-** the typical rotation for good timber larch will be 70-90 years. In mixed stands, the spruce element may have come out earlier but Scots pine, Douglas fir and hardwoods go on to full rotation with larch. Larch is not the heaviest yielding of species and GYC is 4-16 (typically 8-12). Some very fine larch is produced in mixed irregular stands, producing widely-spaced trophy stems on a "plum pudding" basis. Side shelter appears to be beneficial. In regular larch stands, thinning must begin early and be regular and frequent to keep the crowns and quality stems expanding. The aim is to produce long clean logs of 40-70cm+ dbh. Sudden heavy regeneration thinnings in the late rotation are ill-advised as they may cause the timber to split through wind-sway on more exposed sites and there is likely to be a flush of competitive weeds that will impede natural regeneration in any case. If natural regeneration does not come, underplanting with Douglas fir or western red cedar may be considered, using residual top shelter.

Presentation of boatskin larch logs for sale at roadside - FCS Duror Forest, Appin, Argyll - later utilised for local heritage boatbuilding

Processing - larch is sawn by the full range of processor scales. Large industrial mills at the regional scale can often saw larch for fencing, even where their main business is spruce carcassing. This has been noticeable in recent years with the decline in volume house-building. Larch for small-beam construction and volume cladding are the province of small industrial processors specialising in these products at the regional scale, although a good deal of larch cladding and decking is being sawn by the independent and mobile millers as a side-line to their quality local hardwood trade. Some architects operate mobile mills and will saw larch for small decorative beams and cladding for bespoke building projects. Some larch for smaller-size boat-building is sawn by independent processors or the boatbuilders themselves. Large-section marine beam and premier boatskin larch are the business of a few long-established specialist mills in or near traditional ports. They will buy by private treaty and fell and extract pole-length larch timber themselves.

Marketing - as compared with Douglas fir, size does not matter quite as much with larch, but stem quality is essential. Felling should be careful and if in doubt, motor-manual methods should be preferred. Good larch crops can be degraded by stem splitting if under-sized harvesters are used. Small-diameter roundwood of larch will normally be sold for industrial woodfuel rather than for pulp and particle-board. Log material from mid-rotation thinnings are typically sold to regional fencing mills, although the better material is now being taken for cladding, especially in Scotland. As the crop matures, the range of markets expands to include premium cladding, small-section beams and boat-building, for which the buyers and markets are usually local or regional (e.g. West Highlands). Very high quality larch can be used for premium boat-building, including boatskin, and heavy-section beams for premium construction and ships' timbers. This is a small, specialist and high-value market sector with expert national buyers.

Premium larch for marine beamworks - extraction (JB Timber Ltd) and as sawn into long-length beams (Gilmour & Aitken Ltd)

Private Estates in Perthshire - European larch began to be grown in Scotland in the late 1600's, initially on private estates in Perthshire, including Atholl and Breadalbane. The discovery of the hybrid larch took place around 1900 on the Atholl Estate at Dunkeld. Many sites in this area have now seen several generation of even-aged larch crops. The sheltered valleys of the Rivers Tay, Tummel and Garry, with reasonably fertile brown earth soils derived from the Dalradian metamorphic rocks, provide optimal growing conditions. Timber was traditionally grown for boat-building on the east coast of Scotland, but is now more often processed more locally for fencing, cladding and other timber construction. In many cases owners are now seeking to manage their larch under non-clearfell systems for amenity. Some of the best stands of larch within Perthshire can be found in the following areas:-

- Atholl Estate - some famous larch stands on the Atholl Estates were felled during the last war, but fine material remains, particularly to the north of Dunkeld (NO 005460). These stands are on free-draining grass and bracken slopes and typically have GYC=10. Within the grounds of Dunkeld House can be found the "parent populations" of European larch (planted in the 1700's) and Japanese larch (planted in the 1800's) that gave rise to the first naturally-arising hybrid or Dunkeld larch around the turn of the twentieth century.
- Murthly Estate - also well known for good quality larch, especially on the north bank of the Tay (NO 055400) on bracken-covered river terraces (p1920, GYC=10)

Fine stands of even-aged larch in Highland Perthshire - Murthly and Atholl Estates

Private Estates in Dumfries-shire - another of the long-established European-larch growing areas of Scotland is Dumfries-shire, with the relatively mild, sheltered climate of Nithsdale, Annandale and the Solway Firth lowlands. Some of the key examples are:-

- Drumlanrig Estate - particularly important as one of the best Scottish examples of the growing of larch under mixed-species selection forestry systems. Some of the best stands are on sheltered brown-earth slopes around NX 877987 and NX 878983, over grass, fern and bracken vegetation. Smaller stems are marketed for the more general fencing, cladding, decking and small beam markets, whereas premium stems from selection stands are sold to specialist boatskin and construction beam markets on Humberside and Clydeside. It is intended by the estate to restock largely by natural regeneration.
- Shambellie Estate - this estate has a record of productive forestry using pine and larch since the late 1700's but the current well-thinned stands of premium European larch date from 1911, established on a sheltered south-facing brown-earth bracken slope (NX 958666). GYC as measured in Permanent Sample Plots has been 10-12, typical for good larch. In places these stands are in mixture with mature Douglas fir of similar quality. No larch has been sold in recent years but it would be of premium grades/ high log value.
- Castlemilk Estate - grows quality larch on shorter rotations, restocking by planting.

Private Estates on the Moray Firth **-** there is a long record of growing high-quality European larch on private estates on both sides of the Moray Firth. This goes back at least to Victorian times and most likely to the late 1700's/ early 1800's. By contrast with the previous two regions, the larch sites here are generally coastal lowlands that experience quite a warm dry climate and have freely-drained sandy soils of poor-medium fertility. Larch has traditonally been grown in even-aged pure stands or in mixtures with Scots pine. Key examples are:-

- Cawdor Estate - has some of the best larch growing in this region at present, including four Registered Seed Stands. The oldest larch is found in mixture with oak and beech in the Cawdor Old Wood (NH 841484) dating from 1843, with very fine material planted in the 1930's in Budgate Wood immediately to the east (NH 839490), which has been partly underplanted with western hemlock more recently. There is also fine larch (p1890) on the south-facing slopes at Drynachan Lodge in the Findhorn Valley (NH 865399).

- Darnaway Estate - have traditionally grown European larch, Scots pine and oak, with Douglas fir used increasingly in more recent plantations. Much of the best larch is in the woodlands along the west side of the River Findhorn at Dounduff and Conicavel. Although the percentage of larch had been declining, the decision has been taken to use it to restock some clearfell sites recently due to the high timber prices now obtainable.

- Novar Estate - on the north side of the Moray Firth has grown fine larch in the past, often underplanting later with more sensitive conifers such as western red cedar, Lawson cypress and western hemlock. Much premium larch was windblown in the 1953 gale.

Good stands of FC larch in Scotland - European larch (Trossachs), Hybrid larch (Kincardineshire)

Public forests **-** the Forestry Commission have used larch in Scottish plantations since their establishment in 1919. Due to the more upland nature of their acquisition portfolio, use of Japanese larch and, to a lesser extent, hybrid larch, has tended to predominate. However they also have some fine stands of pre-war European larch on the more sheltered sites. Certain parts of Scotland have seen particular use of European and hybrid larch by the Commission:-

- Aberdeenshire and Kincardineshire - especially in some of the lower lying woods such as Leschangie Hill (NJ 744146) and Aquhythie (NJ 738183) both near Kemnay, where European and hybrid larches respectively planted in the 1920-30's have GYC = 10.
- Great Glen - good crops of European larch were established in the early 1930's in Port Clair Forest (Fort Augustus) and in Duror Forest, Appin (NN 004551), in both cases on steep mid-slopes with brown-earth soils, from which fine timber has been harvested.
- Perthshire and the Trossachs - particularly at the "Achray Face" above Aberfoyle (NN 530015) where even-aged p1938 (GYC =10) European larch is being converted to non-clearfell systems, but also within Drummond Hill and Craigvinean Forests in Perthshire.

Scotlarch cladding (Russwood of Newtonmore) - trials of alternative finishes at the sawmill and as installed on NTS Culloden Battlefield Centre

Boat-building - as well as being durable, larch is also a strong, heavy timber (500-600 kg/m^3) that has traditionally been used for boat-building, substituting for oak, cedar and tropical hardwoods. On large sailing-ships and fishing vessels, larch was mainly used for the "skin" of the ship (strong, flexible planks) and old European larch with good stem form and clear timber was valued as "boatskin larch". On smaller wooden boats, larch could also be used for the beams and cruck-framing of the hull. Although construction of larger vessels from larch (e.g. fishing vessels on the Buchan coast) has declined in recent decades, there remains an active sector for the repair of these and the construction of smaller boats, including reconstruction of historic boat types (e.g. Gaelic birlinns). Larch of suitable quality is still sought by the surviving traditional boatskin mills (e.g. JB Timber on Humberside and Gilmour & Aitken on Clydeside) but is also processed by small independent/ mobile millers for heritage boat-builders on the Scottish coast.

Cladding systems - the largest Scottish application of larch timber is for cladding. This takes advantage of the good natural durability of this species. Traditionally slow-grown Siberian larch was used for much of the cladding installed in Scotland, but more recently, good Scottish material has become much more widely accepted. Valuable new research on larch cladding systems has been undertaken at the Centre for Timber Engineering (Edinburgh Napier University). Larch cladding is produced in Scotland by a range of processors, including Russwood of Newtonmore (marketed as *Scotlarch*) and by many small independent sawmillers using mobile equipment. The product is installed on a wide spectrum of building types, including major high-profile projects (such as FC/ SNH office buildings, National Trust for Scotland visitor centres), individual bespoke and rural social housing projects (by architects such as Gaia and Neil Sutherland of Inverness) and smaller builds of community centres, village halls, sports pavilions and sheds across Scotland.

Traditional larch boatbuilding - Viking Boats, Ullapool (above), Macduff Shipyards (below)

Section beamwork and fencing- "standard grade larch", including much of the hybrid larch brought to market is used for short-run beamwork, fencing, decking and garden shed construction. Some of this material may be treated for added durability, as in traditonal larch-lap fencing, which was creosoted in service. The major industrial sawmillers such as James Jones and BSW/ Howies are able to process large volumes of this type of larch timber, sourced within their own regions of Scotland. Many of these fast-throughput mills switch between sawing spruce for carcassing and pine and larch for dimension-stock fencing. This means that they will only accept larch of similar dimensions to their standard spruce specification (usually 30-50cm dbh). This provides a suitable market for late rotation thinnings from premier larch stands and final crops from more average stands. Some mills (notably James Jones at Kirriemuir) are able to accept larger-section larch logs (>60cm dbh) for production of short beams for decorative construction applications.

Dimension-sawn construction stock of larch at James Jones & Sons (Kirriemuir) above and Russwood (Newtonmore) below

Larch gridshell roof - Savill Building, Windsor

Engineered timber systems - an alternative way to use the high volumes of smaller-dimension larch logs is through "engineered timber systems" which joint together a number of small "battens" of larch to form larger structural elements for construction. This takes advantage of the inherently high strength of the larch timber, while offering cost savings over use of large-dimension premium beam stocks of Douglas fir or oak. The wave-form gridshell roofing system recently installed at the Savill Garden Visitor Centre (Windsor Great Park) by InWood Developments Ltd and Green Oak Carpentry Co. was manufactured by finger and scarf jointing of small larch battens sawn by English Woodlands Timber Ltd. from regular post-war larch plantations on the Windsor Forest (Crown Estates). Other engineered timber systems such as glue-lamination and cross-lamination have the potential to use large volumes of second-grade larch from Scottish plantations, allowing these to be properly thinned whilst yielding affordable durable building timber.

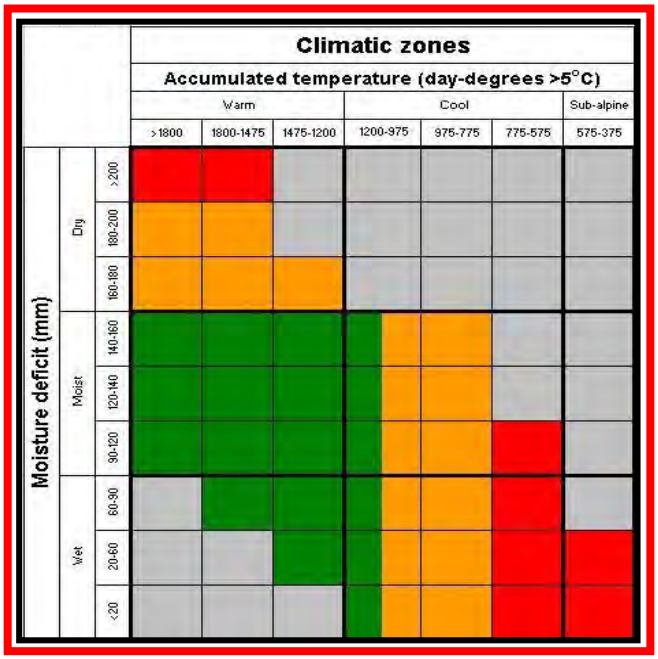
Western red cedar

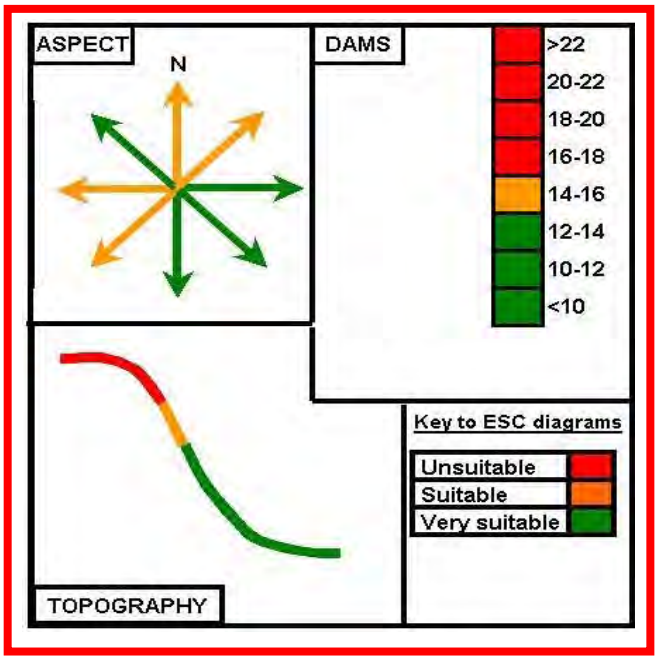
Potential for use in Scotland

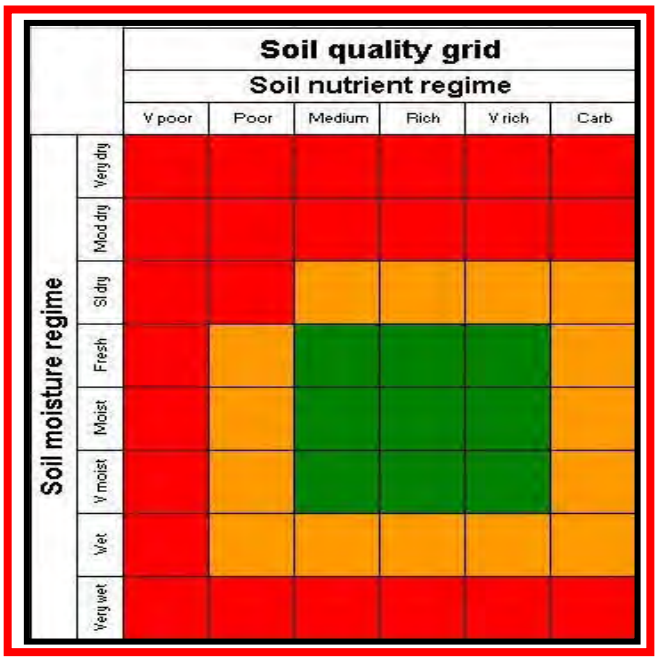
Record and potential **-** western red cedar (*Thuja plicata*) is an established, valuable timber species from the coastal forests of the Pacific Northwest, with the native range stretching from Alaska to California. It grows naturally together with Sitka spruce, Douglas fir, western hemlock, grand fir, Lawson cypress and coast redwood in different parts of its range, rarely forming pure stands. It is one of the longest-lived Pacific conifers, often reaching 900-1000 years. Its timber, although of low density, is highly durable, cleaves easily and was valued for boarding and cladding, roof shingles and boat-building in the American west. It was introduced to Britain in 1852 by William Lobb. Although trialed in private arboreta and forest gardens, it was never widely adopted for plantation forestry in Scotland. There were a number of small-scale plantings on private and Forestry Commission ground between 1870 and 1940, but there has been a tendency to regard the species as being too tender for widespread use in Scotland. There was continued small-scale planting after the war, including trials on peat sites. Red cedar has been planted much more extensively in SW England and Wales, where a small-scale industry, processing its timber for durable applications, has developed. It has considerable potential for expansion into Scotland under climate-change, producing a durable and attractive timber. However its processing is likely to remain a more specialist activity.

Fine stands of western red cedar - Kyloe Estate; Forest of Dean (p1916), Monaughty Forest (p1928)

Existing resource- the National Inventory of Woodlands and Trees recorded some 40ha of western red cedar in Scotland, most of that being of post-war date. However this misses a small number of older plantations on private estates (1870-1910) and Forestry Commission sites (1920-1940) that better demonstrate the potential of this species in Scotland, when grown on suitable sites. These include good stands at Darnaway Estate and the FC Monaughty Forest in Morayshire with several locations along the Great Glen (Craig Phadraig and Port Clair Forests) and Argyll (Lochgoilhead, Benmore and recently felled at Inverliever). Western red cedar has also been very successfully grown for over 100 years at the Kyloe Estate in Northumberland, just over the Border. Further south there are more extensive mature plantings - in Wales (notably at FC Gwydyr and Dyfi-Corris Forests) and in SW England (notably in the Forest of Dean and the private Dunster, Tavistock, Longleat and Stourhead Estates). While only very small amounts of home-grown timber have come onto the market in Scotland, larger volumes have been processed for cladding, boarding, fencing, glass-house framing, beehives etc in England, especially in recent years. With a small standing resource, any good regular material of >30cm dbh brought to market attracts interest, but until the recent advent of woodfuel demand, small bars were very difficult to sell.







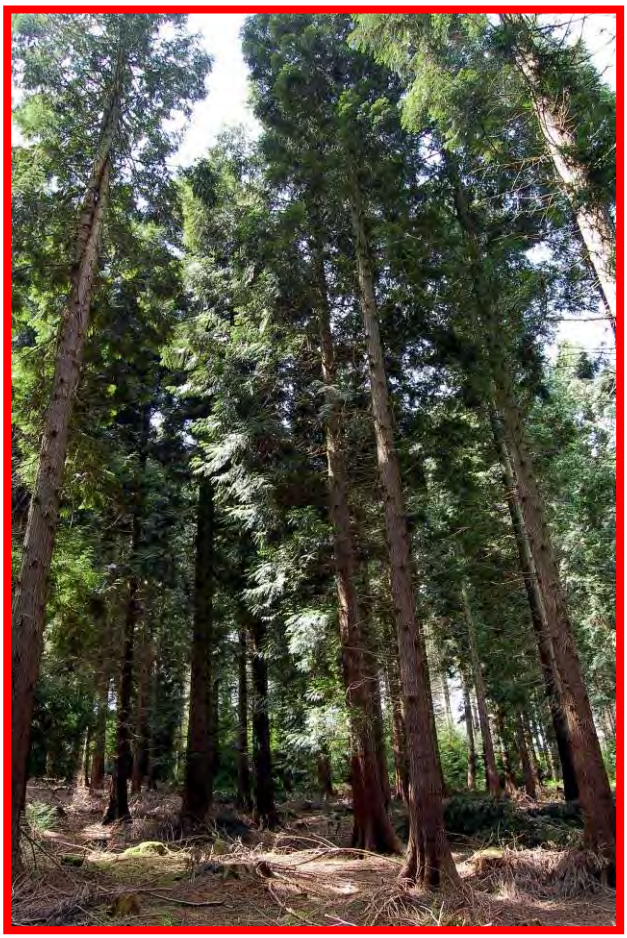
Site suitability - the limited experience to date with western red cedar in Scotland confirms that it is suitable for the warm moist climates of Galloway, Argyll, Lochaber and Wester Ross. Optimum sites are wind-sheltered and frost-free, with moist but freely-draining soils of moderate to high fertility. However western red cedar also appears to have the ability to operate well under less favourable conditions - notably the drier climates and poorer, freely-draining soils of eastern Scotland (for example the Laigh of Moray) and eastern England (for example at Thetford). There is also evidence that it will use poorly-drained gley and peat sites, as long as these are not heathery or very infertile. Growth will be less rapid on these more difficult sites, but western red cedar offers an option for a range of site conditions unsuitable for many other trees. Exposed sites above 200m are not suitable. There is known susceptibility to butt-rot/ bottle-stems and also to honey fungal decay. Frost tolerance is, at best, moderate.

Provenance- very limited study of provenance variation in western red cedar has been undertaken in Britain, and this species should be seen as a priority for future work of this kind. Imported seed origins from the coastal Washington (e.g. Olympic Mountain) and Vancouver Island (e.g. Ladysmith) areas of the native range should prove suitable. Interior origins from Montana, Idaho and inland British Columbia are best avoided for Scotland, but may have a role in south-east England. Home-collected material should be very suitable - there are three Registered Seed Stands (one in Scotland at Darnaway and two in western England). Other Scottish stands at Monaughty and Lochgoilhead could be registered in future. Nurseries currently handle limited western red cedar and contract-growing is likely to be required. Fungal disease can be a problem when raising nursery stock of this species. Western red cedar naturally regenerates well in western Britain, and this is the major method of restocking at present in SW English and Welsh growing areas.

Natural regeneration of western red cedar - initiation (above) and respacing stage (below)

Establishment and early tending - the best conditions for establishing western red cedar are within existing woodland, where it benefits from early shelter. Where there is a seed source, there is very likely to be prolific natural regeneration. Otherwise enrichment planting under open-canopy mature woodlands of other species is often a successful approach. Planting of red cedar onto open ground is only sensible on sheltered valley sites - planting onto exposed sites is unwise. Some very successful pure stands have been established in the past, but equally, red cedar can be established in even-aged mixture with productive conifers or hardwoods. Mixtures with Douglas fir and oak are particularly successful. Deer palatability is less than for *Abies* firs, for example, but greater than for Sitka spruce. Effective protection remains essential. Weed control is important, despite the seedlings of western red cedar being very shade-tolerant. Dense regeneration should be respaced to avoid "beanpole" material.

Silviculture - when grown on the correct sites, western red cedar is a high yielding species, with GYC of 12-26, typically 16-20. Due to the very high shade-tolerance, thinning must be sufficiently heavy to regulate basal area and allocate increment to a suitable number of good final crop trees. This applies both in pure stands and in selection mixtures with Douglas fir etc. Markets favour material of 30-60cm dbh, with little added value for larger-section logs >60cm. Hence target diameter felling on a "regular offtake" basis is usually optimal. As with Lawson cypress, there can be a delayed reaction to thinning, giving stands a temporary feel of understocking. Some of the best material is produced on those estates with a long record of mixed-species irregular silviculture. However very poor markets for small roundwood in the past have too often deterred adequate early thinning, giving rise to a high proportion of over-stocked stands that may not reach the valuable sizes. Better woodfuel demand should reduce that problem in the future.



Western red cedar - progressive thinning work

Marketing - in the past it was hard to sell small-roundwood of western red cedar as it was too dark for mechanical pulping and there was no chemical pulp mill in Britain. It is also not favoured for particle-board due to its stringy bark. Recent increased demand for industrial woodfuel should provide a better outlet for early thinnings to the regional markets. In many parts of England and Wales it is possible to sell log material of 30-60cm dbh to local small-industrial processors producing cladding, fencing, shed-boards, glass-house framing, beehives and other external carpentry products where natural durability is most sought after. Reasonable prices (e.g. £40-50/ m^3) are paid at auction for good, regular material. In Scotland, these markets are less well-developed and the small amounts of good material presented tend to be sold to mobile millers or self-sawn. Old trees can display a marked "bottle bottom", although this is not always indicative of butt-rot in red cedar. Larger-diameter material with sound heartwood is accepted, even if irregular.

Stacking and machine edge-profiling of tongue-and-groove red cedar cladding boards, Rawnsley Woodland Products, Cornwall

Yarding and mobile-sawmilling of 30-40cm dbh western red cedar logs for cladding

Processing - processing of western red cedar is almost all for light boarding and cladding stock, deployed for fencing, shed-building, cladding, bee-hives etc. A small amount of small-section post and beam material is also sawn, mainly for bespoke traditional glass-house framing. Heartwood is favoured due to its higher natural durability - this means that the rotation length should ideally be 70-90+ years. Experienced sawmillers can "saw around" central cavities in older material to make use of the durable heartwood. Some fresher home-grown material is treated as it is believed to be less durable than imports. Only a very small quantity of sawn roof shingles are produced from home-grown stock - this is the most demanding application and old-growth imported timber is often favoured. The scale of operation varies from small-industrial to independent and mobile mills. The latter dominate in Scotland. In England, the market for cedar cladding is expanding and some medium-scale processors have recently emerged.

Scotland - good mature stands of western red cedar can be found on a number of private estates and Forestry Commission holdings in Scotland. Examples include:-

- Darnaway Estate, Moray (NH 993506) - planted on a level, acid brown soil site in 1914, this is one of the finest stands in Scotland, with good natural regeneration.
- FCS Monaughty Forest, Moray (NJ 158586) - a good stand, although confined and somewhat under-thinned, on a dry, south-facing lower slope (planted 1928, GYC = 18)
- Murthly Estate, Perthshire (NO 050397) - a narrow stand, established 1940, on rich, level valley-bottom ground at the foot of Birnam Wood. Some mortality becoming evident.
- FCS Benmore Forest, Cowal (NS 144855) - the oldest stand (as opposed to individual) in Scotland (p 1870) on a sheltered slope-foot near the Benmore Garden (GYC=8)
- FCS Lochgoilhead, Cowal (NN 202027) - planted in 1921 on a sheltered slope-foot site with good brown soil, might have benefited from heavier rotational thinning (GYC=18)
- FCS Craig Phadraig, Inverness (NH 643463) - planted in 1929 on a steep, rather exposed, north-facing slope. Good form but rather underthinned during the rotation (GYC=14)

There are also stands of western red cedar in the Crarae, Kilmun and Lael forest gardens.

Mature stands of western red cedar in Scotland - Murthly Estate and FCS Lochgoilhead (p1921)

England and Wales - there is a more established record of productive silviculture of western red cedar in various parts of England and Wales. Notable examples include:-

- FCE Forest of Dean - there are a number of good stands of western red cedar, but especially the Permanent Sample Plot at Little Drybrook. This fine stand is on the lower slopes of a very sheltered small valley and was established in 1916 (GYC=24). Contains a small proportion of elite Douglas fir, known to have been planted in after 10-15 years.
- FCW Gwydyr and Dyfi-Corris Forests - early plots of western red cedar in the FC plantations of Snowdonia (p1928-35) show the excellent potential of western red cedar for sheltered valley sites in the warm wet conditions of west Wales. There has been a tendency for under-thinning in some cases. Recently natural regeneration has initiated. Timber has been used locally for cladding and roof shingles in a new forest visitor centre.
- Dunster, Stourhead, Tavistock and Duchy of Cornwall Estates - these private estates in south-west England have grown red cedar over a considerable number of years, often in mixture with western hemlock and Douglas fir. The flow of timber has helped to develop a regional cladding sector with both small-scale industrial and self processing activity.
- Kyloe and Fulmodeston Estates - private estates in Northumberland and Norfolk that grow western red cedar under selection forestry systems for beehive manufacture.

Local use of rustic western red cedar cladding in Highland Scotland - an alternative to larch

Local processing in Scotland - as little Scottish-grown timber of western red cedar has come onto the market to date, the local processing sector has not developed as far as that in SW England and Wales. In the past there has been weak communication between growers and potential processors of this alternative timber. The recent FCS niche marketing project in Argyll and Lochaber has highlighted a latent demand for the material for local house-cladding, shed-building and boat-building projects. In many cases western red cedar is now seen as an attractive, usually somewhat less expensive, alternative to the use of larch for these applications where the colour is an added attraction. Processing is almost exclusively with mobile sawmills (although in many cases at fixed locations). Ongoing development of expertise and facility in Scottish processing is required to produce a consistent product and finish. Good logs of regular profile are keenly sought after, as these allow home-grown red cedar to compete with imports for premier cladding.

Cladding, beehives and glasshouses - in England and Wales there are longer-established markets for western red cedar logs that can absorb most of the regular material of 30-60cm coming to market. With limited planting in recent years, the processors depending on supplies from pre-war estate and FC plantings may encounter future shortages. Cladding and fencing stock is produced by both estate sawmills (often using mobile equipment) and the small-scale industrial processors (e.g. Rawnsley Woodland Products, Cornwall; Minehead Sawmills, Somerset). Some material is treated for added durability. Glass-housing framing is another high value-added application, where home-grown material now competes with Canadian imports (e.g. Woodpecker Joinery, Staffs). Western red cedar is also used for the manufacture of traditional flat-pack beehives (e.g. WH Thorne, Lincs), having been pre-sawn by industrial mills (e.g. Job Earnshaws, Lincs). Trial sawing of home-grown roof shingles is a recent trend.

Other ways to use durable western red cedar timber - above - bespoke glasshouse framing (BBC/ Woodpecker Joinery); left - traditional beehive manufacture (W.H. Thorne) below- canoe building (Bear Mountain Boats, Ca)

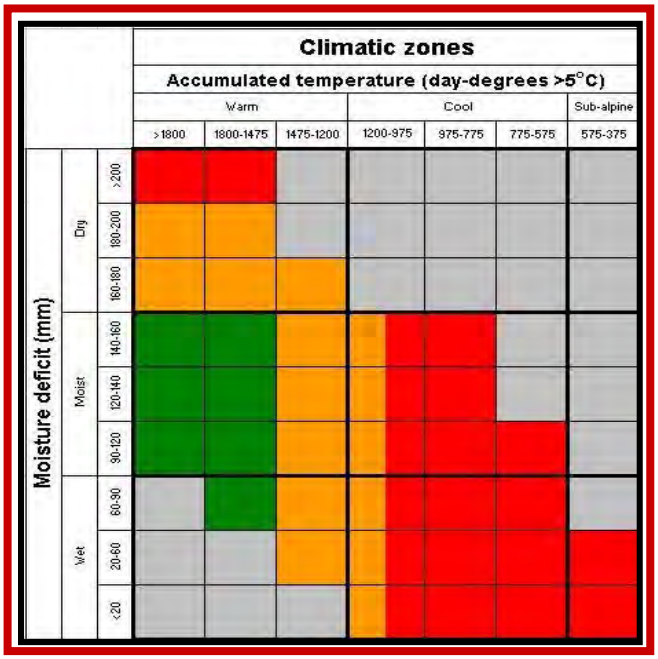
Sequoia redwoods

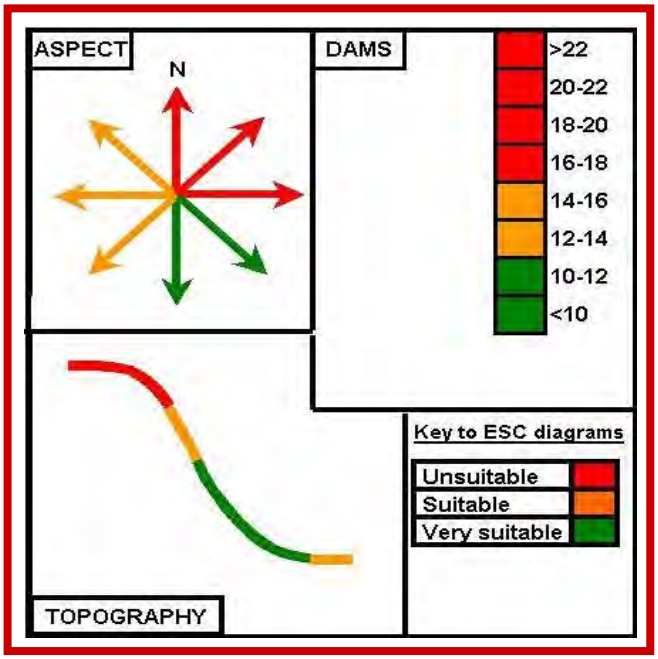
Potential for use in Scotland

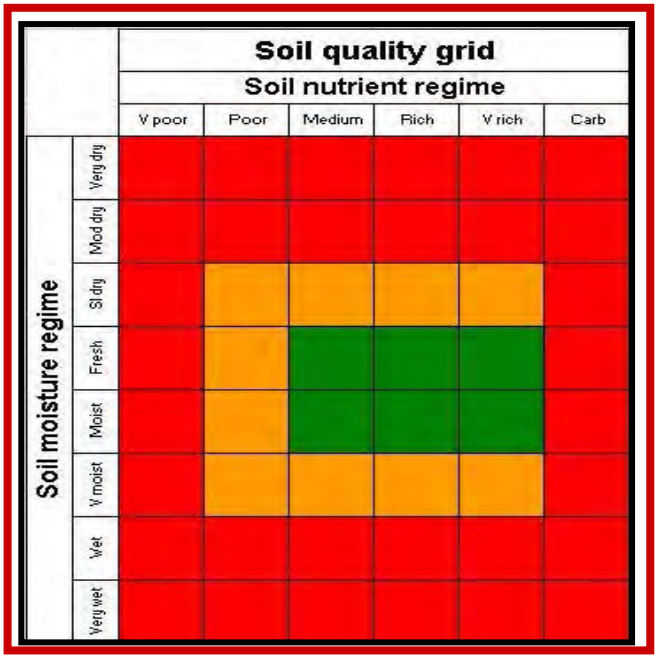
Record and potential **-** the two *Sequoia* redwood species have native ranges in California and Oregon (for coast redwood). Both were major early producers of valuable, highly durable construction timber in the American west. The giant sequoia (*Sequoiadendron giganteum*) or Wellingtonia is a light-demanding species that grows in forests with an open structure at high elevations in the Sierra Nevada mountains of inland California, which experience hot dry summers and cold, snowy winters. It was introduced to Britain during the 1850's and has been extensively planted as an arboretum, avenue and specimen tree on major private estates (e.g. Scone, Murthly, Drumlanrig and Benmore). It has proved fairly hardy across Scotland. There are few plantation stands of this species in Britain and it has never been viewed as a significant potential source of timber here. The coast redwood (*Sequoia sempervirens*) is a much more shade tolerant species that grows in dense stands or "groves" in the mild, moist climate of the California and Oregon coasts. It has been used in arboreta and landscape plantings, since its introduction in the 1840's, but it has also been established in a number of notable plantations in milder parts of SW England and Wales, producing small volumes of a good quality timber that is suitable for outdoor decorative carpentry uses. It is more frost sensitive than the Wellingtonia and may only be suitable for growth in milder areas of Britain.

Fine examples of the Wellingtonia in Scotland- Drumlanrig, House of Dun and Brodick Castle Estates

Existing resource- the vast majority of the standing resource of *Sequoia* species in Scotland is actually of the Wellingtonia. The National Inventory of Woodlands and Trees data is not reliable for this species, which usually occurs in very small stands or narrow avenue features. Almost all of the standing material will date from the period 1850-1900 when the species was particularly fashionable with major private landowners. The largest stand is probably that at Drumlanrig Estate, but there are very fine avenues at Benmore, Murthly, Castle Kennedy, House of Dun and elsewhere. As a number of these old open-grown trees have been felled on safety grounds or wind-blown, there is a slow but steady flow of large-section timber, much of which is used for decorative or display purposes (e.g. chainsaw carving). The trial plot of this species at the FC Kilmun Forest Garden (p1961) is unimpressive, with GYC of 12. By contrast the nearby plot of coast redwood (p1954) has a GYC of 22 and shows the productive potential of that species for the mild moist conditions of Argyll, Lochaber and Wester Ross. There is a similarly impressive stand within the National Trust for Scotland Crarae Forest Garden. Very little coast redwood timber has been processed to date in Scotland, but small amounts from famous stands at Leighton in Wales, the Forest of Dean and the Huntley, Longleat and Dartington Hall estates in England have been used for decorative carpentry.







Site suitability - the diagrams opposite refer to the coast redwood which should be the focus for future timber production. This is a fairly sensitive tree species and should only be considered for use on very well sheltered sites with a mild, moist climate. Fog can supply some of the moisture demand. At present these conditions are found mainly in south-west Scotland and Argyll, but may well expand in some other regions with predicted climate change. Frost, exposure or serious drought are likely to prove damaging. Coast redwood needs a freely draining, but not drought prone, soil and will not tolerate peat or water-logging. It is not especially demanding of soil fertility - the ESC Poor, Medium and Rich SNR classes are very suitable. Wellingtonia can be planted to replace existing specimens and takes drier soils.

Provenance- for the coast redwood, seed would need to be obtained from the native range, preferably from alluvial flats in the northern part of that range, which are thought to produce hardier stock with milder timber than do the dry southern origins. Seed viability can be very low and nursery stock very prone to frost damage, so use of vegetative propagation could be a valuable approach for wider planting. That would allow the fine English and Welsh stands to act as sources. Coast redwood stands can also be regenerated by coppice. *Wellingtonia* seed will all come from the native range. Both species require contract-growing.

Silvics- there is British experience now, especially from the RFS stands at Leighton in Wales. Young crops need shelter by mature hardwoods or spaced conifers, but must be well weeded as close interference with the plant by ground vegetation is problematic. Likely to be very palatable to deer. Volume production is very high and regular selective thinning is beneficial to keep the final crop stems expanding well. Thinnings of >30cm dbh are in demand but large clean logs >60cm dbh more so.

Marketing and processing

Marketing- *Sequoia* redwood timber is inherently very valuable with good natural durability and attractive colour. However it cannot be sold to mainstream sawmills which are generally not equipped to make the best of it. Some growers with very high quality material may choose to include it in timber auctions, most often as an "honorary hardwood". Most will however process it themselves on-site or develop a relationship with a local artisan sawmiller or craftsman who seeks it for a specific use. Thinning material of ~30-40cm from coast redwood is probably best for cladding and decorative boarding, whereas final crop trees will find premium markets for street furniture, garden/ landscape features and sculpture. This type of market is best served by a steady, predictable flow of material of known dimension and quality, rather than by a sudden peak of supply that may not be able to be absorbed. Production of redwood timber from selection forestry systems as at Drumlanrig, Kyloe and Longleat Estates is therefore probably the better way forward.

Premium coast redwood logs, Longleat Estate

Coast redwood plot (p1954), Kilmun Arboretum

Processing- traditionally redwood timber in North America was sawn into posts, beams and wide boards for building construction. This was a major, industrial-scale activity until concerns over conservation of the redwood groves of California achieved high profile in the early 20th century. Early harvest was of natural first-growth material, whereas, more recently, second-growth material has been the mainstay. Limited amounts of *Sequoia* redwood timber reaching the market in Britain at the present time are processed by small sawmillers using either fixed or mobile equipment. Morgan (2008) provides an excellent review of his experience with this timber. Durability may vary more than in old-growth material and careful seasoning and sawing are required. Some material is sawn for cladding in south-west England, where it is interchangeable with western red cedar. Another noted use is for luxury "skelf-free" marine and marina decking, where it substitutes for tropical hardwoods. Most is used for decorative carpentry or carvings.

Demonstration stands- the following locations demonstrate the potential of the two *Sequoia* redwood species growing in northern and western Britain:-

Wellingtonia - Drumlanrig Estate, Dumfries-shire (NS 866008); Benmore Botanic Gardens, Cowal (NS 141855); Scone Arboretum, Perth (NO 118265); House of Dun, Angus (NO 670600); Kyloe Estate, Northumberland. These are mostly old stands of Victorian/ Edwardian material in landscaped grounds, avenues and arboreta on good sites. Yield data are generally not available or meaningful. The stand at Kyloe is a productive mixture with Douglas fir.

Coast redwood - the main stands in Scotland are at the FC Kilmun Forest Garden, Cowal (NS 164823) and the National Trust for Scotland Crarae Forest Garden, Argyll (no access). The Kilmun stand (p1954) has been highly productive with a GYC of 22. The best stands in Britain are the RFS grove at Leighton near Welshpool, in the Forest of Dean and on the private Huntley Estate (Gloucs), Longleat Estate (Wilts) and Dartington Hall Estate (Devon).

Utilisation examples - some recent examples of the processing of both Wellingtonia and coast redwood timbers in Britain include (see illustrations clockwise above):-

- interior beams and panelling for the new Royal Forestry Society chalet at Leighton in Wales, sawn locally from thinnings of their famous coast redwood grove. The chalet received a larch cladding and roof shingles made from Welsh-grown western red cedar.
- decorative garden sculpture and "wet decking" for a Chelsea show garden in 2008, designed by Thomas Hoblyn, sponsored by the Foreign & Colonial Investment Trust. Timber was sawn by Honeysuckle Bottom sawmill in Surrey from an old windblown tree.
- local artist's chainsaw carving of giant redwood timber from the Drumlanrig Estate to produce an outdoor sculpture of a hand for a new college campus in Dumfries.
- sawing of coast redwood timber from the Duchy of Cornwall estates for cladding/ boarding by Rawnsley Woodland Products (Cornwall).

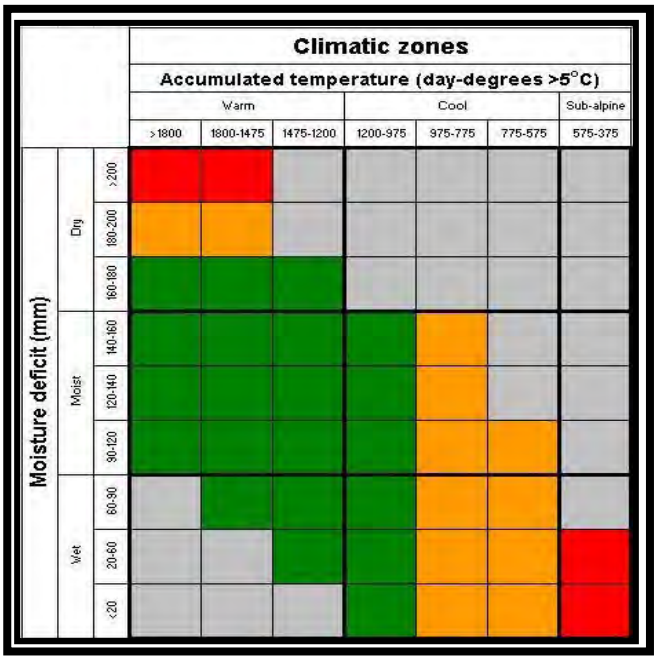
Western hemlock

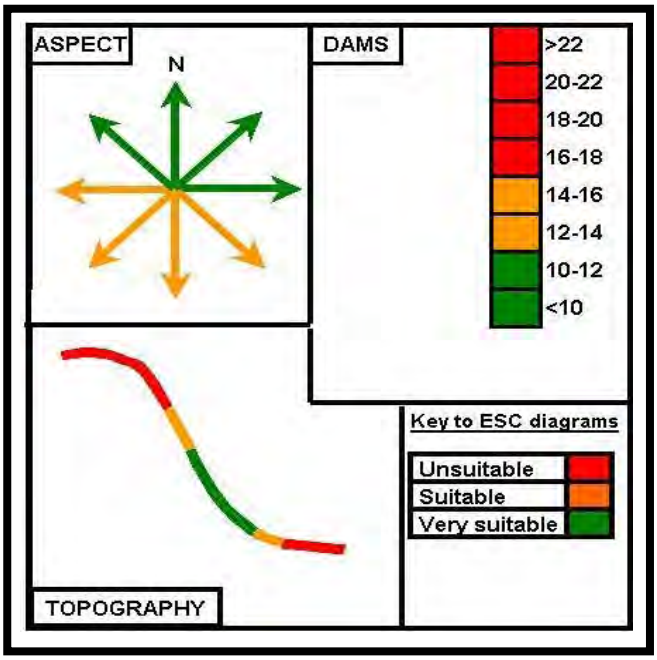
Potential for use in Scotland

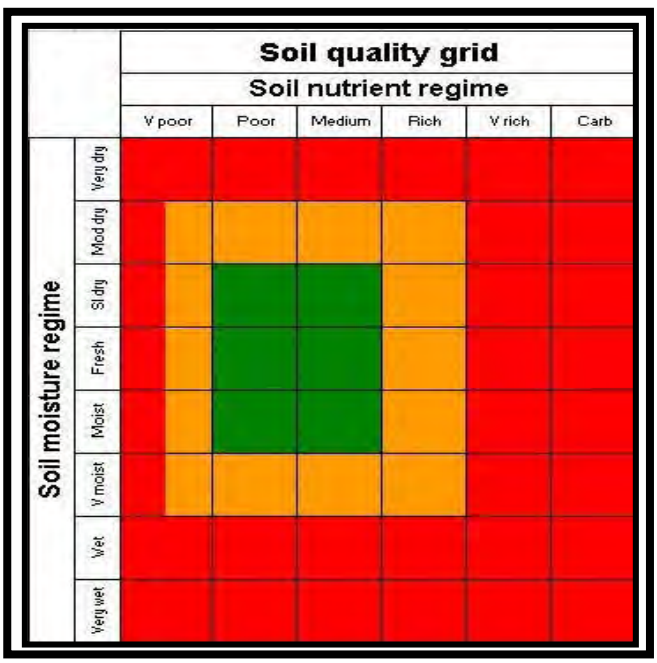
Record and potential **-** western hemlock (*Tsuga heterophylla*) is a highly shade-tolerant conifer, native to the coastal regions of Alaska, British Columbia, Washington and Oregon, where it grows in association with Sitka spruce, grand fir, Douglas fir and western red cedar. It was introduced to Scotland during the 1850's by Jeffrey for the Oregon Association. Although grown successfully in some private arboreta, it did not attract early interest for wider plantation forestry. It was regarded as being site-sensitive and difficult to establish, and its timber was less valued than alternative American species such as Douglas fir. Western hemlock was later planted on a number of Scottish private estates, especially Inveraray, Drumlanrig and Novar, and on some FC forests such as Clashindarroch, Laurieston, Monaughty and Port Clair Forests in Scotland and at Dyfi-Corris and Gwydyr Forests in north Wales. In fact, western hemlock can be grown successfully on a fairly wide range of site types and produces a timber, which although not especially durable, has good strength and working properties for general indoor and outdoor construction, joinery timber and rustic weather-boarding. However most British stands have been poorly tended and thinned, giving the species an undeservedly bad reputation at the sawmill. Its strong powers of natural regeneration make it ideal for use in continuous-cover forestry, but also pose serious challenges for silvicultural practice and the conservation of adjoining native woodland sites.

Fine mature stands of western hemlock - Novar and Drumlanrig Estate; Gwydyr Forest (FC Wales)

Existing resource **-** the National Inventory of Woodlands and Trees recorded ~1500ha of western hemlock in Scotland. There was a fairly even age-distribution between p1920 and p1990. It is likely that a major proportion of the older material has been harvested over recent years, especially where western hemlock had been planted in or near ancient/ native woodland where its regeneration would be unwelcome on conservation grounds. A proportion of surviving stands are of poorly thinned mid-rotation "beanpole" material that will attract little market value for timber. These stands are also associated with high incidence of stem fluting, included bark and butt-rot. Little western hemlock has been planted in recent years due to conservation concerns and the unfavourable reputation of its timber. Among the species considered in this publication, western hemlock has the largest discrepancy between its poor acceptance and low valuation by sawmillers (£20-30/ m^3) and its inherent timber potential. In North America it is accepted as a good general construction timber, not as strong as Douglas fir or as durable as western red cedar, but superior in strength to the *Abies* firs. There are a small number of superior, properly tended stands, especially in south-west Scotland, in Argyll and at Novar Estate in Easter Ross, which demonstrate its true Scottish potential. The yield of western hemlock varies with site, but GYC is 12-24, very often 14-16.







Site suitability - the key to success with western hemlock is to use it only on suitable sites. It is capable of survival and growth on a wider range of site types, but for the production of good timber it should be restricted to the more sheltered lower and mid-slope sites, together with its natural associates Douglas fir and western red cedar. Exposed sites should be avoided, also those with a high risk of late frosts (e.g. valley bottom hollows). It will tolerate a range of rainfall regimes but will do best with >1000mm. An ESC-SMR of Slightly Dry to Moist is required. However, as with Norway spruce, in the eastern lowland areas with less than 900mm of rainfall, it needs to be restricted to those soils with a higher water capacity, such as moist loamy clays. ESC- SNR is best to be between Poor and Medium. Heathery sites and over-rich sites are not optimal. Western hemlock is highly susceptible to butt-rot on old conifer sites unless prior stump treatment has been thorough.

Provenance **-** the other key to success is to get good planting stock. There has been limited provenance research on hemlock, and further investigation of genetic influences on timber quality/ degrades would be beneficial. Origins with a record of stem fluting must be avoided. There is currently only one UK Registered Seed Stand of western hemlock, at Laurieston (SW Scotland). This is of British Columbia origin and would be a suitable seed source for fresh plantings, although dense natural hemlock regeneration within the stand would make seed collection logistically difficult. There are a few other fine stands in SW Scotland, Argyll, North Wales and around the Moray Firth that could be suitable for seed stand registration. In the native range, seed sources from the British Columbian seaboard, including Vancouver Island, are most suitable for Scottish conditions. In practice, most establishment of western hemlock is currently by natural regeneration and that may remain so.

Novar Estate - natural regeneration of western hemlock by group felling (~ 6 year interval)

Silviculture **-** hemlock can be managed in pure or mixed even-aged stands and in mixed species selection forestry. Thinning regimes must be regular and fairly intensive to keep the species under control, remove defective stems and produce a crop of the target diameter. Hemlock is sometimes managed as an understorey crop to clean Douglas fir or western red cedar stems, being removed as small-diameter thinnings for woodfuel or fencing material during the rotation. For a final crop, the aim is to produce pole-length stems, without fluting or other defects, that will be marketable at better prices for sawing into wide boards or rustic beams. During the rotation, a flow of bar material (15-30cm) can be abstracted by thinning, feeding local fencing, ship-lap and similar markets. Advance regeneration, which can be very dense, may have to be respaced (or at least line racked) to allow continued access to thin the upper storeys. In selection stands hemlock should be kept in check and not allowed to crowd out less competitive trees (e.g. larch, Douglas fir).

Establishment and early tending **-** western hemlock is a late-successional species and should not be planted onto exposed sites. It can be established as an even-aged crop by restocking coupe-fellings where there will be close side-shelter or by planting under a mature conifer stand such as Douglas fir, larch or spruce. This should only be done after careful consideration, as hemlock is likely to become a permanent component due to its very strong natural regeneration capacity. Hemlock should not be planted in or near any ancient or native woodland but can be valuably combined with beech. Any planting done should be at 2,000-2,500 stems/ha to allow for later selection against stem defects, and needs to be very well protected from deer. Mixtures with species such as grand fir, western red cedar, Douglas fir, Sitka spruce or even larch are possible. On poor sites, plants may start slowly but release after canopy closure. In established forests where already present, hemlock will naturally regenerate at very high density, without any need for planting.

Well-thinned western hemlock (Dunster Estate)

Marketing **-** hemlock is more difficult to sell in Britain due to traditional bias against it by sawmills. Small-diameter roundwood is not always accepted for pulp and particle board due to its colour (slightly stronger than spruce), but does now meet demands for woodfuel. Dense natural regeneration cleared from the understorey at below 7cm dbh should be sold for biomass fuel whereas material 7-15cm dbh would be sent to chip and pellet plants. In England, bar material of 15-30cm dbh is accepted by generalist sawmills for treated fencing stock, but in Scotland those often prefer pine and larch. Self-processing may be a better option. Small amounts of large-section timber of western hemlock coming on to the market appear to attract a better demand for processing by independent/ mobile mills. Applications include landscape sleepers, joinery panels, rustic beams, doors and coffin boards. Good contacts in the trade are essential to sell such material. Rotation for hemlock is similar to, or longer than, spruce, with premier material at 70-90yrs.

Western hemlock stem grown under selection forestry with potential as a structural beam

Quality western hemlock poles at roadside

Processing - although in many ways a strong timber (density ~ 500 kg/m^3), there is currently relatively restricted large-scale commercial processing activity in Scotland. Small-diameter material is acceptable as woodfuel, and some better quality bar and medium log material is taken by the major fencing and carcassing mills, often as a minor component of mixed parcels, along with pine, spruce and Douglas fir. At present Scotland lacks the generalist local mills, producing treated fencing and shed boarding that are found in areas such as the New Forest, Forest of Dean and SW England, which commonly accept western hemlock. Those Scottish growers with a large supply of hemlock material of these dimensions might find self-processing a viable choice, if they can find local outlets - for example mountain-biking and other boardwalks. Availability of local treatment facilities can be an obstacle where that is required by the end user. A niche market has developed for locally-sawn wide hemlock boards, panels and rustic beams.

Private estates **-** a number of private estates in Britain have used western hemlock as a significant element of their forestry. In some cases there has been a tendency for very strong natural regeneration which requires ongoing regulation to retain species diversity. Some good examples of productive western hemlock growing on private estates include:-

- Novar Estate, Easter Ross (NH 628696). Fine stands established around 1900 on a level sandy pozdol site at 90m asl (poss u/p to EL). Profuse natural regen. into felling coupes.
- Drumlanrig Estate, Dumfries-shire (NX 847996). Good stand established 1939 on a plateau site at 170m asl. Mixture with noble fir. Strong regeneration onto adjoining site.
- Kyloe Estate, Northumberland. Mature hemlock, on undulating ground at 170m asl, now a component of mixed CCF woodlands. Profuse regeneration requires regulation.
- Stourhead Western Estate, Wiltshire (ST 753335). Large diameter individual hemlock (late 1800's) in mixed-species irregular forestry (DF, SS, JL) over productive greensands.
- Tavistock Estate, Devon (SX 42x73x). Hemlock planted under Douglas fir (p1950-60) as part of the Bradford-Hutt silvicultural system over mining spoil above the Tamar valley.
- Weasenham Estate, Norfolk. Exceptional beam quality pruned hemlock stems in mixed-species selection conifer stands, planted 1905-07 onwards onto acid sandy podzols.

Demonstration plot of western hemlock (p1936), FC Clashindarroch Forest, Aberdeenshire

Public forests- the Forestry Commission have used western hemlock as an element of their plantings in the past, most successfully during the period 1920-40. These have often been under-thinned, which is a mistake with this species, leading to drawn-up "beanpole" stands. A number of the better stands have been felled over the past 20 years (e.g. Corris and Glen Urquhart), especially where the priority was to restore plantations on ancient woodland sites or to avert regeneration into ancient woodlands. Some of the best remaining locations are:-

- Laurieston Forest, Castle Douglas (NX 671670) - seed stand, planted 1941 onto east-facing brown-earth slopes (GYC = 22). Fine mature stems amid a sea of dense regen.
- Loch Eck, Kilmun and Ardentinny, Cowal (NS 137930, NS 164822, NS 184879, NS 169901) - fine stands planted in the early 1930's, some with NF. At Kilmun GYC = 16.
- Clashindarroch Forest, Aberdeenshire (NJ 507326) - one of a number of local trial plots, p1936 at 3,500 st/ha onto heather podzol, GYC =14. Under-thinned at 1350 st/ha today.
- Port Clair Forest, Fort Augustus (NH 395113) - survivors of famous p1932 plantings on steep east-facing slopes with peaty soils, quality stems, under-thinned due to road access.
- Gwydyr Forest, North Wales (SH 781569) - one of the very finest stands of hemlock in Britain, p1921 on very shelted south-facing colluvial slope, very well thinned (GYC=22)

Uses of western hemlock - treated landscape sleepers and mountain-bike Northshore boards

FC Scotland for local processing- western hemlock is a species that FC Scotland have found difficult to sell into their more usual industrial processing channels. In recent years, FCS initiatives have encouraged local species-specific marketing of the alternative conifers in the north and west Highlands. This has helped obtain better prices and foster development of the local independent wood-processing sector - one strand of sustainable rural development. Sales have been arranged by tender/ auction either from roadside or from sorting yards by means of "log-shop" events. There has been a surprising level of interest in large-section logs of western hemlock from local carpenters and craftsmen. Clean timber can be used to produce wide boards for internal joinery use, having an attractive colour and grain while much less expensive (typically £25-40/ m3) than equivalent dimensions of Douglas fir or larch. Outdoor carpentry work such as garden retaining sleepers and mountain bike "Northshore" tracks can also use western hemlock timber where a need for frequent replacement is accepted.

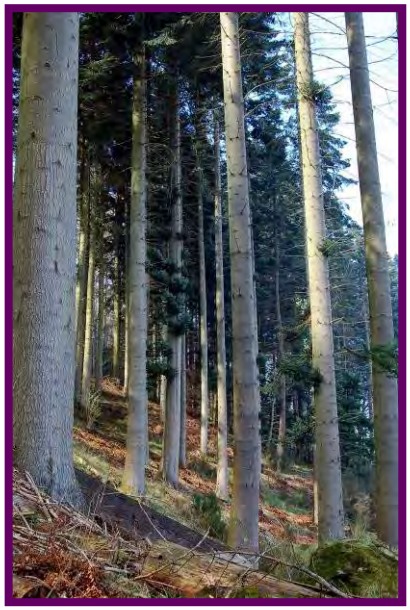
Private estates with identified markets - Scottish growers of western hemlock have concentrated on supplying local pallet and box-making markets. A former market for sapling poles for aluminium smelting has declined but may be replaced by growing demands for biomass. Further south, private estates with significant resources of western hemlock have sought alternative outlets. Many supply local sawmills that produce treated fencing and ship-lap boards from standard hemlock logs - effectively acting as a "poor man's larch". This is the route taken by Tavistock and Dunster estates. Those estates with very old, large section hemlock (Stourhead Western) or high grade long stems (Weasenham) have been able to attract interest from specialist sawmillers (e.g. East Bros of Salisbury, F.A. Aldridge of Norfolk) for more rustic beamwork - effectively acting as a "poor man's Douglas fir". As yet it remains difficult to get British hemlock timber mechanically stress-graded. Wide boards for doors and coffins are also a potentially valuable outlet for big hemlock.

Uses of western hemlock - treated ship-lap weather boarding and rustic post and beam

Grand fir

Potential for use in Scotland

Record and potential **-** the grand fir (*Abies grandis*) is a highly productive shade-tolerant conifer, native to the Coastal and Cascade Mountains of Washington and Oregon and some parts of British Columbia. It was brought to Britain in 1831, with wider introductions through the 1850's by Jeffrey and by Lobb for Veitch's nursery at Exeter. It was grown in many early private arboreta, such as those at Scone and Murthly. It proved capable of very rapid growth on the more sheltered low-ground sites, but is more vulnerable to exposure than noble fir. Grand fir was later planted out on a number of Scottish private estates, especially Inveraray Castle, Buccleuch and Novar, but also on early FC purchases such as Clashindarroch, Craigvinean, Monaughty and Port Clair Forests in Scotland and similarly at Dyfi-Corris and Gwydyr Forests in north Wales. The timber is a whitewood, lighter and weaker than those of Norway spruce, Douglas fir or European silver fir. While accepted for carcassing and interior joinery uses in America, grand fir from even-aged stands has largely been restricted to the lower grade markets in Britain, mainly due to its brittleness on sudden loading and incidence of "drought-crack". It may be possible to use more slow grown material from selection stands for large-sections and false beams. The main interest in Scotland is likely to be for mixtures with Sitka spruce, Douglas fir, western hemlock and red cedar on better valley sites.



Premier stands of grand fir in north Scotland - Clashindarroch, Monaughty and Craigvinean Forests

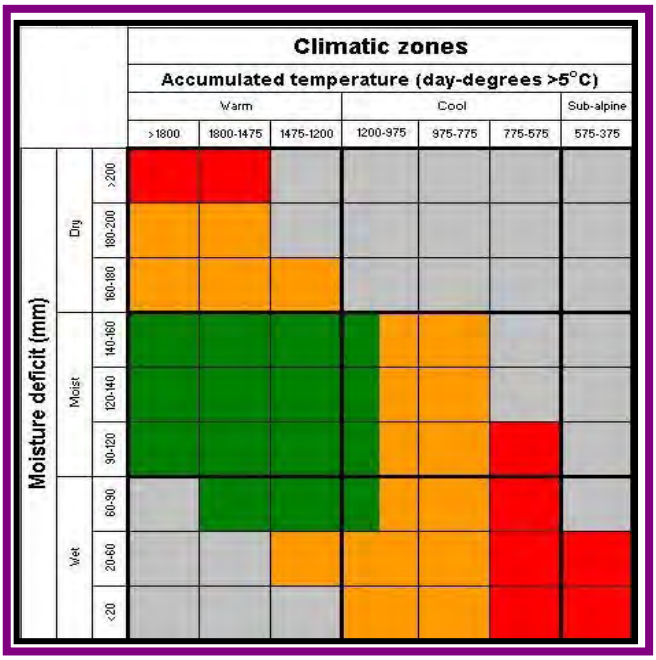
Existing resource **-** the National Inventory of Woodland and Trees records ~1000ha of grand fir in Scotland, with almost all being younger material from the period 1950-1990. Aldhous & Low (1974) recorded ~150ha of standing material on both public and private forests, having been established before 1950, with some of the finest stands retained to the present time. The existing resource in Scotland can essentially be divided into three major elements:-

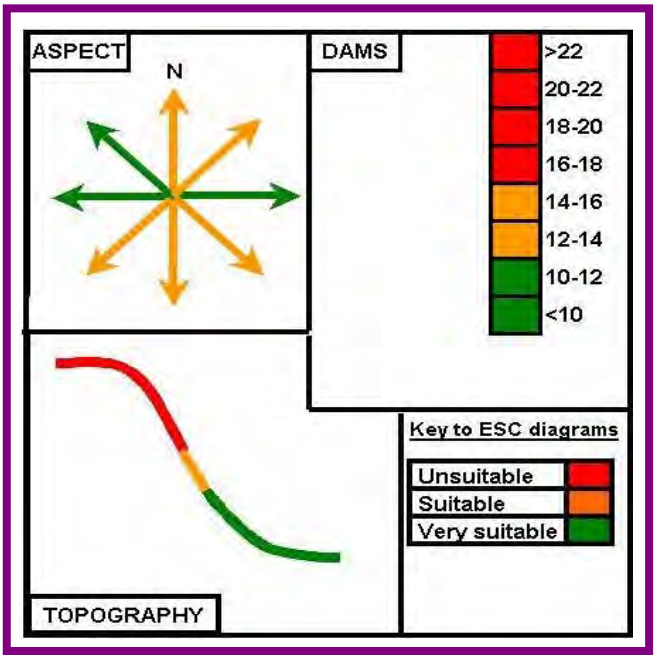
(a) pre-1920 plantings on private estates and arboreta where the species was favoured by owners and their forestry advisers - e.g. Scone, Murthly, Inveraray, Novar, Drumlanrig.

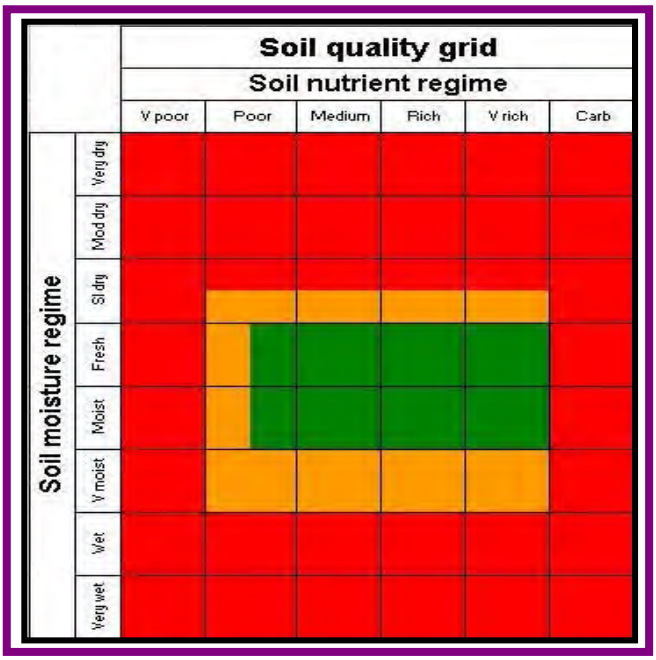
(b) good p1920-1960 mature even-aged plantations in several parts of the country - particularly on some of the older FC acquisitions such as Monaughty, Clashindarroch, Laurieston and notably at Craigvinean in Perthshire, where the GYC achieved was 36.

(c) younger plantations, on a variety of sites on both public and private forests. Due to its high shade-tolerance (though less than hemlock and the silver firs), grand fir has often been under-planted into stands of pine, larch, Douglas fir and spruce, forming productive mixed stands that may be managed in the future under selection forestry systems.

Grand fir is seen as a very high yielding species, with GYC 8-34, typically 14, often 20-30.







Site suitability - grand fir is a species that should be used on the more sheltered sites of the valley bottom and lower-slopes. It is intolerant of exposure, frost and snow. As a result, it will generally be used at lower elevations, certainly than noble fir and in most cases than Pacific silver fir. On some site types it is interchangeable with European silver fir, but will produce a greater yield, albeit of a lighter timber. It will tolerate many British climates, but in districts with much less 1000mm rainfall, drought crack is a noted risk on soils than do not hold moisture. Soil moisture is the most important issue - this must be sufficient to supply the tree and avoid cracking in the early season. Optimum conditions are Fresh to Very Moist ESC-SMR at the slope foot, but avoiding heavy clays. Some very good stands, especially mixtures with Norway spruce, can be found on the alluvial flats. Although visually fine stands are certainly found over sandy podzols in dry eastern areas (e.g. Monaughty/ Laigh of Moray), these carry a higher risk of drought cracking. Grand fir is not very demanding of soil fertility and will operate well on Poor to Rich ESC-SNR sites. Heathery and peaty sites are better avoided. Resistance to disease is generally strong in grand fir.

Provenance - some research work has been undertaken on provenance variation in grand fir as regards its performance in Britain (as reported by Samuel, 1996). This has suggested, that, as with Douglas fir, the best provenances from the native range are those from coastal Washington (Zone I), such as Louella and Elwha. As with Douglas fir, some of the fine older plantation stands in Britain were planted with material sourced from coastal British Columbia/ Vancouver Island (Zone VII). This is more conservative on yield, but can produce very good stem form and might foster timber of higher density. There are three Registered Seed Stands (all in Scotland, two at Craigvinean), but there are a number of stands elsewhere (e.g. at Clashindarroch and Monaughty) that could be eligible.

Establishment and early tending- grand fir can be established in even-aged stands more readily than noble fir as it is more shade tolerant and will achieve better weed suppression at an earlier stage. It is also much less prone to a slow start than the other *Abies* firs, making it rather easier to establish in mixture with spruce, Douglas fir, western hemlock, western red cedar and Lawson cypress. Disease and pest problems are few, with the exception of deer which find grand fir very palatable and must be excluded/ controlled. Grand fir regenerates very strongly during the rotation, under its own shade, and will very often deliver satisfactory restocking at clear-fell, along with western hemlock, where present. Establishment should be at 2,000-2,500 stems/ ha when planted, and will often be far more when naturally regenerated. Young stands should be kept tight to discourage over-rapid early growth and low timber density. Pruning is easy and may be worthwhile to produce large section clears.

Natural regen of grand fir - clearfell, Windsor (above); by shelterwood, Hamsterley (below)

Grand fir stem grown under selection forestry with potential as a large-section baulk/ beam

Silviculture - grand fir has been well grown in both pure and mixed even-aged stands in Britain. Where pure, thinning needs to be moderate to heavy to maintain a "slow and steady" growth rate, avoiding excessive ring width and drought-cracking due to heavy moisture demand on the drier sites. In such a productive species it is also essential to remove enough of the increment in thinnings, producing a final crop of large-diameter stems. Neglected stands can become critically overstocked, brittle and wind-prone. Even-aged "two storey" mixtures with larch, spruce or Douglas fir can be very good where the necessary skills and attention are applied. Grand fir can also be very effective in selection forestry, where it is one of the few options that suit single species "constant offtake" harvesting on good sites. Selection mixtures with other shade-tolerant species such as western hemlock and western red cedar work well, mimicing the natural stand dynamics found in the Pacific North West. Those few estates having tried this approach generally find their grand fir timber is denser and more sought-after.

Marketing- grand fir gives a whitewood timber, but, at least as grown in Britain, rather lighter and weaker than spruce or pine. Marketing is tackled in four phases:-

- Foliage/ Christmas trees - much less significant than for noble fir. Can be sold to national buyers/ agents or to more local artisan craftsmen/ florists.
- Small roundwood - sale of thinnings up to 15cm dbh for woodfuel, pulp and particle board, usually to regional industrial plants or their timber buyers.
- Standard sawlogs - 20-60cm, currently mostly sold to local small-industrial sawyers for potato-boxes, pallets etc., but some fencing mills do accept grand fir for "run-of-the-mill" treated stocks.
- Outsize logs - >60cm especially where straight and clear of knots, can be sold as large-section "baulks" of clean soft timber for sacrificial uses, gardening and landscaping works. There is some acceptance for decorative/ rustic beams and rolled steel-joist boxing/ false beams where clear material is available.

Rotation is typically similar to the spruces.

Estate-grown grand fir logs - thinnings for fencing (above), >60cm for potato box (below)

Thinning of p1950's grand fir - Longleat Estate

Processing - small roundwood thinnings of grand fir will enter the same industrial processing markets as spruce, pine and Douglas fir of similar dimensions - namely woodfuel, pulp and particle board. The high volume production of grand fir suggests that it should be considered for rapid biomass production for woodfuel use, although moisture content can be high and calorific density low. In North America, although less sought-after than noble fir and western hemlock, grand fir sawlogs are widely accepted along with Pacific silver fir for lightly specified interior construction and joinery use. Some British sawmillers will accept it for standard-grade treated fencing stock - although of low natural durability it soaks up chemical preservative better than does Sitka spruce. Most material in the 20-60cm dbh range is used for potato box and pallet manufacture. Large dimension logs are a favoured wood for clean landscaping/ playground sleepers and there are now a few instances of grand fir being accepted for decorative false beams/ joist casings that do not carry loads.

North Scotland **-** in northern Scotland, grand fir has been used on a fairly localised basis and then mainly by the Forestry Commission in its pre-war plantings. Scottish Highland estates have used noble fir to a considerably greater extent due to its ability to grow on harder upland sites. The main locations where good crops of grand fir have been retained are:-

- Monaughty Forest, Moray (NJ 157585) - a long-term measurement plot planted in 1928 on a dry south-facing slope foot site (50m asl) with a podzol soil. Has produced a very fine stand with GYC = 21. Western hemlock, red cedar, Douglas fir were also tested here.
- Clashindarroch Forest, Aberdeenshire (NJ 489318, NJ 469401) - very fine stands planted 1936-38 and having GYC = 20-22. Both sites were fairly rich, moist brown earths at ~200m asl, Kirkney of special interest as the best Scottish alluvial valley floor stand.
- Port Clair Forest, Fort Augustus (NH 406132) - as with many other conifer species, the early plantings at Port Clair included trial areas of grand fir, planted 1934 on steep brown-earth slopes above Loch Ness (GYC = 20). Progressive felling has altered these woods.
- Craigvinean Forest, Perthshire (NN 995460, NO 003425) - stands planted in 1940 (with BC provenance) and 1950 (with Washington provenance), the former (now reduced in area) reported to have GYC =36, and certainly with exceptional girth, height and form.

The Murthly and Darnaway Estates have also used grand fir to an extent, more so at Murthly.

Mature FC stands of grand fir - Fearnoch Forest, Argyll and in mixed with larch at Laurieston Forest

South Scotland/ North England- across south Scotland and northern England, grand fir has often been used as a minority crop by both the Forestry Commission and private estates, especially as an attractive, elegant tree on the more prominent landscape sites. Examples:-

- FCS Laurieston Forest, Castle Douglas (NX 673666) - planted in 1955 on a moist, fairly fertile brown soil site at 60m asl beside Woodhall Loch. Has formed a very interesting and successful mixture with larch (GYC = 24). Good Norway spruce and hemlock nearby.
- FCE Hamsterley Forest, Co. Durham (NZ 069300) - a fine stand, originally planted 1935 on sheltered valley slope, well grown (GYC = 18) with abundant natural regeneration and forming a prominent landscape feature within this well-visited recreational forest.
- Bowhill Estate, Selkirk (NT 422279, NT 433275) - grand fir forming part of attractive mixed woodlands around Bowhill House (Buccleuch Estates). Pure stand on steep slope of Pernassie Hill and also within mixed CCF stands at “the Cants”.

Grand fir has also proved particularly suited to the warm, moist conditions of North Wales, and more suprisingly, on dry lowland estates such as Windsor and Weasenham (Norfolk).

Potato boxes and pallets - the major outlets for grand fir timber of standard log-sizes in Scotland at present are for pallet and potato-box manufacture. While not especially lucrative, these markets provide steady demand for light timber that is less suitable for structural or cladding uses. As pallets and potato-boxes need to be replaced frequently when worn, the lack of durability of the timber is less of an issue and the market is less cyclical than those depending on the volume housing market. In order for this form of timber utilisation to profit the grower, there should be a minimum need for transportation - ideally the mill should be within 20-50 miles. A very good example is offered by the two Buccleuch Estates at Bowhill and Drumlanrig which produce a flow of grand fir, noble fir and western hemlock logs which are sold to the local sawmill at Rammerscales, Dumfries [A.G. King Ltd.], who produce a range of packaging products from them. Such local partnership marketing and processing is ideal for lower value species like grand fir.

Packaging and handling products typically sawn from grand fir - potato boxes and pallets

Run-of-the mill dimension stock - treated grand fir landscape sleepers (above); mixed species sawn fencing posts, grand fir and others (below)

Landscape sleepers and fencing- larger dimension grand fir logs can be used for non load-bearing large-section products such as landscape sleepers and false beams (e.g. boxing in rolled steel joists). With the recent school building programme and associated landscaping works, clean timber-treated landscape sleepers have been sought for many situations where recycled railway sleepers are unsuitable on health grounds. A variety of sawmillers such as James Jones at Kirriemuir and Job Earnshaw at Wakefield produce these from grand fir, which has a clean, white appearance. Grand fir can also be used to produce treated "run-of-the-mill" fencing stock, along with western hemlock and pine. There is more acceptance of grand fir for this kind of application in southern England. Some sawmillers (e.g. FA Aldridge in Norfolk) will saw large-section grand fir beams for barn conversions and other situations where the span is short and load carried is limited. These uses require the best quality stems, such as those grown in mixed CCF stands.

Noble fir

Potential for use in Scotland

Record and potential **-** the noble fir (*Abies procera*) is an attractive and productive conifer, native to the upper slopes of the Cascade Mountains of Washington and Oregon and to smaller areas of the Coastal Range. It attracted attention by "plant hunters", including David Douglas, due to its unusual regular shape and silvery-blue foliage. It was introduced to Britain as early as 1831, with larger introductions through the 1850's for the Oregon Association and by Lobb for Veitch's nursery. It was grown in many early private arboreta, such as Scone and Balmoral. As it derived from higher elevations than other Pacific Northwest conifer introductions, it was adopted during the late 1800's and early 1900's by a number of private estates in the Scottish Highlands, including Balmoral, Ardverikie and by Stirling-Maxwell at Corrour. Some of the p1870's plantings survive at Ardverikie and are now naturally regenerating. It proved capable of productive growth on high, exposed sites with heavy snowfall and hard frosts. While never a major component of Forestry Commission plantings, noble fir did attract FC interest in the late 1920's and early 1930's, with pure stands established in early forests - for example Port Clair, Glen Urquhart, Ratagan, Glen Branter and Glen Finart Forests in Scotland and Gwydyr and Dyfi-Corris Forests in north Wales. The timber is a whitewood, lighter and weaker than that of Sitka spruce. While accepted for light beamwork, carcassing and interior joinery uses in America, noble fir has tended to be restricted to box-making, pallet, pannelling and dunnage in Britain, partly due to the incidence of "drought-crack" when the species is planted onto unsuitable sites. The main interest in Scotland is likely to be for diversification of plantations at higher elevations or the replacement of more exposed Sitka spruce stands in the event of any major disease outbreak.

Premier pre-war FC stands of noble fir - Gwydyr Forest (Wales) and Glen Urquhart (Scotland)

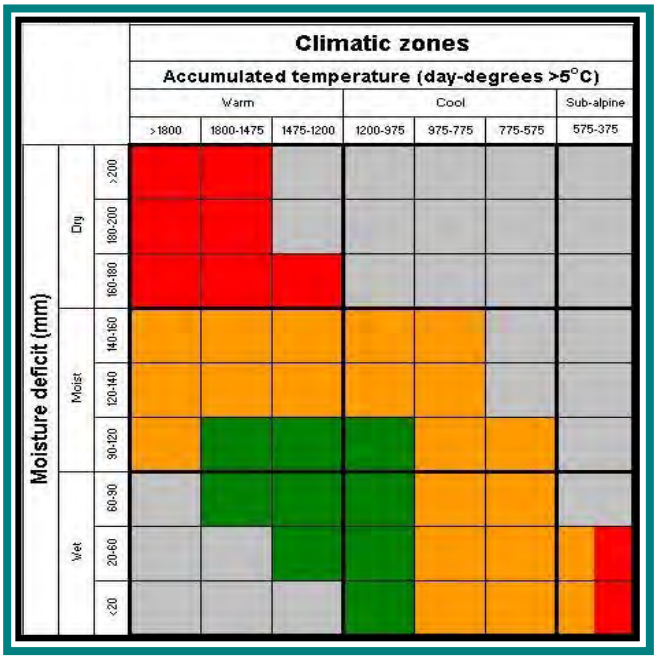
Existing resource **-** the National Inventory of Woodland and Trees records ~1400ha of noble fir in Scotland, with almost all being younger material from the period 1960-1990. Aldhous & Low (1974) recorded ~150ha of standing material on both public and private forests, having been established before 1950. ~30ha of this still survived by the mid-1990's. The standing resource in Scotland can essentially be divided into three major elements:-

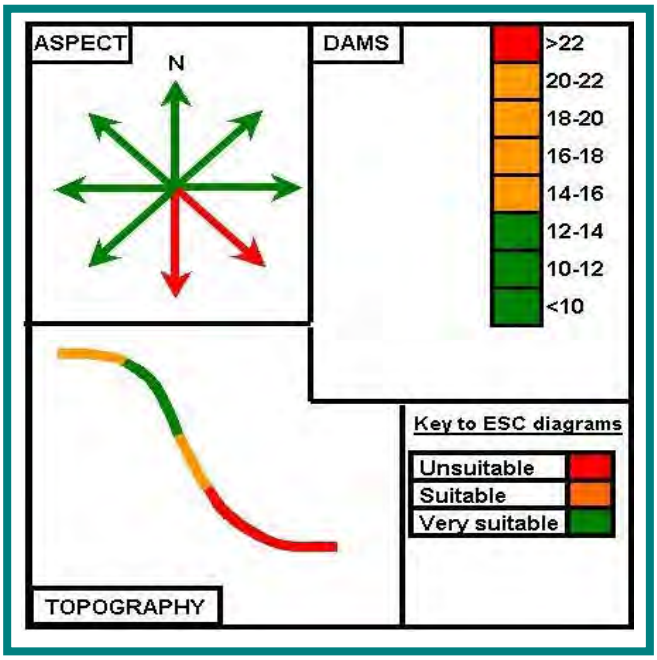
(a) pre-1920 plantings on private estates in the Highlands where the species was favoured by owners and their forestry advisers - e.g. Scone, Corrour, Balmoral and Ardverikie. The Ardverikie stands (p1870's) are the most ecologically mature in Scotland, with abundant natural regeneration coming through in mixture with grand fir and western hemlock.

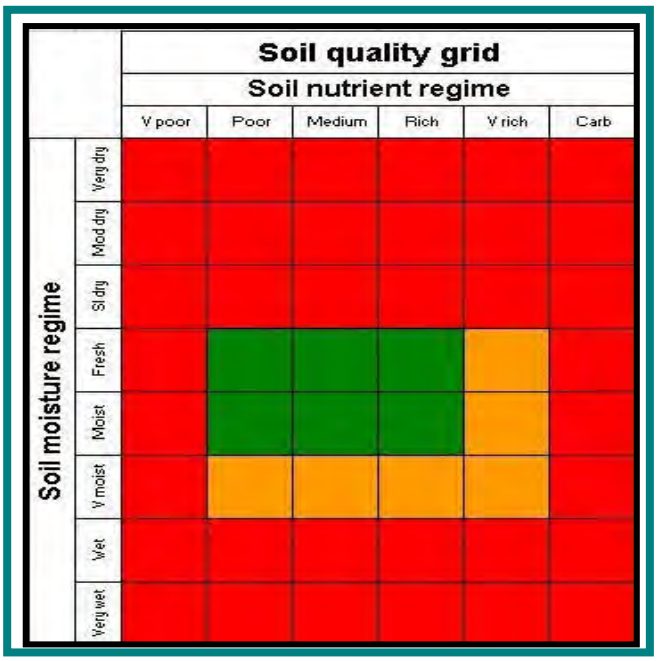
(b) good p1920-1960 mature even-aged plantations in several parts of the country - on private estates such as Drumlanrig and Glen Tanar and in some of the older FC plantations - for example, Glen Urquhart, Glen Branter, Port Clair, Glen Finart and Glen Nevis.

(c) younger plantations, mostly on poor upland sites, with some managed mainly for foliage harvest and as Christmas trees on a commercial basis on farms and private estates.

Noble fir is seen as a high yielding species, with GYC 8-34, typically 14, often 18-24.







Site suitability - noble fir is hardy and can be grown on high elevation sites with significant wind exposure and incidence of snow and frost. It is able to operate in the upper part of the Sitka spruce range in Scotland, unlike Douglas fir, grand fir and western red cedar. This is significant in the light of disease issues affecting other alternatives such as Japanese larch and lodgepole pine. Noble fir has a sturdy stem, avoiding wind deformation, and replaces a broken leader more easily than other conifers. Aspect needs to be selected to limit risk of climatic drought and the associated longitudinal cracking of the stem - south and south-east aspects are not advised. It is also unwise to use noble fir at lower elevations, where drought is more likely - the European silver or grand firs will be better choices for use in such areas. Optimum ESC-SMR is Fresh to Very Moist. Noble fir is not demanding in terms of soil fertility, but performs best with a Poor-Medium ESC-SNR. However it cannot be established easily in competition with heather. Pest resistance is usually good.

Provenance- there have been limited provenance studies of noble fir as regards performance in Britain. Collections from good British stands were preferred before the war and remain one possible option. Many fine (p1920-1940) plantations derive from home-collected seed from stands originally planted with seed imported 1830-1860. A number might themselves now make good seed stands, such as those in Gwydyr Forest (North Wales) and at Loch Eck, Glen Finart and Glen Urquhart in Scotland. There are six Registered Seed Stands in Britain, five in Wales with only one being in Scotland (Strathmashie), but all are younger stands (p1941-1964). Collections from sources in the native range are worth considering, particularly those from ~1000m elevation in the Washington/ Oregon Cascades, such as Larch Mountain, Oregon. Southern origins with introgression with the Shasta red fir (*Abies magnifica*) are better avoided for Scottish conditions.

Above - good natural regeneration of noble fir
Below- young crop suitable for foliage pruning

Establishment and early tending **-** noble fir can be established in even-aged stands on bare-land sites, although it sometimes makes a slow start compared with spruce and pine. Competiton from heather is a major cause of failure and adequate weed control for a sufficient period is essential. Deer palatability is high, as with the other *Abies* fir species, so protection is vital. Noble fir is best established at 2,000-2,500 stems/ha to limit the need for subsequent beating-up, which can be high. Noble fir will often naturally regenerate in Britain once stands reach 50-60 years old and reliably by 120-150 years. Some stands produce seed with low viability, possibly due to a narrow genetic base. Dense natural regeneration under a high canopy is less prone to deer browsing and weed competition than transplants. Noble fir is rather less shade-tolerant than grand fir, silver fir and western hemlock and, if mixed forestry is the aim, combination with Scots pine, European/ Hybrid larch and possibly Douglas fir may be a wiser choice.

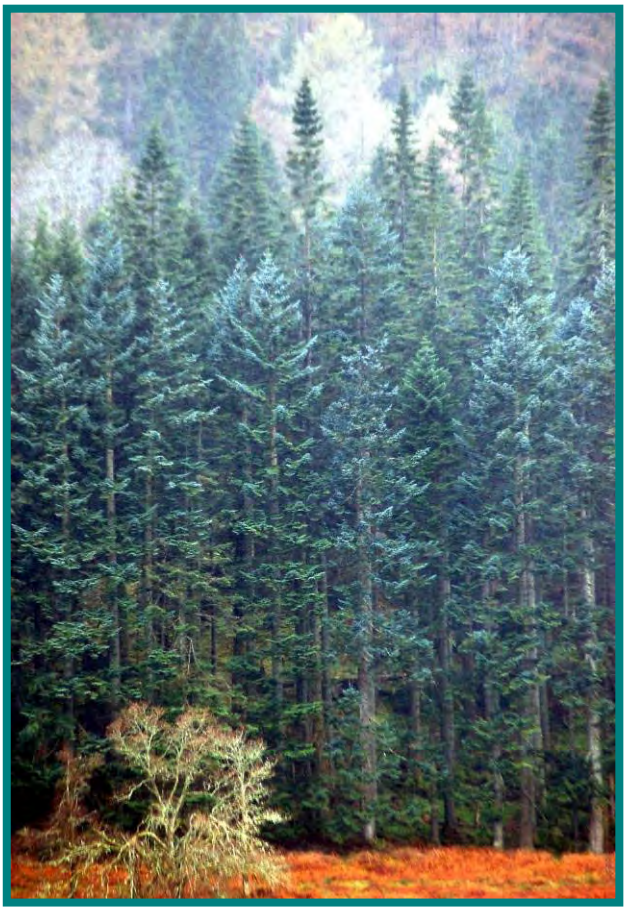
Silviculture **-** as with other alternative conifers that may not self-thin well, the key objective is to produce a sensible number of final crop trees of marketable dimensions. Over-stocked stands will attract poor prices and may become brittle and wind-prone. It is also suspected that even-aged stands at high stocking may impose excessive spring moisture demands, raising the risk of stem crack. On the other hand, heavy thinning may promote over-rapid diameter growth, with final timber having a low density and strength. A moderate thinning regime is therefore advisable. Stem form is inherently very good. Due to the strong markets for noble fir as Christmas trees it should be possible to market early thinnings for a fair return, either from transplants or natural seedlings. The foliage is also in high demand for wreaths and floristry, allowing pole stage material to be pruned. This helps to produce clears that will have enhanced value for box manufacture, skirting and interior panelling. Mixtures with pine, larch and some broadleaves appear to work well.

Mid-rotation noble fir after thinning (Wales)

Marketing **-** noble fir gives a whitewood timber, but, at least as grown in Britain, rather lighter and weaker than spruce or pine. Marketing is tackled in four phases:-

- Foliage/ Christmas trees - a lucrative by-product, helping to support the costs of establishment and early tending. Can be sold to national buyers/ agents or to more local artisan craftsmen/ florists.
- Small roundwood - sale of thinnings up to 15cm dbh for woodfuel, pulp and particle board, usually to regional industrial plants or their timber buyers.
- Standard sawlogs - 20-60cm, currently mostly sold to local small-industrial sawyers for potato-boxes, pallets etc., but self-processing for boarding or cladding is sometimes more lucrative.
- Outsize logs - >60cm especially where straight and clear of knots, can be attractive to local buyers wanting large-section "baulks" of clean soft timber for lightly-specified sacrificial, equestrian, gardening and landscaping works.

The rotation is typically similar to spruces.



Mature noble fir crop - Loch Eck, Cowal (FCS)

Above - noble fir logs from thinning at roadside
Below - heat-treated noble fir (Coed Cymru)

Processing **-** small roundwood thinnings of noble fir will enter the same industrial processing markets as spruce, pine and Douglas fir of similar dimensions - namely woodfuel, pulp and particle board. Such small quantities of noble fir have come onto these markets in Scotland that it is not possible to identify any specific issues. In North America, noble fir sawlogs are accepted along with grand fir, Pacific silver fir and western hemlock for light framing, studwork, skirting, panelling etc., but many British sawmillers will not take it for these end-uses. Most material in the 20-60cm dbh range is used for dunnage, potato box and pallet manufacture. Self-processors have developed applications for lightly-specified cladding and weather-boarding (see overleaf). Heat-treatment can improve interior joinery performance by hardening the timber for planing and nailing. Very large dimension clears of good stem form can be sawn into baulks and wide boards for local non-industrial markets - sacrificial timber for dunnage etc., stable linings, garden retainers and playground sleepers.

Private estates **-** from the 1870's onwards, noble fir has been adopted by a number of major private estates in Scotland, especially those with higher elevation, more exposed sites. The species was tried on such sites within Sir John Stirling-Maxwell's early plantings at Loch Ossian (Corrour Estate), but those stands were mainly felled some years ago. Private estate locations of most interest for standing noble fir within Scotland currently include:-

- Ardverikie Estate, Kinloch Laggan (NN 495869) holds some of Scotland's oldest plantations of noble fir, dating from the 1870's. The species was planted along the lower slopes along the southern side of Loch Laggan, approaching 300m asl, with infertile peaty soils. Other species such as grand fir and western hemlock were also trialed here. Noble fir has performed well, with strong regeneretation arising from surviving older stands.
- Drumlanrig Estate, Dumfries (NX 846995) holds a good stand of mature noble fir, planted in the late 1930's on an undulating brown soil site at ~170m asl. The trees grown have been of notably good form. The stand has been suitably thinned, with timber sold to a local processor for pallet and box making. Noble fir foliage is also sold by the estate.

Noble fir has also been grown on the Inveraray Castle Estate in Argyll, the Glen Livet Estate on Speyside and the Glen Tanar and Balmoral Estates on South Deeside, Aberdeenshire.

Fine noble fir stands on private estates in Scotland - Ardverikie (left) and Drumlanrig (right)

Public forests **-** noble fir has always been a relatively minor component of the plantings on Forestry Commission ground, but was used at a number of locations in western Britain, particularly in the late 1920's and early 1930's. In some cases these stands were intended as demonstrations of species potential and were later managed as permanent sample plots:-

- Glen Urquhart, Inverness-shire (NH 457293). One of the best stands of noble fir in Scotland, established as a pure crop in 1931 on the steep north-facing slopes of Glen Urquhart. Has achieved a GYC of 22, with very good stem form but has been rather under-thinned, which may limit the potential for silvicultural conversion of the stand.
- Bernice, Lock Eck and Glen Finart, Cowal (NS 134922; NS 169902). Stands of noble fir planted in 1931, in both cases with comparison with adjoining western hemlock of the same age (GYC =18, 14). Both stands are on lower slopes/ slope foot sites close to sea level, with high rainfall regime typical of the region and mainly brown forest soils. The species is clearly suitable for such moist conditions but needs to be progressively thinned.
- Gwydyr Forest, North Wales (SH 782569). This permanent sample plot, probably the most impressive stand of noble fir in Britain, was established on a freely-draining valley-bottom/ slope-foot site in 1927. The stand has been well-thinned over the years and regularly measured. Its reported GYC is 20. There has been significant stem cracking in the stand over much of its lifetime, so the site might well now be considered too dry for it.

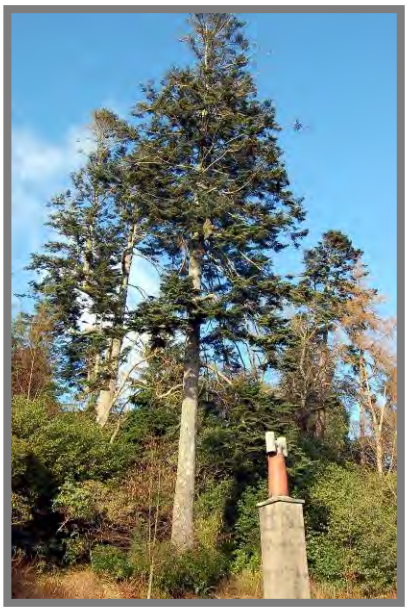
Noble fir cladding (Edistone Ltd., Wales)

Timber quality research and development - as one of the few alternative conifers that may be suitable for the high elevation part of the Sitka spruce/ Japanese larch range, attention is being given to how noble fir timber can be made widely acceptable for British joinery and structural uses. It is accepted for those uses in America, and work at the former timber research laboratory, Princes Risborough, showed that home-grown material was only slightly weaker than comparable grades of Sitka spruce. Drought-crack is an issue and must be tackled by provenance and site studies, and if need be, tree breeding. Lack of durability is more readily tackled as noble fir timber is much less resistant than spruce to preservative uptake, and careful barrier detailing and chamfer-edging can reduce the risk of decay in service for untreated cladding. Recent research by Coed Cymru has shown that Welsh-grown noble fir can be much enhanced for interior joinery (e.g. planing) by a new heat treatment process.

Self-processing in Scotland and Wales - noble fir is a clear example of a timber that has considerably greater potential in service than might be suggested by the major industrial sawmilling markets. The FCS niche marketing initiative in Argyll and Lochaber has found that it attracts interest from local joiners for interior panelling - particularly in stables/ barns. An excellent case-study of self-processing is offered by Edistone Ltd, a family business which has purchased a former Forestry Commission plantation on steep ground in mid-Wales (Coed Caeau-gwynedd, by Llanfyllin), this included a variety of conifer and hardwood crops, but notably p1950's noble fir in mixed stands. A key aspect of their business is the sale of hardwood logs, which are supplied in log stores constructed using self-sawn noble fir. It was found that if profiled correctly, the fact that noble fir is not very durable did not lead to decay, as moisture was drip-shed. This has led on to trial applications of the timber for weather-boarding on rural buildings. Foliage is also a key product, from prunings of noble fir.

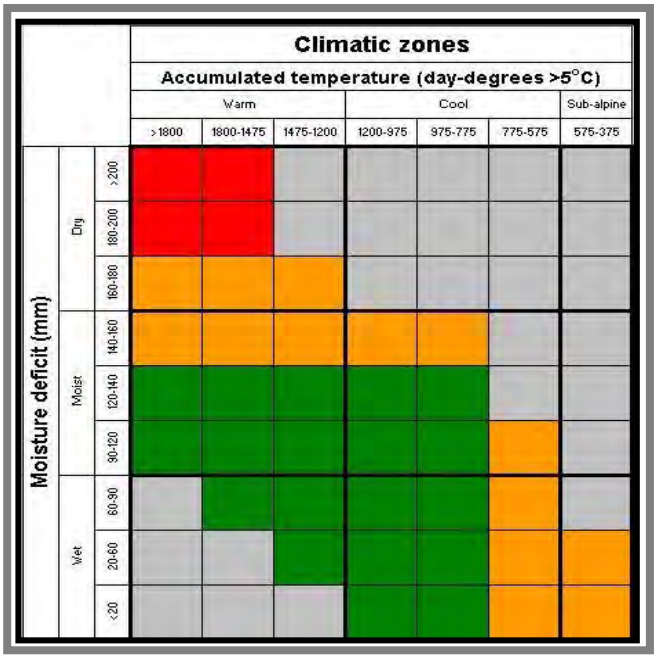
Noble fir roofed log-box (Edistone Ltd., Wales)

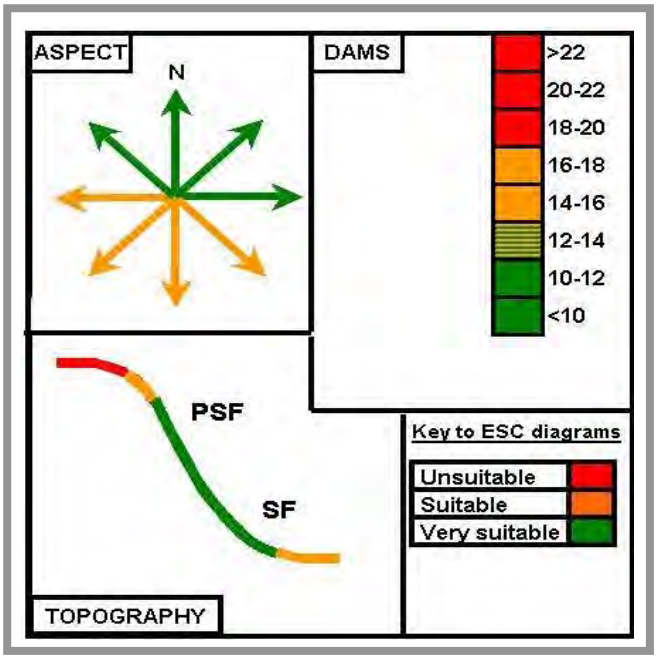
Record and potential - in addition to the grand and noble firs, there are a number of other members of the silver fir genus (*Abies*) that are of potential value for forestry in Scotland. The Nordmann fir (*Abies nordmanniana*) from the Caucasus is widely planted for Christmas tree production. However for timber production, attention centres on the European silver fir (*Abies alba*) and the Pacific silver fir (*Abies amabilis*). Both of these species could potentially find a place for "mid-slope" forestry in Scotland, between the ranges of grand fir (lower slopes and valley bottom) and noble fir (upper slopes and plateau). Their use is particularly associated with the operation of continuous cover forestry as they are both extremely shade-tolerant. These species produce light white timbers that are potentially suitable for non load-bearing applications and are widely traded in their home ranges. The European silver fir was introduced to Scotland during the 1600's and was fairly widely planted in both mixed woodland and plantation forestry contexts, producing whitewood timber. It fell out of favour in late Victorian/ Edwardian times, due to the incidence of an introduced insect pest (*Adelgid/ Dreyfusia nusslini*). The Pacific silver fir was introduced in 1830, and again in 1882, but has only been tried so far in arboreta and forest gardens, where it has performed very well, especially in Argyll and west Wales, indicating a preference for the moister oceanic climates.

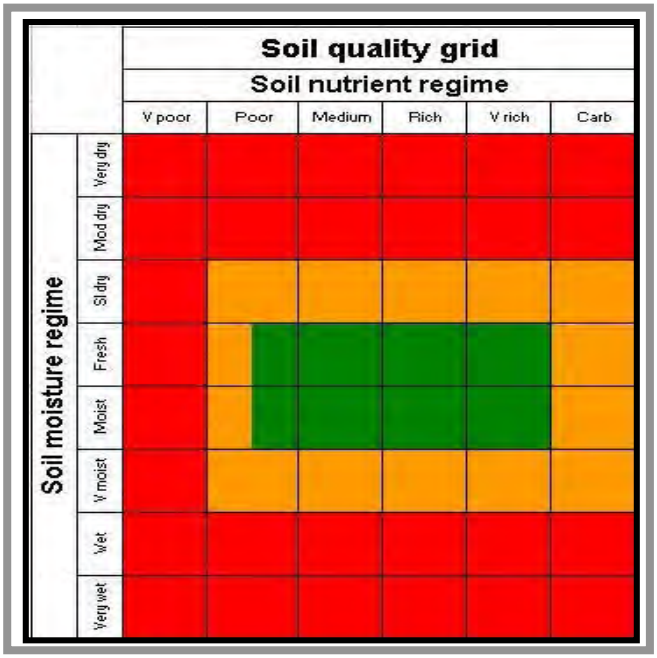


European silver fir in Scotland - Brodick Castle, Kilmun Arboretum and Glentress Forest

Existing resource -data from the National Inventory of Woodlands and Trees records some 50ha of silver firs in Scotland, all being of pre-1900 date. However this gives only a partial view of the resource that is actually present. In the case of European silver fir, there are essentially three categories of material:- (a) old specimen trees dating from the period 1700-1900 in mixed policy woodlands on private estates, (b) a small number of pure stands of even-aged material from the period 1900-1960 in forest gardens and arboreta and (c) younger material in mixed-species selection forests, particularly in southern Scotland. Only a small amount of material is being established at present, by a combination of natural regeneration and experimental-scale plantings. Due to the perceived higher risk of attack by the *Adelgid* pest in pure stands, the species is mainly now used in mixed-species woodlands. There are inadequate measured stands to give a reliable estimate of yield potential in Scotland, but the p1956 trial plot, at Kilmun Forest Garden on Cowal, has achieved a GYC of 18. While there are occasional specimens of Pacific silver fir in private arboretum collections, the most important stands are trial plots at the Crarae and Kilmun Forest Gardens, both in Argyll. At the latter, Pacific silver fir (p1958) has achieved a high GYC of 24. Future trials of this species at the forest stand scale are required to evaluate its potential across eastern Scotland.







Site suitability - the diagrams opposite refer to European silver fir, which grows well in upland areas such as Argyll, Aberdeenshire, Perth and the Borders. Both species are best suited to warm moist mid-slope growing conditions, being rather frost-sensitive and intolerant of exposure and drought. This needs to be considered in selection of sites on topographical and aspect criteria. Soils should be Fresh or Moist, with fertility ranging from Poor to Rich. Pacific silver fir can use some wetter, less fertile soils. Neither species establishes well in competition with heather and both peaty and dry sandy soils are unsuitable. Pacific silver fir is susceptible to butt-rot.

Provenance - seed taken from the limited British forest resource is not now available in any quantity. For European silver fir, provenances from the Czech Republic and other central European areas are advised. For Pacific silver fir, provenances from coastal Washington state are likely to be best suited to Scottish conditions. In both cases, special-order contract growing will be required to obtain good planting stock.

Silvics - both silver fir species are most usefully deployed as a component of mixed-species selection forestry, due to their shade tolerance. For the European silver fir, use in pure stands is not advised at present due to the *Adelgid* risk, but the Pacific silver fir has grown well in even-aged stands in western Scotland. Both species would naturally establish within a forest microclimate and make a slow start in even-aged plantings on open sites. Under-planting an old conifer canopy is beneficial. Both silver firs are highly palatable to deer and protection is vital. Thinning regimes should aim to maintain stability and a steady rate of growth to target diameter for sawlogs, avoiding over-rapid growth with wide ring-width and drought-crack. Thinnings should be suitable for pulp, particle-board or woodfuel uses. Yield is typically high (GYC 18-24) under suitable conditions, allowing a choice of rotation length/ target felling diameter.

Demonstration stands- the Forestry Commission's Kilmun Forest Garden near Dunoon (NS 164823) and the National Trust for Scotland's Crarae Forest Garden near Inveraray (no access) contain even-aged plots of European silver fir and Pacific silver fir that can be compared. In the case of Kilmun Forest Garden, these plots, established in the late 1950's, are well-tended and have been subject to periodic measurement, yield and health assessments (most recently in 1997). Both of the silver firs have performed well, with high survival rates and volume production (18 m^3/ha/yr for European silver fir and 24 m^3/ha/yr for Pacific silver fir). Fresh plantings of Pacific silver fir have been undertaken in recent years. At Crarae Forest Garden, the plots were established in the 1930's, but physical access and regular measurement have been difficult in recent years. The Forestry Commission Lael Forest Garden near Ullapool (NH 196806) has good specimens of European silver fir, dating from the late 1800's. National Trust for Scotland properties at Brodick Castle on the Isle of Arran (NS 013380) and Culzean Castle and Country Park in Ayrshire (NS 230095) contain some of the best examples in Scotland of older European silver fir dating from the 1700's. The Edinburgh University Silvicultural Trial within the Forestry Commission Glentress Forest at Peebles (NT 280415) contains European silver fir of several ages (ranging from young regeneration to 50-60 years) within mixed-species selection forestry stands. Young European silver fir has been planted on a restock site on Drumlanrig Estate near Dumfries (NS 866007).

Pacific silver fir, Kilmun Arboretum

Sawing European silver fir for boarding and use in cross-laminated panels

Processing examples **-** European silver fir produces a non-durable whitewood timber with comparable strength and milling characteristics to Norway spruce (density 480kg/m3). It is often regarded as having better strength than the other *Abies* firs grown in Britain, such as grand and noble. In Europe it is traditionally used for building timber (large-section beams) , wide boards (e.g. doors and coffins) and interior carpentry and panelling work, for which it proves easy to work. In recent years it has been incorporated into new engineered timber construction elements such as cross-laminated panels. As it is a relatively soft timber, it tends to be used for the interior bulk layers of the panels, with a harder timber such as larch, Norway spruce or Douglas fir forming the outward facings. These "massive timber" construction techniques are gaining attention in Scotland as a way to use second-grade home-grown conifer timbers in an application that will sequester embodied carbon over long periods. Recent experience with the processing of home-grown European silver fir is very limited, with most applied to low-specification heavy-section uses such as pipe-wedging, offshore-oil machinery pads and shipbuilding keel-blocks for which prices can be quite good on occasion. Pacific silver fir has not been processed in Britain in any quantity, but in the Pacific Northwest it is marketed as part of the "Hem-Fir" lumber category along with grand and noble firs and western hemlock. The timber (410 kg/m3) is used for light-weight house framing, interior carpentry and panelling work, on a par with grand fir, noble fir and hemlock.

Traditional construction methods- the European silver fir has been widely used as a traditional building timber in parts of southern Germany and much of Austria, where it grows naturally as an element of montane beech-spruce-silver fir stands. These are generally managed under selection forestry systems. In some areas fir represents up to 50% of the standing volume and is seen as a valuable resource. Vernacular alpine building methods used the timber both as short-span, large-section beams and wide "deal" boards. The large roof overhang typical of buildings in this region, coupled with the cold dry winter climate, limited the need for timber treatment. In more recent times, sawn timber of silver fir has been used, along with Norway spruce, in modern timber building designs, both as external cladding panels and as internal decorative roof and wall panels. The white, clean appearance of silver fir timber makes it particularly suitable for indoor finishes. British-grown silver fir could well be used in similar ways.

Management of European silver fir selection forests in Austria (Raphael Thomas Klumpp)

Modern timber construction - Austria (above) and Acharacle, Scotland (Gaia Architects)

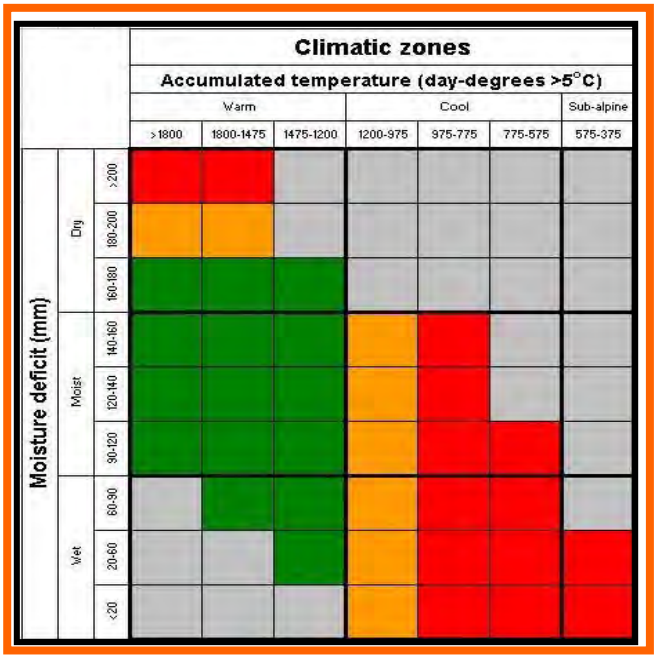
Engineered timber elements - the timber of European silver fir can also be used in the innovative engineered timber systems for massive timber construction. There are a variety of systems involved including the dowel-stapled "Bretstappel" system and the cross-laminated timber systems. Again these building methods have first been developed in Austria and Bavaria, but are now being adopted in other parts of Europe including the Scottish Highlands. These systems have the key advantage of using large volumes of timber in long-service applications, thereby helping to sequester atmospheric carbon. They can also make use of smaller dimension battens of weaker timber, assembled to form large-section members. Usually a harder timber such as Douglas fir or Norway spruce will be used as the "outer layers of the sandwich" with weaker, wetter material such as silver fir timber providing a portion of the filling. A number of examples of massive timber construction have been developed in Britain, including a school at Acharacle, Lochaber, designed by Gaia Architects.

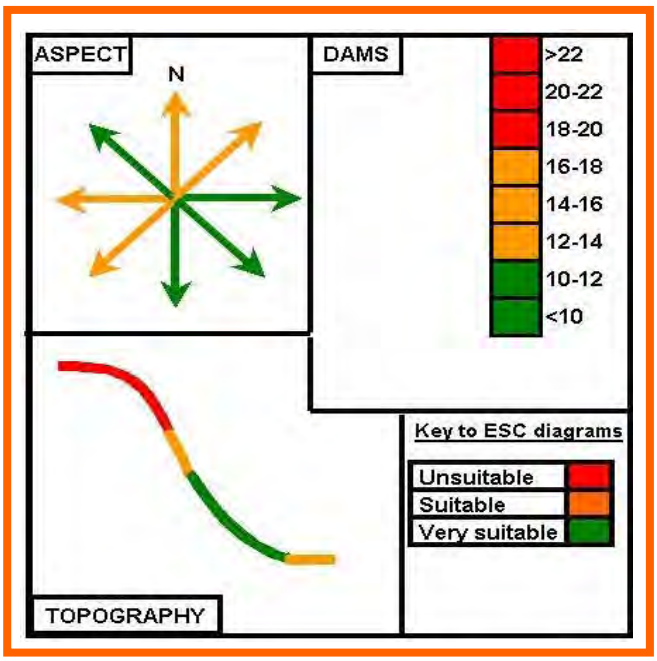
Record and potential - the Lawson cypress (*Chamaecyparis lawsoniana*), also known as Port Orford cedar, is a valuable timber tree from the Pacific Northwest - it has a home range including coastal districts of northern California and southern Oregon, overlapping with that of coast redwood. Its timber, although having a pungent smell, is very stable and durable and was highly valued for cladding, shack-building and other outdoor uses in the American west. It was introduced into Britain in 1854-55 and grown in a number of arboreta and tree collections. The Leyland cypress (*x Cuprocyparis leylandii*) is a natural hybrid that arose between two other highly valued west-coast durable conifer species - Monterey cypress (*Cupressus macrocarpa*) from California and the Nootka cypress (*Chamaecyparis nootkatensis*) from northern British Columbia and Alaska. The hybrid was first observed between 1880 and 1911 at the Leighton estate in north Wales. It does not produce fertile offspring. Although distinct species, Lawson and Leyland cypresses look rather alike, have comparable ecological and silvicultural characteristics and produce timbers with similar milling properties. Neither species has been grown on a sufficient scale and with suitable silvicultural attention to fully demonstrate its Scottish potential, but those good stands that do exist and the useful timber they have produced, suggest we should take them more seriously.

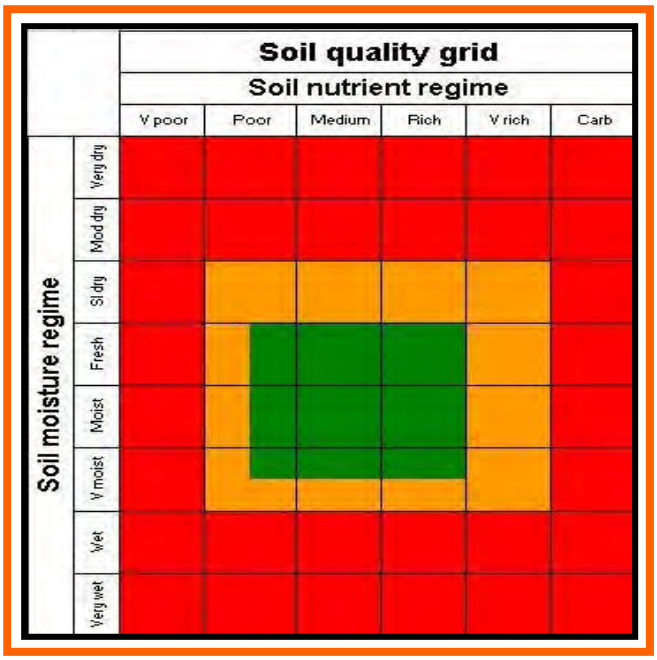


Fine Lawson cypress stands at Novar (Scotland), Gwydyr Forest (Wales) and Longleat (England)

Existing resource - there is a large stock of these species currently in use for hedging and landscaping purposes, but the Scottish forestry plantation resource is small and scattered across the public and private forests. Data from the National Inventory of Woodlands and Trees records ~140ha of all cypress species combined, of which most will be Lawson cypress. Most of this material dates from plantings in the period 1940-1960. Due to the low intensity of sampling this may be an underestimate of the resource. An equivalent survey in the late 1940's estimated that ~325ha of Lawson cypress had been planted out across Britain by then, but much older material will since have been felled. Little of these species has been planted for forestry purposes in recent years. A large part of the existing Lawson cypress resource consists of dense, under-thinned "beanpole" stands that have not developed good stem form. These provide an unreliable indication of the potential of the species if well grown on suitable sites. Lawson cypress has produced a few fine stands in Scotland in Argyll, north along the steep sides of the Great Glen and Glen Urquhart and at Novar Estate in Easter Ross. Further south, fine mature stands at Gwydyr Forest in Snowdonia and on the Longleat Estate in Wiltshire suggest that these species can certainly produce good stem form and valuable timber across warm moist, sheltered parts of Britain. GYC ranges from 8-20, typically 12.







Site suitability - the diagrams opposite refer to Lawson cypress. Both species should only be considered for productive forestry on wind-sheltered sites. Other than as transplants, they are usually frost hardy, but do not tolerate wind exposure and may be badly damaged by snow. Soil SMR should be Fresh or Moist, with SNR Poor to Rich. Leyland cypress is also tolerant of some drier soil types. Peaty and heathery sites are unsuitable. These species are best for lower valley-slope and valley-bottom sites, with brown earth soils. There is known susceptibility to honey fungus and now to *Phytophthora lateralis* fungal disease.

Provenance - there has been little study of provenance variation in the Lawson and Leyland cypresses for forestry in Britain. For Lawson cypress, seed should either be obtained from one of the two seed stands in Scotland (Glen Urquhart and Novar) or from recognised natural forest sources in Oregon and upper California. Sources from the coastal part of the range should be better for Scottish climates. Seed collected from hedge or garden plantings must be avoided. For Leyland cypress, nursery plants should be propagated only from forestry clones.

Silvics - these are shade-tolerant species which can be used in either even-aged or selection forestry. Both can be grown well in mixture with other conifers. Lawson cypress will regenerate naturally, whereas Leyland cypress is an infertile hybrid, that must be regenerated by planting clonal stock. Initial growth of the Leyland cypress is more rapid. Establishment under an old canopy of pine or larch will assist with early shelter. Thinning should be light in the early years to discourage stem-forking, but later it can be increased to allocate increment to a selection of the better stems. Response to thinning may be slower than in most other conifers, leaving canopy gaps apparent for some time. Thinnings will find a market for woodfuel or run-of-the-mill fencing. Final crops are grown to target diameters for cladding or log-cabin construction.

Demonstration stands - within Scotland there are two notable, but contrasting stands of mature Lawson cypress, both Registered Seed Stands. First, there is the fine 109-year old stand in Fyrish Wood on the Novar Estate in Easter Ross (NH 625694), believed to have been underplanted into a former larch stand on relatively sheltered lowland ground of moderate fertility. This stand, although small, shows the long-term potential of Lawson cypress as a productive timber tree in Scotland over what would probably be its optimum rotation. The other example is on FC ground in Shewglie Wood, Glen Urquhart (NH 421289), where an 80-year old stand of under-thinned Lawson cypress can be found on a steep upland site of low fertility (GYC = 12). Better-thinned material of similar age has recently been harvested from the Port Clair Forest by Loch Ness. Fine stands of mature Lawson cypress can also be found in Gwydyr Forest, Snowdonia (SH 772578) and on the Longleat Estate in Wiltshire (ST 882422). There are no known plantation scale demonstration stands of Leyland cypress within Scotland, but a small plot can be observed in the Kilmun Forest Garden, Cowal. Fine demonstration stands of Leyland cypress certainly occur in southern England/ Isle of Wight.

Processing examples - the timber of Lawson cypress is naturally durable and has traditionally been used mainly for "outdoor joinery" such as fencing, cladding and shed-building. It was widely applied for these purposes in the American west, alongside red cedar and redwood. It also found a specialist market for manufacture of separators in lead-acid wet batteries. Its pungent smell discourages its use for interior carpentry. The relatively small amounts of the timber that reach the market in Britain, mainly in southern England, are usually of small-diameter and are sawn for "run-of-the mill" garden fencing, often treated along with other less durable timbers such as pine and fir. Larger material rarely comes on to the market, and when available is used by locally-based small-scale sawmillers for a variety of occasional cladding and garden building work. A good example of the processing of the timber of Leyland cypress (which has similar properties to Lawson) was the recent construction of a log-cabin at the Forestry Commission visitor centre at Grizedale in the Lake District (SD 337943) (see above). This was constructed by woodworker Mick Read and colleagues from Leyland cypress logs and boards, using timber from FC land at Dalton Crags, in Lancashire.

Japanese red cedar

Potential for use in Scotland

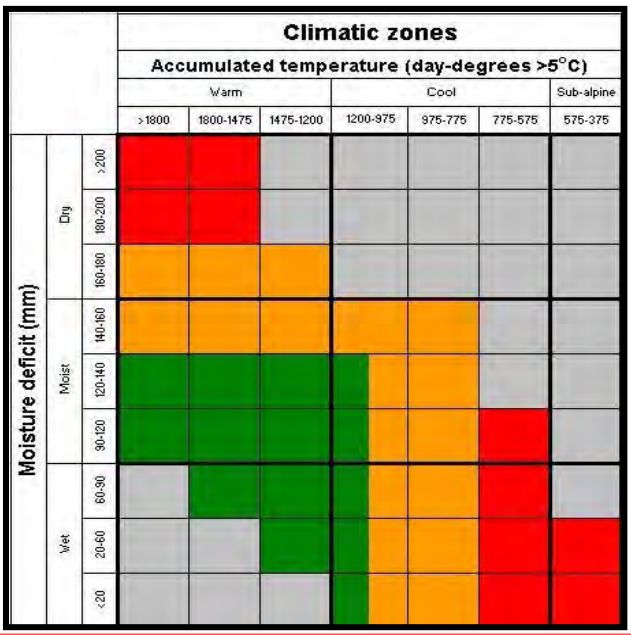
Potential for adoption - the Japanese red cedar (*Cryptomeria japonica*) is often referred to simply as "*Cryptomeria*". It is a conifer, native to Japan and parts of China, that has a long record of producing a high-quality durable construction timber of very high value. Natural stands in the mountains of Japan were exploited for timber over many centuries for construction of temples, palaces and other high-status buildings. Plantations of the species have been managed for at least 400-500 years and continue to be a major source of timber within the native range. It was also used as a plantation species in British India, notably in the Darjeeling Hills. The species is known in Japan as "sugi" and in India as "dhuppi". *Cryptomeria* was introduced to Britain from the Chinese part of its range in 1842 and again from the Japanese part of its range in 1879. Both in arboretum collections and forest gardens, it has demonstrated a potential for rapid and productive growth in the warm, wet conditions of oceanic areas such as Cornwall, Wales, Argyll and Wester Ross. Its yield in these areas is comparable with the productive Pacific Northwest conifers such as Douglas fir, grand fir and western red cedar. It will also grow, perhaps less rapidly, under the drier conditions of south-eastern Britain (e.g. on the Isle of Wight). Given its timber quality, surprisingly little attention has been paid to expanding the British resource of *Cryptomeria*, but that may well change.

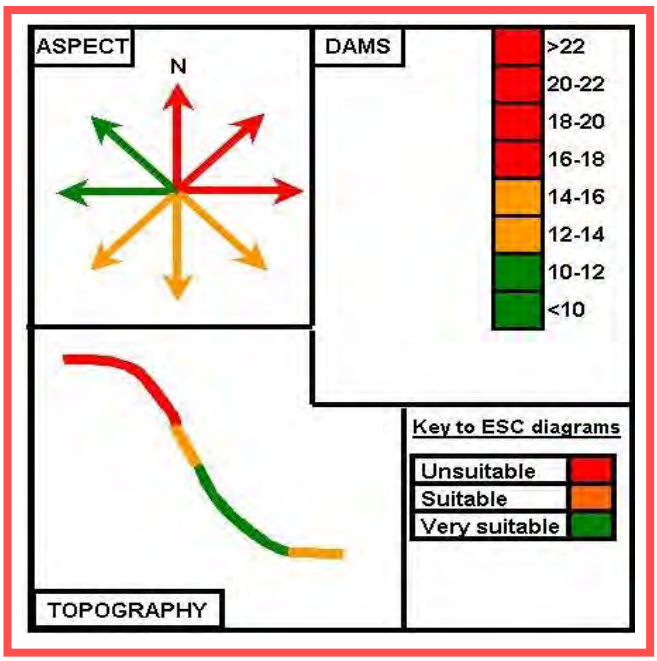
Scottish trial plots of Japanese cedar (Cryptomeria japonica) at the FC Lael and Kilmun arboreta

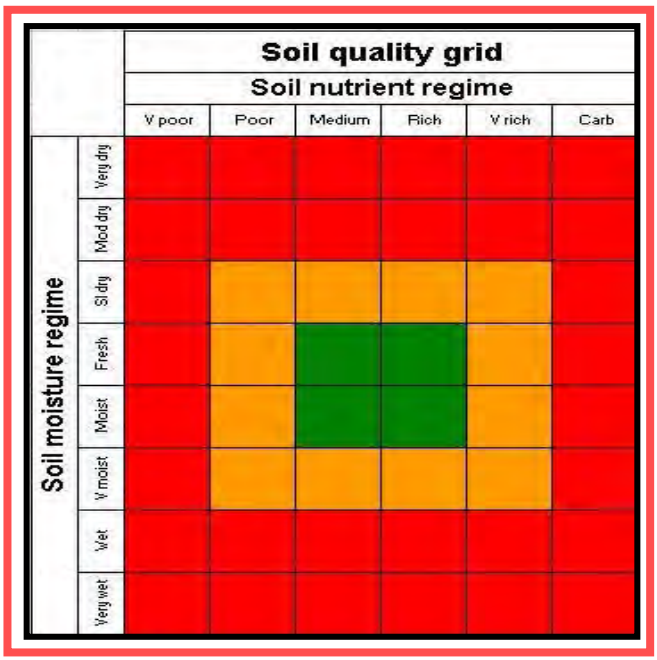
Previous record - the National Inventory of Woodlands and trees lists 5ha of the Japanese red cedar in Scotland (this being 60-70 years old). Due to the low intensity of sampling, this may be something of an underestimate for an infrequent species. The best known locations today are certainly at the three west-coast forest gardens - Kilmun, Lael and Crarae - which are described in more detail opposite. During the 1930-1960 period, the species was used in a number of first-rotation Forestry Commission plantations in Cowal, Argyll and the Great Glen - at locations such as Knapdale, South Laggan - and also at the private Cumlodden Forest in Argyll. The level of planting was perhaps only slightly less than for western red cedar in Scotland. Some stands were well-tended, producing sawlog material, others were left unthinned, producing only small roundwood and bar material of limited value for processing. As the better stands were on productive sites, most have been felled, particularly where PAWS restoration has become a management priority over recent years. There were also quite a number of small plantations in Wales and the Marches, for example near Aberystwyth, at Brechfa and in the Forest of Dean. A small steep-sided valley in Cornwall represents one of the largest British plantings. In south-east England there are trial FC plantations within Alice Holt and Bere Forests and at Parkhurst Forest on the Isle of Wight.

Japanese red cedar

Site suitability and silviculture







Site suitability - the conventional wisdom is that *Cryptomeria* requires warm, moist and fairly sheltered climatic conditions. These are certainly found in those parts of the country where *Cryptomeria* has grown most rapidly to date (Cornwall, Wales, Argyll, Wester Ross), but there is evidence that it can grow in drier areas of south-east England (albeit rather more slowly). Possible provenance effects have not been studied, but more research is planned. Japanese red cedar will accept a wide range of soils in terms of both moisture and fertility, but heather sites, peaty sites and very dry soils all need to be avoided. The species will take moderate exposure but is damaged by frost and wet snow. There is evidence for susceptibility to honey fungus and root *Phytophthora*.

Provenance - little seed is currently taken from the small areas of Japanese red cedar in Britain, although it should be possible to collect from those at Kilmun, Crarae and elsewhere as these mature. Seed from the northern part of the Japanese range is the more suitable for Scottish conditions. Decorative and garden cultivars should be avoided as they are often of poor form. This species can also be reproduced easily by striking small vegetative cuttings and then propagating those in nursery beds.

Silvics - Japanese red cedar is a very high volume producer and needs to be well thinned to allocate increment to a sensible number of stems. Neglected stands have tended to take on a "beanpole" structure with spindly, low value stems. Thinnings should be saleable for woodfuel/ fencing. Final crop trees (especially with side-light) may benefit from pruning, which forms part of the Japanese silvicultural practice. However mid-stand trees may self-prune. Target diameter will be >30cm dbh. Most British experience with this species has been in even-aged pure stands, but it is very shade-tolerant and should be able to be used in mixtures with a range of compatible conifers such as western red cedar, Lawson cypress and Douglas fir.

Demonstration stands **-** the best opportunities to see successful stands of Japanese red cedar in Scotland are at the Forestry Commission's Kilmun Forest Garden near Dunoon (NS 164823) and Lael Forest Garden near Ullapool (NH 196806). There are also good stands in the Forestry Commission's Brechfa Forest Garden in mid-Wales and at the National Trust for Scotland's Crarae Forest Garden near Inveraray. In the case of Kilmun Forest Garden, the plots, established in 1935 and 1954, have preformed well and have been subject to regular measurement (most recently in 1997). The larger p1954 plot has produced 24 m^3/ha/yr, a high rate of growth, comparable with Douglas fir, the *Abies* firs and western red cedar. It is now being considered for selective thinning, which should provide an opportunity for experimental processing and assessment of the timber produced. At Crarae Forest Garden, the plot was established in the late 1930's and is one of the tallest and most successful in the collection, although no longer accessible to unaccompanied visitors. A number of other plantation stands in Argyll, for example within Knapdale Forest, have apparently been felled over recent years, but there remain good stands of the species in public and private woodlands in Wales, Cornwall and south-east England/ Isle of Wight. Japanese red cedar will be included in climate-change species trials in Scotland being planned by Forest Research.

Japanese red cedar stem/ bark

Foliage of Japanese red cedar

Processing examples- there is very limited reported experience of processing the timber of Japanese red cedar in Britain. Material harvested from plantation stands in Cornwall, Wales and Argyll is likely to have been sold for "run-of-the-mill" applications, such as fencing. Some of these stands had been rather poorly thinned, producing a large volume of small-diameter material that would not have attracted good prices or been suitable for more demanding end-uses. Very limited volumes of larger-diameter Japenese red cedar timber harvested to date have been used for small-scale exterior applications relying on their durability in ground contact, such as garden landscaping retaining walls. However, the timber is recognised in Japan and India to be of very high quality and durability. It was used historically as a major building construction timber in Japan, particularly associated with religious sites. Natural-growth material in the mountains had been heavily exploited, but there are reported to be plantations of 400-500 years of age. Timber for industrial processing is harvested from stands of 100-150 years. In India it is used for the manufacture of tea chests. Were larger quantities of heavier-section Japanese red cedar timber grown in Scotland in future, it should enter similar markets as Lawson cypress, western red cedar and *Sequoia* where natural durability is sought - e.g. exterior cladding, garden carpentry, glasshouses etc.

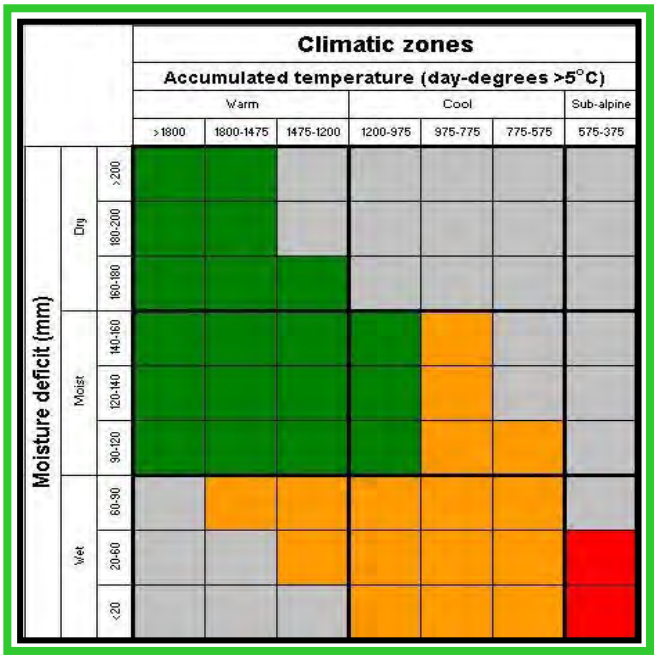
Macedonian pine

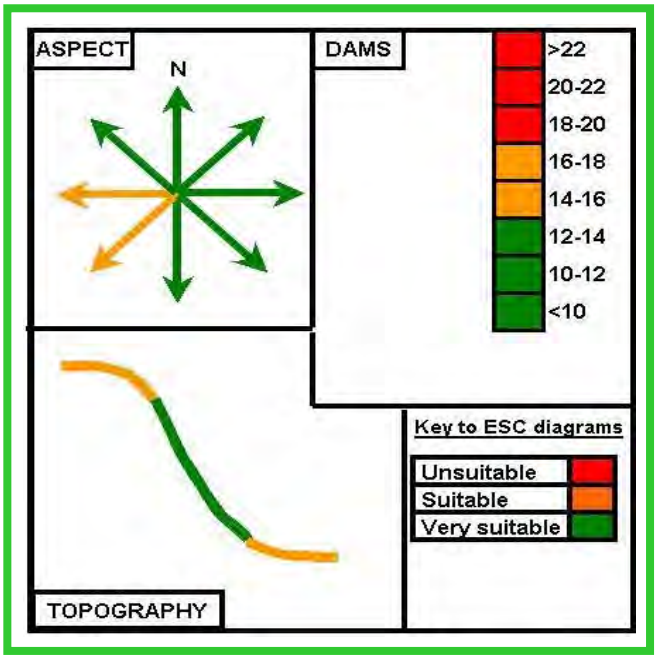
Potential for use in Scotland

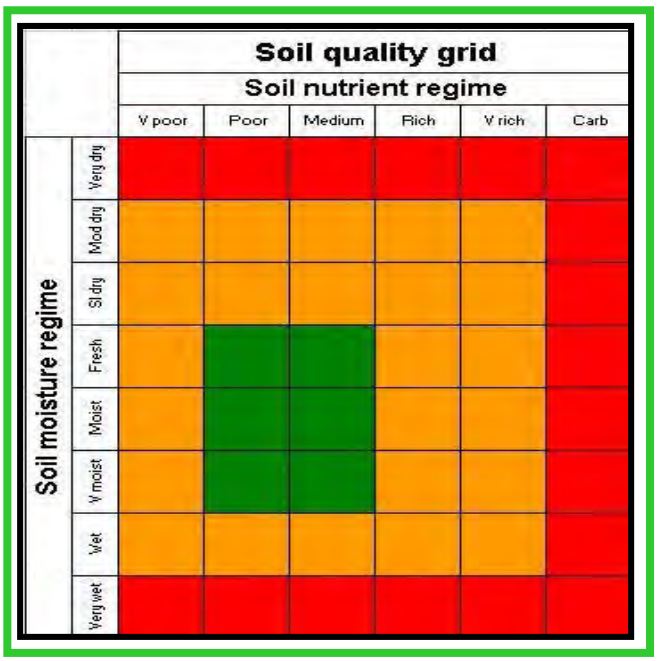
Potential for adoption **-** alongside the native Scots pine, a number of other two-needle pines have been trialed for forestry use in Scotland in the past. Of these, only the lodgepole pine (*Pinus contorta*) from Canada and the Corsican pine (*Pinus nigra v. maritima*) from southern Europe have been planted on any scale. Unfortunately both of these species are now seriously affected by red-band needle blight, and little planting is currently being pursued as a result. However the long-term potential of lodgepole pine for poor upland sites (especially with peat), and of the Corsican pine for warm dry lowland sites on the east coast of Scotland, should not be ignored. Research work may offer future solutions to the identified disease problems. In the meantime, pine species remain an attractive option for the higher, more exposed, sites. The Macedonian pine (*Pinus peuce*) is a five-needle pine, native to remote mountainous areas of Macedonia, Bulgaria and Albania. It is thought to have good resistance to pine blister rust, red-band needle blight and other fungal pathogens. This makes it a potential candidate as an "alternative pine" for use under suitable conditions in Scotland. First introduced in 1863-64, and later trialed by the Forestry Commission at several sites, it has proven to be capable of productive growth under a range of conditions in Scotland. The timber is light, and not especially strong, but is suitable for indoor joinery and carpentry.

Trial plots of Macedonian pine in forest gardens - Crarae and Kilmun (Argyll) and Brechfa (Wales)

Previous record **-** the National Inventory of Woodlands and Trees does not provide any information on the existing Scottish resource of Macedonian pine as it is included in an "other pines" category that contains a number of species. Early Scottish experience with this species, particularly within Sir John Stirling Maxwell's experimental high-elevation plantings at Corrour, had been rather promising. Trials planted out by the Forestry Commission in the early 1960's, at contrasting sites across Scotland and northern England, showed that the species was capable of operating on a range of site types/ elevations. While it made a slow start in the nursery and on the planting site, its later production was at least equivalent to other pines, and its survival and vigour was often rather better. Many of these trials have later been felled. There remain good plots of the species at the FC Kilmun Forest Garden in Cowal and the Brechfa Forest Garden in Wales (both dating from the late 1950's) which confirmed the potential of the species for British forestry. The yield of Macedonian pine is comparable with that of Scots pine on similar sites (GYC of 10). There is also a small remnant plot of Macedonian pine, dating from the late 1930's, at the Crarae Forest Garden in Argyll, which illustrates the species closer to its typical rotation age (~70yrs). This species is likely to be included in future trials by Forest Research to further assess its climatic change tolerances.







Site suitability- in contrast to some of the other alternative conifers discussed in this publication, Macedonian pine can be used on a wider range of site types in Scotland with reasonable productive potential. It is tolerant of frosts, cold climates and at least moderate wind-exposure. It is quite capable of dealing with peaty soils (where flushed), thus offering an alternative to lodgepole pine on those sites. It also performs well on infertile sandy soils, including some podzols, providing a potential alternative to Scots and Corsican pines for plantations. Like most pines, it is not recommended for moist, rich fertile sites, where there is a much greater risk of poor stem form. Macedonian pine could be used in many regions of Scotland.

Provenance - it may be possible to collect seed in future from the older trial plots in Britain - in some cases natural regeneration has begun. Most seedlots will come from the native range of this species in the Balkans, where there are a number of seed stands within forest conservation areas. Limited trials in Britain have not shown major differences in growth and survival between native provenances. At present, contract growing will be required as the species is in limited demand from the nurseries and requires special seed pre-treatment to secure adequate germination. It can take 4-5 years to reach a size for planting out.

Silvics - Macedonian pine grows slowly to begin with, during which it is very palatable to deer and needs protection. However, later in the rotation it tends to be a higher volume producer compared to other pines. It has a higher girth-to-height ratio than many other conifers, making it potentially more stable in high wind-throw hazard environments. While almost all British experience has been with pure even-aged trial plantations, Macedonian pine does grow naturally together with Norway spruce, European silver fir and Scots pine in its native Balkans, making it potentially an option for mixed-species forestry use (regular or selection) on our poorer upland sites.

Demonstration stands **-** within Scotland, Macedonian pine is best seen growing in the Forestry Commission's Kilmun Forest Garden on Cowal (NS 164823), where there is a large plot (p1959) at the north-east corner of the site, at the end of a stiff climb to 200m asl. This has achieved a growth rate of 10 m^3/ha/yr at the most recent measure and is one of the most healthy and vigorous plots of any pine species within this extensive collection. There is also a good stand of Macedonian pine within the Forestry Commission's Brechfa Forest Garden in mid-Wales. A small remnant stand of older trees, dating from 1937, is located within the National Trust for Scotland's Crarae Forest Garden near Inveraray. There is also a surviving plantation stand within Kielder Forest, Northumberland. An alternative approach is to examine the potential of the species within its small native range in the Balkan mountains. A tour of inspection was made by Roger Lines in 1982 (Lines, 1985). There are believed to be only 20,000-30,000 ha of natural Macedonian pine forest remaining, and the species is considered to be under threat. The mountainous range includes conservation areas in the territories of Bulgaria, Macedonia, Serbia, Montenegro and Albania. Some of the best stands are reported to be within Perister National Park, Macedonia. Macedonian pine is found naturally at elevations ranging from 1100-2300m asl. At lower elevations it grows together in mixture with Norway spruce, European silver fir, Scots pine and beech, but higher up it forms either pure stands or combines with the mountain pine (*Pinus mugo*) and with juniper.

Sample plot of Macedonian pine at the Kilmun Arboretum, Cowal, Argyll (planted 1959)

Processing examples- the only recorded experience of processing the timber of the Macedonian pine in Britain was work conducted at the former Princes Risborough timber laboratory, using four logs from 43-year old trees harvested from a trial plot in Kielder Forest. These were compared with similar British material of Scots pine, Sitka spruce and Weymouth pine (*Pinus strobus*) - a five-needle pine from eastern North America that has traditionally supplied high quality construction timber. The timber (at 350 kg/m^3) proved to be both lighter and weaker than either Scots pine or Sitka spruce, but comparable to the Weymouth pine (British samples). This is obviously quite a narrow base of experimental evidence, but suggests that timber from Macedonian pine would be more likely to serve non load-bearing markets such as joinery timber, interior panelling and furniture-making, rather than timber-framing/ carcassing. The light-coloured timber suggests that small roundwood thinnings would be acceptable for pulp and chip-board applications as well as supplying woodfuel. Further research on the timber properties of British-grown Macedonian pine should become available from the thinning of forest garden trial plots. There is obviously longer experience of utilising the timber in the Balkans, where it has traditionally been sawn for furniture and interior carpentry, and also used by wood-carvers. At present, limited material is being harvested due to the conservation designations applied to remnant natural forest areas, but plantations outside these areas are considered suitable for final harvest at ~70 years.

Harvesting and extraction of pole-length Douglas fir at Fort Augustus for structural beamwork (FCS Huntly office project)

As with Sitka spruce and Scots pine, alternative conifers should be harvested at the log sizes best suited to their intended markets, while bearing in mind the silvicultural development of the stand. However there will be significant differences in the optimum log sizes between species - in particular the "upper limit" of 50-60cm dbh that is often quoted for Sitka spruce logs by highly-mechanised mills does not apply to specialist grades of Douglas fir and larch. Some growers will carry out their own harvesting work and present material at roadside, whereas others will prefer to sell their material standing, with the purchaser's contractor carrying out felling and extraction work. A balance needs to be struck between the wishes of the purchaser and the needs of the grower to protect retained trees in the stand and soil condition. Only contractors with the confidence of the grower and necessary skills should be used. Large dimension material (above ~60cm dbh), particularly of high value species such as Douglas fir and larch, will normally be felled by motor-manual methods, with the need for woodworkers or contractors with the necessary skills and experience. Purchasers of high-value beam length material will often prefer to harvest timber themselves. Over-extension of harvesting machines, either as to log size, terrain class or ground pressure should be avoided.

The main harvesting categories of material from alternative conifer species are:-

Small roundwood thinnings - traditionally used for pit props, but now mainly sold for pulp, particle board or woodfuel. Lighter-coloured timbers such as Norway spruce, Douglas fir, *Abies* firs and Macedonian pine should be suitable for pulp and particle-board, whereas stronger coloured species such as larch, red cedar and Lawson cypress go for woodfuels.

Bar and standard dimension log material - log material in the dbh range 15-60cm is used for a variety of dimension stock applications (e.g. grand fir and western hemlock for pallet and boxwood, larch for fencing and cladding, Douglas fir for decking and small beams). The better lighter coloured timbers (e.g. Douglas fir) enter the same markets as Sitka spruce and Scots pine, whereas larch, western red cedar, Lawson cypress etc tend to go to smaller specialist mills, often locally-based. Large industrial mills can still switch between sawing spruce for carcassing and larch for fencing depending on the strength of current demands.

Beam and large dimension log material - more specialist outlets with a dbh requirement > 50-60cm - these include high value beam length markets for Douglas fir and larch, large-section shortwood landscape sleeper markets for grand/ noble fir and western hemlock and specialist decorative markets for western red cedar, Japanese red cedar and *Sequoia* redwood.

Many growers will be seeking to sell the timber harvested from stands of alternative conifer species to commercial timber merchants or direct to industrial timber processors. A variety of marketing channels are available including existing personal contacts, short-list tenders, on-line auctions etc, each with their advantages and disadvantages. As a general rule it is better to sell any timber "for what it is" on a species-specific basis than to attempt to sell it as a minor element of a parcel of a different species, such as Sitka spruce or Scots pine. Certain alternative species may be better reserved for on-site or specialist local milling (see below).

Woodfuel, pulp and particle markets - lower grade, small dimension "biomass" material is generally sold directly to the larger industrial-scale processors operating at the regional level, or to timber merchants and harvesting contractors acting on their behalf. The current growth in the demand for woodfuel for chip and pellet plants means that it should be possible to sell thinnings of most conifer species that are on reasonably accessible sites. Lighter timbers including Norway spruce, Douglas fir, *Abies* firs, Macedonian pine and some western hemlock should also be acceptable as "spruce-equivalent" for pulp and chipwood markets.

Standard-dimension log markets - material of this type, up to ~60cm dbh is mostly sold to commercial sawmills or to timber merchants and harvesting contractors acting on their behalf, usually within a given region (e.g. South Scotland/ North England). Light but strong timbers such as Norway spruce, Douglas fir and pines of these dimensions are often accepted as "spruce equivalent" for kiln-dried carcassing/ system timber framing/ decking markets. Weaker timbers such as *Abies* firs and western hemlock are more likely to go to pallet and boxwood markets, but may be better allowed to grow larger for production of landscape sleepers etc. Larch of this size will go to smaller industrial mills for small beams, cladding and fencing. Western red cedar is a special case - in England and Wales there are small-industrial outlets for material of 30-60cm dbh for cladding, beehives, glass-house framing etc., but in Scotland (especially the north) it is best to pursue on-site/ local processing options.

Specialist large-dimension beam and log markets - these generally operate at the regional or national levels, with specialist small-industrial processors and expert buyers. High-value examples include large-section beam length Douglas fir for construction, marine and dockwork applications, high-quality larch for cladding and boat-building and very specialist niche outlets for transmission poles (Douglas fir) and temple posts (Japanese red cedar). *Abies* firs and western hemlock tend to become more valuable at large section sizes for landscape sleepers, decorative panelling and carpentry, sacrificial timber baulks, keel blocks etc.

Alternative conifer timbers assembled for sale - Argyll

Species	Value (£/m3)
Norway spruce	30-50
Douglas fir (beam)	60-100+
Douglas fir (<60cm)	30-50
Larch (fine quality)	60-90
Western red cedar	30-50+
Western hemlock	25-40
Grand/ noble firs	20-30

Indicative timber values as at 2011

Comparison of wood properties - when evaluating the suitability of different alterative conifer timbers for intended processing applications, it is important to have a good understanding of their respective wood properties. Valuable research work in this field was undertaken between 1940 and 1980 by the former Timber Products Research Laboratory at Princes Risborough, Bucks. This has been taken forward more recently by the Centre for Timber Engineering (Edinburgh Napier University) and the Building Research Establishment. Key wood properties and parameters that need to be considered in each case are:-

- **Appearance, colour and figure** - some of the alternative conifers have stronger coloured timbers (red, orange, yellow) - this may be good for decorative cladding but not for pulp.
- **Moisture content and calorific value** - important characteristics that determine suitability for biomass applications (pulp, particle board, woodfuel) and also kiln-drying.
- **Natural durability** - the length of time that a timber will retain its integrity (physical properties and appearance) when exposed to exterior climates (wind, sun, water, soil). There may be a distinction in natural durability between heartwood and sapwood battens.
- **Strength** - key mechanical properties such as density, stiffness, modulus of elasticity, modulus of rupture and brittleness affecting load-bearing performance of beam timbers.
- **Dimensional stability** - the tendency or otherwise of a planked timber to distort in service (or during seasoning or kiln-drying) - examples include twisting, cupping and bowing.
- **Working properties** - how the timber responds to final wood-working operations - e.g. sawing, nailing, planing - those that check, split or tear are less favoured by the trade.
- **Defects** - undesirable flaws that are more common in some timbers than others - for example drought cracks, checks, ring shake, knots, pipe rot, fluting and included bark.

Species	Wood Density	Durability	Bending strength	Stiffness	Compressive strength	Hardness	Main applications
	kg/m^3, dried		psi, dried	at 1000 psi, dried	psi, dried	lb to indent, dried	
Norway spruce	470-490	Low-Moderate	9700	1140	5110	420	Structural (*also cladding, packaging*)
Douglas fir	530	Moderate	13700	1510	7170	790	Structural (*also cladding, decking*)
European/ Hybrid larch	480 (HL) - 640 (EL)	Moderate-High	15100 (EL)	1560 (EL)	7340 (EL)	890 (EL)	Cladding (*also structural, fencing*)
Western red cedar	390	Moderate-High	9400	1010	5080	450	Cladding (*also outdoor carpentry*)
Sequoia redwood	420	Moderate-High	N/A	N/A	N/A	N/A	Outdoor carpentry (*also cladding*)
Western hemlock	500	Low-Moderate	11600	1190	6270	600	Packaging (*also structural, joinery*)
Grand fir	450	Low	8300	960	4770	340	Packaging (*also lighter joinery work*)
Noble fir	420	Low	9200	1170	4500	450	Packaging (*also lighter joinery work*)
Silver firs	410 (PSF) - 480 (SF)	Low-Moderate	11100 (SF)	1270 (SF)	5880 (SF)	560 (SF)	Packaging (*also structural, joinery*)
Lawson/ Leyland cypress	500	Moderate-High	11400 (LEC)	910 (LEC)	5810 (LEC)	720 (LEC)	Outdoor carpentry (*also cladding*)
Japanese red cedar	N/A	Moderate-High	N/A	N/A	N/A	N/A	Outdoor carpentry (*also cladding*)
Macedonian pine	350	Low-Moderate	N/A	N/A	N/A	N/A	General joinery (*also poss structural*)
SOURCE	SAVILL, PATTERSON	WILSON	PRINCES RISBOROUGH BULLETINS				WILSON

Indicative wood property information for a range of alternative conifer timbers (sources stated above)

Some growers of alternative conifers become directly involved with local processing of their timbers for identified "niche" markets. This activity, increasingly known as "artisan sawmilling", often involves the processing of locally-grown hardwood timbers as well as those of alternative conifers. It may initially begin from personal enthusiasm or interest, usually in developing timber outlets that do not require long-distance road transportation and help to strengthen the local rural economy. These considerations apply particularly in the remoter North and West Highlands of Scotland. In many cases it is also felt that greater economic returns are obtained by the grower from sale of a final sawn product, such as cedar cladding, or even a manufactured wood-based product, such as larch boats or flat-pack beehives, than from initial sale of the unsawn roundwood logs to commercial markets. A particular focus is on those timbers, such as western red cedar, *Sequoia* redwood and western hemlock, which are recognised to be valuable in European or North American markets but which remain less familiar to, and less valued by, the major commercial sawmills in Scotland.

There are two alternative routes into local processing of alternative conifer timbers:-

Vertically-integrated or self-processing - situations where grower and processor are the same business entity, such as a smaller private estate owner or community-woodland initiative. They grow the timber, harvest it and process it on-site or at a small nearby sawmill or workshop. The sawn timber or assembled product is sold from a woodyard or gallery, or increasingly, over the internet. The owner makes a private investment in timber handling and processing equipment, although there are business development grants that can support this. This model represents a revival of the traditional private estate sawmill, which had generally declined during the post-war decades. Self processing has tended to be adopted earlier in southern England, with western red cedar being a favoured timber on small private estates.

Local partnership processing - situations where a timber grower works together with a separate local business who process their timber, either in the wood or at a nearby site. This is particularly attractive where a small but regular harvest of suitable material arises from thinnings or selection fellings - for example quality larch for heritage boat-building. The processor may invest in a saw, but the landowner will perhaps offer a milling site. There may be a joint-effort on selling the sawn product, with a profit-sharing agreement in some cases.

Under both models, the increasing availability of efficient and capable mobile circular and bandsaws for outdoor processing has provided an opportunity by reducing entry capital costs.

Below: industrial processing of Douglas fir for short-span beams
Left: small-scale processing of western red cedar for cladding

At the present time, the main source of grant-aid for the establishment, management and timber processing of alternative conifers is through the Rural Development Contract (RDC) mechanism of the Scottish Rural Development Programme (SRDP). As details of these schemes change over time, current advice should always be sought from the local Conservancy Office of the Forestry Commission or from the relevant official websites (see back inside cover). The main categories of grant assistance relevant to the subject of this publication are:-

Woodland Creation - assistance for the creation of new woodlands on bare ground sites**.** Many schemes involving the establishment of alternative conifers should qualify for the "high-cost conifer" model, reflecting greater costs for plants, protection and early tending as compared with conventional establishment of extensive upland spruce and pine plantations.

Woodland Improvement Grants - assistance for work in existing woodlands that enhances their silvicultural, landscape and environmental characteristics. Some types of work that may be relevant are (a) restocking with an alternative species to diversify woodlands, (b) thinning, enrichment planting and other works to improve the woodland structure (c) deer management to reduce the deer impact in woodlands. Measures related to the conservation of red squirrel may also be relevant in some parts of Scotland, as a diversity of conifer species, including Norway spruce, can be beneficial to squirrel numbers.

Sustainable Management of Forests **–** includes support to encourage the use of low-impact silvicultural systems (LISS). These systems are often relevant to use with alternative conifer species.

Landscape restoration - where plantations of alternative conifers form part of historic designed landscapes that have been subject to relevant research, there can be assistance for restorative tree plantings, clearing of obstructing vegetation (e.g. *Rhododendron*), management of the impacts of tree disease outbreaks and measures relevant to the enhancement of landscape amenity and the encouragement of public access/ recreation. These measures are often relevant to conifer collections, arboreta and forest garden situations.

Community and business development - this relatively new grant stream is relevant to capacity building and enhanced resource utilisation in the local forest management and timber processing sectors (e.g. woodfuel businesses, forestry contractors, mobile processing, timber building systems etc). Alternative conifers present many opportunities for such new ventures.

Operation	***For detailed information on current rates of grant available for establishment, management and utilisation of alternative conifer timbers, please contact your local Forestry Commission Conservancy office (see contact details overleaf) or refer in the first instance to:-***
Planting (high-cost conifer)	**www.forestry.gov.uk/scotland**
Farmland premium on new planting on farmland	**www.scotland.gov.uk/topics/farmingrural/SRDP/ruralpriorities**
Deer fencing (new planting schemes)	
Restructuring of even-aged plantations (coupe-felling)	
Restocking with diverse conifers	
Management (pruning, early thinning, respacing)	
Business development (e.g. mobile sawmill)	

Categories of grant available under the SRDP scheme for relevant forestry operations as at 2011

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Website sources for further information

Forestry Commission Scotland (policy, forestry grants) [www.forestry.gov.uk/scotland]
Scottish Government (SRDP) [www.scotland.gov.uk/topics/farmingrural/SRDP/ruralpriorities]
Forestry Commission (Forest Reproductive Material) [www.forestry.gov.uk/ frm]
Forest Research (ESC, climate change, provenance, silvics) [www.forestry.gov.uk/research]
UK Climate Impacts Programme (UKCIP) [http://ukclimateprojections.defra.gov.uk]
Building Research Establishment (Watford and Inverness) [www.bre.co.uk]
TRADA, Princes Risborough [www.trada.co.uk]
Centre for Timber Engineering, Edinburgh Napier University [www.cte.napier.ac.uk]

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