Forest Resilience in British Forests, Woods & Plantations

3. Past and Future Forests in Britain

In a further part of his series on resilience in forestry, **Jonathan Spencer** looks at forest composition in the distant past and the likely possible near future.

The hot summer of 2018 brought home to us one of the key characteristics of recent climate change predictions; extremes of heat and drought, with the fires on Salisbury Plain and Saddleworth Moor emphasising the more dramatic consequences. Increased extremes in the weather have long been predicted, but the science also points out that we can only avert the worst if we act boldly and act soon. Recent reassessment by the Intergovernmental Panel on Climate Change (IPCC, 2018) makes it very clear that to keep within 1.5°C of pre-industrial levels of greenhouse gases in the atmosphere we have to make major adjustments to the structure of the world economy and that we have only some 10 to 15 years to do so. Dramatic changes to the environment within which the next generation of our trees will be maturing thus appear inevitable. Even if we stop pumping carbon dioxide into the atmosphere and limit global warming to 2°C, a cascade of tipping points may result in a warming of 4 or 5°C or more; an environment not seen since the mid Tertiary some 20 million years ago. In planning for future forest resilience, we face climatic uncertainty, with potential conditions last seen in a distant sub-tropical past or the climate of a very warm interglacial if we manage to exert some control over carbon emissions.

In the Forestry Commissions centenary year, looking ahead to the challenges of the coming century would seem appropriate. For forest managers these challenges include tree establishment and silviculture having to accommodate conditions not anticipated at all a century ago. The case for resilient forests and the management implications of doing so have already been considered (Spencer, 2018a and 2018b). In this article consideration is given to why tree species diversity, especially those valued for timber production, is so limited in north western Europe, and why forest timber tree species from north-west America are so strongly favoured in northern and western Britain. Comment is also made on the lost native trees from the Tertiary and from earlier Pleistocene interglacials. Foresters and the forest industry tend to see the future in terms of alternative tree species. Forest ecologists tend to see the future in terms of forest tree communities and species diversity imparting forest resilience. Given that forest resilience is so bound up with the establishment of tree species diversity and genetic variation, but forestry and forest production in the performance of particular tree species, this review is presented largely in terms of the key timber-yielding species present in our past forests. The continuing role of forests in the provision of timber, fuel and fibre as society moves towards the establishment of a low carbon economy in the 21st century will remain extremely important. This commentary is intended to provide some insight into the potentially more radical choices that may need to be considered in the likely event of unprecedented climate change.

Past climates and past forests

For most of the past 50 million years, before the onset of the ice ages some two and a half million years ago, much of the earth has been much hotter than today, with few frosts and hot summers (see Figure 1). Rather more recently, the

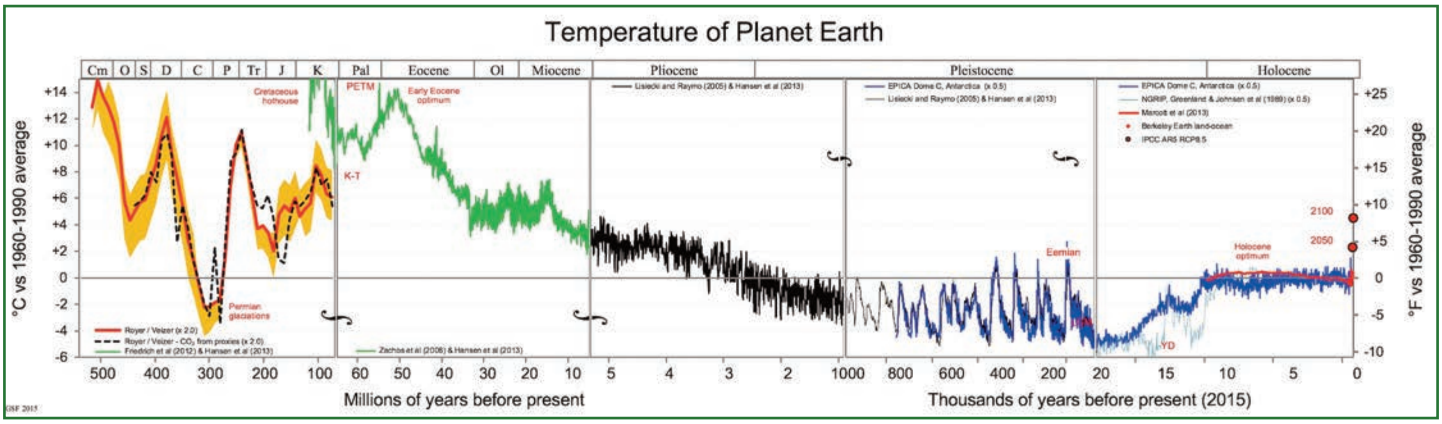


Figure1 Past average temperature across prehistory. For full detail and references, see http://gergs.net/2015/06/updating-the-geological-temperature-plot/all_palaeotemps/ (By Glen Fergus - Own work; data sources are cited below, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=1240577)

interminably long glacial periods were interspersed in the UK with periods of milder interglacials of varying length and character, when conditions improved and forests returned. These past interludes provide important insights into the nature of our forests in the past and provide plausible models for forests of the future. A sound appreciation of the diversity and character of the forest communities that prevailed under the different climate conditions of the past could inform both future policy and practice.

Forests before the ice…

The ancient forests of Northern Europe were full of familiar species, although in assemblages that appear strange and unexpected today. We can look back at forest composition throughout the Tertiary and consider forests at a time when the climate was similar to that we may well be experiencing soon; with average temperatures reaching several degrees higher than at present and with little or no ice or frost. The Tertiary period started about 65 million years ago and lasted until the onset of the ice ages some 2 million years ago. The early Tertiary forests were essentially tropical in character; the later Oligocene and Miocene forests were more familiar temperate forests with average temperatures some 4 to 10°C or so above those of today.

Late Tertiary forests in Europe shared many characteristic species with forests worldwide at the time. They were dominated by frost-sensitive conifers and large leaved broadleaves. Although the trees were from familiar genera, the species were clearly rather different. 'Timber'-bearing species included *Sequoia* spp, *Metasequoia* spp, *Abies* firs, *Picea* spruces, pines, *Tsugas*, *Taxodium* (swamp cypresses), *Fagus* spp. *Cryptomeria*, *Carpinus* spp, *Pterocarya* (wingnuts), chestnuts, yews, *Liquidambar*, elms, oaks, *Acers* and *Platanus* (planes), limes, magnolias and *Liriodendron* spp (tulip trees), with laurels, hazels and palms in the understory (Ingrouille, 1995). The far drier and cooler Pliocene started about 7 million years ago and led to significant changes in the tree flora of Europe, and a shift towards broadleaves. Horse chestnut, walnut and elm seem to have retreated to the Caucasus at this time, to reappear in southeastern Europe with the improving climate at the end of the Tertiary. These forests occurred across northern Europe, Eurasia and North America and were the precursors of forests that lived through, were destroyed by, or responded to, the glacial and interglacial periods that shaped the forests of Europe and North America as we now know them today.

Tree species diversity in British Quaternary interglacials

These extraordinary forests were all rapidly swept away, geologically speaking, with the arrival of the prolonged glacial 'ice ages'. Towards the end of the Tertiary repeated cycles of warm and cooler climates became established, each lasting about 100,000 years. These became more pronounced, the cooler periods became much colder and glacial ice spread out from the higher and more northern areas to eventually form continent-wide ice sheets. Seventeen cycles of cold and temperate climates can be recognised in Britain over the past two million years, with ten in the last million. However, in the last 300,000 years things became very cold indeed with three episodes of glaciation covering large parts of Britain. These oscillating advances and retreats eventually swept away all the frost sensitive Tertiary forest trees. With each advance and retreat the forest composition of Europe was reduced in species diversity. Sometimes the recovering forests were of markedly different composition, clearly demonstrating that plant communities are contingent entities and not independent of geographical chance. Some species, such as the Caucasian wingnut *Pterocarya fraxinifolia*, were present in diminishing abundance in early warm periods but disappeared with the arrival of severe cold dry periods; others such as Norway spruce and silver fir appear in some interglacials but not in others, suggesting a degree of chance as to their presence or absence across Britain. The relict *Picea omorika*, the Serbian spruce, was once widespread across Europe but is now confined to one valley in Bosnia. The hemlock, lost to Europe in the early Pleistocene, was one of the last survivors of the Tertiary forests in Europe (*Tsuga caroliniana/ canadensis*, not the *Tsuga heterophylla* from the west coast of North America, though ecologically very similar). The signal is clear; what constitutes the composition of British forests throughout this period of early climate chaos was the result of a combination of ecological necessity (the species that could thrive under the prevailing ecological conditions) and geographical chance (those that perchance were in a position to recover and respond when conditions allowed). Throughout, though, a core suite of familiar native trees responded and returned, demonstrating an inherently high degree of resilience and adaptability that should be carefully considered in any strategy to build resilience into future forest composition. Scots pine, Norway spruce, silver fir, various oaks, limes, hazel, hornbeam, beech, rowan and birch, aspen, elm and alder; all have shown a repeated ability to respond and recover from major climatic events in the past and all are found across most of Western Europe, from Cantabria and the Pyrenees in the south to Scotland and Sweden in the North.

However, the overall diversity of species across Europe diminished considerably. Tertiary relicts were rapidly lost (though some persisted for surprising lengths of time, notably the wingnut, *Pterocarya fraxinifolia*) and most are now confined to very distant relict refugia in European enclaves in the forests of northern Turkey, the Caucasian forests of Georgia, the southern fringes of the Caspian Sea, or in fragments of evergreen forests in the Azores and the Canary Islands. The history of individual tree species is rich and complex (an accessible and full account can be found in Ingrouille, 1995). Tree species assemblages are not arbitrary, but neither are they fixed and immutable; they are the product of both prevailing conditions and the changing fortunes and opportunities driven by the vagaries of climate and biogeography.

Holocene change

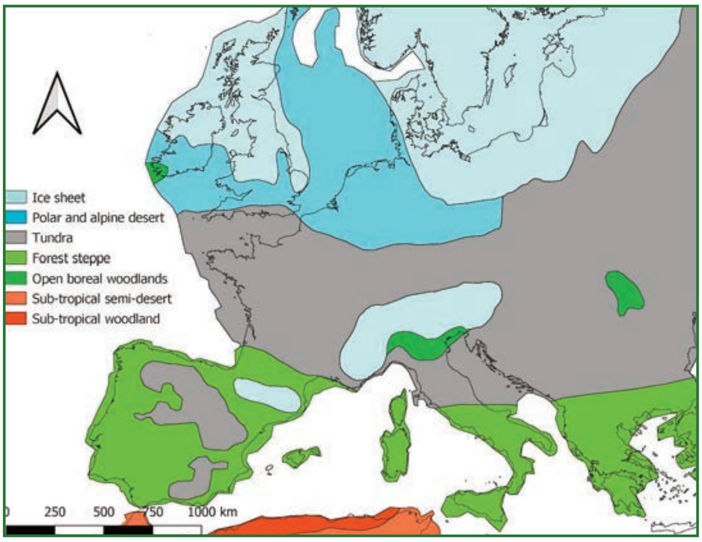
The fluid nature of tree distribution and forest communities in the present, the Holocene and Anthropocene, has also been well described (see Birks and Tinner, 2016). The Holocene,

The Axel Heiburg Island Forest, North West of Greenland.

Under such mild conditions early Tertiary forests spread far to the north of the Arctic Circle. These arctic Eocene forests were warm and sub-tropical in character (similar to those of Florida today) and probably never experienced freezing, even though they experienced three months of darkness each year. They are very well understood given the survival of exquisite fossil beds on Axel Heiburg Island, north-west of Greenland (Jahren, 2007). Dating from about 45 million years ago, this polar forest is preserved as tree stumps, logs, roots, leaves, seeds and cones, and is comprised of tall dawn redwoods, *Metasequoia* spp., by far the most abundant fossil present, along with *Glyptostrobus pensilis*, the Chinese swamp cypress, *Ginkgo* spp., *Larix* spp., spruces, pines, several hemlocks (*Tsuga* spp), several hickories (*Carya* spp), a *Platanus*, *Betula* spp., *Alnus*, *Acers*, chestnut and beech, ash and elms, holly, walnut, *Liquidambar, Nyssa* and a lime (*Tilia* spp); along with the bones of alligator, turtle and an extinct rhino like herbivore… and fossil wood containing galleries of *Dendroctonus* bark beetles.

Middle Eocene fossil Metasequoia stump, Axel Heiburg Island today. (Photo: Ansgar Walk, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=6416489) the span of time since the retreat of the ice some 12,000 years ago, is characterised by both prolonged climate stability (see Figure 1) and the successive and rapid arrival of tree species, subsequent fluctuations in their comparative abundance and distribution, followed by an unremitting history of forest removal and soil degradation since the late Neolithic and Bronze Age.

Few tree species were lost, but many have become localized or scarce (limes in particular have a distribution and history closely tied to past climate and human land use; see Pigott, 1991). Scots pine, *Pinus sylvestris*, persisted as a scarce component of upland northern British forests for far longer into early history than is generally appreciated, with remains of pine branches found in Roman cemeteries in York and as pollen in peaty deposits in Cumbria as late as the 13th century AD (Huntley, 2010). Recent studies of the DNA of the 14 surviving pines from Williams Cleugh, north of Bellingham in Northumberland, demonstrate a strong affinity with the genetic makeup of native pinewoods in the north of Scotland, supporting the view that Scots pine persisted throughout the Holocene, not only in Scotland but over much of northern Britain (Forest Research, 2005). Forest loss and anthropogenic changes to forests and soils alike have long determined forest composition in Britain.



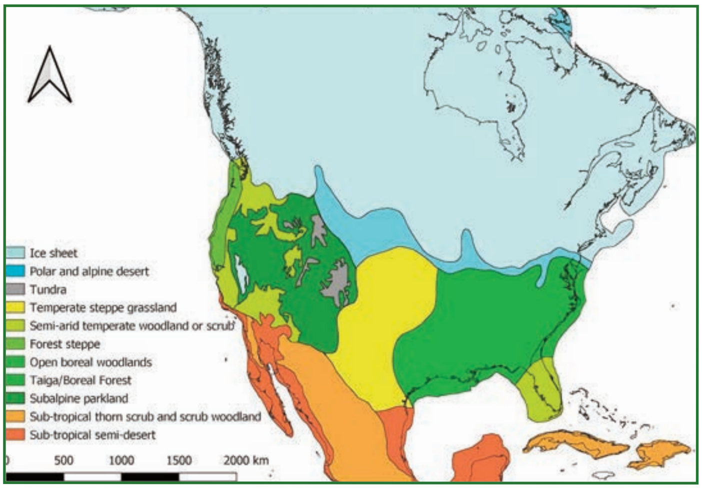
Map 1. Europe in the Late Glacial Maximum. Trees and forests were repeatedly scraped from the face of Europe. The biogeographic barriers run east-west with forest refugia in cold dry Iberian peninsular and the warm, dry southeast of the continent. Tertiary species once found in Europe are now restricted to locations in the Caucasus, the Hyrcanian forests of the Caspian Sea, with more remote survivals in temperate China. Data modified from Ray and Adams (2001).

Europe & North America compared

The tree flora of Europe is much impoverished as a result of the accidents of continental geography. The major geographical barriers (the Sahara, the Mediterranean Sea, the Atlas Mountains, the Pyrenees and Alps, the Channel and Irish Sea), all run east-west, across the advance of the ice from the poles. In North America the mountain ranges of the Rockies and Appalachians, the prairies of the Midwest, the peninsula of Florida, the coasts of the Pacific and Atlantic all run north-south, allowing forests to expand and contract without facing insurmountable biogeographical barriers. This has had profound implications for the character of present day forests across both continents and has determined both the paucity of timber tree species in Europe and their diversity in North America (See Maps 1 and 2).

The situation was exacerbated in Europe by the nature of the refugia within which our tree flora persisted at the time of the Late Glacial Maximum. In Europe the refugia for trees were very dry. They lay in the Iberian Peninsula and across much of the Balkans, both of which experienced continental *dry* climates. The Atlantic seaboard was *dry* and cold; the southern refugia *dry* and warm. It has been speculated that the Atlantic ecotypes of silver fir and Norway spruce both disappeared during these cold *dry* periods, robbing present day foresters of native conifers that might have thrived in cold, wet conditions (Rackham, 1980). In North America the refugia for many conifer species persisted in the western regions of the coastal pacific and in the Rockies; coast redwoods, hemlocks, spruces, cedars and cypresses all persisted here in wet and cold, but essentially mild conditions. Redwoods, spruces and other timber bearing conifers survived and spread north to create the extensive western conifer forests found today. Sitka spruce appears to have survived farther north in cold, wet coastal refuges in modern day Alaska and British Colombia. The wet rainy conditions found in the north and west of Britain today support few native tree species, but the conifers of western Canada and the north west of America thrive under such conditions.

One encouraging consequence of forest history in Europe is that the tree species regarded as native to Britain can reliably be regarded as resilient against future climate change; they have survived and recovered from many dramatic changes over hundreds of thousands of years. They have been memorably described as the weed species that raced back with the retreat of the ice (Richard Jinks, pers comm.). Most have widespread distributions and are genetically very varied. Having coped with the wildly



Map 2. North America in the Late Glacial Maximum. The biogeographic barriers run north-south with extensive forest refugia in the cold wet pacific coast and western mountains, and warm temperate and sub tropical refugia in the South eastern states where many 'Tertiary' forest species persist to the present day. Data modified from Ray and Adams (2001)

fluctuating environmental conditions of the past two million years, they will continue to thrive under the changes anticipated by climate scientists today. If we curb emissions and restrict average temperature change to below 2°C we shall be working with forests of familiar composition and character. Should we breach these conditions then we are heading into climate territory not seen since the mid-Tertiary and our ideas for forest composition, and the timber tree components they support, will have to change accordingly.

Lessons learnt

The key lessons to be drawn from a study of past climates and forests appear to be:

- Forest composition is not arbitrary, but neither is it fixed and immutable; it is the product of both prevailing conditions and the changing fortunes and opportunities driven by the vagaries of climate and biogeography.

- Forests are resilient to both extremes of climate and rapid changes in temperature, adjusting over time as conditions prevail (though within timescales that are not well suited to human lifespans, our inherent impatience, nor the immediate needs of society for the goods and services that forests provide).

- Our native tree species demonstrate an inherent high degree of resilience and adaptability. They have shown a repeated ability to respond and recover from major climatic events in the past and all are found across most of Western Europe.

- British forests are a subset of a wider (but not much wider) range of European trees, some of which have occurred here in previous interglacial warm periods and some of which simply did not return fast enough over the past 8,000 years to become regarded as native trees.

- We nevertheless have either lost, or never had, a suite of trees adapted to the cold wet conditions and the gleyed or peaty soils of north-western Europe. To make our upland and western forests more resilient and maintain their capacity for timber production we will have to look to north-west American forest trees, chosen for their performance as timber, and find European or north-American associates that might impart resilience against changing conditions and novel pests and diseases.

- Longer term changes in our possible climate future may take us towards uncomfortable territory and the need to

Table 1. Past and present native timber trees … a brief review.

Present interglacial native British trees…	Oaks, beech, elms, ash, small-leaved and large-leaved lime, field maple, hornbeam, birches, alder, aspen, black poplar, cherry, wild service tree, rowan, Scots pine, yew, juniper. Plus sycamore and sweet chestnut as long established introductions.
Past interglacial native British tree species…	All species above plus: Silver fir, Norway spruce, Serbian spruce, hemlock (*Tsuga*), sycamore, Norway maple, Montpellier maple (*Acer monspessulanum*), hickory (*Carya*) Caucasian wingnut (*Pterocarya*), walnut (*Juglans*), tulip tree (*Liriodendron*).
Past European Tertiary natives… before the ice.	All the above plus: *Sequoias*, *Metasequoia*, *Cryptomeria*, *Cedrus* spp., *Abies* firs, *Picea* spruces, *Thuja* spp., pines, *Taxodium*, *Tsuga* spp., *Ginkgo*, *Larix* spp., *Fagus* spp., *Quercus* spp., *Liriodendron*, Magnolias, *Parrotia*, *Liquidambar*, *Acer* spp., *Platanus* spp., *Juglans* spp., *Tilia* spp., *Zelkova* spp., *Ostrya* spp., *Carya* & *Pterocarya* spp., *Betula* spp., *Alnus* spp.

consider forest species that have long since been lost to Europe as native elements.

- Many of these trees are already present in the modern landscape in parks, gardens and arboreta. These trees will no doubt respond in any event as changing climatic conditions allow for their reproduction and spread across the landscape. We should consider such species on their merits and assess our response accordingly (see Thomas, 2017).

The European forest landscape of the past was very different. Its forests were direct descendants of forests that had persisted in one form or another for many millions of years. They were extensive, complex, and comprised of a great diversity of tree species and genera. These forests stretched from North Africa to the Arctic Circle. Changes in climate are not new challenges to forests per se; forests in some form will persist and thrive. But they will be forests of species and composition unfamiliar to foresters and conservationists alike. If we wish to remain comfortably within our existing forest and nature conservation paradigms, then addressing climate change has to remain our highest priority. Change though, now appears to be inevitable. Sustaining the status quo for forestry or nature conservation alike will sadly no longer be an option.

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