Eucalyptus - Part 2

Findings from trial plantings, and silvicultural requirements in the British Isles

In the second part of their profile of eucalypts **John Purse** and **Andrew Leslie** review the results of planting trials in the UK and the opportunities and risks they have highlighted.

Despite a long history of growing *Eucalyptus* species in arboriculture in Britain (Purse and Leslie, 2016), there has been little interest in their potential for forestry until very recently. This situation is in marked contrast to that in many other countries, where many species found various forestry uses, notably for firewood production and for land reclamation (Zacharin, 1978; FAO, 1979). However, they did not become important timber species due to the poor sawmilling properties of trees, which were young compared to old-growth trees used for timber in their native Australia (e.g. Barr, 1996; Santos 1997).

This situation changed in many countries with the discovery that certain eucalypts produce excellent quality short-fibre pulp using the Kraft and sulphite chemical processes (Doughty, 2000). There was burgeoning demand for such pulp from the 1950s, and increasingly limited supplies of other suitable hardwood feedstocks, such as birch in Scandinavia and mixed hardwoods in the USA. This led to a surge of commercially-driven research on *Eucalyptus*, spanning silviculture, genetics, propagation and wood properties. This established that many eucalypts respond well to intensive silviculture, and can produce trees of a size and quality suitable for pulp on rotations of 7-10 years. The approach became known as short rotation forestry (SRF), and is practiced on an immense scale worldwide today, largely by the private sector (Marcus Wallenberg Foundation, 1984; Carle and Holmgren, 2008).

The UK never has had a chemical pulp industry, and so these developments had little impact. Small trials of *Eucalyptus* for forestry in the UK only started in the 1950s (Macdonald et. al., 1957) while the first systematic trials in the UK were in the 1980s (Evans, 1986), although in Ireland trials started earlier in the 20th century (O'Beirne, 1945; Mooney, 1960). Few of these trials were successful, and survival of the trees was frequently poor (Evans, 1980). These findings, coupled with poor timber quality, meant that little interest was generated. An exception was the small commercial coppice plantations supplying the floristry market with cut foliage. These have existed in Britain since the 1960s, mainly in south-west England and in north Wales. Similar plantations were developed in Ireland at this time (Pollock, 1984; Forrest, 2000).

In this article we review these and more recent trials in the context of commercial eucalyptus forestry elsewhere in the world, and identify the opportunities and risks that would be associated with undertaking larger-scale plantings of *Eucalyptus* species in Britain. We have previously discussed the species that are likely to be most suitable for this purpose (Purse and Leslie, 2016).

Cold-tolerant species of eucalypts in short rotation forestry

The species of *Eucalyptus* that have been used for SRF in temperate climates experiencing cold winters are native either to the mountains of Tasmania, or the sub-alpine parts of the Great Dividing Range in Victoria and New South Wales (NSW). They have been planted in temperate areas having similar climates around the world. The most commonly used species is *Eucalyptus nitens*, which effectively extends the range of sites suitable for the related but less cold-tolerant *Eucalyptus globulus* ssp. *globulus* in Chile and northern Iberia (Purse and Richardson, 2001). *Eucalyptus dalrympleana* has been used in inland Catalonia (Ruiz, 1992), and clonal selections of *Eucalyptus gunnii* and *Eucalyptus gunnii* x *dalrympleana* hybrids are grown in south-west France (FCBA, undated). There is experience with several other species in the far south of South Island, New Zealand (Nicholas, 2009).

In all these locations establishment practices are more intensive than those normally employed for other forestry genera. The methods involve significant cultivation, rigorous weed control, site-specific fertiliser application (usually applied close to the trees) and use of genetically well-defined planting material. Planting is invariably carried out in spring, as soon as the risk of serious frosts has passed. Methods used for site preparation and establishment vary considerably between locations, due to different abiotic and biotic constraints. The overall objective is to achieve rapid and uniform early growth in the first year, to ensure that the trees (and their associated root systems) are as large as possible prior to their first winter. Much research and development has been carried out to develop recommendations for cost-effective establishment (AFOCEL, 2007; ENCE, 2008).

The wide variation in conditions and of species are reflected by a broad range of yields. SRF stands of *E. nitens* on good quality sites in Chile can give a MAI of $40m^3ha^{-1}year^1$ on rotations of around 8-10 years. A set of 46 research SRF plots of *E. nitens* in one region of Chile, deliberately placed across a very wide range of site types, gave MAIs in the range 12 to 60 $m^3ha^{-1}y^{-1}$ at 10 years (Rodríguez et. al., 2009). Modelling of the data indicated that water availability (due to both rainfall and soil water-holding capacity) was the largest determinant of yield. By contrast, yield was little influenced by altitude or average temperature. Similar findings have been reported for sub-tropical eucalypts in Brazil (Stape et. al., 2004). If this holds true for other species of *Eucalyptus*, then yields in Britain clearly will be very site-specific as well as species-specific. The little growth data that is available supports this; Evans (1986) found considerable differences in growth rates of *E. gunnii* in a series of plantings across Britain and the basis for this pattern was not clear.

Forestry trials from 1950 until 2010

Since the 1950s there have been several periods of formal and informal *Eucalyptus* research, and trial plantings, in both Britain and Ireland. These have been tested by some severe winters, notably 1978/79, 1981/82, 1984/85, January 1986, 2009/10 and 2010/11. The results therefore provide some indication of the species that may be grown successfully in specific areas of the UK and Ireland (Purse and Leslie, 2016).

Of the surviving plantings dating from the 1960s and 1970s, there is a notable stand of P1968 *E. gunnii* planted by the Forestry Commission in Glenbranter forest, Argyll. Around 1971 various species were planted at Blue Gums, Lamberhurst, Kent (unmissable by those travelling on the A21 north of Lamberhurst today). These were examined and measured in 2014; *E. glaucescens* proved to be the most impressive, though several other species have grown well (TROBI, 2015).

The first systematic attempt to introduce and screen origins of cold tolerant eucalypts in the UK was undertaken by Forest Research in the 1980s (Evans, 1986). The young trees were severely challenged by the cold winters that followed, but reasonable numbers survived in some locations, and have since provided useful information on growth rates (Bennett and Leslie, 2003; Leslie et. al., 2014). Table 1 presents data on the size and survival from a range of successful plantations or trial plots from the 1980s experiments.

Table 1. Size of trees and survival from experimental plots and operational plantings.

Species	Location	Survival (%)	Age (years)	Dbh (cm)	Height (m)
E. delegatenisis[1]	Small replicated plots at Chudleigh, near Haldon Forest, Devon (NGR SX882827)	48	28	48	18.8
E. glaucescens[2]	Small replicated plots at Thetford, Norfolk (NGR TL772825)	31	21	25	22.6
E. gunnii[3]	Operational SRF planting, Daneshill, Notts (NGR SK679859)[3]	89	5	12	10.6
	Dalton, Cumbria (NGR SD457865)[3]	N/A	23	23	17.8
	Glenbranter, Argyll (NGR NS102969)[3]	N/A	43	35	30.1
E. nitens[3]	Small line plots at Torridge, Devon (NGR SS419024)	N/A	25	36	28.7
E. subcrenulata[1]	Small replicated plots at Chudleigh, near Haldon Forest, Devon (NGR SX882827)	68	28	31	21.4
E. urnigera[3]	Dalton, Cumbria (NGR SD457865)	N/A	23	26	21.2

[1]Leslie et al (2014), [2]Bennett and Leslie (2003), [3]Leslie, unpublished data.

Figure 1. Demonstration planting of Eucalyptus nitens age 10 years, grown using SRF principles in north Kent.

In the 20 years following the severe cold of January 1986 there was limited interest in the genus in the UK, although there were a few plantings after 2001. A SRF planting of *E. nitens* at Newnham, north Kent in 2001 has grown impressively, giving an MAI of 40m^{3}ha^{-1}y^{-1} at 8.3 years (Purse, 2010a) (Figure 1). The trees were unaffected by the cold winters at the end of the decade. Adjacent *E. gunnii* ssp. *divaricata* have proved less productive and have much poorer form. In 2005 a 24ha planting of eucalypts was made at Daneshill, near Retford, Notts. The main species planted was *E. gunnii* ssp. *gunnii* (Figure 2). This planting experienced quite severe dessication damage in cold winds in November 2005, even though the minimum air temperature was -9°C. The damage was probably exacerbated by the use of plastic mulch, which was used as a means of weed control; a consequence of its use was that it encouraged surface rooting of the crop, and these roots were unable to function properly in the cool surface soil, at a time of high transpirational demand. Most plants recovered, though their form was compromised. In 2005 re-stock sites at Rogate Common, West Sussex were planted with a range of *Eucalyptus* species, predominantly *E. nitens*. These established well, and plantings were made in subsequent years with modifications to optimise the establishment conditions.

Figure 2. Comparison of E.gunnii managed on SRF principles (left), and birch (Betula sp.) and oak (Quercus sp.) (right) at Daneshill, Nottinghamshire. All trees are 5 years old.

Around 2008 interest in *Eucalyptus* was stimulated again, following a number of policy initiatives aimed at promoting renewable energy. For example, Read et. al. (2009) identified establishing fast growing hardwood species as being one of the most cost-effective means of sequestering atmospheric carbon. In 2009 a series of trials was established across England testing the growth and survival of a range of potential species for short rotation forestry (McKay, 2011). These trials included large areas of *E. nitens*. In Thetford Forest the Forestry Commission undertook a significant planting of a range of *Eucalyptus* species in 2010, as part of efforts to find alternatives to pine (*Pinus* spp) and larch (*Larix* spp). This planting included *E. glaucescens* and *E. urnigera*.

The exceptional cold winter of 2009/10, followed by another extremely cold winter in 2010/11 caused considerable damage to eucalypts in many of these trials, particularly in inland and northern areas. Most of the areas of *E. nitens* planted in 2009 were killed. At Daneshill, in the winter of 2010/ 2011, there was complete mortality of *E. nitens* on the site and *E. gunnii* was killed down to the root collar. The *E. gunnii* subsequently resprouted and has grown vigorously. The stems of both species were harvested in June 2011 and the weight of wood was 2,076Mg over 24.4ha, representing an impressive growth rate of 17 tonnes ha^{-1}y^{-1} at five years of age (the moisture content of the harvested material is not known) (Woodisse, 2011). The losses dented the enthusiasm for planting eucalypts; nevertheless, many young stands survived, and provided the confidence for some landowners to continue planting. The survival of the P2010 *E. glaucescens* and *E. urnigera* at Thetford, coupled with their general immunity to deer, was widely noted. In

Figure 3. Re-growth of coppice age 4 years on Eucalyptus gunnii at Daneshill, Nottinghamshire, following severe cold-damage to the tops in 2010/11, and harvesting in 2011.

Ireland there has been more widespread planting since 2009, and by 2011 220ha had been established by Coillte. The aim is to produce woodchip for the Irish board industry, and biomass for energy; trials have shown that *E. nitens* is an acceptable substitute for Sitka spruce (*Picea sitchensis*) feedstock for board production (Hutchinson, 2011).

General comments on eucalypts for forestry in Britain: Coppicing

Most *Eucalyptus* species coppice well, and this can be a practical option for second and third rotations with many species. A study in New Zealand showed that *E. urnigera* and *E. rodwayi* would coppice successfully over five rotations (Sims et al., 1999). Coppice rotations are also usually more productive, as the root systems are already established (AFOCEL ,2007). A mixed stand of *E. gunnii* and *E. dalrympleana* at Redmarley, Gloucestershire yielded of 317m^3ha^{-1} at ten years of age in its second coppice rotation (McKay, 2010). Coppicing is also a useful response to cold damage, in that it can avoid the cost of replanting following death of the original stem. However a few species, notably *E. nitens*, do not coppice well (Sims et al., 1999). Furthermore, certain coppicing species, including *E. gunnii*, tend to produce a large number of co-dominant coppice shoots of small diameter, which are costly to thin (Figure 3).

Environmental impacts

Potential environmental impacts of SRF using hardwoods including *Eucalyptus* species in Britain have been comprehensively reviewed (McKay, 2011). Overall, there appear to be no reasons to consider the impacts of *Eucalyptus* species differently from any other candidate species for SRF. For *E. gunnii* and *E. nitens* invasiveness risk assessments have been conducted and they are considered to pose only a low to moderate risk (GB Non Native Species Secretariat, 2011a; GB Non Native Species Secretariat, 2011b). Booth (2012) assessed the general threat of invasiveness of eucalypts in cold climates and, due to the small seed size and the resulting vulnerability to competition from weeds, scored it as low.

Wood properties and utilisation

The principal use for eucalyptus wood worldwide today is for pulp production. A key factor governing the value and suitability of the wood for pulp production is its basic density (BD), defined as the oven dry weight per unit volume of green solid wood. For this reason, much information on basic density of eucalypts has been generated, although much remains unpublished. BD strongly influences the energy content of wood per unit volume, as calorific value of wood varies little with unit dry weight (18-20MJ dry kg^{-1}) (Klass, 1998).

The BD within *Eucalyptus* stems varies considerably, between outerwood and inner core, with age of tree and genotype, and due to growing conditions. Thus, getting a representative whole-tree BD requires careful sampling. Taking all these points into account, the average BD of young (<15yr) eucalypts that are grown in Britain is generally in the range 450-500kgm^{-3} (Evans, 1983; Kibblewhite et al., 2000; AFOCEL, 2004; Hutchinson et al., 2011). This is intermediate between most conifers, willow and poplars (<400kgm^{-3}), and the native hardwoods (>540 kgm^{-3}) (Serup, 1999). Thus the fuelwood value of *Eucalyptus* that can be grown in UK is intrinsically quite good, but less good than the species most valued as firewood logs. Logs of SRF *E. nitens* air-dry readily, especially in summer (Bown and Laserre, 2015). Dry eucalyptus logs burn well, without spitting. In recent years eucalyptus logs have become the premium-priced firewood log type in parts of New Zealand (Milligan, 2012).

SRF eucalyptus wood is rarely used for sawn timber, though there are a few significant exceptions. The main constraints concern the splitting of logs within days of felling, as intrinsic stem tensions are released, and the checking during drying. All these factors lead to poor board recoveries. Appropriate genetic selection, silviculture and milling procedures have been necessary in the situations where these issues have been overcome on a commercial scale (Purse, 2015b). It seems unlikely that *Eucalyptus* grown in

Britain will be utilised in sawmills, unless there is considerable investment in appropriate research and development.

Recent developments

Both direct and indirect evidence shows that good stands of *Eucalyptus* can be grown to rotation in less than ten years in parts of Britain. As would be predicted from experience elsewhere, SRF standards of silviculture are essential in order to achieve uniform and satisfactory establishment. However, whether this means that *Eucalyptus* species can be grown reliably and cost-effectively in parts of Britain remains less clear, and in this section we will consider the prospects in the light of the evidence.

Over the five years from 2011 British nurseries have sold a total of almost 220,000 eucalyptus plants, all of which have been cell-grown. Over 90% of these plants comprise just five species (Figure 4), with *E. glaucescens* comprising 40% of the total. This scale of planting implies an average national planting of slightly over 20ha per year, assuming no mixed plantings (this assumption appears largely true, with one interesting exception that is discussed later). From a national perspective, planting on this scale is essentially informal trialling. But it does indicate that some landowners are sufficiently interested in the potential of eucalypts to contribute to their forest-based enterprises. Some excellent young stands have been created, based on SRF principles (Figures 5 and 6), but not all the recent plantings have been successful. However, there has been little evidence of cold-damage to well-established young trees, which is consistent with the winters in this period being relatively mild; the failures seem to have been mainly due to poor weed control, and browsing.

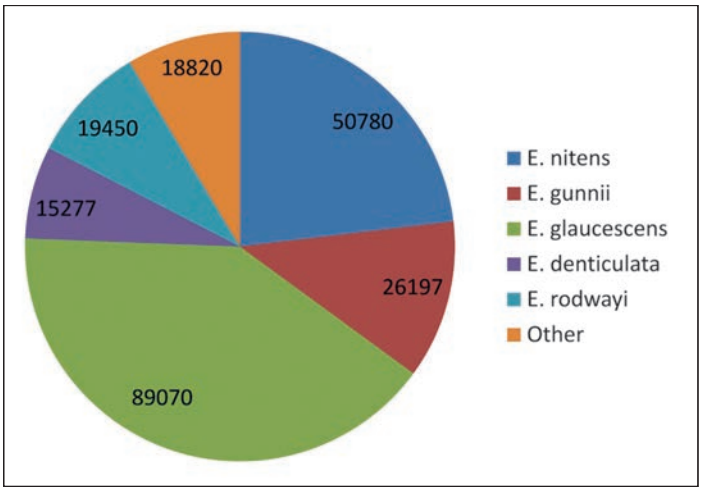

Figure 4. Sales of eucalypt plugs in Great Britain and Ireland between 2011 and 2015 (data provided by Alba Trees, Cheviot Trees, Christie Elite Nursery and Prima Bio).

The landowners involved have used different methods to achieve effective establishment at acceptable cost, and details of their approaches vary considerably. Visits by one of the authors (JGP) to many of the sites during 2015 allow some general comments:

- Eucalypts benefit from some sort of soil cultivation, as recommended by Evans (1986). On certain sites, an imbalance develops between stem growth and root growth and instability can result. This may be lessened by sub-soiling, facilitating root growth.

Figure 5. Eucalyptus glaucescens age 16 months on a fertile pasture site near Upton-on-Severn, Worcestershire. Standards of weed control have been consistently excellent.

Figure 6. Eucalyptus glaucescens age 33 months on a fertile pasture site near Upton-on-Severn, Worcestershire. This is the same stand as illustrated in Figure 4. The crop is now dominating the site and further weed control will probably not be necessary.

- Spacings of 1600-2000 plants ha^{-1} appear appropriate (this is consistent with SRF eucalypts in reasonably productive locations elsewhere in the world).

- Only one location has successfully coupled the presence of deer and not using tree guards (Thetford Forest, using *E. glaucescens* and *E. urnigera*).

- On sites where perennial grasses and bracken have not been eliminated pre-planting, and on fertile arable sites, it is essential to use tree guards to permit chemical weed control over the rooting zone. Adequate control of these weeds without guards has not proved possible.

- Spiral tree guards have been used successfully with all species other than *E. nitens*, though spraying a systemic herbicide around a eucalypt in a spiral guard requires great care.

- Solid tree guards work well, provided they have strong stakes. *E. nitens* requires guards of larger cross-sectional area.

- On good quality restock sites that are free of weeds at planting and have plenty of natural mulch, eucalypts may establish sufficiently rapidly that post-planting weed control is not necessary for good crop establishment. However, post-planting weed control may still have been beneficial in these cases. Poor weed control during the months following planting leads to poor establishment, slow growth and poor survival.

It is not possible to objectively justify the cost of the necessary establishment silviculture, without knowing the expected yields and the likely value of the crop. The logical response is to start planting on a modest scale, with two or three species likely to be suitable for the site, and apply excellent SRF practice at modest cost. This will allow the yield potential of the species on the site to be assessed, and appropriate establishment practices devised.

Assuming that SRF silviculture is practiced, then the greatest risk is likely to be from cold damage, or browsing. The risk of browsing is very species and site-specific, and can only be assessed by local trials. Most eucalypts are not inherently particularly palatable, and tree guards seem to be sufficient to protect against damaging browsing by rabbits and hares. The popularity of *E. glaucescens* for planting in recent years is in part due to its unpalatability to deer, but such unpalatability is not always apparent, and trials are an essential part of determining the feasibility of growing eucalypts of any species in a particular locality.

The risk of cold damage is somewhat more predictable, provided SRF is used to produce plants of a good size (1.5m in height is a reasonable target for most species on moist sites) in their first winter. The hardiest species can be expected to survive short periods of screen temperatures of -15°C in their first winter with little damage, but damage is likely at temperatures much below this. Older trees are likely to be able to withstand temperatures 2-3 degrees colder, and may be able to recover from even lower temperatures. For less hardy species, most obviously *E. nitens* and *E. denticulata*, damage is likely if temperatures drop much below -10°C in their first winter. Thus, the risk of crop loss becomes higher with increasing frequency of critical low temperatures and with the less hardy the species. For commercial forestry, the decision of whether to plant a particular species depends on the risk of partial or complete failure, the financial return and the other options available.

To date, almost all eucalypts in Britain (and around the world) have been planted as monocultures. These are usually clearfelled without thinning, though thinning has been used to a limited extent where there is demand for large logs. In Britain the commercial objective is usually to produce firewood logs or chipped biomass fuel, though finding an economic alternative to pine and larch in lowland Britain has often been an underlying driver. Kerr and Evans (2011) suggest that more imaginative approaches than monoculture plantations should be considered for eucalypts. One example exists; a trial planting in 2012 of Douglas fir (*Pseudotsuga mensieszii*) and *E. glaucescens* on an ex-pine re-stock site at Rogate Common, West Sussex, has indicated that the *E. glaucescens* might provide a suitable nurse crop for the Douglas fir. A further planting of this type was made in spring 2015.

For the majority of species, the supply of nursery stock in Britain has not been a limitation to date, although for significant numbers of plants of particular species it has usually been necessary to place orders in advance. In this regard, the fast growth of eucalypts is an advantage, as it means that orders placed in late spring or summer (depending on species) allow plants to be raised to order for delivery the following spring. Of the species identified as having potential, a looming difficulty is the limited global supplies of seed of *E. glaucescens*, as demand is starting to outstrip supply.

Outlook

It seems probable that interested landowners will continue informal testing of eucalypts in Britain. Where successful, they will refine their approach in subsequent plantings. This should allow a body of valuable experience to be generated and it would be beneficial if this is shared, for example on SilviFuture (SilviFuture, no date). It is likely that eucalyptus will become a more familiar small-scale component of forestry in certain localities in Britain, particularly in milder areas in which a shortfall in supplies of firewood logs is anticipated in the future. Whether this leads to planting on a much larger scale will probably depend on whether worthwhile industrial fuel or fibre markets develop.

The experience elsewhere in the world suggests that the emergence of industrial markets for eucalyptus fibre can lead to a very rapid expansion of planting programmes. For example, in 2014 there were 232,000ha of *E. nitens* in Chile, all planted in the previous 25 years (Instituto Forestal, 2014). Planting on this scale would be a catalyst for innovation. For example, while the experience of growing eucalypts in the English midlands is disappointing, the existence of some old trees in collections suggests there are opportunities to define the more suitable sites, in the manner done in France (Terraux, 2000). It may also permit selection of particularly cold-tolerant species and seed sources that are likely to perform well on such sites.

Conclusion

This article has shown that several *Eucalyptus* species may become a more familiar feature of the British landscape in future. The key reason of course will be an economic one – eucalypts will only be planted on any scale by landowners who see them offering the opportunity to improve their income from forestry activities. The prospect of doing this by growing trees on rotations of 10-15 years will obviously be attractive, provided that there are worthwhile markets for the wood, and that the likely yields justify the establishment costs. Some of the plantings made in recent years have the prospect of providing good data on yields with several species in a range of locations. Such data will be of great interest, and may well prove to be a catalyst for further planting.

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