Keeping Rivers Cool: A Guidance Manual

Creating riparian shade for climate change adaptation

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Foreword

Edward Parker/WTML

This manual is intended to help those seeking to create shade over rivers (riparian shade) in order to maintain suitable freshwater habitats for biological communities at risk from the effects of climate change, particularly salmon and brown trout (salmonids).

It has been created by the Keeping Rivers Cool partnership initiative in order to explain the benefits of riparian shade and provide consistent advice on its creation. While aimed at those leading and delivering Keeping Rivers Cool projects, it can also be used by anyone with an interest in riparian land management.

Keeping Rivers Cool is a partnership initiative supported by:
Angling Trust, Environment Agency, Freshwater Biological Association, Forestry Commission, National Trust
Natural England, The Rivers Trust, the University of Birmingham, the University of Nottingham and the Woodland Trust.

Front cover image: Edward Parker/WTML

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1. Introduction

Historically in the UK, the land beside natural rivers and streams, and their floodplains, were more extensively wooded than they are today. Much of this tree cover has been lost[1]. Woody debris would also have been a common feature in river channels.

Shading from riparian trees and shrubs can help reduce local stream temperatures, with summer mean and maximum water temperatures on average 2°C – 3°C lower in shaded areas than in open rivers[2]. Increasing riparian tree and shrub cover also provides in-stream woody debris which is beneficial for many species of plants, invertebrates and fish[3].

Climate change and river temperature

The threat from climate change to river ecosystems cannot be ignored. In the next 60 – 70 years, projected increases in water temperatures will make some rivers inhospitable for our freshwater wildlife, upsetting finely balanced ecosystems. It is imperative that we find ways of keeping rivers cool to mitigate the effects of climate change. Using trees, shrubs and other vegetation to create shade is a low-risk action which can deliver a range of ecological benefits and provide a good start to keeping rivers cool.

Current projections show that average summer air temperatures will rise between 2°C and 4°C by the 2050s compared to the long-term 1961 – 90 average temperature[4]. River temperatures are also expected to rise by a similar amount[5]. Even these small changes can have an impact on the health of wildlife living in freshwaters. Brown trout and Atlantic salmon are particularly vulnerable, with an increase in water temperature to above 22°C for more than seven consecutive days being potentially lethal for brown trout[6]. Some rivers in England and Wales have already reached these lethal temperatures during recent hot, dry summers, putting trout and salmon populations under stress.

Ecological benefits

Water temperature affects all physical, chemical and biological processes in the freshwater environment. It displays natural daily and seasonal variations, depending upon location and climate[7]. Daily temperature fluctuations are more pronounced in small streams, particularly if they are not shaded. In freshwater systems, most species require a specific temperature range. For salmonids this is between 5°C and 15°C for normal growth. In smaller freshwater streams in southern England, temperatures in excess of 31°C have already been recorded[8]. This highlights the need to take action to reduce water temperatures in streams in order to protect trout and salmon populations.

Riparian vegetation also has much wider ecological benefits as it improves habitat quality for a range of biological communities and helps to maintain ecosystem function. For example, it provides organic inputs in the form of leaf litter and insects, accounting for up to 50 per cent of the energy in a river system. Leaf litter accumulates against woody debris, providing food for shredding macro-invertebrates. Research in the UK has shown that 147 invertebrate species, some rare, are strongly associated with woody debris[9]. Otters use woody debris for 'resting' sites, and it also plays a key role in protecting salmonid fish through the creation of thermal refugia or 'cool pools'. The influence of riparian trees on the habitat quality of a river is determined by tree species, extent and structure of the woodland, and the topography of the riparian zone (please see later sections of the guide).

Wider environmental benefits

Trees, shrubs and other vegetation can also provide many additional water management benefits. For instance:

- Trees trap and retain nutrients such as phosphates and nitrates as well as sediment in polluted run-off before it reaches rivers and streams.
- They act as a physical barrier, preventing the spray drift of pesticides from reaching watercourses.
- Water penetrates more deeply into woodland soils due to higher infiltration rates, leading to less surface water run-off.
- Trees, shrubs and large woody debris alongside and within rivers and streams and on floodplains act as a drag on flood waters; slowing down flood flows and increasing water storage.
- The ability of trees to protect soil from erosion and reduce sediment run-off helps the passage of water in river channels which reduces the need for dredging.
- Tree roots help stabilise river banks and create structural complexity in the freshwater habitat.
- The leaves, branches and trunks of trees slow the speed at which rain reaches the ground, with some rain evaporating into the atmosphere. Even in winter native deciduous trees intercept up to 12 per cent of rainfall.
- Deepwater pools can be created behind coarse woody debris dams, which in some waterbodies can help mix cooler ground water with surface water.
- Trees alongside rivers can connect areas of woodland, helping certain species move through the landscape.

1 Peterken, G.F., Hughes, F.M.R. (1995) 2 Bowler, D.E., et al.(2012) & Caissie, D. (2006) 3 Braccia, A. & Batzer, D.P. (1999) 4 Jenkins, G.J., Perry, M.C., and Prior, M.J. (2008) 5 Webb, B.W. & Nobilis, F. (1997) 6 Elliot JM and Elliot JA 7 Broadmeadow, S., et al. (2010) 8 Elliot, J.M. and Elliot J.A. (2010) 9 Godfrey, A. (2003)

Zone	Location	Component	Functions
Aquatic zone	River bank/ in stream	Tree roots/coarse woody debris	Stream bank erosion control; provision of thermal refugia; shelter from predators; and nutrient uptake. Coarse woody debris creates habit and cover for wildlife and thermal refugia. Woody debris can also help to slow flood flows.
		Herbaceous vegetation	Provides shade at stream margins; erosion control; sediment retention; nutrient source (e.g. leaf litter and terrestrial invertebrates); uptake of nutrients; and habitat for wildlife.
Riparian zone	Marginal land/ floodplain	Canopy and trunks of trees and shrubs	Shade moderates water temperature and in-stream productivity, and increases nutrient sources (e.g. retained leaf litter, wood and terrestrial invertebrates) and uptake of nutrients.
Adjacent land	Areas adjoining the riparian zone	Woodland and shrub and field layer vegetation	A woody buffer between stream and adjacent land use can improve soil structure which increases infiltration and slows surface water run-off, leading to uptake of nutrients and retention of sediment.

Table 1. The functional roles of different vegetation components

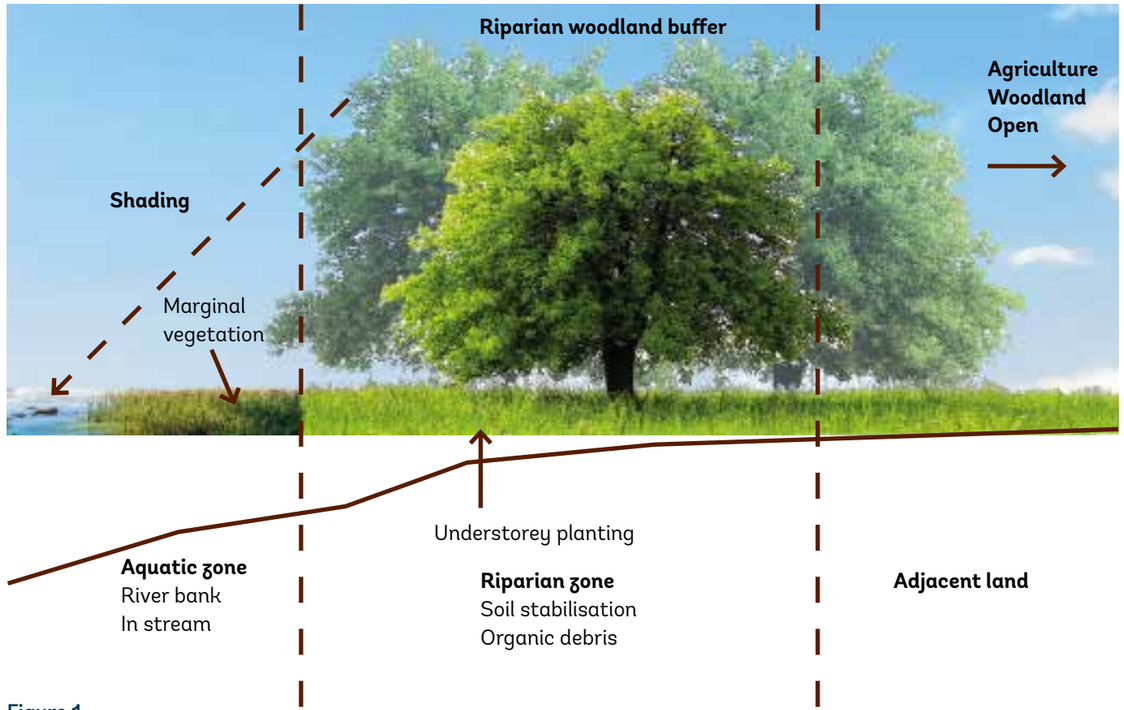


Figure 1.
The riparian zone is defined as the area of land adjoining a river channel and includes the river bank but not the wider floodplain. Trees in the riparian zone can provide shade to cool the stream, stabilise stream banks and act as a source of nutrients and woody debris

2. Site selection and design

Site selection

Shade cast by riparian vegetation reduces the rate at which water warms as it flows downstream[10]. Therefore, the focus of riparian planting or regeneration to reduce in-stream temperatures should be around headwaters and small water courses, where water is cooler and more responsive to shading. However, it may also be beneficial to plant riparian trees downstream to create thermal refugia for fish.

Planting the banks of headwater streams is likely to be the most effective way of cooling water within a river catchment[1]. However, other factors also need to be considered. As Figure 2 shows, tributary inflows can affect stream temperature, suggesting tributaries should be considered for tree planting to maximise the benefits.

The influence of shade in controlling water temperature is highly dependent on the size of catchments and channels, and groundwater input. Larger rivers are more likely to warm despite catchment characteristics, meaning some lower reaches are likely to receive little benefit from upstream shading[12].

Site selection also depends on specific local issues such as existing shade, availability of land and the support of landowners. Additionally, other catchment/water management objectives such as reducing flood risk, the role of woody debris in river restoration and the impacts of diffuse pollution[13] need to be considered. These issues and considerations will also influence species choice and planting design.

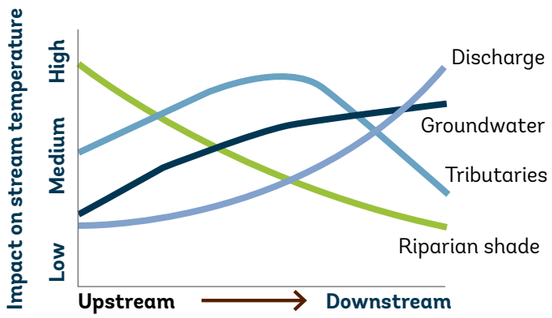


Figure 2
Conceptual impact of riparian shading, tributary influences and discharge on stream temperature, from catchment headwaters to outlets (based on Poole & Berman, 2001)

The length of tree shade required to reduce downstream warming of water is dependent on a number of complex, interacting factors,[14] but Table 2 provides an estimate based on the depth and speed of the water flow.

In selecting your site you should also consider whether there are any species or habitats (protected or high priority) that could be adversely affected by the planting or natural regeneration of trees and shrubs, or whether there are strong aesthetic or landscape reasons not to proceed. If so, consider an alternative site.

For more information on constraints in site selection and information on support and guidance please see section 6.

Strahler Stream Classification

The Strahler Stream Classification is used to define stream order based on a hierarchy of tributaries. Streams are classified in orders 1, 2 and 3 (first, second and third). Headwaters are order 1, being the smallest and the very start of the watercourse. When two first order streams come together they form a second order stream, and as this process continues, the size of the watercourse grows. A second order must join another second order to make a third order stream. Headwaters in terms of small tributaries can occur anywhere in the river system, as the figure below illustrates.

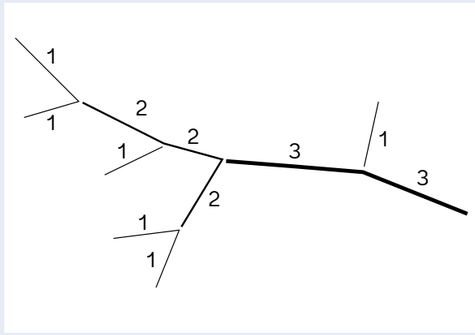


Figure 3
Strahler Stream Classification

WTML/Edward Parker

An established tree providing shade

The table shows the estimated length of continuous tree shade in metres, which is required to prevent a 1 °C increase in water temperature during the middle of summer for different combinations of average water depth and average speed (velocity). Note that a 1 °C rise in temperature is predicted by the end of the century so shorter lengths of continuous tree shade than those quoted here may still be of great significance. Also note that channel width is not significant here as long as the entire channel width is shaded. Therefore, rivers wider than 10 metres are likely to require substantially greater lengths of tree cover than those included here.

Depth (m) \ Velocity (m/s)	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
0.1	48	96	144	192	240	288	336	384	432	480
0.2	102	204	306	408	510	612	714	816	918	1020
0.3	150	300	450	600	750	900	1050	1200	1350	1500
0.4	192	384	576	768	960	1152	1344	1536	1728	1920
0.5	240	480	720	960	1200	1440	1680	1920	2160	2400
0.6	300	600	900	1200	1500	1800	2100	2400	2700	3000
0.7	360	720	1080	1440	1800	2160	2520	2880	3240	3600
0.8	390	780	1170	1560	1950	2340	2730	3120	3510	3900
0.9	450	900	1350	1800	2250	2700	3150	3600	4050	4500
1	498	996	1494	1992	2490	2988	3486	3984	4482	4980

Table 2. Potential length (in metres) of tree shade required to reduce downstream warming of water
Source: Derived from Johnson and Wilby, 2015

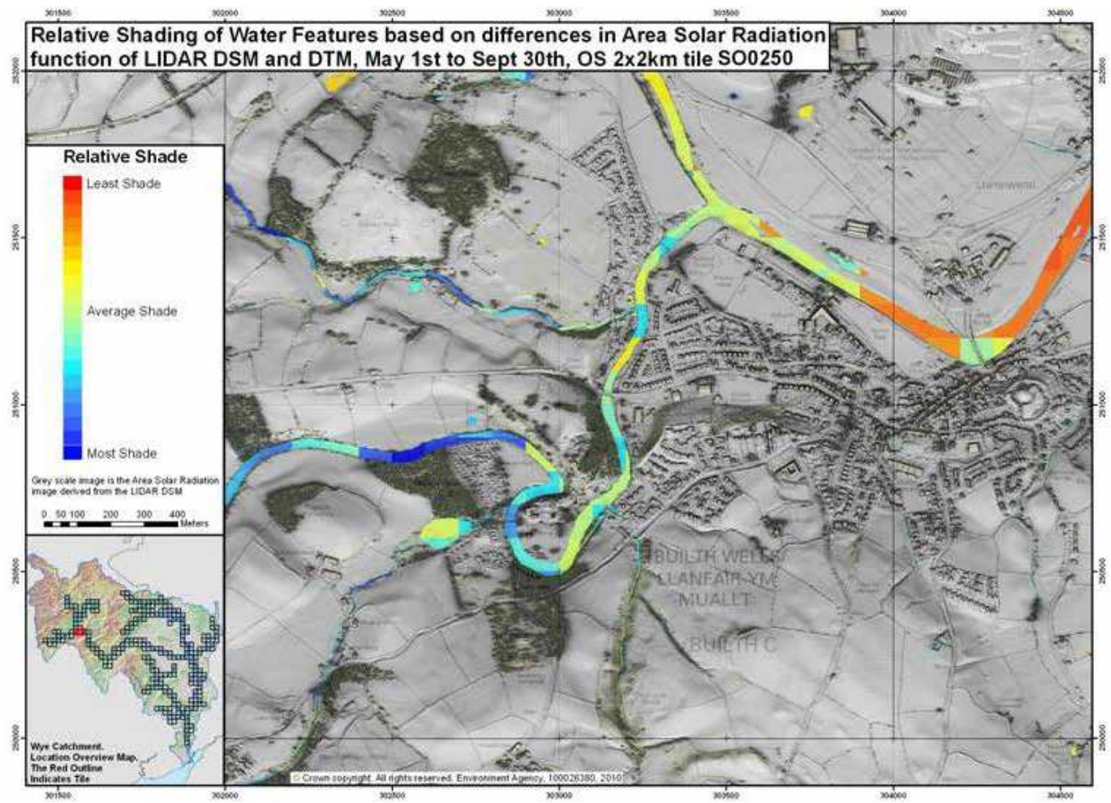
10 Garner et al (2014) 11 Correll, D.L. (2005) 12 Garner et al. (2013) 13 Forestry Commission (2011). p.46 'Water quality and buffer areas'. 14 Johnson and Wilby (2015)

Riparian shade mapping

Existing shade can be assessed using remote sensing technology. Maps have been produced using models showing average incoming solar radiation within catchments, where there is Light Detection and Ranging data (LiDAR). The estimated incoming solar radiation indicates the amount of shade provided by the landscape through, for instance, topography and existing vegetation.

In England, the Environment Agency (EA) has developed catchment 'shade maps' for every Water Framework Directive management catchment in England. These shade maps can be used to support the identification of key areas to increase riparian shade. The amount of shade shown is relative within the catchment, meaning that the map shows, and colour codes, the most and least shaded areas within a catchment. This means that the maps are not comparable between catchments. The shade maps are intended as guidelines only and decisions made using these should be supported by local site information or survey. In Wales, LiDAR data is held by Natural Resources Wales (NRW). Both EA and NRW are able to offer free access to LiDAR. Shade map PDFs are also licensed as Environment Agency Open Data and are available on DVD by contacting Geomatics.

Unfortunately, as LiDAR data was initially collected for the purpose of mapping flood risk, there are some gaps in the available data across the country. Using various data sets in GIS (Geographic Information System), it is possible to overlay catchment data and identify where the most benefits from planting and fencing can be obtained. The Rivers Trust has developed a catchment mapping portal which allows non-GIS users to do this – see Rivers Trust Catchment Mapping Portal.



Example of a shade map PDF showing areas with most shade (blue) and those with least shade (red)

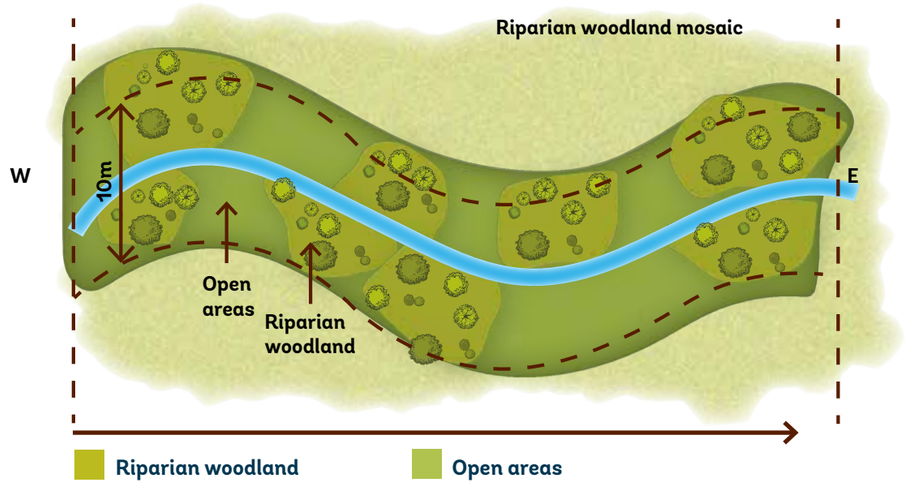


Figure 4. Riparian planting should create a mosaic of tree cover to produce dappled shade

Design

Planting belts of riparian trees as small as 2 – 5 metres wide will have some shade impacts, but to achieve optimum shading it is recommended that belts of riparian trees should be at least 10 metres wide. This is particularly important when seeking to deliver additional water management benefits such as reducing diffuse pollution. The aim should be to provide a mix of shaded and lightly shaded habitat in the riparian zone (see figure 4), guided by local circumstances and the requirements of priority species. On chalk streams Natural England recommends the shading of about 30 per cent, as over-shading of in-channel macrophytes needs to be avoided.

Stream orientation should also be considered in the design of tree planting or fencing schemes to optimise shading over the stream channel. The orientation of the channel will determine the extent and duration of shade cast over the water's surface during the day. On a watercourse orientated east-west, light will reach the river bank for a large proportion of the day unless shaded by woodland situated on the southern bank. Rivers with a north-south orientation will have more restricted light levels, except for the middle of the day when they will receive little protection from woodland on either bank, particularly if the river channel is wide (see Figure 5).

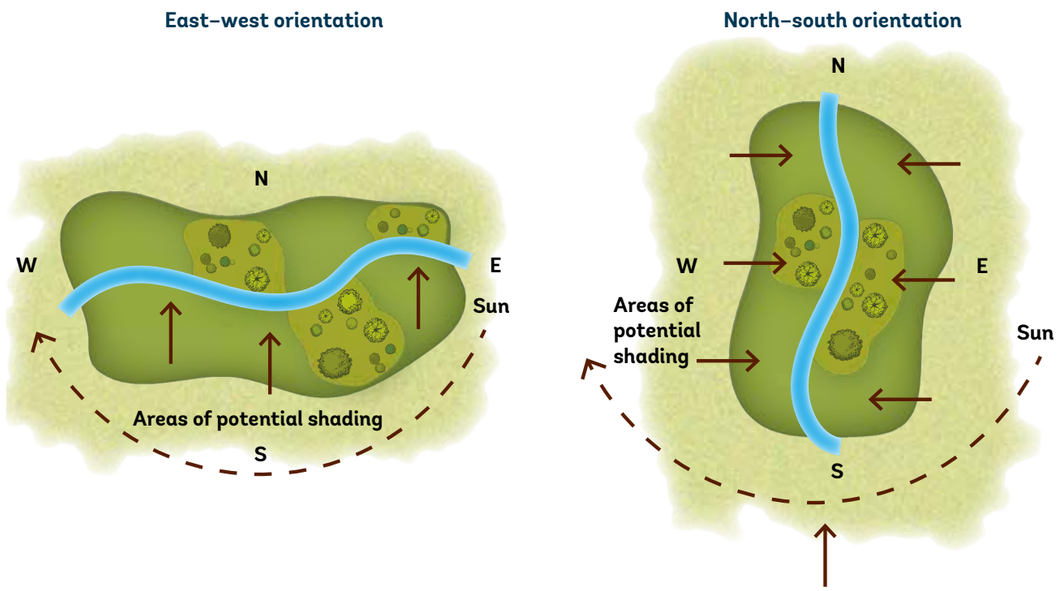


Figure 5. Direction of sun travel showing the areas where new planting could create effective shade

Planting or natural regeneration?

There are different views on the merits of just fencing to allow natural regeneration to take place, versus actively planting trees alongside rivers. In areas where existing native flora has been removed or damaged there may be little opportunity for a diverse native flora to propagate from local seed sources. In these cases the natural regeneration approach may not be successful and introducing tree stock becomes essential. Also, often a time imperative means that trees are best planted when a fence is new rather than waiting a few years.

Where there is a broad range of local seed sources, natural regeneration may generate hardy plants of local provenance, well adapted to existing local conditions. Natural regeneration can also be a very cost-effective measure if location and timescale permit, but there is far less control over the structure and design of the local site and it can result in the dominance of one or two species.

When opting for natural regeneration, the risk of invasion of non-native species must be considered, and their control will need to be costed within the long-term management plan. Effective management can move vegetation in the right direction by combining natural regeneration with planting desired species or adding plants from a different provenance which may be more suited to future climate conditions.

Careful analysis of the advantages and disadvantages of actively planting trees versus promoting natural regeneration is needed in the early design stages of a project. Site-specific characteristics will play an important part in the outcome. If the area is a heavily modified water body in need of measures to restore its morphology, then planting might be better; whereas if the site is in an SSSI, for example, you should consider natural regeneration.

The number of plants required for each area will depend on the design used. Once the areas to be planted and the species have been decided, the number of plants of each species can be calculated.

High stocking rates can be used to speed up canopy closure and gain 'control' of a site more rapidly, especially on weedy sites, to keep maintenance costs down or where rabbits may cause high losses. One to two-year old trees (30 – 60cm) planted at 2 to 2.5 metre centre spacing is the most common approach and provides reasonably rapid canopy closure. Older, taller trees will cost disproportionately more, grow more slowly when first transplanted and have a lower survival rate.

The following is a guide to the number of trees you will need depending on planting density:

- Planted at 3 metre centres – 1,111 trees per hectare
- Planted at 2.5 metre centres – 1,600 trees per hectare
- Planted at 2 metre centres – 2,500 trees per hectare

Planting is best undertaken between October and March when trees are fully dormant and most tolerant of stress caused by lifting, handling, storage and transporting.

See Further information, page 19 for sources of guidance on tree planting and management.

Constraints and opportunities

All woodland planting must be checked to see if consent under the Environmental Impact Assessment (EIA) regulations is required (see table below).

If the area of land to be planted meets or exceeds the thresholds then consent must be sought from the Forestry Commission (NRW in Wales).

The Forestry Commission Land Information Search (LIS) is a map-based tool that provides information about land designations or features, e.g. Special Protection Areas, Grant Schemes, etc. in any chosen area. This will allow identification of both constraints and opportunities such as grant scheme target areas. Woodland planting grant schemes are available in all countries in the UK although different rules and targets apply. See Further information, page 19, for information regarding map-based tools.

Environmental Impact Assessment area thresholds

Project	Threshold where any part of the land is in a sensitive area	Threshold where no part of the land is in a sensitive area
Afforestation	2 hectares where the land is in a National Park, Area of Outstanding Natural Beauty (AONB) or National Scenic Area (NSA). 0 hectares in all other sensitive areas - opinion always required.	5 hectares

3. What to plant

Establishing native woodland in riparian zones can enhance the biodiversity of the area. Woodland in this context has a wide definition, ranging from dense high forest to single trees, and small groups of trees to scrub. Native tree species support a great diversity and abundance of terrestrial invertebrates and provide high quality leaf litter which is beneficial to the aquatic zone[15].

There are several issues to consider when selecting planting material, including the species, provenance and origin of seed stock which are discussed below. Water use by trees might also be a consideration in areas which could suffer drought or where water resources are already under pressure.

Provenance

This guide recommends planting British native trees of local provenance. Native trees are defined as species that re-colonised Britain naturally, without human intervention, after the last Ice Age some 10,000 years ago. A tree of British native provenance is one whose seed was collected from a known location in the wild within Britain. Over many generations these species have adapted to specific local conditions (soil type, climate, etc.) resulting in the genetic make-up of woodland of local provenance[16].

The Forestry Commission has designated a number of seed zones, and trees of local provenance are defined as those which will be planted in the same Forestry Commission seed zone as the origin of their seed.

We recommend largely planting trees from the corresponding seed zones as they should be better adapted to the existing local environment and contain characteristics that can add to the local distinctiveness of an area. We also recommend that steps are taken to ensure that stock has been grown in Britain to avoid introducing new pests and diseases. However, given uncertainties about future climate conditions, and the need for adaptability, we also support planting an element of stock from other seed zones. Local provenance stock must always be used within wooded Sites of Special Scientific Interest (SSSIs), ancient woodland and historic landscapes. In such areas, natural regeneration may be a better option than planting.

Using local provenance stock can require advance planning in order to ensure available stock.
See Further information, page 19, for information regarding sourcing and planting local stock.

Broadleaves or conifers?

Planting non-native conifers in floodplains or adjacent to rivers can have adverse impacts. For example:

- In some river catchments extensive conifer planting on sites with acidic soils can indirectly lead to acidification of rivers[17].
- Conifer woodland creates a heavy shade cast by the canopy all year round. This can adversely affect riparian habitat quality as it restricts growth of plants, leading to bare stream banks and beds and high rates of sedimentation [18].
- Water intake by conifers is generally higher than by broadleaves. As conifers retain their leaves throughout the year, they intercept more rain which is then lost via evaporation rather than drainage, preventing it from reaching the ground[19] for use by other flora before running off into rivers.
- Conifers often grow with a shallow root plate making them more susceptible to wind damage. If blown over, this can create a significant erosion risk to stream and river banks.
- Conifers shade and out-compete other tree species. Mixed schemes, unless comprising a very low density of native conifer, tend towards conifer-only after 15 years.

Species considerations

To deliver shade which works to keep rivers cool in summer while also providing in-river and broader biodiversity benefits, the aim should be to create a varied shade profile along the river bank. This can be achieved by interspersing areas of lighter foliage with more complete foliage cover, and also by looking at structural differences and considering the neighbouring landscape as a component of the decision-making process.

Common native broadleaves with lighter foliage include birch (downy and silver), willow, rowan, hazel, aspen, hawthorn, blackthorn and cherry (wild and bird). These will provide dappled shade for rivers, with reduced water interception. Other less common species to consider would include spindle, wild service or guelder rose which can be interspersed with species that have denser crowns of foliage such as oak and beech. Native evergreens such as holly and Scots pine are an integral part of many woodland habitats but the possible negative impacts of their all-year-round shade profile must be taken into account.

15 Broadmeadow, S. & Nisbet, T. (2002) 16 Herbert, R. Samuel, S. & Patterson, G. (1999) 17 Nisbet, T., et al. (2011) 18 Broadmeadow, S. and Nisbet, T.R. (2004) 19 Nisbet (2005), & Calder, I.R., et al. (2008)

Other considerations in species selection include their susceptibility to tree pests and diseases. Key examples are Chalara dieback of ash which is likely to spread to most parts of the UK, and *Phytophthora alni* which affects alder. More information and advice is available from the Forestry Commission (see Support section 7).

While alder is considered a riparian specialist and is useful for stabilising river banks, in areas of acid sensitivity it is recommended that the use of alder should be limited. The UK Forestry Standard Guidelines for Forests and Water 2011 [20] recommend that planting of alder should be limited to less than 10 per cent of the area within riparian zones where waterbodies are failing, or at risk of failing, good status due to acidification.

Water uptake and use varies between broadleaf tree species, so the impact of trees on water resources should be considered, especially at sites draining onto wetland habitats. For more information on this topic see 'Water use by trees', Forestry Commission Information Note 65 [21].

Creating a diverse structure

The long-term aim is to create an intricate structural mosaic of habitat to produce a varied shade profile on the water course. As well as helping to keep the river cool, greater diversity of riparian vegetation incorporating a mixed age structure, mixed species and vegetation heights, can increase the conservation value for invertebrates, birds and other organisms[24].

Five key structural habitats can be used to achieve this mosaic effect.

1. Closed canopy native woodland
2. Patches of scrub
3. Open glades within the woodland
4. Occasional isolated trees that will ultimately achieve a grand size
5. Open ground, particularly in the marginal aquatic zone

A management plan should be prepared to ensure that, in time, a mix of tree and shrub ages is achieved. Initial planting should include quick-growing, short-lived species amongst slower-growing species that will hopefully become veteran landscape trees. Mature trees are especially important in providing wood and woody debris for the stream. When developing a planting plan, consider the desired height of riparian trees in order to provide enough shade for your stream width.
For information on tree heights at different ages for different broadleaf native species, see Annex 1.

It is also necessary to take into account the long-term management of your new woodland area. For example, open ground may need to be maintained by mowing or light grazing. There may be practical considerations around access or fencing for this purpose, and cost implications. Creating the ideal habitat conditions needs to be balanced against ensuring that maintenance is sustainable in the long-term.

WTML/Edward Parker

Planting as part of a Keeping Rivers Cool project with the Environment Agency in Wessex

20 Forestry Commission (2011) 21 Forestry Commission (2005) 24 Broadmeadow, S. & Nisbet, T. (2004)

4. Protection of trees and shrubs

Rachel Lenane

An unfenced tributary of the River Ithon, Wye

An important element in establishing new riparian trees is protecting them from damage caused, by deer, rabbits or voles. Fencing may also be needed to protect trees from browsing and trampling by domestic livestock and from adjacent land uses, as well as delineating the area to be managed appropriately.

Most, if not all areas of tree planting and natural regeneration, will require stock-proof fencing. Other benefits of fencing include the reduction of 'poaching' by animal hooves which can cause bank erosion, and reduction of stream pollution by animal waste. In some areas, where it is not practicable or landowners are not willing to fence out land, it may be possible to plant individual scattered trees. These will need robust protection in the form of tree shelters to prevent damage from livestock.

Key considerations and recommendations for improving protection:

- Tree tubes to protect young saplings, at least initially until the newly planted stock is established, and especially where rabbit or deer grazing is evident locally.
- Rabbit spiral guards may be more cost-effective than tree shelters and require less maintenance. In exposed conditions, however, tree shelters can be readily blown over and if not spotted and rectified quickly, can cause abnormal growth of the emerging tree. In areas prone to flooding, tubes can also be washed away and could end up looking unsightly on someone else's land, so their use should be carefully considered.
- Fencing should be robust and able to withstand flooding of marginal areas year-round.
- Ideally the line of the fence should be positioned as far from the watercourse as possible, reducing the risk of bank erosion caused by flooding from undermining the fence line.
- In flood-prone areas, line and wire (rather than netting) is recommended as it reduces the likelihood of flood debris getting caught. Running fencing parallel to the direction of the watercourse helps to reduce flood damage and minimises accumulation of debris.
- Where it is impossible to avoid placing fences across the direction of water flow it is important to strengthen key strainers and posts, bracing as necessary. Separating the fence into more and less vulnerable sections will avoid losing tension in long stretches of fencing. One technique is to build-in 'sacrificial' weak links which will give way under moderate pressure, preventing excessive strain on the overall fence line and minimising the cost of re-building flood-damaged fencing.
- Where livestock require access to the watercourse, this should be managed in a controlled way. In some cases, provision of watering troughs or field pumps may provide a solution, thereby reducing livestock access. Where crossing points are needed, water-gates may be necessary.
- Consider the need for: gates and deer-jumps to ease the removal of stray livestock and for maintenance; kissing-gates or stiles on footpaths for visitor access; and the possible need for badger gates. Vehicles may also require access, and where this leads to a ford it is preferable to have a hard base.
- Be aware of local species considerations, for example whether the fencing needs to include bird strike markers to deter black grouse from becoming entangled in the fencing, or whether the area is a known water vole habitat (see section 6).

- **Warning!** Use of fences across the river should be minimised. The risk of severe injury or death of individuals caught in the flow of the river and trapped in wire should be considered very seriously. Individuals at risk may include river users such as kayakers and wading fisherman. The default option should be no fence across the flow. However, where this is not possible, the risk can be significantly reduced by paying careful attention to the location, choice of materials and methods of construction.

Stock watering

Fencing riparian areas may prevent livestock from accessing water, in which case alternatives will need to be provided. Pasture pumps can be low maintenance solutions to providing stock watering in remote locations where streams have been fenced off. They are portable and can be placed up to 50 metres from the river. However, consideration needs to be given to use of these in the winter as frozen pumps and pipes can be a problem.

Rachel Lenane

Sheep-operated pasture pump providing water from a fenced-off tributary of the River Ithon in the Wye

5. Maintenance

It is important to consider the long-term maintenance of the area at the earliest stage. Where the land is not owned by the person or group wishing to carry out works there needs to be agreement on who will be responsible for maintenance in the short, medium and long term and how this will be carried out. The cost and sustainability of maintenance should be built into the design and management plan.

Options for maintenance include:

- Funding of a contractor for three to five years, with maintenance then reverting to the landowner.
- Volunteer commitment to maintenance if suitably qualified such as Rivers Trust volunteers, then reverting to the landowner.
- Agreement with the landowner for a maintenance period.

On most riparian planting schemes it is beneficial to have a maintenance programme where landscape contractors maintain and manage all planting until the trees are established, which is usually around three to five years. After this, the landowner should assume ownership and responsibility for the planting and maintenance of fencing where appropriate. It is important that the landowner is entirely involved when the tree planting or fencing plans are being developed, and is aware of the long-term nature of the project.

The contractor should be responsible for all horticultural operations, including weed control, until the trees are established. The landscape contractor should also remove any planting sundries (spiral shelters, mulch mats, stakes, etc.) at the end of the maintenance period. The lead partner should provide landowners with a management plan so they understand how to manage the trees and fencing.

A maintenance contract or agreement should include:

- Regular visits to ensure trees are growing and to assess any losses with a view to replacement.
- Checking that fences are stock-proof to ensure no browsing occurs.
- Ensuring that where tubes and stakes are used, they are effective, upright and not choked with weed growth.
- Weeding, where appropriate, which may include hand pulling of weeds or a chemical spray designed to leave a weed-free area of 1m^2 around the base of each plant.

Failure or poor growth of newly planted trees and shrubs can be driven by numerous factors such as drought, supply of unhealthy material, compacted ground/poor ground preparation, poor planting technique or planting late in the season and lack of weed control.

A transplanted tree will have lost a proportion of its roots during transplanting and will find it difficult to compete with a dense network of grass roots. Various options are available prior to planting such as ripping/aerating soil and spraying of grass/weed growth with appropriate herbicide which will help the establishment of the tree. (NB. If using any herbicide within 10 metres of a watercourse you may be required to obtain written consent from the appropriate consenting body and ensure you have relevant training and qualifications.)

Reducing competition from grasses and other weeds post-planting dramatically improves plant growth. Lowland schemes often suffer from over-fertility in ground conditions, leading to intense competition; while in the uplands it is often the species chosen that is a greater factor in success.

Two common methods of controlling weeds are mulching and the use of chemical herbicides.

Mulches vary in performance and the best have several advantages:

- They are less likely to damage aquatic life.
- They control weeds and help retain soil moisture.
- They do not need to be reapplied like herbicide.
- The area covered is specific and does not vary.

They do have some disadvantages compared to herbicide:

- They are expensive.
- They can encourage vole and mouse damage, providing warmth and cover for these animals.
- In windy situations they can be blown away.
- They can be washed away if the area is subject to flooding.
- They can attract the attention of vandals.
- Mulches of straw or chipped wood may need topping up to remain effective.
- Although some are degradable, they may need to be removed at the end of the maintenance period.

Polypropylene mulch mats can be cost-effective for small schemes. However, other treatments such as woodchip and herbicide may be more appropriate under certain circumstances and budgetary constraints. To reduce the likelihood of mulch mats attracting the attention of vandals they can be covered with wood or bark mulch. Fresh wood mulch should be avoided in favour of mulch that has been decomposing for some time prior to application. Mulches are not appropriate where plants are within the normal flood flow of a river.

See Further information, page 19, for details of useful available guides on best practice methods of managing riparian trees and vegetation.

6. Other considerations

Consents

Before planting trees or erecting fences it is advisable to contact the local office of the Environment Agency, Natural Resources Wales or the Scottish Environment Protection Agency – depending on the location of the site – to ensure they are aware of your plans and can advise on avoiding emergency and maintenance access routes. Early communication will prevent any conflicts of interest arising.

A flood defence consent may be required for planting or installing fencing close to main rivers (a main river being a watercourse marked as such on a main river map). This is known as the 'byelaw strip' and different widths apply in different regions. The distance is measured from the top of the riverbank, or from the landward edge of a flood defence structure such as a wall or embankment.

You may also need consent for any planting within a designated flood storage area. Byelaws vary between regions so you will need advice on all flood-related consents from your local flood risk management authority. The flood risk to properties must not be increased and the maintenance of watercourses to reduce flood risk should still be possible. However, be aware that strategically placed woodlands, trees and shrubs in floodplains can reduce downstream flood risk by holding and slowing back flood flows and reducing soil erosion.

The EA encourages a risk-based approach when considering riverside planting, with a greater level of consideration needed in higher flood risk locations (see box). For details of further consent requirements, see Section 2.

Taking flood risk into consideration when planting riparian trees

Planting individual or small groups (four to 25) of trees and shrubs within the byelaw strip will generally be acceptable as long as they do not:

1. Obstruct maintenance access.
2. Significantly interfere with flood flows in critical channels or reduce the capacity of flood storage areas.
3. Sit within the normal river channel.
4. Affect the approach to bridges, flood span openings or other control structures.

If planted at two-metre centres, this would occupy an area of between 4m^2 and 100m^2. However, this is not a strict definition and each case should be looked at on its merits. The scale of the proposal in relation to the overall floodplain is the key consideration.

Source: National Environmental Assessment Service, 2007

Local authorities

Lead Local Flood Authorities (or Internal Drainage Boards) are now responsible for flood defence consents on ordinary watercourses. An ordinary watercourse is every river, stream, ditch, drain, cut, dyke, sluice, sewer (other than a public sewer) and passage through which water flows and which does not form part of a main river. Consent is not required for planting trees on the banks of ordinary watercourses although the works should be discussed with the Lead Local Flood Authority [22].

Local engagement

It is important to consult the right interest groups when starting projects which have the potential to alter the way the landscape looks or riverside access. For example, if you are considering planting or fencing within an Area of Outstanding Natural Beauty (AONB) it will be important to consult with the local AONB partnership. It is also good practice to consult with the local planning authority's landscape and/or tree officer. Depending on the scale of the planting, it could be important to engage local interest groups early on in the decision-making process. These will include parish/community councils, local angling and rambling groups and canoeists. Your local catchment officer or Forestry Commission woodland officer should be able to advise on key contacts, or you could speak to your local catchment partnership.

Access rights

The riparian zone is often accessed by other groups, such as anglers, either by right or prior legal agreement. As such, tree planting and fencing schemes, however inherently valuable and important they may be, need to accommodate other users. Commonly, footpaths or bridleways will follow sections of water courses. Grazing and watering rights for stock may affect fence locations, while access for draining and maintenance or overhead/underground cables and pipes often needs to be considered. Where appropriate, ensure that footpaths/rights of way are inclusive and accessible for all.

Common land

Secretary of State approval is required for planting or fencing on common land by owners or commoners. The process is similar to any other planning application, including stages such as a formal application and advertisement of the application in a local paper by the applicant. The Secretary of State must allow 28 days for members of the public to make representations.

The Planning Inspectorate is responsible for decisions on cases and generally requires that consultations are held prior to the submission of applications for fences. In most cases, this is relatively simple with access, landscape and other partners. In larger cases, the process can be a significant burden in terms of time and effort and should not be under-estimated. Where agreement cannot be found and objections are considerable, a Public Enquiry may be called.

Impacts on habitats and species

Increasing riparian vegetation and trees will benefit some fauna and flora, but care should be taken to avoid detrimental effects on others, particularly existing valuable habitats such as species-rich grassland and important wetland. A number of plants and animals are protected under European Protected Species legislation. Local experts, such as staff from the statutory conservation agencies, should be able to provide advice on habitats, species and designations. Wildlife, habitats and issues to consider include:

Rauno Kalda

Daubenton's bat

Bats

Rivers are important for foraging and commuting bats. Riparian tree lines act as linear flight paths and are a navigational aid for commuting bats. They also provide protection from aerial predators and unfavourable climatic conditions such as wind. The quality of the riparian zone is also important. For example, continuous riparian zones with complex vegetation can improve foraging and activity of some species. Bats also use other linear features so options for connectivity with the wider environment should not be missed. Often walls and hedges provide cover and navigation aids, and works which support regenerating corridors should be encouraged.

Breeding waders and ground-nesting birds

In open wetland habitats that support populations of ground-nesting birds, such as the Somerset Levels, trees can be used as look-out posts for predators. This can deter ground-nesting birds from using this otherwise suitable habitat if it is close to trees. Leaving areas as tall grassy or reedy vegetation may be more appropriate in these habitats. Equally, some low scrub can sometimes be beneficial.

Paul Broad

Water voles

Extensive planting may shade out lots of ground flora, and a lack of grazing may promote competitive or coarse vegetation which can reduce suitable feeding habitat and vegetation for water voles. Excluding grazing on river banks has in some cases led to a proliferation of Himalayan balsam which shades out ground cover and dies back in the winter to leave largely bare ground - creating unsuitable conditions for water voles.

Other species of concern

Both the white clawed crayfish and the freshwater pearl mussel are protected and can be negatively affected by actions that alter the substrate, although both would benefit from actions that maintain low water temperatures. A number of fish species, including allis shad, twaite shad and sturgeon, are also protected but information on habitat requirements within rivers is limited. The presence of non-navigable obstructions, however, is known to be a contributory factor in species decline.

Invasive non-native species (INNS)

These may need to be eradicated or controlled in order to protect any enhancement measures. Experience shows that if giant hogweed and Japanese knotweed are eradicated the other major riparian non-native, Himalayan balsam, struggles on a shaded ungrazed site. Details of non-native species which need control, and the preferred method of that control, should be worked into the planting and fencing plan along with a clear

22 Main rivers in England are designated by Defra; in Wales they are designated by the Welsh Government.

explanation about the potential time and cost involved. Further information can be found via the statutory agency websites.

Creation of shade tunnels

Many important instream macrophytes, such as the Ranunculus-dependent species commonly found in chalk streams in southern England, require sunlight. Allowing trees to form a shade tunnel over long lengths of a river will prevent them from thriving and this should be taken into account when planning where and what riparian vegetation to plant. Upland streams, while benefiting hugely from the increased shade, leaf litter and stability offered by trees, also need light and the sun's warmth. Schemes should be designed to deliver a varied shade profile along a river bank including, ideally, leaving some warm, south-facing elements open.

Exposed riverine sediment (ERS)

This unusual habitat supports unique and diverse communities of rare beetles as well as endangered and declining river flies[23]. Surveys have shown ERS to be rich in fly species with nationally rare or scarce species. While some studies show that increasing riparian vegetation can increase the richness and diversity of invertebrates by providing habitat, food and emergence sites, it is important that areas of ERS are avoided. In addition, these sites are likely to be readily mobilised in floods, and trees will be washed away.

Sunny lowland riverside rocks (SLRRs)

Rock outcrops adjacent to rivers provide some of the only natural exposures of sunny rock in lowland Britain that have not been subject to quarrying or fertiliser drift. Where rivers are wide enough, in hard-rock areas of lowland Britain, sunshine can hit rocks on the north or east banks for most of the day. This gives a highly unusual niche habitat where a range of rare mosses, liverworts and lichens grow.

Damage to habitat suitable for these species can be avoided by ensuring that any tree planting or fencing to encourage regeneration is suitably located. If the river has rock shelves or low cliffs that are currently exposed to sunlight for much of the day, there is a good chance that these rocks will support some of the rarer mosses, liverworts or lichens of sunny lowland riverside rocks. Planting schemes should be designed to avoid casting additional shade on to these rocks (including on the opposite bank). Known sensitive areas cover an extremely small proportion of the total river resource.

Woody debris

The loss of twigs, leaves and branches from riparian trees promotes the development of in-stream woody debris; the accumulation of which within rivers and streams has been shown to have a number of ecological benefits. These include providing shelter, food and spawning grounds for a variety of species, additional in-stream shading and catching silt. Many of these benefits can also be attained by installing large woody debris dams, though care must always be taken to avoid contributing to flood risk.

Derek Harper

Water crowfoot bed, River Isle, Somerset

23 Drake, C.M.; Godfrey, A.; Hewitt, S.M. and Parker, J. (2007)

7. Support

Advice

The Keeping Rivers Cool partnership can provide information on the evidence and tools to help you develop a project, as well as put you in touch with others who have taken a similar approach. For initial enquiries please email: conservation@woodlandtrust.org.uk

Individual partners who may be able to provide specific support:

The Woodland Trust is working with partners across the UK on water-related projects, including those intending to increase riparian shade. It has a range of materials available that can be used to engage with landowners and encourage them to plant trees on their land. There is a team of advisers who can visit sites, draw up planting schemes and speak directly with interested landowners seeking to plant more than 0.5ha.
woodlandtrust.org.uk/water

The Rivers Trust represents rivers trusts across a large part of England and Wales. Rivers Trusts will be able to identify where there is a catchment partnership in your area and point you to sources of advice and support.
www.theriverstrust.org

The Freshwater Biological Association promotes freshwater biology and the sound and sustainable management of freshwater ecosystems. It can provide training to identify and understand freshwater plants and animals.
www.fba.org.uk

The Angling Trust represents all game, coarse and sea anglers and angling in England. It works both locally and nationally to improve habitats and fish stocks.
anglingtrust.net

Several government agencies are also part of the partnership and will be able to provide relevant advice.

Environment Agency for information on environmental permits, licences and consents in England, and advice on freshwater management and funding.
gov.uk/environment-agency

Forestry Commission England is the government department responsible for protecting, expanding and promoting the sustainable management of woodlands and increasing their value to society and the environment. It can provide information on grants and regulations, tree pests and diseases and good practice guidance on planting and maintaining trees.
forestry.gov.uk/england

Natural England is the Government's adviser for the natural environment in England. It can provide information on grants and regulations as well as species and management advice.
gov.uk/natural-england

Natural Resources Wales is the principal adviser to the Welsh Government about issues relating to the environment and its natural resources. It can provide information on species and habitat management, regulation, pests and diseases.
naturalresources.wales

Welsh Government: Glastir is the sustainable land management scheme through which the Welsh Government offers financial support to farmers and land managers. Search 'Glastir' at gov.wales

Rivers and Fisheries Trusts of Scotland: represents Scotland's national network rivers and fisheries Trusts and Foundations.
rafts.org.uk

Scottish Environment Protection Agency: SEPA is Scotland's principal environmental regulator, protecting and improving Scotland's environment.
sepa.org.uk

Scottish Natural Heritage promotes the care and improvement of the natural heritage, and provides advice on its sustainable use and on species and habitat management.
snh.gov.uk

Forestry Commission Scotland: its core purpose is to deliver multiple benefits by promoting the sustainable management of trees, woods and forests across Scotland. It can provide information on grants and regulations as well as management advice.
scotland.forestry.gov.uk

Scotland Rural Development Programme: information on grants and support for land management.
Search 'Rural development programme' at gov.scot

Annex 1

British native trees: growth rates and soil preferences (from Agate, E., 2002).

				Soil type					
Common name	**Species name**	**Maximum height (m)**	**Growth rate**	**Wet ground**	**Light sandy soil**	**Heavy soil**	**Acid**	**Alkaline**	**Ok in shade**
alder, common	Alnus glutinosa	25	fast	•				•	•
ash	Fraxinus excelsior	40	medium	•	•	•		•	•
aspen	Populus tremula	18	fast			•	•	•	
beech	Fagus sylvatica	40	medium		•	•			•
birch, downy	Betula pubescens	25	fast	•			•		
birch, silver	Betula pendula	26	fast		•		•		
cherry, bird	Prunus padus	30	medium		•			•	
crab apple	Malus sylvestris	10	slow		•	•	•	•	
elm, wych	Ulmus glabra	40	medium			•		•	•
hawthorn	Crataegus monogyna	15	slow		•	•	•	•	
hawthorn, midland	Crataegus laevigata	10	slow			•		•	•
hazel	Corylus avellana	6	fast			•		•	•
holly	Ilex aquifolium	15	slow		•	•	•	•	•
hornbeam	Carpinus betulus	30	medium	•		•		•	•
lime, small-leaved	Tilia cordata	32	medium			•		•	•
maple, field	Acer campestre	26	medium			•		•	•
oak, pedunculate	Quercus robur	36	medium	•		•		•	
oak, sessile	Quercus petraea	43	medium	•	•	•	•		•
poplar, black	Populus nigra var. Betulifolia	32	fast	•	•	•		•	
rowan	Sorbus aucuparia	20	fast		•		•		
whitebeam, common	Sorbus aria sensu lato	25	medium		•	•		•	
wild service	Sorbus torminalis	20	medium			•		•	•
willow, crack	Salix fragilis	25	fast	•				•	
willow, white	Salix alba	25	fast	•				•	•

Further information

Tree planting and management advice

The Conservation Volunteers have produced 'Tree Planting & Aftercare – A Practical Handbook' available at store.tcv.org.uk

Practical tree planting advice from the Woodland Trust is available at woodlandtrust.org.uk/planttrees

Local stock

Flora Locale is an independent charity promoting the conservation and enhancement of native wild plant populations and communities. For information on sourcing local provenance stock and information on British flora suppliers visit floralocale.org

Shade mapping

Environment Agency riparian shade maps for England can be viewed on the Rivers Trust catchment mapping portal: www.theriverstrust.org/catchment_mapping

To request PDFs of EA shade maps please email archived-lidardata@environment-agency.gov.uk

To see areas where grants may be available for Keeping Rivers Cool schemes visit the Forestry Commission's Land Information Search portal in England at forestry.gov.uk/england-lis

Scotland's environment web page: environment.scotland.gov.uk

Natural Resources Wales maps: naturalresources.wales/our-evidence-and-reports

Tree health

For the latest information on pests and diseases visit forestry.gov.uk/pestsanddiseases

Trees species

The UK Forestry Standard Guidelines on Forests and Water provides valuable information on best practice relating to species selection for riparian planting: forestry.gov.uk/ukfs

For information about different British tree species: woodlandtrust.org.uk/britishtrees

Management of trees and shrubs

The Scottish Environment Protection Agency's 'Engineering in the Water Environment Good Practice guide - Riparian Vegetation Management, Second edition, June 2009', is available from the SEPA library: sepa.org.uk/library

Forestry Commission's 'The management of semi-natural woodlands: 8. Wet woodlands (2003)': Search 'semi natural woodlands' at forestry.gov.uk

Forestry Commission advice and guidance

Opportunity mapping for woodland creation to reduce diffuse water pollution and flood risk in England and Wales. S. Broadmeadow, H. Thomas and T. Nisbet, March 2014.

The national opportunity mapping report can be found on the FC website. Search 'reduce diffuse water pollution' at forestry.gov.uk

Woodland for Water: woodland measures for meeting Water Framework Directive objectives.
T. Nisbet, M. Silgram, N. Shah, K. Morrow, & S. Broadmeadow, June 2011

Both the main report and EA's summary report can be found on the FC website: forestry.gov.uk/forestresearch

The UK Forestry Standard, Forestry Commission, 2011. forestry.gov.uk/ukfs

The UK Forestry Standard is the governments' approach to sustainable forestry. It encompasses a series of detailed guidelines, including 'Forests and Water' forestry.gov.uk/ukfs
which in turn are supported by a series of Practice Guides addressing specific subject areas such as acidification, forest operations and riparian management.

Managing Ancient and Native Woodland in England, Forestry Commission, 2010.

This practice guide can be downloaded from the FC website: forestry.gov.uk/anwpracticeguide

Woodland Design for Water, Forestry Commission, 2015. Search 'design for water' at forestry.gov.uk
This web page sets out how woodland interacts with the water environment and hence how woodland creation can be used to help reduce flood risk and improve water quality. A set of 'Design Principles' are included at the foot of the page. These are used as a template for planting schemes supported under the Countryside Stewardship grant programme.

Managing England's Woodlands and Climate Change
forestry.gov.uk/climatechangeengland
This webpage summarises current advice from the Forestry Commission about the impacts of climate change and the implications for woodlands in England. It includes advice on issues such as species and provenance, and provides a link to the 'Ecological Site Classification' decision support tool for tree species.

UK Woodland Carbon Code
forestry.gov.uk/carboncode
The Woodland Carbon Code is the voluntary standard for UK woodland creation projects where claims are made about the carbon dioxide they sequester. Independent certification to this standard provides assurance and clarity about the carbon savings of these sustainably managed woodlands.

Managing Ancient and Native Woodland in England. Practice Guide (2010). Forestry Commission England, Bristol. forestry.gov.uk/anwpracticeguide

Managing Native Broadleaved Woodland. Harmer, R., Kerr, G. and Thompson, R. (2010), Forestry Commission. Search 'managing broadleaved woodland' at forestry.gov.uk

Further general information is available from:

Forestry Commission England at
forestry.gov.uk/england

Forestry Commission Scotland at
scotland.forestry.gov.uk

Forest Research at
forestry.gov.uk/forestresearch

FC Publications at
forestry.gov.uk/publications

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