Environment Agency

Asiantaeth yr Amgylchedd Cymru
Environment Agency Wales

Keeping Rivers Cool

Getting ready for climate change by creating riparian shade

V.2

01/10/12

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Keeping Rivers Cool

Getting ready for climate change by creating riparian shade

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Environment Agency
01/10/2012 v.2

Foreword

Getting ready for climate change by creating riparian shade

Purpose: This guidance has been produced to support the creation of shade over rivers using riparian trees and vegetation (riparian shade). The focus is on maintaining suitable freshwater habitat for salmon and brown trout (salmonid) populations that we expect to be at risk from the effects of climate change. It has been written to explain the benefits of riparian shade (sections 1 and 2) and provide consistent advice on creating riparian shade (sections 3-10) to support the Environment Agency's initiative on Keeping Rivers Cool. It has been designed for use by the Environment Agency 'Keeping Rivers Cool' pilot catchment officers and 'Keeping Rivers Cool' leads in external partner organisations. As we gather more information on best practice ways of creating riparian shade we will add to and develop this guide, making it more widely available to land owners and other interested organisations in the second year of the project.

How to use this guide: This is designed to be used as a digital guide containing brief summarised information on creating riparian shade. It contains embedded electronic links to additional useful information. Because of these electronic links it is easier to use the guidance on a computer (rather than a print out) in order to go straight to recommended websites.

If you would like to suggest any changes to this document, let someone know that an electronic link needs updating, or have further information that could be included, please contact Rachel Lenane.

Contents

1. Introduction

1.1 Climate change and river temperature

Predicting the future is fraught with uncertainty however, climate experts have tried to capture some of this uncertainty in the current set of scenarios for the UK in the UKCP09 projections[1]. The models predict that average summer air temperatures will warm by between 2°C and 4°C by the 2050s compared to the long-term 1961-90 average temperature. River temperatures are sensitive to changes in climate and water temperatures are expected to rise by a similar amount[2]. It may not seem much but even small changes like this can have an impact on the health of wildlife living in freshwaters. Brown trout and salmon are particularly vulnerable to predicted climate change. A rise in water temperature above 22°C for more than seven consecutive days can be lethal for brown trout[3].

The Environment Agency is looking at ways of keeping rivers cool and taking action now to prevent, where possible, rivers in England and Wales becoming inhospitable for our freshwater wildlife over the next 60-70 years. Trout and salmon populations in England and Wales are already under stress with some rivers reaching temperatures above the lethal limit for these species during recent hot, dry summers.

Historically natural rivers, streams and their floodplains across the UK were more densely wooded, and woody debris would have been a common feature in river channels[4]. Much of this tree cover has been lost and many rivers now lack shade. Riparian trees and shrubs can help reduce local stream temperatures on hot summer days. Summer mean and maximum water temperatures are on average 2-3ºC lower in shaded than in open rivers[5]. Increasing tree and shrub cover in the riparian zone will also help to provide a natural source of in stream woody debris. Woody debris is beneficial for many species of plants, invertebrates and fish[6]. Leaf litter accumulates against woody debris and is an important food reserve for shredding macro-invertebrates. Research in the UK showed 147 invertebrates, some rare, were strongly associated with woody debris[7]. Otters also use woody debris for “resting” sites. It also has a key role in protecting salmonid fish through the creation of thermal refugia as water temperature at the stream bed can be significantly cooler than at the stream surface particularly during periods of low flow when temperatures are likely to be highest. EA staff should see our internal policy position, ‘Woody debris in rivers (43_12)[8]’, for more information on this topic.

In the right location natural regeneration, through livestock exclusion and fencing-off lengths of river, is a good habitat restoration method as the new woodland will closely match existing woodland in proximity to the site. Natural regeneration also has a good survival rate, so if the site and time frame allows it is also a cost effective method of woodland creation. Where planting is more appropriate (or a combination of natural regeneration and planting) a planting design plan should be prepared which takes account of specific site conditions, appropriate sources for plant stock and includes consideration of future management.

In certain circumstances other interventions for cooling rivers for example, river restoration, heated effluent control, modified abstraction regimes and water meadow management may also be beneficial and we will be exploring these in the future. In the mean time we aim to help create riparian shade where we think it will have the greatest benefits for river ecology.

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

Although there are still some knowledge gaps about the cooling effects of introducing more riparian trees we can't ignore the risks of climate change to river conservation. Creating riparian shade in the right places can also provide a range of wider ecological benefits. We recognise that it is not a standalone measure to managing warming in rivers, but it is a low-risk reversible action, providing a range of ecosystem services and a good start to keeping rivers cool.

1.2 Optimum river temperatures for salmon and brown trout

Water temperature affects all physical, chemical and biological processes in the freshwater environment and it displays natural diurnal and seasonal variations, dependent on location and climate[9]. These daily temperature fluctuations are more pronounced in small streams, particularly if they are not shaded by riparian vegetation.
In freshwater systems most species have a specific temperature range in which they can live. Salmonids require temperatures of between 5 and 15°C for normal growth and temperatures above 22°C for more than seven consecutive days can be lethal for brown trout [10]. In smaller fresh water streams in Southern England, temperatures in excess of 31°C have already been recorded[11]. These recorded temperatures highlight the need to take action to try and reduce water temperatures in streams in order to protect trout and salmon populations and maintain a suitable habitat to support them.

1.3 Wider ecological benefits of riparian vegetation

The influence riparian trees have on the habitat quality of the river is determined by tree species, extent and structure of the woodland, and the topography of the riparian zone. Organic inputs from the riparian zone in the form of leaf litter, and insects can account for up to 50% of the energy in a river system. The many benefits provided by riparian vegetation (

Figure 1) in helping to maintain natural stream functions are shown in **Table 1.**

Table 1. The functional roles of different vegetation components of the riparian zone and adjacent land (provided by SKM Enviros).

Zone	Location	Component	Functions
Riparian Zone – Aquatic Zone	River Bank	Tree roots	Stream bank erosion control, provision of thermal refugia and shelter from predators, and nutrient uptake.
		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.
	Margins of Rivers	Canopy and Trunks of Trees and Shrubs	Shade moderates water temperature and instream productivity, nutrient sources (e.g. retained leaf litter, wood and terrestrial invertebrates), uptake of nutrients, CWD creates habitat and cover for wildlife and thermal refugia. Trees and woody debris can

[9] Broadmeadow, S., et al. (2010)
[10] Elliott, J. M. & Elliott and J. A. (2010).
[11] Broadmeadow, S. et al. (2010).

Zone	Location	Component	Functions
			help to slow flood flows
Adjacent Land	Areas adjoining the riparian zone	Woodland and shrub and field layer vegetation	Barrier between stream and adjacent land use, improves soil structure increasing infiltration and slowing surface run off leading to uptake of nutrients and retention of sediment and provides habitat for wildlife, particularly otters.

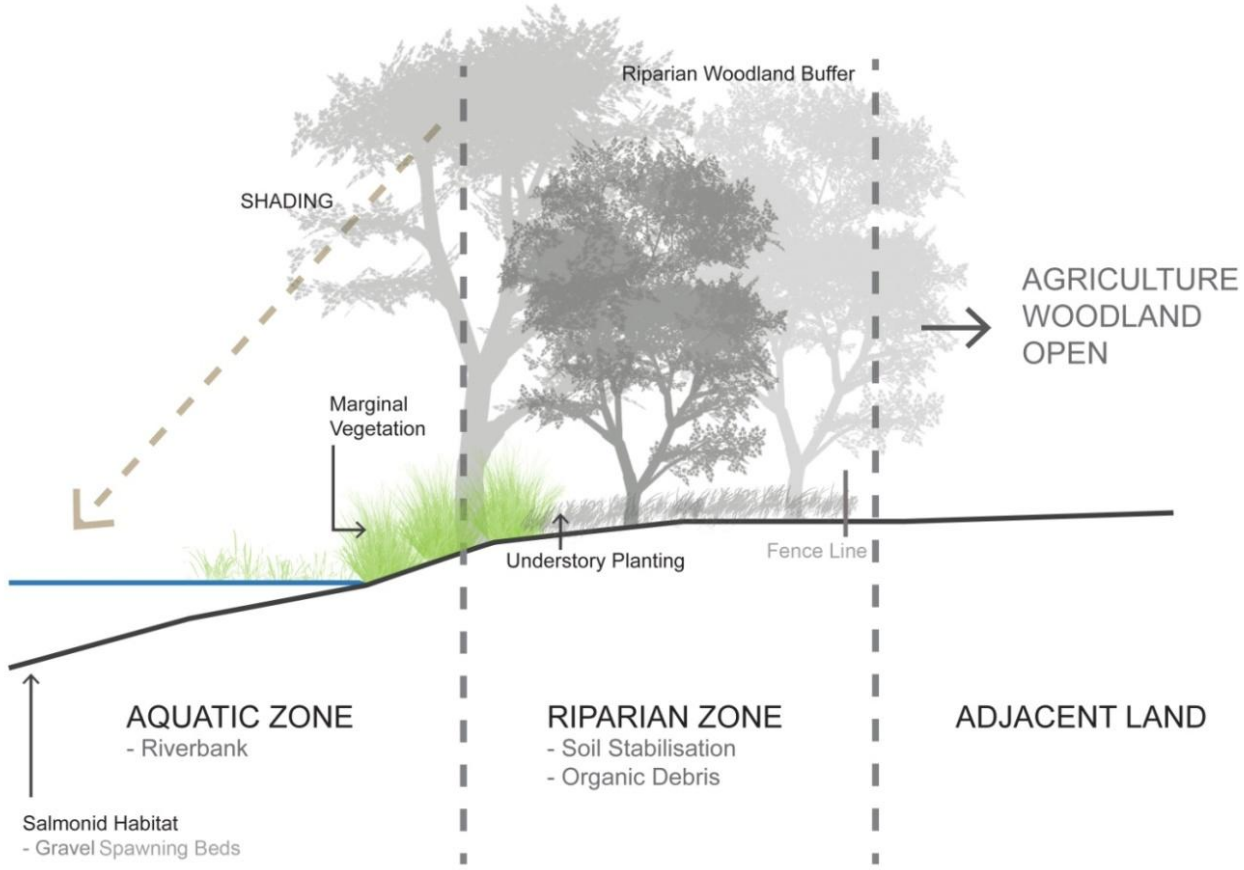


Figure 1. The riparian zone is defined as the area of land adjoining a river channel, including the river bank but not the wider floodplain. It can provide shade to cool the stream, stabilise stream banks, and act as a source of nutrients and woody debris (provided by SKM Enviros).

2. Site selection and design - targeting planting and fencing

2.1 Factors influencing water temperature

Figure 2 indicates the complex interplay of some of the dominant factors influencing river water temperature and shows how the efficacy of riparian shading in cooling stream temperatures reduces downstream. Planting the banks of the headwater streams is likely to offer the greatest benefits to water temperature within a river basin[12]. The graph also indicates the impact that tributary inflows can have on stream temperature and may indicate that all tributaries to a point should be considered for tree planting to maximise the benefits. These upstream/ downstream influences obviously depend on the size of catchments and channels and no evidence has yet come to light about how to quantify how far such impacts extend downstream in UK catchments.

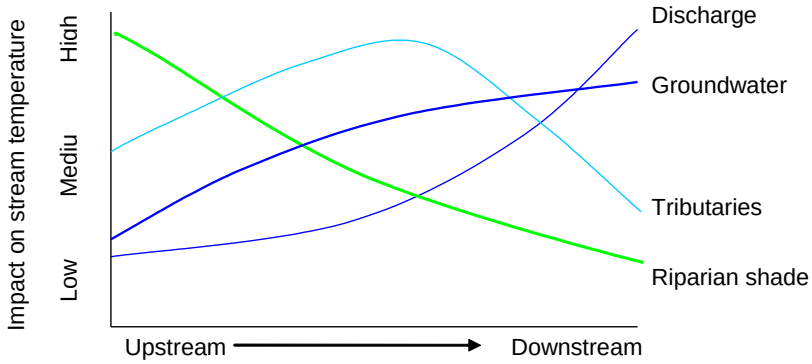


Figure 2. Conceptual impact of riparian shading, tributary influences and discharge on stream temperature from catchment headwaters to outlets (based on Poole & Berman, 2001).

The focus of riparian planting or fencing to reduce instream temperatures should be in uplands or head waters on smaller low order streams (see Error! Reference source not found.**). Stream orientation hould also be considered in the design of tree planting or fencing schemes to optimise shading over the stream channel. In addition to the creation of riparian shade in the streams of the upper catchment, there may be benefits of planting riparian trees further downstream to create thermal refuges for fish.**

Specific local issues will influence site selection for tree planting or fencing. An important consideration will be the availability of land and support of landowners. Other catchment objectives such as the reduction of flood risk and the impacts of diffuse pollution[13] will influence choice of species, planting design and site selection.

The width of the riparian zone that needs to be planted to provide optimum shade is not yet clear. To gain more evidence it would beneficial to plant a range of widths within the 'Keeping Rivers Cool' pilot catchments. When considering planting or fencing to create riparian shade, we initially recommend:

- Selecting headwaters (low order streams)
- Planting and fencing on streams of less than 5m width
- Planting belts of riparian trees between 2 – 5m wide (although greater widths than this are preferable, with land owner support, for other measures such as reducing diffuse pollution).
- Fencing should be on both banks for effective stock proofing.

[12] Correll, D.L. (2005)
[13] Forestry Commission (2011). p.46 'Water quality and buffer areas'.

- Shading 50% of the water surface with dappled shade[14] as shown in Figure 3, unless working on chalkstreams where Natural England have recommended shading of about 30% where in-channel macrophytes need to be considered.

Box 1. How many trees to plant[15]

How many trees to plant?

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 for each species can be calculated. The Woodland Trust provides the following guidance on planting per hectare:

"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 2–2.5 metre centre spacing is the most common 'formula' 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."

• Planted every 3 metre centres – 1,111 trees per hectare

• Planted every 2.5 metres centres– 1,600 trees per hectare

• Planted every 2 metre centres – 2,500 trees per hectare

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

For information about different British tree species please refer to: http://www.british-trees.com/introduction

British Trust Conservation Volunteers have a useful practical guide on how to plant and manage trees: '*Trees and Aftercare: a practical handbook':* www.btcv.org/handbooks

The Woodland Trust also have a plethora of practical tree planting information. Advice is available here including species information, tree planting costs, funding advice, design considerations and a picture guide to planting trees.

[14] Broadmeadow, S. & Nisbet, T. (2002)T (p.6 Summary of findings)
[15] Woodland Trust (2010)

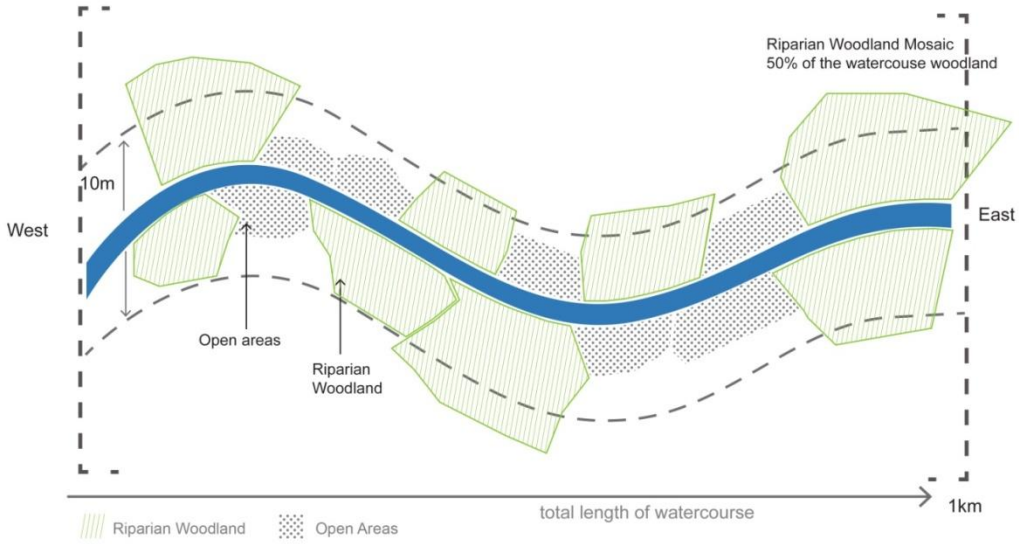


Figure 3. Riparian planting should create a mosaic of tree cover producing dappled shade that covers around 50% of a reach (provided by SKM Enviros).

Box 2. Strahler Stream Classification

Strahler Stream Classification

The Strahler Stream Classification is used to define stream order based on a hierarchy of tributaries (Figure 4) Streams are classed in orders, 1, 2 and 3. Headwaters are order 1, being the smallest and very start of a watercourse. When two 1st order streams come together they form a 2nd order stream, this process continues, as the size of the watercourse grows. A 2nd order must join another 2nd order to make a 3rd order stream.

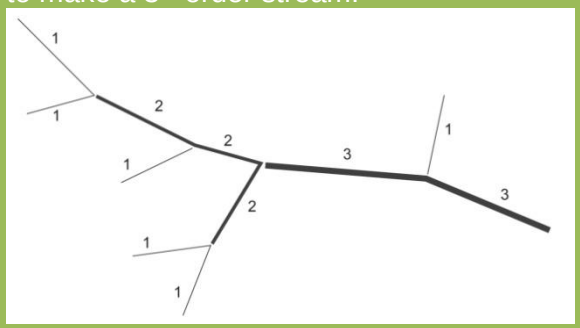


Figure 4. Strahler Stream Classification

2.2 Channel orientation

The orientation of the channel is an important consideration as it 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 (Figure 5).

East – West Orientation *North – South Orientation*

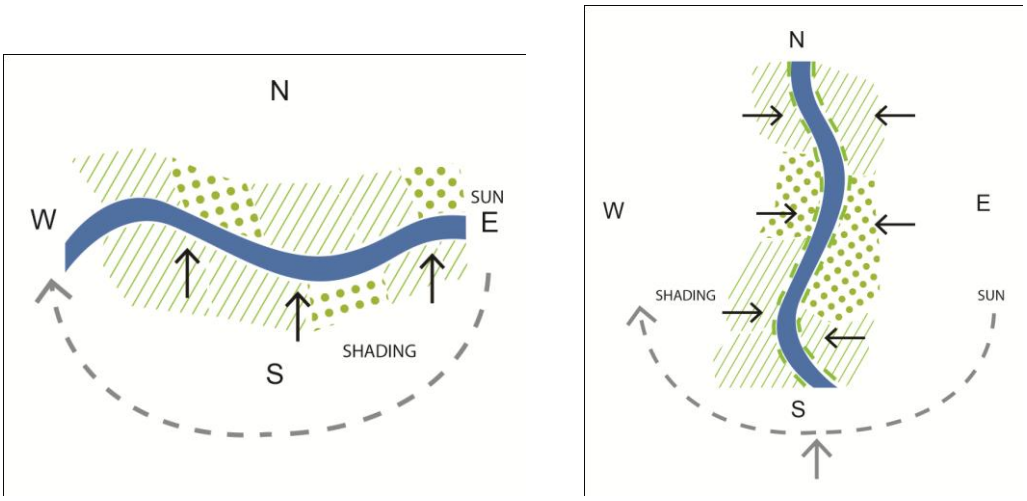


Figure 5. Direction of sun travel and corresponding shade cast (provided by SKM Enviros).

2.3 Tree and shade mapping tools

We have developed two mapping tools to help identify the right places to plant trees to create more shade. One shows you where there are gaps in tree cover and the other helps identify the degree of existing shading. Both tools are derived from LIDAR (Light Detection And Ranging) data for England and Wales collected by the Environment Agency. We provide accurate maps of riparian tree distribution, indicating presence and absence of riparian vegetation over 2.5m (this is how we defined existing trees), and shade maps, indicating where rivers are most and least shaded within a catchment. These maps are intended as guidelines only and decisions should be supported by local site information and survey.

2.3.1 Catchment shade maps

For a limited number of catchments we have developed 'shade maps' (Figure 6) using models showing average incoming solar radiation within catchments, where there is LiDAR data (there are some gaps across the country). The measure of incoming solar radiation indicates the likely amount of shade created by the landscape e.g. hill and valley effects as well as shading caused by existing vegetation. These shade maps can be used to support the identification of key areas to target to increase riparian shade. The shade maps are intended as guidelines only and decisions made using these should be supported by local site information or survey.

2.3.3 What catchments are shade maps are available for?

Shade maps involve a lot of computer processing time. We have only produced a limited number for the River Basin management pilot catchments and 'Keeping Rivers Cool' pilot catchments, as well as a few for catchments that managers have contacted us about because they are planning tree planting projects. At the time of writing shade maps are available for: Wye, Rivers Test & Itchen, Hampshire Avon, Derbyshire Derwent, Tyne, Frome (Dorset), Cherwell (West Thames), Dove (Midlands), Ribble, Shropshire Middle Severn, Kennet & Pang, Wey, Adur & Ouse, River Don, Wear, Tone, Ecclesbourne, River Leam, Welland and Irwell.

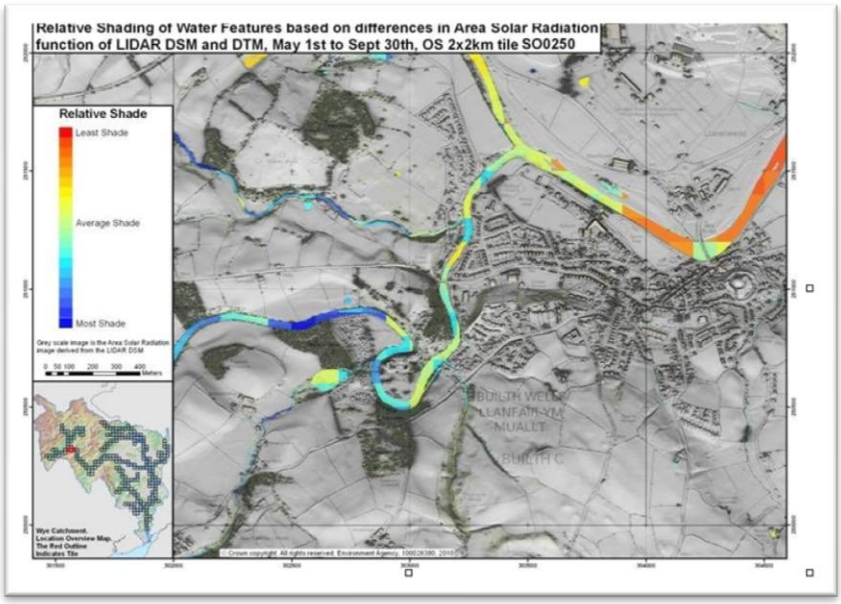


Figure 6. Example of a shade map pdf

Shade map pdfs are licensed as EA Opendata. For more information on shade maps, or access to the data, please contact Alastair Duncan.

2.3.4 Existing tree cover (LiDAR derived vegetation object maps)

Data about the presence of existing trees are available in two formats. One is easy to view and can be used without any special software as Georeferenced JPEGs **(**Figure 7**)**, which are a visual representation. The second is Binary Grid format which contains the vegetation objects >2.5m (trees) and can be used with Geographic Information Systems (GIS). Both data formats are available under license as special data. They are both chargeable for non-commercial & commercial use, but the license also allows exemption from the charges where the organisation requesting the data is a co-deliverer of the 'Keeping Rivers Cool Project[16]' or has a partnership agreement with the EA. The data are presence/absence so do not give actual heights of individual trees but just note them if they are greater than 2.5m high.

Figure 7. Part of JPEG image of LiDAR derived vegetation object map showing vegetation over 2.5m

For more information on shade maps, or access to the data, please contact Alastair Duncan.

[16] Agreements are currently in development and likely to include Rivers Trusts, The Woodland Trust, Forest Research, Forestry Commission and Natural England.

2.3.5 Rivers Trust catchment mapping portal

Using various partner organisation data sets in GIS, it is possible to overlay various catchment data and identify where the most benefits from planting and fencing can be obtained. The Rivers Trust have developed a catchment mapping portal which allows non-GIS users to do this. For more information and a link to the portal visit: http://www.theriverstrust.org/catchment_mapping/index.html

The Ribble Rivers Trust is also working on developing a GIS based system for prioritising sites for planting and fencing.

3. Species selection for tree planting schemes

3.1 Planting native woodland

The establishment of native woodland within riparian zones presents an opportunity to enhance the biodiversity of the area. Native tree species support a greater diversity and abundance of terrestrial invertebrates and provide high quality of leaf litter, which is beneficial to the aquatic zone[17]. There are several issues to consider when selecting planting material including the species, provenance and origin of seed stock. These are discussed below in Boxes 2-4. Water use by trees might also be a consideration in areas which may suffer drought.

Box 2. British Native Trees[18]

British Native Trees
British native trees are those that re-colonised the British Isles naturally, without human intervention, after the retreat of the last Ice Age some 10,000 years ago. Over many generations populations of these species have adapted to specific local conditions (soil type, climate etc) resulting in the genetic make-up of woodland of local provenance.
The Environment Agency only recommends planting of British Native trees.

Box 3. British Native Provenance

British Native Provenance
A tree of British Native Provenance is one whose seed was collected from a known location in the wild within Britain. Its Forestry Commission Seed Zone should be given (see information in Box 4.).

[17] Broadmeadow, S. & Nisbet, T. (2002)
[18] NEAS (2007)

Box 4. Local Provenance[19]

Local Provenance
A tree of local provenance is one whose seed was collected from within the same Forestry Commission Seed Zone as it is to be planted.
Ideally a plant's parents should come from that catchment or at least the general area. These plants will be better adapted to the local environment and contain characteristics that can add to the local distinctiveness of an area.
The Environment Agency encourages the use of local provenance stock in its schemes. There are certain areas where local provenance stock must always be used, for example within wooded Sites of Special Scientific Interest (SSSIs), Ancient Woodland and historic landscapes. For these sites we do not recommend planting, natural regeneration is the better option.
Using local provenance stock can require advance planning. For information about British flora suppliers visit the Flora Locale website. Flora Locale is an independent charity promoting the conservation and enhancement of native wild plant populations and communities.

The Forestry Commission has developed a system to help the identification of, and trade in, locally sourced stock for planting native trees and shrubs. This is a map of local seed zones (based on major geoclimatic influences and taking account of geological and landform boundaries); and guidance on its use. It also includes a voluntary scheme to allow seeds and plants to be identified and monitored in a consistent way.

For more information about Using local stock for planting native trees and shrubs please refer to Forestry Commission practice note 008.

3.2 Broadleaves not conifers

The optimum tree type to plant to provide shade on rivers are broadleaves with lighter foliage for example birch, willow, rowan, ash, hazel, aspen and bird cherry[20]. These will provide dappled shade for rivers, with reduced water interception. Species with denser crowns of foliage such as oak and beech can be interspersed with these[21].

We do not support the planting of conifer in floodplains or adjacent to rivers[22] for several reasons:

- Extensive conifer planting in river catchments with poorly buffered soils can indirectly lead to acidification of rivers[23].
- Coniferous woodland, should not be planted within 20m of the stream bank due to the heavy shade cast by the canopy all year round which can be detrimental to riparian habitat quality due to the restricted growth of the understory leading to bare stream banks and high rates of sedimentation[24]
- Water use by conifers is generally higher than by broadleaves. As conifers retain their leaves throughout the year they intercept more rain which is lost via evaporation rather than drainage, preventing it from reaching the ground[25] for use by other flora and running off into rivers.

[19] Herbert, R. Samuel, S. & Patterson, G. (1999)
[20] Forestry Commission (2003)
[21] Nisbet, T. (2005)
[22] NEAS (2007)
[23] Nisbet, T., et al. (2011)
[24] Broadmeadow, S. and Nisbet, T.R. (2004)
[25] Nisbet (2005), & Calder, I.R., et al. (2008)

3.3 Using National Character Area Profiles

The trees planted on riparian banks should reflect the geographical location and character of the area. England has been divided into National Character Areas (NCAs) by Natural England (Figure 8) to promote conservation planning at a landscape scale. NCA profiles will be published in September 2012 and will include a section on the trees and woodland which provides information about local species. This should be used to inform planting plans in terms of choice of species and type of planting.

Figure 8. Front cover of Natural England's National Character Area Profile for the Southern Pennines

3.4 Creating a diverse vegetation structure

The aim when designing new lengths of riparian trees and shrubs is to create an intricate structural mosaic of habitat producing dappled shade 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[26].
Five key structural habitats can be used to achieve this mosaic effect[27]:

1. Open ground, particularly in the marginal aquatic zone;
2. Occasional isolated trees that will ultimately achieve a grand size
3. Open glades within the woodland[28]
4. Patches of scrub; and
5. Closed canopy native broadleaf woodland.

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 eventually as mature trees are especially important in providing wood and woody debris to the stream.'[i] When developing a planting plan consider the desired height of riparian trees in order to provide enough shade for your stream width (**Figure 9**). For information on tree heights at different ages for different broadleaf native species see graphs and tables in Annex I.

Your local Woodland Trust contact may be able to help you develop a planting plan.

[26] Broadmeadow, S. & Nisbet, T. (2004)
[27] Forestry Commission (2003)
[28] if a woodland, rather than a riparian belt is being created

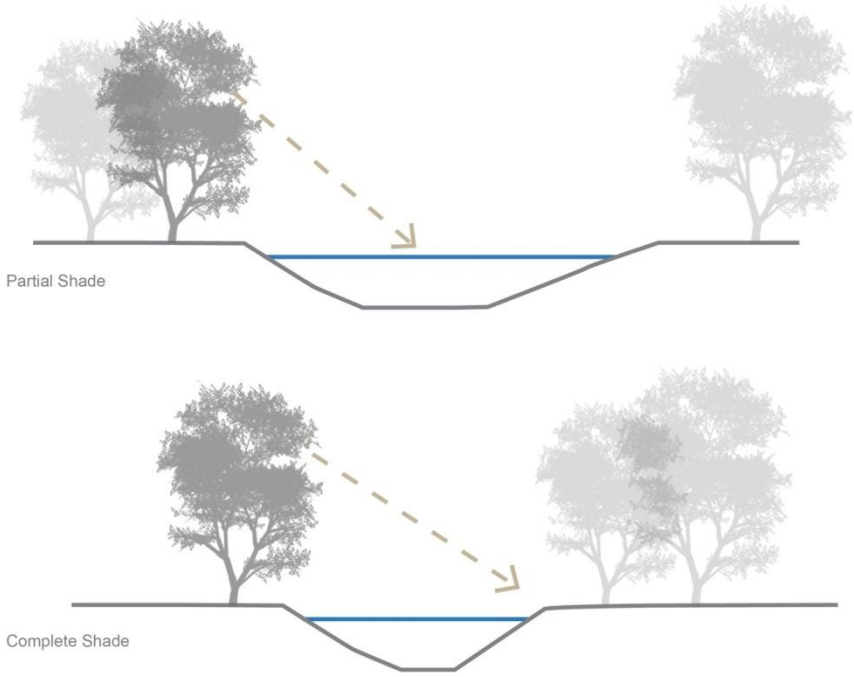


Figure 9. Vegetation structure and height can have a direct effect on the level of shade cast over the water's surface and thus on water temperature (not to scale, provided by SKM Enviros). *(also see graphs and tables in Annex I)*

3.5 Other tree species considerations

Tree Disease

Alder is considered a 'riparian specialist' and is useful at stabilising riverbanks; however it is suggested that in areas of acid sensitivity 'the use of alder should be limited'. The UK Forestry Standard 'Forests and Water Guidelines 2011' recommend that the planting of alder should be limited to less than 10% of the area within riparian zones of water bodies failing or at risk of failing good status due to acidification. More information is available from the Forestry Commission here.

Information on other plant pests and diseases can also be found on the Forestry Commission website here**.**

Water use by trees

Predicted drier summers will create a higher water demand and increased pressure on water resources. As water uptake and use can vary between different broadleaf trees, the impact of trees on the water regime of adjacent land should be considered particularly at sites draining on to wetland habitats. Riparian woodland planting is unlikely to have a significantly detrimental impact on the general water resource although it may be unacceptable to other stakeholders in catchments which have recently been affected by drought.

More research is needed to quantify the water use of a wide range of native woodland species. It is known that Willow and Poplar can sustain high transpiration rates of over 500 mm yr^{-1} in wet soil conditions[29] which is higher than other broadleaf species. It should be noted that tree shading may in some circumstances reduce evaporative losses from streams and this is part of the reason why the interactions between riparian trees and water use is not straight forward. For more information on this topic see 'Water use by trees'. A Forestry Commission Information Note 065

[29] Hall, R.L. *et al.*(1996)

4. Natural regeneration & protecting trees with fencing

An important element in establishing new riparian trees is protection by fencing from browsing and trampling domestic livestock and adjacent land uses, as well as delineating the area to be managed appropriately. Most, if not all areas of tree planting 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 (Figure 10). Fencing should be on both banks to prevent stock from crossing the stream to browse on the adjacent side (Figure 11.)

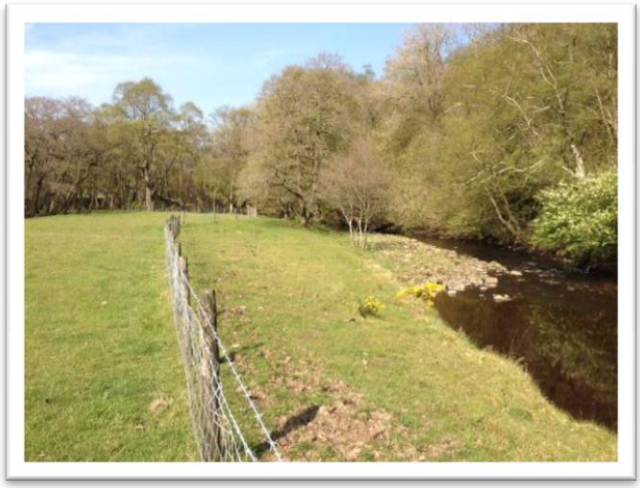


Figure 10. Example of cattle poaching, over grazing and bank erosion on an un-fenced tributary of the River Ithon, Wye (photo by Rachel Lenane).

Figure 11. Example of riparian banks with only one bank fenced, allowing access to grazing livestock on both sides, tributary of the Tyne (photo by Rachel Lenane).

There are different views as to the merits of fencing to allow natural regeneration to take place, versus actively planting trees along rivers. In upland areas where there is very little opportunity for native flora to propagate from local seed sources the natural regeneration approach may not be successful. Alternatively, where there are local seed sources the approach may generate hardy plants of local provenance, well adapted to local conditions. Natural regeneration can be a very cost effective measure, if location and time frame permit, but there is far less control over the structure and design of the local site. When opting for natural selection invasion of non-native species like sycamore, Italian alder or Japanese knotweed must be considered.

Careful analysis of advantages and disadvantages of actively planting trees against promoting natural regeneration is needed in the early design stages of a project. Site specific characteristics will play an important part in the outcome.

The merits of the different approaches will be something that will be explored through the 'Keeping Rivers Cool' pilot catchments.

4.1 Fencing design considerations

The Conservation Volunteers (formerly known as 'British Trust of Conservation Volunteers') has published an excellent handbook on fencing: BTCV – Agate, E., 2001. Fencing a practical handbook. BTCV Enterprise Ltd. Which can be purchased from Amazon or through the EA's online book purchase system.

Key fencing recommendations:

- Tree tubes are recommended to provide protection to the young saplings especially where rabbit or deer grazing is evident locally, at least initially until the newly planted stock is established.
- Rabbit spiral guards may be more cost effective than tree shelters and require less maintenance. In exposed conditions tree shelters can be readily blown over, and if not spotted and rectified quickly, cause abnormal growth of the emerging tree.
- Fencing should be designed to be robust and able to accommodate the full extent of the watercourse through the year to take account of the patterns of flooding of marginal areas year round, as this will be a key influence on fencing design and layout.
- Ideally the line of the fence should be positioned as far from the watercourse as possible, which reduces 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 for riparian fencing as it reduces the chances of flood debris getting caught. Running fencing parallel to the direction of the watercourse helps to reduce flood damage, and minimises the 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 weak links which will give way under moderate pressure, prevent excessive strain on the overall fence line. These 'Sacrificial' weaker sections are designed to minimise the cost of re-building flood damaged fencing, as it is cheaper to re-wire rather than completely re-fence. Please see '**Warning!**' text box below.
- The fence line should have frequent access points, for maintenance and access for river users
- In situations where livestock require access to the watercourse it is important this is done 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.
- 'When fencing riparian schemes, it is important to 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, it is preferably for any ford access there is a hard base.
- 'It is also essential to check fences and water-gates regularly, and especially after floods'
- It is important to 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 (e.g. in the Ribble catchment).

Warning!

Use of fences across the river should be minimized. The risk of serious injury or death for individuals caught in the flow of the river and trapped in wire is very serious. 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.

4.2 Stock watering

Where livestock are prevented from accessing water from adjacent streams new solutions 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 (Figure 12, Figure 13, Figure 14). They are portable and can be placed up to 50 metres away from the river. More information on these can be found on the Defra website.

Figure 12. Sheep operated pasture pump providing water from a fenced off tributary of the River Ithon in the Wye (photo by Rachel Lenane)

Figure 13. A cattle operated pasture pump for more details look on the Defra website

Figure 14. Solar powered stock watering trough in the Ribble catchment (Photo provided by Jack Spees, Ribble Rivers Trust Director)

5. Funding available for planting trees

Various schemes and sources of funding are available to assist landowners and communities plant trees or create woodland. The Royal Forestry Society has a list of over 50 grants and funding schemes available for woodland creation and management available here.

Below is a quick guide to the current funding schemes that you are most likely to find useful for creating new small native riparian woodlands. None of the schemes below explicitly provide funding for planting less than a hectare. However, exceptions can be made, so it may be worth contacting the relevant organisation to discuss your planting scheme further.

The Woodland Trust woodland creation team can provide advice on Forestry Commission funding. Their details can be found by clicking here. Some examples of available funding are as follows:

5.1 The Woodland Trust MOREwoods scheme

If the grants summarised below are not appropriate for your planting scheme, the Woodland Trust (WT) may be able to help. The 'MOREwoods' scheme run by the Trust offers support and guidance in the first instance to help you with your scheme but can also provide small grants of materials in appropriate circumstances. The scheme is ideal for small-scale, scattered, low density planting on sites of 0.5ha and above. Riparian planting or planting in diffuse or narrow blocks (such as shelterbelts, riparian schemes or maximising field corners). Where appropriate landowners receive help with materials (trees / stakes / tubes) – whilst the landowner is still required to pay towards the materials they receive them at a 60% discount to their actual cost; £1,000 worth of materials costs the landowner only £400.

WT officers provide help with species choices and planting design. When the landowner is happy with the proposal WT will arrange to deliver the trees and associated materials. The WT can also arrange planting through a contractor, if desired, with the landowner being asked to provide 70% of the total costs.

It is worth noting that unlike the Forestry Commission England and Welsh Glastir grant schemes, planting under MOREwoods may affect your Single Farm Payment. If you are claiming this and wish to continue to claim it please check implications prior to planting.

Further information on the MOREwoods scheme can be found by clicking here.

5.2 Funding from local councils

Some local councils offer support for small scale woodland creation schemes. This can be anything from 25 free trees to grants of up to £500. In the first instance contact your local authority to find out what is available in your area.

5.3 Heritage Lottery Fund

We will be encouraging partners in the 'Keeping Rivers Cool' project to apply for Heritage Lottery Funding from 2014-2016. For information on how to make an application please visit the HLF web pages here. Please also contact Rachel Lenane to let her know that you are considering this option so she can coordinate the applications under the 'Keeping Rivers Cool' banner.

5.4 Grants available for woodland creation in Wales

Welsh Government, Glastir

From 2012 Glastir is replacing existing agri-environment schemes. It has a 'Woodlands Element' designed to support land managers who wish to create new woodland and/or manage existing woodlands.

Forestry Commission Wales, Woodland Creation Grant

The Glastir Woodland Creation Grant (WCG) is administered by Forestry Commission Wales:

- For all landowners across Wales with more than 0.25 hectares of land
- On land designated by Forestry Commission Wales and conservation bodies in Wales as suitable for new planting.
- Where there is no conflict with other agri-environmental schemes.
- The grant includes an allowance for fencing including gates and stiles

Comprehensive information on the grant, including a list of Glastir project officers to contact and a helpful FAQ section, is available here

5.5 Grants available for woodland creation in England

Funding for woodland creation is normally supported through the Forestry Commission's English Woodland Grant Scheme, though there are some instances where Natural England's Environmental Stewardship Scheme is more appropriate, for example where woodlands are grazed by livestock, or for woodlands on common land. If neither of these schemes are suitable the Woodland Trust's 'MOREwoods' scheme, mentioned above, may also be able to provide funding.

Forestry Commission's English Woodland Grant Scheme
The Forestry Commission's (FC) English Woodland Grant Scheme (EWGS) offers a suite of 6 grants to help create and enhance woodlands for environmental and social. The Woodland Creation Grant (WCG) is the FC's main grant contributing to the costs of establishing new woodland. A summary is provided below, for more comprehensive information from the FC please click here.

Forestry Commission's Woodland Creation Grant (WCG)
The aim of this grant is to create woodlands that generate public benefits. Particular priorities are new woodlands:

- For wildlife, particularly where they can act as protective buffers and link important woodland habitats or other associated natural areas
- That reduce flood risk, improve water quality and prevent soil erosion;
- That are resilient and can adapt to climate change
- Near to where people live, particularly within the urban fringe and that provide access and recreation
- To enhance the landscape and restore former industrial land
- To create productive woodlands and wood products that support the rural economy and capture carbon

Application for WCGs should normally be for planting areas of no less than 0.25ha and on average, no narrower than 30m with a minimum width of 15m. This may rule out a lot of planting proposals to create riparian shade.

If you are considering planting trees with other objectives, such as decreasing flood risk and/ or reducing diffuse pollution the FC provide 'Additional Contributions' designed to support the creation of appropriately targeted and designed new woodland. To be eligible for additional contributions the new woodland must comply with specific design principles outlined in these guidelines.

Natural England's Environmental Stewardship Scheme (England)
The Environmental Stewardship scheme is administered by Natural England under two headline categories Entry Level Stewardship (ELS) and Higher Level Stewardship (HLS). It provides funding to farmers and other land managers, who deliver effective environmental management on their land, including woodland. See *Box 5* for more information.

Box 5. Information on NE's Environmental Stewardship Scheme - from information in Forestry Commission England note, 'Funding for Farm Woodlands in England'. Grants and Regulations National Team. Version 3.0 Jan 2011 and 'Look after your land with Environmental Stewardship (NE124).

Entry Level Stewardship (ELS)

Acceptance into Entry Level Stewardship (ELS) is determined by a 'points per hectare' calculation across an entire farm. On achieving a points target, meeting the scheme conditions and agreeing to deliver the options chosen, the farm owner will automatically receive funding.

£30 /ha /yr is available for eligible woodland on a points basis e.g. a 100ha holding would need to achieve 3000 points. The woodland on a holding does not need to be included. An example option is "maintenance of a stock-proof woodland boundary" – to prevent livestock grazing the woodland and causing environmental damage @ 4 points per 100 m of boundary.

Points are earned for the range of environmental management options agreed to. There are over 65 management options to choose from. For the comprehensive list of options please refer to the 'Environmental Stewardship handbook, third edition (NE226)', Section 3. For 'Keeping Rivers Cool - creating riparian shade', the most relevant ELS options may be in sections C 'Options for trees and woodland', E; 'Options for buffer strips', and J, 'Options to protect soil and water'. For more information, please visit the Natural England website.

Higher Level Stewardship (HLS)

HLS is a targeted and competitive scheme that is only available to farmers and land managers in 110 areas across England with particular high priority features on their holding. Support for woodlands is based on a set of targeting maps where Natural England are seeking the most environmental benefits from HLS agreements for wildlife, landscape, the historic environment and resource protection. A Farm Environment Plan is first produced to identify the special environmental features and their condition. HLS can pay for capital work and annual payments, with supplements also available. For example, woodland creation may include capital payment for tree planting and protection work; annual payment for income forgone and tree maintenance; supplementary payment if public access is provided.

6. Maintenance of riparian trees and vegetation

Useful available guides on best practice ways of managing riparian trees and vegetation include:

- SEPA's: *'Engineering in the Water Environment Good Practice guide: Riparian Vegetation Management, Second edition, June 2009'*
- Forestry Commission's: '*The management of semi-natural woodlands: 8. Wet woodlands (2003)*.
- British Trust Conservation Volunteers (Now 'The Conservation Volunteers') have a useful practical guide on how to plant and manage trees: '*Trees and Aftercare: a practical handbook'* (which can be bought online, or through the Environment Agency online book purchasing system).

In nearly every case the Environment Agency or other partner will not own the land where tree planting is to take place. Where the land is not owned by the person or group wishing to carry out works3 landowner consent and a long-term commitment to maintenance should be obtained before the planting scheme starts. On most riparian planting schemes it would be beneficial to have at least a 3-5 year maintenance programme where landscape contractors maintain and manage all planting. After this the landowner should assume ownership and responsibility for the planting and maintenance of fencing where appropriate. It is important that the land owner is entirely involved when the tree planting or fencing plans are being developed and aware of the long term nature of the project.

The contractor should be responsible for all horticultural operations including weed control, for the 3-5 years after planting. The landscape contractor should also remove any planting sundries (spiral shelters, mulch mats, stakes etc) at the end of the maintenance period.

The EA, Rivers Trust, Woodland Trust or other lead partner should provide landowners with a management plan so they understand how to manage the trees and fencing.

7. Consents and local engagement

If you are working with an Area Environment Agency Officer they will be able to help you through the process of gaining consent for riparian planting and fencing. This may involve contacting local EA Flood Defence Consents Officers, in Area Partnership & Strategic Overview (PSO) teams to check if new riparian planting is suitable in your area.

7.1 Environment Agency consents

Before planting trees, or erecting fences ask your local EA catchment lead to consult EA Area Asset Performance teams. They need to be aware of your plans and will advise on avoiding emergency and maintenance access routes. Early communication will prevent any conflicts of interest arising.

The EA may require Flood Defence Consent for planting within 7 to 16m of main rivers (a main river is a watercourse marked as such on a main river map)[30]. This is known as the byelaw strip and different widths apply to different regions; check with the local office by speaking to the Partnership and Strategic Overview team. The distance begins at the top of the riverbank, or where there is a flood defence structure, like a wall or embankment, then it is from the landward edge of that feature.

The Environment Agency may also want to consent for any planting within a designated flood storage area and within the 1 in 100 year floodplain. As byelaws vary between regions you need to liaise with the Partnership and Strategic Overview team to see if this is required.

Herbicide treatment adjacent to watercourses will require Herbicide Application consent.

7.2 Local Authority consents

Lead Local Flood Authorities 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 or ordinary watercourses, however, the works should be discussed with the Lead Local Flood Authority.

7.3 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.

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 landscape and/or tree officer.

It will also 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. The local Area Environment Agency Officer should be in a good position to know who to contact.

7.4 Access rights

Please bear in mind that the riparian zone is also accessed by other groups from time to time and much access is *by right* or *by 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. Angling groups may have access. Grazing and watering rights for stock may affect fence locations. Access for draining and maintenance or overhead / underground cables and pipes is also often a feature.

[30] Main rivers in England are designated by Defra, in Wales they are designated by Welsh Government.

Where appropriate, ensure that footpaths/rights of way are inclusive and accessible for all by considering the “Access for All Design Guidance”. This guidance will shortly be available on the Environment Agency internet pages.

7.5 Secretary of State approval

It would be advisable to avoid proposing planting or fencing on common land as Secretary of State approval is required for planting or fencing on common land by owners or commoners. The person wishing to build the fence must advertise the application in a local paper, and the Secretary of State must allow 28 days for members of the public to make representations.

8. Taking flood risk into account

The Information below is taken from the Environment Agency (2012) ‘Trees near Rivers’ Quick Guide.

Strategically placed woodlands, trees and shrubs in floodplains can reduce flood risk, by slowing down soil erosion and holding back flood flows. However, when considering planting trees near rivers EA must ensure they do not increase the risk of flooding to property; and prevent watercourses and flood defences from being maintained.

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 5).

Box 5. Taking flood risk into consideration when planting riparian trees[31]

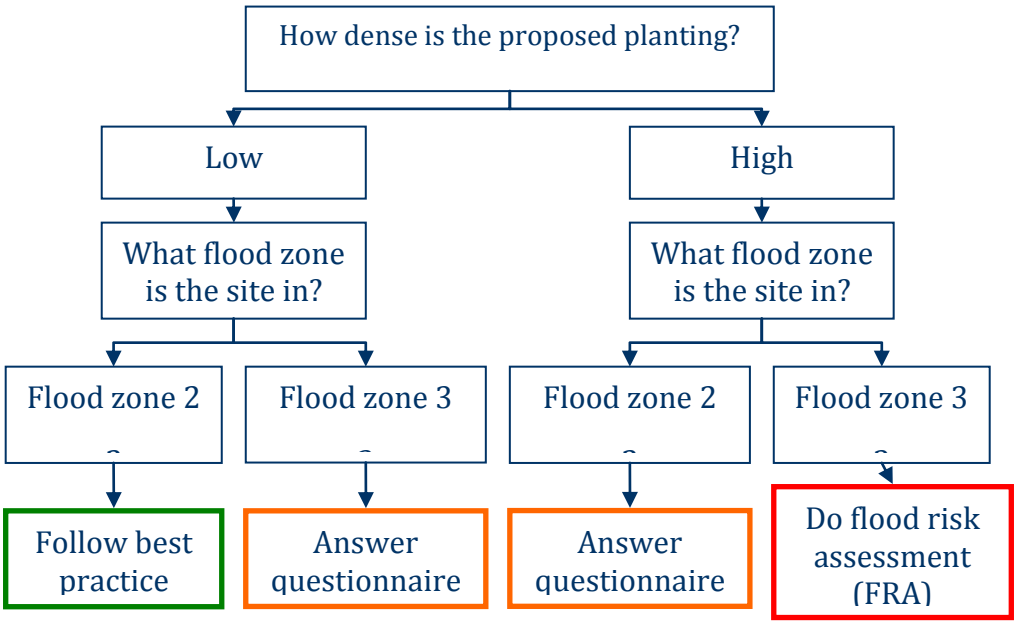
Planting individual or small groups (4 to 25) of trees and shrubs within the byelaw strip will generally be acceptable as long as they do not:

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 2 metre centres this would occupy an area 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.

Follow the flow chart below to help you decide whether to plant trees or not:

[31] NEAS (2007)



Follow Best Practice

If introducing low density planting in Flood Zone 2, follow best practice guidance below.

Do plant trees/shrubs	Unless
▪ which are appropriate native species (seek advice from F&B)	▪ they obstruct flood flows or access to the watercourse for maintenance (you will need to follow advice set out in the maintenance standards).
▪ as individuals or small groups	
▪ in rides which run parallel with the direction of flow	
▪ to help achieve woodland planting CFMP action	
▪ leaving a buffer zone to reduce siltation and decreased pH	

Answer the questionnaire

For low density proposals in Flood Zone 3, or high density proposals in Flood Zone 2 answer the following questions to help decide next steps to take, then follow the best practice guidance.

Will planting	Action if answer is 'yes'
▪ prevent access for maintenance?	▪ provide a sufficient margin around all structures to enable maintenance access and avoid damage to FCRM infrastructure
▪ destabilise, flood defences/embankments/walls	
▪ in the channel affect capacity or create blockage?	▪ **STOP** do not undertake planting
▪ increase flood risk to third parties?	▪ reduce density of planting to less than 30% of the floodplain width; provide a sufficient margin around all structures to enable maintenance access and do not plant trees
▪ obstruct flood flows?	

	in flood flow routes
▪ have cumulative effects?	▪ undertake an FRA[32] if proposed planting takes up more than 30% of the floodplain

Do a flood risk assessment (FRA)

For high density planting proposals in Flood Zone 3 undertake an FRA. Its scope should be relative to the scale of the proposal, including:

- location plan
- level survey to ordnance datum
- plan showing structures affecting local hydraulics
- assessment of:
    - impact of planting areas on water levels
    - impact of displaced water on other property
    - potential for blockage of structures
    - impact on fluvial morphology

If the FRA shows the proposal is acceptable follow best practice guidance (above).

Box 6. England flood zone definitions

Flood Zone 1 – Areas with the lowest probability of flooding from rivers and sea. The chance of flood is estimated to be less than 0.1%

Flood Zone 2 – Area with chance of flooding between 0.1% and 1% fluvial or 0.5% tidal

Flood Zone 3 – Chance of flooding in any one year is greater than or equal to 1% for river flooding and greater than or equal to 0.5% for coastal and tidal flooding.

[32] In Wales FRAs are called Flood Consequence Assessments.

9. Other potential constraints on tree planting

9.1 Avoiding priority habitats and species

Increases in riparian vegetation and trees will not benefit all organisms and care must be taken to avoid detrimental impacts on existing valuable habitats such as species rich grassland, important wetlands, and terrestrial SSSIs. Local expertise should be sought when developing planting or fencing plans to ensure that conflict with other priority species or habitats is avoided. Your local Natural England Officer and Area of Outstanding Natural Beauty Officer (where applicable) should be able to provide advice on habitat, species and designations to be aware of, including the species and habitats listed below.

Effects on breeding waders and ground nesting birds
Although trees generally provide a valuable habitat, there are places where they can be detrimental. for example in open wetland habitats such as the Somerset Levels and Moors that support populations of ground nesting birds can provide look out posts for predators who watch and then raid nests. For this reason many ground nesting birds do not use otherwise suitable habitat if it is close to trees. Leaving areas as tall grassy or reedy vegetation may be appropriate here. Equally some low scrub can sometimes be appropriate.

Avoiding planting on exposed riverine sediment (ERS)
This unusual habitat supports unique and diverse communities of rare beetles as well as endangered and declining river flies[33]. Surveys have shown ERS to be rich in fly species with nationally rare or scarce species. Whilst 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.

Tunnelling or creating too much shade
Instream macrophytes such as the *Ranunculus* species commonly found in chalk streams in Southern England require sunlight. Creating too much shade will prevent these important plant communities from thriving and should be taken into account when planning where and what riparian vegetation to plant.

9.2 Invasive non-native species control

Invasive non-native species (INNS) may need to be eradicated or controlled in order to protect any enhancement measures. **Details on which non-native species need control, and the preferred method of control should be worked into the planting and fencing plan**, along with a clear explanation about the potential time and costs involved.

[33] Buglife website

10. Examples of good practice of creating riparian shade

All photos for section 10 provided by Dr Stephen Marsh-Smith OBE

10.1 Wye & Usk Foundation (WUF) - Natural regeneration to create shade and prevent erosion on the Upper Afon Clywedog, Ithon Catchment, Wye valley

A short section of this 3rd order stream (Figures 14-19) had been straightened and all trees removed in the early 1990s. The resulting erosion, channel widening and loss of features was exacerbated by unrestricted grazing. In 1997, WUF fenced the steam after repairing bank erosions with soft revetment. In 2009, the site was re-coppiced and "pleached" with repair to an eroding section near a pylon.
A series of historic photos show the changes in stream width and increasing riparian vegetation over time. Note the Oak tree in the background of most of the photos (top left hand corner) which helps to show where the photograph has been taken each year.

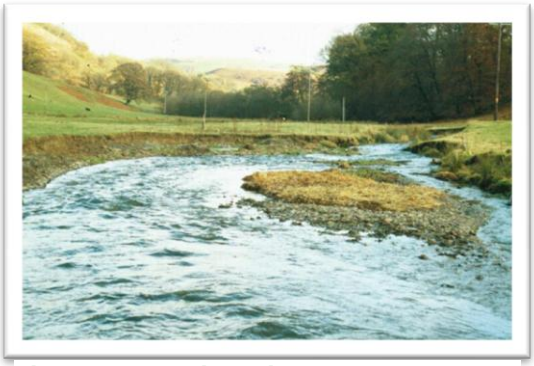


Figure 15. A. Clywedog 1998: Pre restoration

Figure 16. A. Clywedog 1999: 1 year after restoration. Note revetment consisting of Alder logs and tree tops, fence. The stream has started to narrow and many riparian species of plant have returned

Figure 19. A. Clywedog 2005: Further narrowing and regrowth of native Alder trees

Figure 18. A. Clywedog 2009: Repair in progress

Figure 18. A. Clywedog 2009: Alders thinned (RHS) and laid in "pleached" LHS. Further narrowing

Figure 17. A. Clywedog 2012: Further narrowing and full riparian shade provided by natural regeneration

10.2 Eden Rivers Trust – Creating shade and preventing erosion through planting riparian trees on the River Petteril, Eden catchment

The River Petteril, a tributary of the River Eden catchment has been degraded by excessive livestock trampling by livestock, leading to poaching and pollution from agricultural run-off. As a result the river was targeted for a habitat improvement program by the Eden Rivers Trust. They aimed to restore riparian buffer strips to reduce erosion and restore habitat for salmonids and invertebrates. Work included fencing, tree planting, willow planting, tree thinning and the installation of large woody debris.

Eight areas of habitat were improved by creating buffers along 4km of the Petteril. It was achieved through the involvement of communities and volunteers with the Trust's existing partnerships.
.

Figure 20. Crooks Mill Farm, R. Petteril before the restoration project

Figure 21. Crooks Mill Farm, R. Petteril after the restoration project

At Crooks Mill Farm, on the River Petteril, 250 broad leaved trees were planted and protected from livestock damage by 1027m of fencing. Tree tubes were found to be necessary to protect young trees.

Annex I

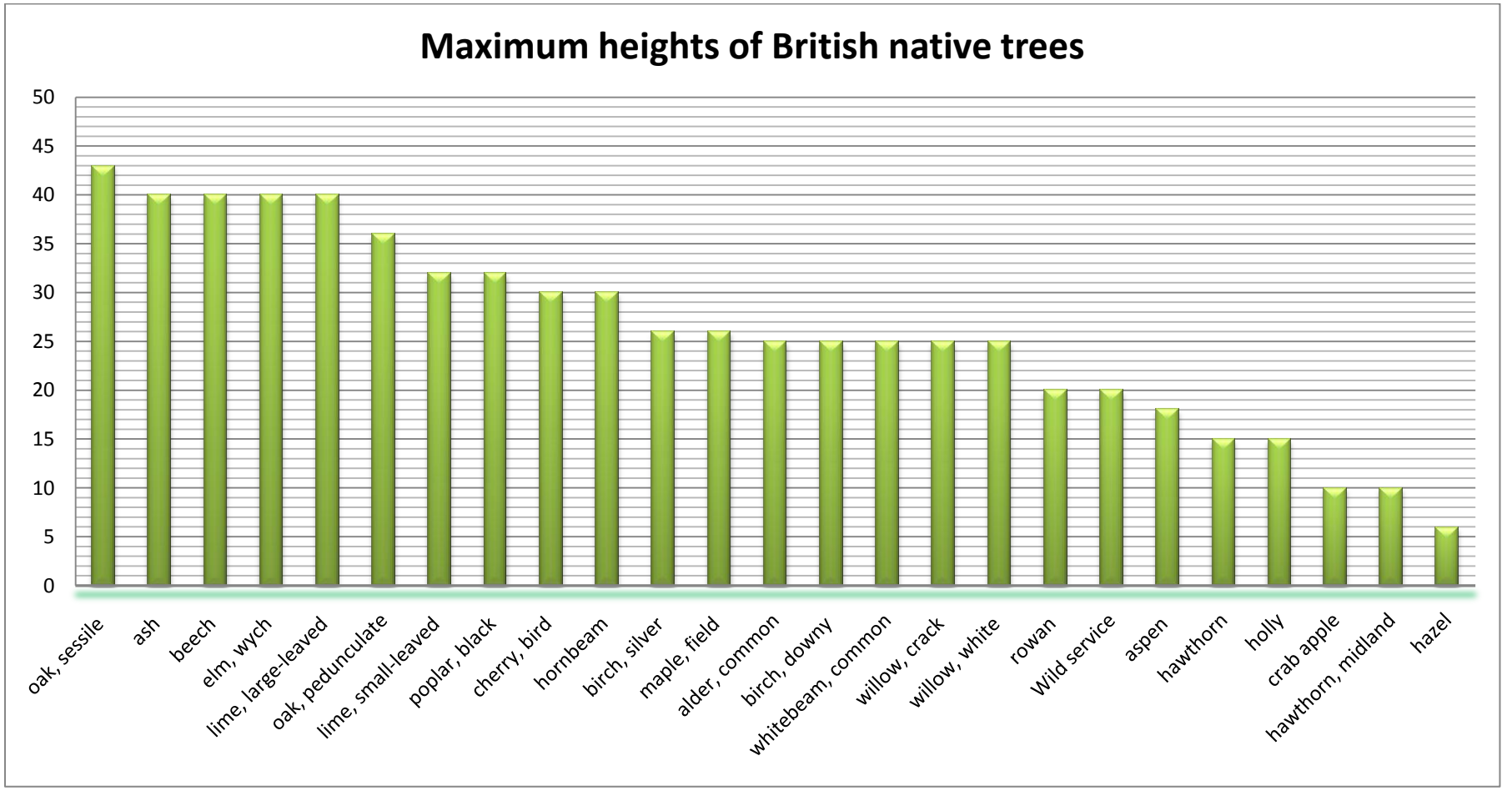


Figure 22. The maximum heights of British native trees (in metres) taken from Collins 'Complete Guide to British Trees' (2007).

Table 2. 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	●				●	●

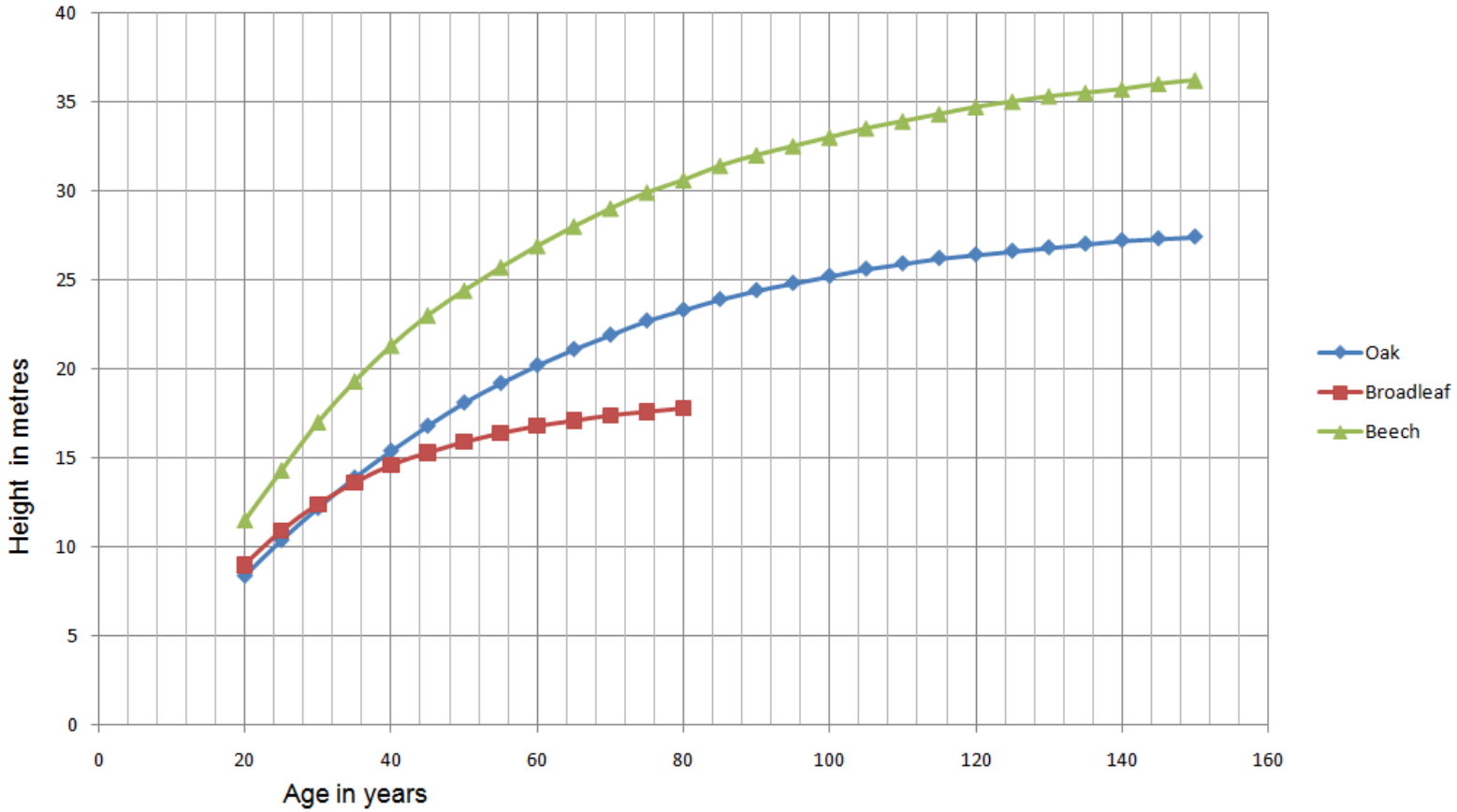


Figure 23. Average heights over time for broadleaf native trees*

*This graph is from data supplied by Forest Research used for estimating timber yield. Tree height in this data set is taken from trees grown in stands of single species. Trees would tend to grow shorter and squatter if they are out in the open rather than in a close planted stand. The 'Broadleaf' tree data is from Sycamore stands which are used as proxy for all broadleaves other than Beech, Oak or Poplar.

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