Forest Research

DROUGHT-TOLERANT TREE SPECIES FOR LAND REGENERATION

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BPG

NOTE 20

Best Practice Guidance for Land Regeneration

Introduction

Drought can be defined as 'a meteorological occurrence characterised by below normal rainfall' (Cregg, 2004); if prolonged, it can lead to soil water deficits causing wilting and eventual death of vegetation. Soil water content is governed by climate (precipitation and evaporation), soil permeability, effective rooting depth and soil water-holding capacity. For a given volume of soil, the principal factors that affect water availability for plant growth are soil texture and soil organic matter content. Soils and soil-forming materials on brownfield land are generally stony, compacted and have a low organic matter content. As a result, their water-holding capacity is limited and reclamation of the soil is required to improve the chances of achieving satisfactory tree growth. Where a brownfield site is not regenerated to best practice standards, it can take many years before the soils build up sufficient organic matter and soil structure to improve water-holding capacity and drought is a common cause of slow growth and death for saplings and trees in such regeneration projects (Figure 1). Even where a site is regenerated to best practice standards, both the current and the future projected climate (including drought) are key considerations when selecting suitable tree species for land regeneration to greenspace.

Figure 1 Summer drought damage to sycamore (*Acer pseudoplatanus*) growing in sandy soil in southeast England.

Factors affecting soil water availability

Current climate and climate change

Britain's climate has been changing. Of particular relevance to this note are the clear trends towards warmer conditions and reduced summer rainfall. These trends are expected to continue – by 2080 UK climate projections show a likely increase in mean summer temperature of between 2.5 and 4.2°C and a decrease in summer rainfall of up to 40% in southern England. Projected changes are not identical throughout Britain and more information about different regions can be found on the UKCP09 website (see Useful links section).

As climate affects tree establishment and growth, species must be chosen that are resilient and suited to current and projected UK climate conditions. Climate projections should be used to explore likely future temperature and rainfall conditions at the regenerated site. Likely reductions in summer rainfall should, for example, encourage the selection of drought-tolerant species. See also BPG Note 21 for more guidance on land regeneration considerations under a changing climate.

Soil quantity and quality

Provision of an adequate quantity of soil or soil-forming material to sustain plant water needs during the summer months is an important aspect of land regeneration. BPG Note 5 provides advice on the required minimum standards for soil or soil-forming materials for use in land regeneration.

For landfill sites, the Forestry Commission has recommended a minimum rootable soil depth of 1.5 m – the most appropriate depth will depend on the water-holding capacity of the soil and its availability for plant growth, which itself is determined mainly by soil texture

and stoniness. The pores in soil are filled with air and water and the amount of water that soils can hold varies considerably between soil types. Generally, the coarser the particle size the larger the pores and the less water stored (after drainage) that is available to tree roots. Sandy soils and those containing high quantities of stones and gravel hold less water than soils containing fine particles such as clay and loam. The water that remains after drainage is held within the soil and the force with which the water is held increases with decreasing pore size so that very fine soils such as clay may hold a proportion of the water too strongly for plants to absorb, limiting water uptake by trees. Loamy materials with few stones, by comparison, allow a larger amount of water to be extracted by the tree roots, and these are therefore preferable. Soil water content and availability are also affected by the soil organic matter content and degradation of the soil structure (e.g. by compaction). Incorporation and build-up of organic matter will increase the available water capacity of the soil (see BPG Note 6), as will ensuring the soil is free of compaction both during and after regeneration (see BPG Note 4 for guidance on soil placement to avoid compaction).

As well as soil structure, tree species selection criteria must include other aspects of soil quality, particularly soil pH and nutrient content (see BPG Notes 1 and 2 for guidance on soil sampling and analysis). Where the regeneration project includes an element of soil importation or creation, soil materials should be prepared to a standard suitable to support the desired habitat (see BPG Notes 3, 5 and 7 for further information) and the choice of vegetation should be made after soil provision has been finalised and modified according to expected moisture supply.

Topography, aspect and exposure

Topography, aspect and exposure play an important role in regulating site hydrology and therefore soil moisture availability, and variation in tree species selection should reflect changes in these across a regeneration site. Topography affects the flow of water over a site as well as infiltration into the soil. Gradients greater than 6–10 degrees are not recommended for tree planting at regeneration sites (Doick and Hutchings, 2007). Aspect affects the amount of solar radiation a site receives, which in turn influences air temperature, humidity and soil moisture content (Rosenberg *et al*., 1983). A southwest-facing slope, for example, is sunnier and drier than a northeast-facing slope (Fekedulegn *et al*., 2003). Exposure to wind will affect tree species selection as wind desiccates the soil surface layers, leaving them vulnerable to erosion. Additionally, higher wind speeds at exposed sites increase water loss from trees, and hence increase water uptake by roots. This in turn acts to reduce soil water content.

Native and non-native species

It is important to select the right tree species for the regenerated site to maximise the likelihood of success. Projected future higher temperatures suggest considering selecting tree species that are best adapted to these conditions. Selecting native tree species is not of paramount concern in these situations. Rather, species should be selected on suitability to the current and projected site conditions. A balance of native and non-native species may provide a tree species mix that is more resilient to pests and disease as well as climate change. Some tree nurseries sell planting stock of particular species from a variety of provenances and for some species it is possible to select a provenance with improved drought tolerance. Species and provenance needs should be discussed with the nursery at least two years in advance of planting.

Species choice for drought conditions

Tree species selection should reflect the desired habitat and the site's soil conditions and take account of local climate as well as the projected future climate for the region. Drought tolerance in plants is a complex characteristic involving a suite of morphological and physiological traits; therefore categorising species is difficult and it is important in land regeneration to select species with inherited drought tolerance. Table 1 provides information on the drought tolerance of a selection of (mostly broadleaved) tree species suited to land regeneration projects, together with preferred soil type and pH. Species' drought tolerances are presented as the drought-tolerance index of Niinemets and Valladares (2006); an index of one is very intolerant to drought and an index of five is very tolerant to drought. This index is based on several sources from across different climate zones, so while the index provides an indication of a species' drought tolerance, tree performance in the UK may vary in some cases.

Table 1 can be cross-referenced with BPG Note 8 on native and non-native tree species in land regeneration (where information on exposure and air pollution is also presented) and with The Right Trees for Changing Climate Database website (where further information on the potential size, ornamental qualities and wider attributes of the tree species is also presented, without specific reference to land regeneration).

Reference sources for Table 1:

1: www.rhs.org.uk/advice/profile?pid=848

2: Hodge (1995).

3: Bradshaw and Chadwick (1980).

4: Hibberd (1989).

5: Niinemets and Valladares (2006), Appendix A. In short, the length of drought the tree can survive for each index value is as follows: 1 – a few days; 2 – a few weeks; 3 – a month; 4 – two to three months; 5 more than three months. See the reference for details on how the index is fully defined and constructed.

6: Moffat and McNeill (1994).

7: www.righttrees4cc.org.uk

References

Bradshaw, A.D. and Chadwick, M.J. (1980). *The restoration of land: the ecology and reclamation of derelict and degraded land.* Blackwell Scientific Publications, Oxford.

Cregg, B.M. (2004). Improving drought tolerance of trees: theoretical and practical considerations. *Acta Horticulturae* 630, 147–158.

Doick, K. and Hutchings, T. (2007). *Greenspace establishment on brownfield land: the site selection and investigation process.* Forestry Commission Information Note 91. Forestry Commission, Edinburgh.

Fekedulegn, D., Hicks, R.R. Jr and Colbert, J.J. (2003). Influence of topographic aspect, precipitation and drought on radial growth of four major tree species in an Appalachian watershed. *Forest Ecology and Management* 177, 409–425.

Hibberd, B.G. (ed.) (1989). *Urban forestry practice.* Forestry Commission Handbook 5. HMSO, London.

Hodge, S.J. (1995). *Creating and managing woodlands around towns.* Forestry Commission Handbook 11. HMSO, London.

Moffat, A. and McNeill, J. (1994). *Reclaiming disturbed land for forestry.* Forestry Commission Bulletin 110. HMSO, London.

Niinemets, Ü. and Valladares, F. (2006). Tolerance to shade, drought, and waterlogging of temperate Northern Hemisphere trees and shrubs. *Ecological Monographs* 76(4), 521–547.

Rosenberg, N.J., Blad, B.L. and Verma, S.B. (1983). *Microclimate: the biological environment.* Wiley, New York.

Useful links

Best Practice Guidance (BPG) Notes for Land Regeneration

www.forestry.gov.uk/fr/bpgn

The Right Trees for Changing Climate Database

www.righttrees4cc.org.uk

UK Climate Projections – UKCP09

http://ukclimateprojections.metoffice.gov.uk

Table 1 Tree and shrub species suitable for different soil types, and their relative drought tolerances.

Scientific name	Common name	Native	Acidic soil (pH<7)	Alkali soil (pH>7)	Sandy soil	Loam	Heavy soil/ clay	Drought tolerance index	Drought tolerance
		Ref: 1	Refs: 1,2,3,6,7	Refs: 1,2,3	Refs: 1,4	Refs: 1,4	Refs: 1,4,6,7	Ref: 5	
Acer campestre	Field maple	✓	●	●	●	●	●	2.93	Moderate
Acer ginnala	Amur maple		●	●	●	●	●	2.88	Moderate
Acer negundo	Box elder		●	●	●		●	3.03	Tolerant
Acer platanoides	Norway maple		●	●	●	●	●	2.73	Moderate
Acer pseudoplatanus	Sycamore		●	●		●	●	2.75	Moderate
Acer rubrum	Red maple		●				●	1.84	Intolerant
Acer saccharinum	Silver maple		●	●			●	2.88	Moderate
Alnus cordata	Italian alder			●	●	●	●		
Alnus glutinosa	Common alder	✓	●	●		●	●	2.22	Moderate
Alnus incana	Grey alder		●	●		●	●	1.89	Intolerant
Betula pendula	Silver birch	✓	●	●	●	●	●	1.85	Intolerant
Carpinus betulus	Common hornbeam	✓	●	●	●	●	●	2.66	Moderate
Castanea sativa	Sweet chestnut		●		●		●	3.46	Tolerant
Cornus mas	Cornelian cherry		●	●	●	●	●	3.17	Tolerant
Cornus sanguinea	Dogwood	✓		●	●	●	●	3.04	Tolerant
Corylus avellana	Hazel	✓	●	●	●	●		3.04	Tolerant
Corylus colurna	Turkish hazel		●	●	●	●	●	3.13	Tolerant
Cotinus coggygria	Smoketree		●	●	●	●	●	3.74	Tolerant
Cotinus obovatus	Chittamwood		●	●	●	●	●	3.69	Tolerant
Crataegus laevigata	Midland hawthorn	✓	●	●	●	●	●	2.90	Moderate
Crataegus x *lavallei*	Hybrid cockspur thorn		●	●	●	●	●	3.46	Tolerant
Crataegus monogyna	Hawthorn	✓	●	●		●	●	3.69	Tolerant
Fagus sylvatica	Beech	✓	●	●	●	●		2.40	Moderate
Fraxinus americana	White ash			●	●	●	●	2.38	Moderate
Fraxinus excelsior	Ash	✓	x	●		●	●	2.50	Moderate
Fraxinus pennsylvanica	Green ash		●	●	●	●	●	3.85	Tolerant
Gleditsia triacanthos	Honey locust		●	●	●	●	●	4.98	Moderate
Hippophae rhamnoides	Sea buckthorn	✓		●	●			3.46	Tolerant
Ilex aquifolium	Holly	✓	●	●	●	●	●	3.04	Tolerant
Morus alba	White mulberry		●	●	●	●	●	2.88	Moderate
Pinus sylvestris	Scots pine	✓	●	●	●	●	x	4.34	Very tolerant
Populus alba	White poplar		●	●	●		●	2.67	Moderate
Prunus avium	Wild cherry	✓		●	●	●	●	2.66	Moderate
Prunus padus	Bird cherry	✓		●	●	●	●	1.93	Intolerant
Pyrus communis	Wild pear		●	●	●		●	2.73	Moderate
Quercus ilex	Holm oak			●	●	●	●	4.72	Very tolerant
Quercus petraea	Sessile oak	✓	●		●		●	3.02	Tolerant
Quercus robur	Pedunculate oak	✓	●	●	●		●	2.95	Moderate
Quercus rubra	Red oak		●	●	●		●	2.88	Moderate
Rhamnus cathartica	Common buckthorn	✓		●	●	●	●	3.46	Tolerant
Salix caprea	Goatwillow	✓	●	●	●		●	2.24	Moderate
Sorbus aria	Whitebeam	✓	●	●	●	●	●	3.55	Tolerant
Sorbus aucuparia	Rowan	✓	●	●	●	●	●	2.11	Moderate
Sorbus intermedia	Swedish whitebeam			●	●	●	●	2.21	Moderate
Tilia cordata	Small-leaved lime	✓		●	●	●	●	2.75	Moderate
Tilia tomentosa	Weeping silver lime			●	●	●	●	2.81	Moderate
Viburnum lantana	Wayfaring tree	✓		●	●	●	●	3.46	Tolerant

● = tolerant; blank = unknown; x = intolerant

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