
Photo: Emma Shepherd

Woodlands

Draft Report Card 2019

This publication covers the impacts of water scarcity and, in particular, drought on woodlands, their ecosystem response, future scenarios and approaches to management that enhance their resilience.
It has been produced by About Drought, the UK's Drought & Water Scarcity Research Programme, which consists of 5 integrated research projects, funded by the UK research councils.
It is designed to be used by those involved in woodland policy, design, planning and management.
It is one of a series of report cards summarising current and future aspects of water scarcity in the main UK ecosystems.

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Drought in UK woodlands (1)

Water scarcity and drought are becoming more common in the UK partly as a result of climate change, but also due to an increased demand for clean drinking water as the population grows, as well as from agriculture and industry. Woodlands are important habitats for biodiversity and an integral part of our landscape. Also, they provide timber and a wide range of other ecosystem services for people, such as the regulation of water, soil and air quality, as well as recreation opportunities. Woodlands are also important for storing carbon, thus contributing to climate mitigation.

Water scarcity and drought vary in frequency, intensity, spatial extent and duration. Some droughts are regional, others national; they can occur in winter or summer; they can be short lived or span multiple years; each drought event is unique and therefore its impacts are context specific.

Current Impacts of drought

The responses of trees to drought and the accompanying water stress include: decreased leaf size, leaf wilting, rolling and browning, drought crack, promotion of masting (seed production) and crown dieback, which can in severe cases lead to tree mortality. While a response of trees to the high temperatures often associated with drought is stomatal closure, so as to conserve water. This can lead to decreased growth, gross primary productivity and transpiration. There are well-documented impacts of previous droughts on subsequent growth rates, timber quality, increased likelihood of pest and disease outbreaks combined with enhanced tree susceptibility to these outbreaks and tree mortality. Consequences may be long-term and far-reaching, for example, if woodland performance is compromised the carbon sink strength may be reduced or reversed and the large carbon stocks associated with the woodland put at risk. Also, the different response of tree species can lead to changes in woodland composition, with consequences for other components of woodland biodiversity. However, often there several factors contributing to a response and it can be difficult attributing it (solely) to drought.

Drought is a natural phenomenon. Water scarcity is human-related, because we need the right amount of water of the right quality at the right time and in the right place.

Drought in UK woodlands (2)

Possible future Impacts of drought

Establishing the potential future impacts of drought on woodlands is quite difficult, with a variety of lines of possible evidence which can be combined, but all of which need expert interpretation. Experimental work involving established woodland is challenging due to tree size, although some extrapolations could be made based on observed responses of trees to drought. These observations are also important as input for or testing models. However, in woodlands managed for forestry and some semi-natural woodlands, conventional mensuration sample plots only take growth measurements every five years, thus limiting the ability to establish the impacts of drought in specific years. The number of sites where annual measurements are made using girth bands is limited and the length of the data-series is often short or discontinuous. Tree ring analysis provides an alternative approach, while the National Forest Inventory and Natural England's Common Standards Monitoring may provide further information on the effect of drought on woodland condition.

Modelling is sometimes used to assess the potential broad-scale impacts of climate change on woodlands, but most models only consider changes in mean annual or seasonal climatic parameters and thus do not capture more extreme climatic events like drought. The inclusion of climatic extremes is important, certainly for species distribution models, for improving our understanding of the climatic limits of species and their potential future responses (Zimmerman et al., 2009). This lack of inclusion is partly due to the difficulty in deriving future projections of drought and of modelling the biophysical processes and interactions in trees, as well as the limited monitoring of woodland attributes to inform the modelling of drought impacts. Therefore, currently modelling is not sufficiently robust to make local-scale species specific predictions.

The application of the novel drought event set in the AboutDrought programme, combined with a biophysical ecosystems model, enabled some of the potential effects of water scarcity and drought in tree species and woodlands to be modelled. This showed the potential for beech woodland to be particularly affected in southern England and for mixed deciduous woodland to expand in northern England and Scotland.

While natural regeneration and natural selection may also lead to new drought resilient genotypes, some planned adaptation and management will be needed. What we can do to reduce the impacts of climate, water scarcity and drought in woodlands through making them more resilient and helping them adapt to future changes will depend on woodland type and environmental setting, including soil type. This report card has divided woodlands into four types: existing semi-natural woodland, new native woodland, "amenity" woodland and commercial plantations.

Adaptation/management actions

Adaptation/management actions for different woodland types

- **Existing semi-natural woodland**
  - work with nature, reducing other pressures (deer, squirrels)
  - manage to encourage natural regeneration
  - use landscape approaches to expand habitat and reduce fragmentation
- **New native woodland**
  - native species, but include more southerly provenances
  - mainly native species, but consider including near natives
  - a small proportion of exotics may be appropriate
- **'Amenity woodland'**
  - similar to new native woodland, but more scope for exotics
  - fast growing species may create a 'mature feel'
- **Commercial plantations**
  - diverse range of species (landscape or intimate)
    - consider ecology (shade tolerance) and natural species mixes in home ranges
  - consider future wood products alongside species
  - much scope for using provenance to increase resilience

Headline

	Severity of damage to woodlands		
Likelihood*	Mild	Moderate	Severe
Low			Mortality of some old and veteran trees and susceptible species, especially on certain soil types. Local loss of trees/woods to wildfires
Medium		Reduction in the health of trees and increased mortality, partly due to increases in pests and pathogens	High mortality of old and veteran trees and associated species.
High	Short term reduction of growth/productivity. Local loss of trees/woodlands to wildfires	Longer-term reduction in growth and productivity.	High mortality of susceptible species. High level of pests and pathogens possibly contributing to widespread mortality. Longer-term changes in woodland composition. More widespread destruction of woodlands due to wildfires

Figure 1. Likelihood is a coarse indication of the chances of the right kind of droughts occurring that would instigate the damage to the system. It is a combination of the change magnitude, duration and timing of the events and their frequency. Each response requires its own particular combination of drought characteristics. As an example the summer of 2018 water scarcity / drought event, created conditions of moderate and severe impacts and the chances of similar droughts as ‘medium’.

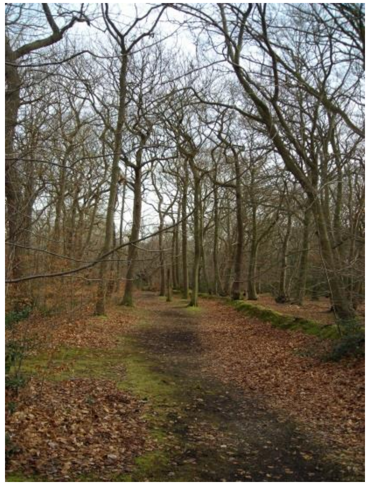
Stages of drought

Stages are probably ‘physiological impacts’ (wilting, marginal browning, mildew), physical impacts (early senescence, impacts on ground flora, mortality of seedlings/saplings, limb dropping, masting, drought crack) and (including longer term) structural impacts (mortality, wildfire, impacts on subsequent growth and pest/disease susceptibility).

Adaptation/management Actions (1)

For the physical effects of drought

Effects	Response	Future scenarios	Adaptation/management actions*
Change in woodland age and/or growth structure	Seedlings and saplings are more susceptible to drought mortality. Older and veteran trees may become more susceptible to disease and/or die[1,2,3,].	Woodlands, especially lowland beech woodlands, may become more scrubby as older trees die[4]	**M1 Ensure a diverse age and structure**[4], potentially through the management (tree thinning and change to continuous systems of management – All types
Drought enhances the combustibility of ground flora and litter fuel load increasing the potential for wildfire	Loss of ground-flora and damage to/loss of entire woodlands[4]. Loss of seedlings and saplings; damage to surrounding assets/property and National Critical Infrastructure.	Increased frequency of occurrence due to climate change and/or increased public use (Ray, 2008)	**M2 Wildfire management planning (in forest design); fire fighting training; fuel load management, public education**[4]
Soil type can affect soil moisture levels and rooting depths	Reduced tree growth on sandy-textured, freely-draining soils. On imperfectly or poorly draining soil types, drought stress could become more critical when winter waterlogging is followed by summer drought leading to a possible reduction of tree growth (Ray, 2008a and b; Ray et al., 2010)	Greater waterlogging in winter may increase, which could reduce tree growth. Increase in Sitka spruce bark cracking on drought-prone soils (Ray, 2008)	**M4 Plant more drought-tolerant species (e.g. Scots pine, Douglas fir or ash or different provenances**[4, 6]**. (Broadmeadow et al., 2005; Green and Ray, 2009). All** **M Focus any planting on wetter sites and/or on north-facing slopes (Natural England and RSPB, 2014). N A**
Drying out of wet woodland			**M3 Manage water levels on susceptible sites e.g. through increasing soil water. SN**



* EN = Existing semi-natural woodland; N = New native woodland; A = Amenity woodland; C = Commercial plantations

Adaptation/management Actions (2)

For the biological effects of drought (i)

Effects	Response	Future scenarios	Adaptation/management actions
Reduction in tree growth (Lonsdale et al 1989; Innes, 1998; Sanders et al., 2014). These may be short or longer-term (Wilson et al., 2008)	Growth may be reduced as trees close their stomata, so as to conserve water. Following the 1976 drought, the recovery of beech varied according to age, site and tree health (Aldous, 1981; Power, 1994; Innes, 1998). Research on Lady Park Wood Gwent, UK, provides a good example of some of these effects on beech. (Peterken and Mountford, 1996; Cavil et al., 2013). The timing of the drought may be important, with drought after May having little effect on twig extension, but later in the season it may affect the following year's growth, although other factors may be involved in this.	While increasing temperatures and CO_2 may increase tree growth in many parts of the UK, reduced summer rainfall and increased frequency of droughts are likely to lead to at least short-term reductions in growth.	**M4 Plant more drought-tolerant species (e.g. Scots pine, Douglas fir, English oak) All** **M Plant different provenances[4, 6] Broadmeadow et al., 2005 N C**
The magnitude of the effect can be a function of various (inter-related) factors including soil type (see Physical effects) and: Reduction in tree growth due to (a) preceding conditions	Drought following a dry winter can exacerbate any effects through the reduction of available water. Beech has shown a significant negative relationship between growth and high soil moisture stress (Power, 1994). Greatest reductions in growth were found when drought years coincided with mast years, but there appeared to be no effect on growth in the subsequent year (Hacket-Pain et al., 2015; 2017).	Potential increase in frequency of water scarcity and drier preceding conditions in summer	**M Increase woodland size to reduce area water stress due to edge effects (Natural England and RSPB, 2014). SN**
Reduction in tree growth related to (b) species	Beech, birch and sycamore appear to be more drought sensitive (Power, 1994). For beech, greatest reductions in growth were found when drought years coincided with mast years (Hacket-Pain et al., 2017). A study of five oak species, including two natives (English oak and Sessile oak) and three non-natives (Scarlet oak, Swamp Spanish oak and Hungarian oak) found all had reduced growth associated with drought year, with recovery being fastest for Swamp Spanish oak, Hungarian oak, and English oak and slowest for Sessile oak (Sanders et al., 2014).	Some autonomous adaptation leading to more drought resistant genotypes may occur	**M4 Plant more drought-tolerant species[4, 6] Natural England and RSPB, 2014). (e.g. Scots pine, Douglas fir, English oak or ash (Green and Ray, 2009); Hornbeam, roble beech and sweet chestnut on sites too dry for beech (Ray et al., 2010). ALL** **M Plant different provenances[4, 6]. Broadmeadow et al., 2005 N C** **M Consider planting new drought-tolerant species (e.g. Swamp Spanish oak or Hungarian oak (Sanders et al., 2014). C?, SN? A**
Reduction in tree growth due to (c) age	A survey of 30 beech woods in southern England found that younger trees were less affected by drought, but some older trees were killed (Aldous, 1981). Beech stands in an ancient mixed deciduous woodland, Lady Park Wood, Gwent, UK, showed that beech trees on the upper part of the slope that survived the 1975-6 drought did not start growing again until 1977 and that growth rates between 1983 and 1992 remained significantly below those from 1955-1977 (Peterken and Mountford, 1996).		**M1 Ensure a diverse age and structure[4].** SN, N

Adaptation/management Actions (3)

For the biological effects of drought (ii)

Effects	Response	Future scenarios	Adaptation/management actions
Mortality – often several years or even decades afterwards (Peterken and Mountford 1996; Bigler et al., 2006).	Attributing mortality to a particular drought is difficult as trees will be affected by various pressures, including subsequent droughts. Old, slow-growing may have a (very) delayed mortality response. Drought can hastened the death of already weakened trees and contribute t the loss of veteran trees and their saproxylic invertebrates, lichens and fungi (Natural England and RSPB, 2014).	Increased mortality, especially of susceptible trees and on susceptible sites in southern England.	**M When replanting, select species with similar decay fungi and mechanisms to existing species (Natural England and RSPB, 2014).** N
Productivity decrease	Drought, through the drying of soils and decreased growth can lead to reduced gross primary productivity (Cias, 2005). In the European drought of 2003, the productivity of temperate beech woodlands were particularly affected. If trees have access to available water, then the increased temperatures associated with the drought can enhance net primary productivity and net ecosystem exchange (Boeck and Verbeeck, 2011; (Wilkinson et al., 2012).	Productivity and yields of some species are likely to decrease due to reduced water availability, especially in summer, and due to droughts (Petr et al., 2014). Trees with modelled reductions in biomass in Great Britain are Downy birch, hornbeam, Norway spruce, Scots pine and small-leaved lime and beech in southern England (Marius results)	**M4 Plant more drought-tolerant species[4, 6] Natural England and RSPB, 2014). (e.g. Scots pine, Douglas fir, English oak or ash (Green and Ray, 2009); Hornbeam, roble beech and sweet chestnut on sites too dry for beech (Ray et al., 2010). All** **M Plant different provenances[4, 6]. Broadmeadow et al., 2005 N, C** **M Consider planting new drought-tolerant species (e.g. Swamp Spanish oak or Hungarian oak (Sanders et al., 2014). C? SN? A**
Woodland species composition	Mortality can open up the canopy, especially if younger trees and sapling are affected, and provide opportunities for new species. Shifts in the composition of native woodland communities/types (Broadmeadow et al. 2009a, 2009b). Epiphytes, particularly ferns, bryophytes and lichens with oceanic distribution patterns may be particularly susceptible (Ray, Morison & Broadmeadow 2010).	In England, ash may become locally dominant in areas affect by drought (Ray et al., 2010). The distribution of beech woodlands may change, with declines in southern Britain (Broadmeadow et. al., 2010; Berry et al., 2012).	**M Reduce the impacts of other pressures, such as pests and diseases, pollutants, over-grazing and Development (Natural England and RSPB, 2014). SN, C** **M Maintain canopy to increase shading and moisture levels (Natural England and RSPB, 2014). SN**

Adaptation/management Actions (4)

For the biological effects of drought (iii)

Effects	Response	Future scenarios	Adaptation/management actions
Condition and health - crown thinness, dieback and chlorosis, reducing tree health	Following the 1976 drought, healthy trees recovered more quickly, but some still showed reduced growth 13 years later, especially in years with high soil moisture stress (Power, 2004). Cases of confirmed or suspected drought damage to trees between 1972 and 2006 found that beech, Sitka spruce, larch and Norway spruce were most frequently affected. Repeated summer droughts are thought to have been a cause of long-term dieback in mature oak, ash and beech in Britain (Gregory and Redfern, 1998).	Health of susceptible trees and species are likely to decrease (Natural England and RSPB, 2014)	**M3 Manage water levels on susceptible sites (short-term). SN** **M4 Plant more drought-tolerant species (longer-term) [4, 6] Natural England and RSPB, 2014). (e.g. Scots pine, Douglas fir, English oak or ash (Green and Ray, 2009); Hornbeam, roble beech and sweet chestnut on sites too dry for beech (ray et al., 2010). All** **M Plant different provenances[4, 6]. Broadmeadow et al., 2005 N, C** **M Consider planting new drought-tolerant species (e.g. Swamp Spanish oak or Hungarian oak (Sanders et al., 2014). ?, SN? A**
Pests – increased numbers of pest and susceptibility	Debarking of trees by grey squirrels seems to have been triggered by the 1976 drought, leading to the damage or death of the trees, in particular beech (Mountford, 2006). This opened the canopy and provided an opportunity for ash and both small- and large-leaved lime to grow. Drought stress can increase tree susceptibility to infestation.	Based on past experience of droughts, susceptible trees/species could be more affected by pests e.g. bark beetle (*Tomicus piniperda*) could affect Scots pine and spruce bark beetle - spruce (Ray, 2008a; Green and Ray, 2009; Ray et al., 2010). Climate change may lead to new (non-native) pests entering the UK (e.g. European spruce bark beetle) and cause reduced growth or mortality of drought-stressed trees.	**M Prompt removal of felled logs or windthrown trees to reduce the likelihood of build-up of local pest populations (Green and Ray, 2009)** **SN?, C** **M Vigilance in ports to prevent accidental introductions**
Pathogens – increased susceptibility to infection (Green and Ray, 2009)	Water-stressed tissues act as a better substrate for pathogen growth, and/or because drought-stressed trees have reduced defence mechanisms (Desprez-Loustauet al., 2006). Root pathogens e,g, *Phytophthoras* may lead to the death of fine roots, with trees suddenly dying when water stressed (Ray, 2008). Bark cracking may facilitate infection.	Based on past experience of droughts, susceptible trees/species could be more affected by pathogens, such as *Armillaria* spp. and *Heterobasidion annosum*, (Ray, 2008a; Green and Ray, 2009; Ray et al., 2010). Climate change may lead to new (non-native) pathogens entering the UK (e.g. and cause reduced growth or mortality of drought-stressed trees.	

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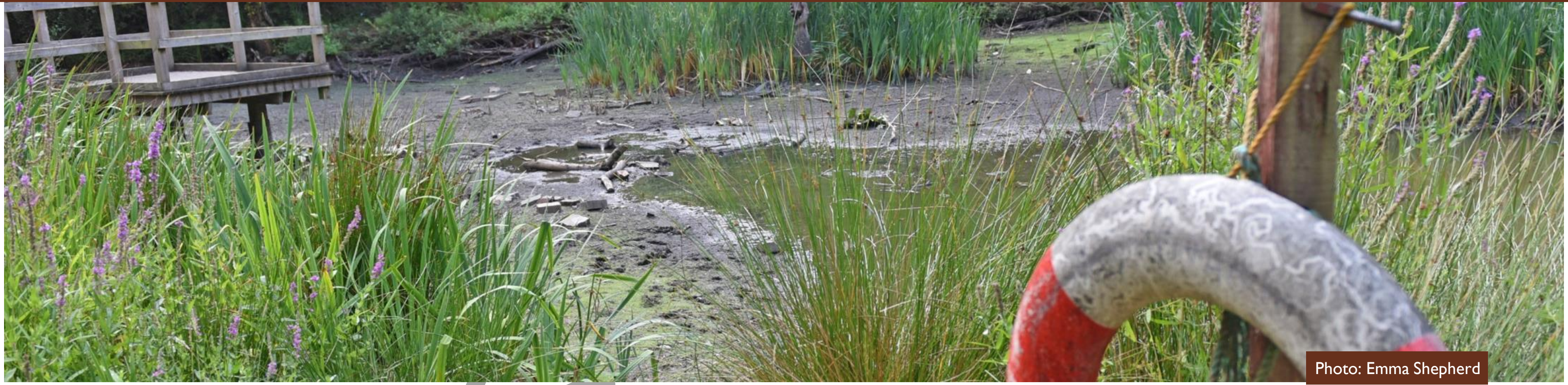

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Adaptation/management actions (2)

For the chemical effects of drought

Effects	Response	Future scenarios	Adaptation/management actions
Ozone can build up in the still conditions associated with drought	Ozone can affect tree growth, but it is difficult disentangling its effect from the more direct drought effects[5,7].	Potentially greater impacts on photosynthesis, tree growth and productivity and root biomass[8].	None recommended in the literature
Decrease in nutrient availability and cycling	Mycorrhizal fungi which help provide trees with moisture and nutrients, as well as resistance to pathogens may be adversely affected by drought [9]. Fine roots maybe die, decreasing nutrient and water supply and the tree's ability to cope with drought the next year (Brunner et al., 2015).	Enhanced drought stress and disease susceptibility	Enhance soil moisture levels??