Forest Ecology and Management 432 (2019) 718–728

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Is the introduction of novel exotic forest tree species a rational response to rapid environmental change? – A British perspective

Richard Ennos[a,*], Joan Cottrell[b], Jeanette Hall[c], David O'Brien[c]

[a] Ashworth Laboratories, Institute of Evolutionary Biology, School of Biological Sciences, University of Edinburgh, Charlotte Auerbach Road, Edinburgh EH9 3FL, UK
[b] Forest Research, Northern Research Station, Roslin, Midlothian EH25 9SY, UK
[c] Scottish Natural Heritage, Great Glen House, Inverness IV3 8NW, UK

ARTICLE INFO

Keywords:
Exotic tree
Introduction
Climate change
Pest
Pathogen
Invasive species

ABSTRACT

Both plantation forests and native woodlands are currently facing challenges in the form of rapid climatic change and unprecedented increases in damage by exotic pests and diseases. To combat these problems it has been proposed that a range of novel exotic tree species (non-native species that have not yet undergone thorough operational testing or previously been grown at a forestry scale) should be grown as part of an adaptive management strategy, and that non-native (including novel) species should be introduced into native woodland. Justifications for this policy are that novel exotic species are required to maintain forest productivity under climate change, to create a more diverse, and by implication more resilient forest, and to substitute for native species threatened by introduced pests and pathogens. Here we examine these arguments in the context of British forestry, where there is a long history of utilising non-native species. On the basis of this documented experience we conclude that in the commercial sector of British forestry, where production is the main objective, there are strong arguments for undertaking a programme of rigorous testing and domestication of a very limited number of the most promising novel exotics which, in addition to good timber and growth, also have attributes that will allow the development of more naturalistic silvicultural systems and a move away from current clear-fell regimes. However this must be undertaken within a comprehensive risk assessment framework, where candidate species are rigorously screened both for any biosecurity threats, and their potential for causing ecological damage if they become invasive outside their initial planting sites. Widespread planting of candidate species should only be recommended after the completion of full species and provenance trials, and when reliable sources of appropriately adapted seed have been established. Conversely where conservation of biodiversity is an objective we find no support for introduction of any non-native species. This is based on the greater ecological and economic risk they pose compared to the use of native species. Use of non-natives is likely to lead to an increase rather than a decrease in pest and disease problems, and to hinder rather than support the retention of threatened native tree species and their associated biodiversity.

1. Introduction

The environment experienced by forest tree species is changing very rapidly, largely as a result of human activity. Anthropogenic rise in greenhouse gases is driving complex changes in the mean and variability of climatic parameters, whose future values cannot be predicted with great certainty (IPCC, 2014). These climatic changes will have direct effects not only on the trees themselves, but also on their associated organisms (Walther, 2010). At the same time large scale movements of species around the globe, both in international trade, and as a consequence of the establishment of exotic plantations, are homogenising global biodiversity (Olden et al., 2004). This is exposing forest trees to novel pests and pathogens that have the power to inflict severe economic and ecological damage in an unpredictable way (Brasier, 2008; Santini et al., 2013; Ennos, 2015; Ghelardini et al., 2016; Budde et al., 2016).

Currently there is vigorous debate about the adaptive forest management policies that should be developed in response to the simultaneous challenges posed by climate change and the rise in exotic pests and pathogens. One proposal involves the introduction, into both plantations and semi-natural forests, of novel exotic tree species, defined here as non-native species that have not yet undergone thorough

* Corresponding author.
E-mail addresses: rennos@ed.ac.uk (R. Ennos), joan.cottrell@forestry.gsi.gov.uk (J. Cottrell), jeanette.hall@nature.scot (J. Hall), david.obrien@nature.scot (D. O'Brien).

https://doi.org/10.1016/j.foreco.2018.10.018
Received 27 May 2018; Received in revised form 2 October 2018; Accepted 7 October 2018

operational testing or previously been grown at a forestry scale (Thorpe et al., 2006; Meason and Mason, 2014; Felton et al., 2013; Kjær et al., 2013, 2014). In this paper we set out the arguments for utilising such novel exotic species as a component of our adaptive forestry response to rapid environmental change. We then assess the commercial risks of adopting this strategy, and the wider ecological impacts that it may have. To provide a real world context for our analysis we focus on forestry in Britain, where there has been encouragement to include novel exotics within a broader mix of species as part of a strategy to adapt forests to climate change and increase their resilience (Natural Resources Wales, 2017; Forestry Commission England, 2018a,b,c,d; Forest Research, 2018a). A detailed appraisal of this situation is particularly pertinent because British foresters already have a long history of utilising exotic tree species (MacDonald et al., 1957; Lines, 1987; Malcolm, 1997).

2. The British forestry context

Forestry in Britain encompasses a range of management objectives, often pursued in close geographic proximity or even within the same stands (Forestry Commission, 2017). These range from intensive timber production, through multipurpose forestry sustaining a variety of ecological and social benefits, to conservation of native woodlands and their associated biodiversity. Scots pine (*Pinus sylvestris* L.), the sole commercially important indigenous conifer, shows good growth over a wide area but is unsuitable on the wetter sites available for much of commercial forestry in northern Britain. The timber production sector in Britain is therefore heavily reliant on exotic tree species. Norway spruce (*Picea abies* L.) was introduced as early as the sixteenth century, while European and Japanese larch (*Larix decidua* Mill. and *L. kaempferi* (Lamb.) Carriére) were eighteenth and nineteenth century introductions (Anderson, 1967) respectively. All three species are now well-established in British forestry (Anderson, 1967). These have been joined by a number of exotic conifers indigenous to NW America that were introduced earlier but were only subjected to intensive trialling in Britain from the 1920s (Malcolm, 1997). The productive conifer sector is now dominated by Sitka spruce (*Picea sitchensis* (Bong.) Carrière), which constitutes 52% of all conifer plantations and has proved adaptable to a wide range of site types (Kerr et al., 2015c). Scots pine stands comprise 17% of conifer planting but there are also significant areas of the following exotics; lodgepole pine (*Pinus contorta* Douglas ex Loudon) (10%), larch (5%), Norway spruce (5%), Corsican pine (*Pinus nigra* J.F. Arnold subsp. *laricio* (Poir.) Maire) (2%), and Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) (2%) with a small contribution from species such as grand fir (*Abies grandis* (Douglas ex D. Don) Lindl.), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western red cedar (*Thuja plicata* Donn ex D.Don) (Kerr et al., 2015c). All of these species have been extensively tested over a long period and are regularly used in commercial forestry. We refer to these as well-established exotics to distinguish them from the novel exotics with which this paper is chiefly concerned.

At the other end of the British forestry management spectrum lie the native woodlands where the major objective is conservation of native woodland communities, the native trees therein, and their associated biodiversity (Peterken, 1977). Native woods range from the Caledonian Scots pinewoods (Mason et al., 2004) to a diversity of broadleaved woodland types where species such as oak (*Quercus robur* L. and *Q. petraea* (Matt.) Liebl.), ash (*Fraxinus excelsior* L.) and birch (*Betula pendula* Roth and *B. pubescens* Ehrh.) are widely important. The native distribution of woods dominated by beech (*Fagus sylvatica* L.) is restricted to southern Britain (Forestry Commission, 2003). Native woods may also contain a proportion of well-established exotic broadleaves such as sycamore (*Acer pseudoplatanus* L.). Native woodlands are typically highly fragmented and have been heavily modified by past management, overgrazing and exploitation, which has often severely reduced the diversity of tree species that they contain (Anderson, 1967; Côté et al., 2004; Watts, 2006). Many of these native woodlands, whether formerly managed for timber or not, are currently showing signs of neglect.

Between these two extremes lie woodlands managed for multiple purposes. These may have their origins in exotic conifer plantations that have been restructured to fulfil objectives other than timber production, or native woodlands where indigenous species may be managed for timber production and within which there may be significant plantations of the well-established exotic species mentioned above, yielding timber returns.

The patchwork of forest types in the British landscape and the different objectives for which they are managed means that actions taken in one forestry sector are likely to have an impact on all other forestry sectors. It is therefore important to consider jointly the effects of novel exotic introductions on timber production in commercial forestry, ecosystem services and social provision in multipurpose forests, and biodiversity conservation in native woodlands.

3. Arguments supporting the introduction of novel exotic species in Britain

In this section we set out the diversity of arguments that make the case for introduction of novel exotic species into Britain's forests.

3.1. Maintaining forest productivity under climate change

Climate change modelling for Britain predicts 2.5–3 °C warming over the period to 2100, and changes in seasonal rainfall distribution leading to an increase in frequency and intensity of summer droughts in the east, particularly the south-east of England (Broadmeadow et al., 2009; Ray et al., 2010; Met Office, 2011). To assess the impact of such climate change on British forests, the ecological site classification (ESC) model (Pyatt et al., 2001) has been used. This relies on empirical measurements of the performance of important forest tree species across different environments to predict their productivity under a variety of anticipated scenarios. Inputs to ESC are the values of four climatic (accumulated temperature, moisture deficit, exposure and continentality) and two edaphic (soil fertility and wetness) factors at a site. The model returns the predicted productivity of a candidate species at the site, relative to its maximum possible productivity in Britain under present conditions. Five productivity bands are defined, ranging from > 70% of maximum possible productivity (very suitable) to < 30% (unsuitable). ESC model projections indicate that over the next century, productivity in the north and west of the UK will increase for many native and well-established exotic species. However a number of commercially important taxa including Sitka spruce are predicted to show significant reductions in timber production by 2080 caused by drought stress, particularly in the east of the country (Broadmeadow et al., 2009). The conclusions drawn from application of the ESC model are supported by independent predictions from process based models of tree growth (Landsberg et al., 2003; Coops and Waring, 2011). These also indicate that warmer and drier climates will lead to significant reductions in productivity of Britain's most important timber producing species Sitka spruce (Meason and Mason, 2014), especially in eastern areas where growth is already commercially marginal due to damage under summer drought (Green et al., 2008; Green and Ray, 2009).

In response to these predictions, a breeding programme to select for more drought tolerant Sitka spruce genotypes could be set up, or Sitka spruce could be replaced on marginal sites by a more drought tolerant species. Given the long lead in time, substantial investment and uncertainty associated with delivering Sitka spruce genotypes with improved drought tolerance, species replacement provides the best short-term solution (Lee and Connolly, 2010). Native or well-established exotic species could be employed as a replacement (e.g. Scots pine or Douglas fir) (Cameron, 2015; Meason and Mason, 2014). Another strategy would be to introduce novel exotics with desirable drought