Available online at www.sciencedirect.com
ScienceDirect
Dendrochronologia 27 (2009) 183–198
DENDROCHRONOLOGIA
www.elsevier.de/dendro

ORIGINAL ARTICLE

Climate signal in tree-ring chronologies in a temperate climate: A multi-species approach

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Received 15 March 2007; accepted 19 May 2009

Abstract

Tree-rings can provide continuous yearly paleoclimatic records for regions or periods of time with no instrumental climate data. However, different species respond to different climate parameters with, for example, some sensitive to moisture and others to temperature. Here, we describe four common species growing in Northern Ireland and their suitability for climate reconstruction.

Our results suggest that beech and ash are the most sensitive to climate, with tree-ring widths more strongly influenced by precipitation and soil moisture in early summer than by temperature or sunshine. Oak is also sensitive to summer rainfall, whereas Scots pine is sensitive to maximum temperature and the soil temperature.

We find that the moisture-related parameters, rainfall and the Palmer Drought Severity Index (PDSI), and to a lesser extent, maximum and mean temperatures, can be reconstructed. Reconstructions of climate parameters with tree-rings as proxies may be relatively stable for some seasons such as May–July. We find that combinations of species are more successful in reconstructing climate than single species.

Keywords: Dendroclimatology; Climate proxies; Oak; Ash; Beech; Scots pine

Introduction

The width of a tree-ring can be influenced by a variety of factors, some of which relate to the unique location of the tree, its age and management, and others to wider environmental factors such as temperature, rainfall and sunshine. Thus, the mean tree-ring chronology incorporates within it a climate signal specific to the environment in which the trees have grown. Species that show a clear climate signal usually live under limiting conditions. Examples include the following: temperature dependent conifers (e.g. Scots pine) in tree line boundaries in Scandinavia and Siberia, and drought dependant species (e.g. bristlecone pine) in western arid regions of the USA.

Around 20 years ago, dendroclimatic studies were discontinued using trees in the British Isles because it was believed that they were less sensitive to climate than those which live under more critical conditions. The limited usefulness of oak as a climate proxy had previously been demonstrated by Briffa (1984) and Pilcher and Baillie (1980a, b). Nevertheless, Hughes et al. (1982) showed that Scots pine in Scotland has a

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doi:10.1016/j.dendro.2009.05.003

temperature dependant growth at high elevations or in north facing slopes.

This work is focused on the relationship between tree-ring widths and climate under non-limiting conditions using multiple species and multivariate analysis. It tests the hypothesis that our understanding of the climate signal embedded in tree-ring patterns could be improved by using several species at the same time as well as by including the influence of a wide variety of meteorological parameters.

To reduce any geographical differences in the climate affecting the trees under study to a minimum, it is evidently preferable that the climate and tree-ring data refer to the same location. For this reason, we have used samples from trees grown very close to Armagh Observatory for which we have well calibrated and extensive meteorological series. We have assessed the strength of the climate signal embedded in the trees and have made some preliminary attempts at climate reconstruction.

Armagh Observatory is a climate reference station for Northern Ireland and has the longest series of meteorological records on the island of Ireland. Starting in 1795, these are also some of the longest from a single site anywhere in the British Isles. The careful standardisation of these meteorological series, in which we have been actively involved, underlies the calibration of the tree-ring/climate links we have found.

In our study, the effect of precipitation, sunshine hours, maximum and minimum temperatures, soil temperatures, cloud cover, PDSI, humidity and pressure have been explored on tree-ring widths of species common to Northern Ireland; oak (*Quercus robur* L.), Sessile Oak (*Quercus sessilis* Lhrh.), beech (*Fagus sylvatica* L.), ash (*Fraxinus excelsior* L.) and Scots pine (*Pinus sylvestris* L.). Dendroclimatic studies for species other than oak have not formerly been undertaken in Ireland.

Data

Tree-ring data

Partly due to its economic and social history, Ireland has reached the 21st century with almost none of its indigenous forests intact. This has clearly compromised the length of our studies to the extent that several of our tree-ring chronologies are shorter than some of the climate series. However, even with this limitation, a dendroclimatology study at Armagh gives us an opportunity to examine the possibility of using several species as climate proxies in Ireland.

Trees used in this study were selected from oak, beech, ash and Scots pine stands in the Observatory Estate or from public parks or private estates less than 10 km from the Observatory. All sites were at an altitude approximately the same as Armagh Observatory (60 m) and had a slope less than 10° to the horizontal. The individual tree-ring widths and the mean chronologies have been archived in the International Tree Ring Data Bank (NOAA).

In addition to these local chronologies, we also include in our study a subset of the wider Northern Ireland oak population extracted from the Tree-Ring Data Bank of Queen's University, Belfast; termed *NI oak*. This regional chronology is longer than the Armagh Observatory oak chronology and allows us to test whether the climate signal depends on the sample size. Our Northern Ireland regional oak chronology is composed of 47 trees of which 30 samples are from the QUB archive and the remainder from Armagh Observatory. The trees selected for our NI oak chronology were those from inland locations closest to Armagh Observatory (less than 25 miles) and at the same elevation.

Our NI Oak chronology commences in 1756 (well replicated from 1786). Previous to this there were several periods when the number of available oak samples is too small for climate studies. The longer Irish Oak chronology, published in 1984 (Pilcher et al., 1984), has several weak periods with a reduced number of trees, e.g. 1150–1400 AD and 1600–1750 AD (see also Baillie, 1982, 1995). These may reflect increased mortality rates due to climatic downturn – for instance, the Little Ice Age in the 17th and 18th centuries (Soon and Yaskell, 2004) – or an increased use of wood for fuel, charcoal production or building. In addition, at this time, forest clearance increased to meet the growing demands of farming (Aalen et al., 1997, p. 123; Mitchell, 1986, pp. 182–183). A decline in Scots pine populations in Fennoscandia in the 12th and 16th century has also been noted by Gunnarson and Linderholm (2002). As those trees in Fennoscandia grow at tree-line boundaries, this coincidence may be suggestive of a wider climatic cause.

Climate data

The site of Armagh Observatory climate station (6° 39′.8 W, 54° 21′.2 N) is well exposed with minimal urban effects (Coughlin and Butler, 1998). The climate series include three independent temperature series (Butler et al., 2005), rainfall (Butler et al., 1998; García-Suárez et al., 2002), sunshine hours (Pallé and Butler, 2001), soil temperatures at 30 and 100 cm depth (García-Suárez et al., 2006), barometric pressure (Ansell et al., 2006), humidity (Butler and García-Suárez, 2009), cloud cover and wind speed and direction. The climate series have been standardised taking into account