Science of the Total Environment 572 (2016) 412–421

Contents lists available at ScienceDirect

Science of the Total Environment

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

Review

Progress in Australian dendroclimatology: Identifying growth limiting factors in four climate zones

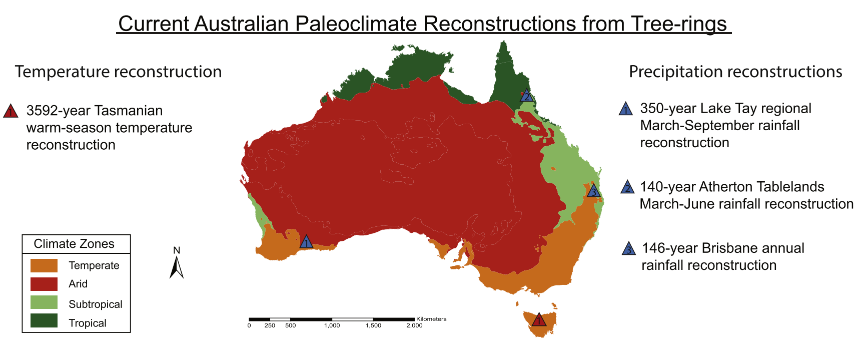
Heather A. Haines [a,*], Jon M. Olley [a], Justine Kemp [a], Nathan B. English [b]

[a] Australian Rivers Institute, Griffith University, 170 Kessels Road, Nathan, QLD 4101, Australia
[b] School of Medical and Applied Sciences, Central Queensland University, 538 Flinders Street West, Townsville, QLD 4810, Australia

HIGHLIGHTS

- Many Australian species have yet to be tested for dendroclimatological potential.
- Only four dendroclimatic reconstructions have been published for Australia.
- There has been recent success in applying both traditional and modern analytical techniques.
- This combined approach should enable more long-term climate records to be developed across Australia.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 4 July 2016
Received in revised form 11 August 2016
Accepted 14 August 2016
Available online xxxx

Editor: Elena Paoletti

Keywords:
Australia
Dendroclimatology
Tree rings
Climate change
Paleoclimate

ABSTRACT

Dendroclimatology can be used to better understand past climate in regions such as Australia where instrumental and historical climate records are sparse and rarely extend beyond 100 years. Here we review 36 Australian dendroclimatic studies which cover the four major climate zones of Australia; temperate, arid, subtropical and tropical. We show that all of these zones contain tree and shrub species which have the potential to provide high quality records of past climate. Despite this potential only four dendroclimatic reconstructions have been published for Australia, one from each of the climate zones: A 3592 year temperature record for the SE-temperate zone, a 350 year rainfall record for the Western arid zone, a 140 year rainfall record for the northern tropics and a 146 year rainfall record for SE-subtropics. We report on the spatial distribution of tree-ring studies, the environmental variables identified as limiting tree growth in each study, and identify the key challenges in using tree-ring records for climate reconstruction in Australia. We show that many Australian species have yet to be tested for dendroclimatological potential, and that the application of newer techniques including isotopic analysis, carbon dating, wood density measurements, and anatomical analysis, combined with traditional ring-width measurements should enable more species in each of the climate zones to be used, and long-term climate records to be developed across the entire continent.

* Corresponding author.
E-mail address: h.haines@griffith.edu.au (H.A. Haines).

http://dx.doi.org/10.1016/j.scitotenv.2016.08.096

Contents

1. Introduction

The Australian climate is among the most variable in the world with many areas of the continent experiencing prolonged periods of drought and above average rainfall (Pittock, 2003; Peel et al., 2004; Gergis et al., 2012). Historic and instrumental records of both rainfall and temperature in most regions of the continent extend back less than 100 years (Bureau of Meteorology, 2001), and prior to 1910 there was no national network of climate observations. This makes assessments of the long-term significance of regional variations in rainfall and/or temperature difficult as these short records do not allow for the impact of low-frequency phenomena on climate variability to be determined. These types of assessments can only be made using multi-centennial to millennial length rainfall and temperature records (see for example, Neukom and Gergis, 2012; Graham et al., 2007; Seager et al., 2007).

In North America and Europe, climate records have been extended beyond the start of instrumental and historical records using tree rings (Briffa et al., 1990; Cook et al., 2007; Luckman et al., 1997; Wilson and Luckman, 2005). In Australia, past reviews on the dendrochronological and/or dendroclimatological potential of Australian tree species have provided mixed views on the usefulness of this proxy for climate reconstructions (Ogden, 1978a; Worbes, 2002; Brookhouse, 2006). Many Australian species do not produce annual growth rings (Heinrich and Allen, 2013), exhibit ring wedging, false rings, and the growth patterns in many juvenile and dense understory trees are dominated by local factors rather than the regional environmental variables (Worbes, 2002). In addition, many Australian species are short-lived and suffer heartwood rot due to a shortage of nutrients and resources to support the large size of tropical trees (Ogden, 1978a, 1981). As a result, potential records are short, and most parts of the continent lack depositional environments conducive to the preservation of ancient wood. Here we review 36 Australia-based dendroclimatology studies and summarize progress isolating climate relationships and the growth limiting factors in temperate, arid, tropical and subtropical environments. We report on the spatial distribution of tree-ring studies and identify the key challenges in using ring-records for climate reconstruction in Australia. We then discuss the potential role of dendroclimatology in the development of long-term paleoclimate records within Australia.

2. Dendroclimatology

Dendroclimatology is the reconstruction of variations in climate through time using several parameters from tree-rings including ring width, wood properties (being features that are represented annually in tree records but are independent of ring-width), and isotopic analysis. The starting point is to determine which environmental variable is the dominant factor limiting tree growth. Common climatic limiting factors are temperature, precipitation and/or moisture availability (Fritts, 1976). Careful site and tree selection is important to locate those trees which are growing at a threshold that would stress the tree so growth occurs when the intended climatic variable for reconstruction is at an optimum (Stokes and Smiley, 1968). For example, sites at high altitude or latitude where trees are stressed due to being at the threshold of their growth range provide the best temperature reconstructions (Brookhouse et al., 2008). Reconstructions of moisture availability and/or rainfall are often derived from trees on well drained slopes that rely on seasonal precipitation to promote growth. However, other non-climatic factors may limit growth, these include: canopy effects, chronic insect or fungal infestation, and/or frost season, among others. These localized effects can cause difficultly in extracting climate data from a tree-ring record (Davidson and Reid, 1985; Fritts, 1976; Morrow and LaMarche, 1978) and are more prevalent in some regions, such as the tropics (Ogden, 1978a).

The regional significance of the tree-ring record is established by crossdating patterns of ring growth within and between individual trees (Fritts, 1976). Crossdating is typically based on variations in ring-width which involves matching the pattern of ring-widths of different radii to create one overall pattern of ring-width variations through time for the site. Crossdating is first applied between several radii within a tree, and then between different trees within a group. The pattern created represents the fluctuations in the limiting environmental variable through time. Issues arise when there are localized influences on tree growth (e.g. insect infestation of an individual tree) but also from the nature of the wood itself. Ring boundaries can be difficult to identify due to faint banding, wedging/pinching rings, narrow ring series, missing rings due to harsh growth conditions, and false rings from variable climatic conditions, among others and this is especially prominent in certain environments such as tropical or arid regions (for details and images of these features see Speer, 2010: Fig. 4.23). Care must be taken at this stage of analysis as it is normal for some trees to not be included in the final chronology due to a lack in crossdating. Once a series of trees have been crossdated they must be checked for quality and measurement accuracy allowing the researcher to determine if there are issues in the dating and work out the cause of any errors. A well crossdated set of tree-ring measurements can then be developed into a chronology for the tree/site/region. Several computer programs exist to assist for quality control and chronology which include, but are not limited to, COFECHA, ARSTAN, Tellervo, dplR, WinDendro all of which have different advantages and disadvantages and are described in more detail elsewhere (see Cook, 1985; Guay et al., 1992; Grissino-Mayer, 2001; Bunn, 2008, 2010; Brewer, 2014). Once a chronology is developed several statistical tests are evaluated to determine the strength of the chronology such as the interseries correlation, mean sensitivity, and expressed population signal (EPS) among others. These statistics have threshold values that determine which portion of the record is statistically sound, for example an EPS value greater than 0.85 indicates a chronology is useful in representing climate (Wigley et al., 1986). The robust portion of the tree-ring