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Edge microclimate of temperate woodlands as affected by adjoining land use

Thomas E. Wright[a], Sabine Kasel[b], Michael Tausz[a], Lauren T. Bennett[a,*]

[a] Department of Forest and Ecosystem Science, Melbourne School of Land and Environment, The University of Melbourne, Water St Creswick, Victoria 3363, Australia
[b] Department of Forest and Ecosystem Science, Melbourne School of Land and Environment, The University of Melbourne, 500 Yarra Boulevard, Richmond, Victoria 3121, Australia

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ABSTRACT

While edge microclimates are well described for closed forests, they remain under-examined in more sparse vegetation types like the temperate woodlands of south-eastern Australia. This limits predictions of edge effects on remnant vegetation in cleared agricultural landscapes, and of changes in these effects with reforestation. Using fixed and roving weather stations, we examined influences on temperate woodland microclimate of adjoining land use (agriculture versus tree plantation), distance from edge (0–150 m), and woodland structural attributes (canopy openness, stem density and basal area). Shading by plantations significantly decreased temperatures and vapour pressure deficit (VPD) at woodland edges in winter (up to 0.8 °C and 75 Pa relative to agricultural edges). However, this effect was reversed in the non-winter months, when daytime temperatures and VPD were generally greater at plantation than agricultural edges (up to 0.5 °C and 300 Pa). This was the opposite of edge-type effects recorded for closed-forest types, and was explained by lower wind speeds at plantation edges, which led to the accumulation of heat in the 25 m firebreak between the two land uses. A similar 'dead zone' also apparently contributed to cooler, moister night-time conditions at plantation edges. Consistent with closed forests, and irrespective of edge type and season, we measured a depth of edge influence of 40–50 m for daytime temperature and VPD. However, magnitude of edge influence (ca. 0.5 °C and 100 Pa) was much less than in closed forests, and woodland interiors were warmer and drier than edges, whereas closed-forest interiors are usually cooler and moister than edges. This unique microclimate gradient into woodlands was explained both by decreasing wind speeds, and by positive relationships of temperature and VPD with basal area and stem density, highlighting the role of sub-canopy heat sinks like tree trunks in regulating interior microclimates of sparse vegetation types.

1. Introduction

Edges of vegetation where there are abrupt transitions in vegetation type or structure have unique microclimates unlike those of vegetation interiors (Murcia, 1995). These are due to a range of interacting factors that influence hydrological and energy cycles (Hobbs and Yates, 2003), including edge orientation (Norton, 2002; Denyer et al., 2006); edge dimensions (Didham and Lawton, 1999; Asbjornsen et al., 2004); time of day (Holst et al., 2004; Newmark, 2005); and season (Young and Mitchell, 1994; Holst et al., 2004). Altered microclimates at edges have many potential ecological consequences, including impacts on: plant life cycles (Hobbs and Yates, 2003; D'Angelo et al., 2004), invasion of exotic propagules (Devlaeminck et al., 2005), nutrient cycling (Didham and Lawton, 1999; Aussenac, 2000) and plant water use (Cienciala et al., 2002; Voicu and Comeau, 2006). Measuring and understanding these microclimates is particularly important in highly fragmented landscapes where edge environments can influence a significant proportion of the remaining native vegetation.

Vegetation structure will likely be a key determinant of edge microclimate (Harper et al., 2005). In mid-dense to dense forests (projective foliage cover 'PFC' of tallest plant layer >30%; Specht, 1981) the canopy is the principal component regulating energy exchange (Raynor, 1971; Aston, 1985). In comparison, in forests of more 'sparse' PFC (e.g. woodlands, PFC <30%; Specht, 1981), energy exchange and thereby microclimates are more likely controlled by below-canopy attributes such as tree trunks and the soil surface (Baldocchi et al., 2000; Silberstein et al., 2001). Greater potential for heat and moisture exchange between sub-canopy strata and the atmosphere in sparse-forest types (Geiger et al., 2009) has led to suggestions that microclimate edge effects near large clearings would be less pronounced than for more dense forests (Harper et al., 2005). However, to our knowledge few if any studies have examined edge-to-interior microclimate gradients in sparse woody vegetation, with the majority instead focussing on dense, closed forests (e.g. coniferous and tropical forests).

Edge microclimates will also be influenced by the edge type; that is, the type and structure of the adjoining land use (Lindenmayer

* Corresponding author. Tel.: +61 3 5321 4300; fax: +61 3 5321 4166.
E-mail address: ltb@unimelb.edu.au (L.T. Bennett).

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and Franklin, 2002; Kupfer et al., 2006). In general, edge effects between adjoining land uses of similar structure are expected to be less than those of contrasting structure (Cadenasso et al., 2003). Thus, increases in temperature, photosynthetically active radiation (PAR) and vapour pressure deficit (VPD) at closed-forest edges are reportedly less when adjoined by plantations or restored forest than by cleared land (Meyer et al., 2001; Denyer et al., 2006). However, whether reforestation has similar ameliorative effects at sparse-forest edges remains largely unexamined. This highlights a significant knowledge gap in the hydrological and energy cycles of such vegetation types, particularly in southern Australia, where they are highly fragmented and increasingly likely to be neighboured by industrial tree plantations.

Temperate woodlands are a sparse vegetation type characteristic of southern Australia. Since European settlement, these woodlands have been reduced to a fraction of their original distribution due to clearing for agriculture (NLWRA, 2001), and the majority of remnants are highly degraded (Lunt and Bennett, 1999). More recently, about 2 million hectares of the agricultural landscapes that support temperate woodlands have been converted to eucalypt plantations to support a growing pulpwood industry (Anon., 2007). To date, there has been minimal evaluation both of the effects of clearing and of plantation establishment on the environment of the remnant native vegetation.

This study examines the relative effects of clearing and plantation establishment on remnant woodland microclimate in south-western Victoria (south-eastern Australia). Detailed microclimate data are presented for six woodland edges—three adjoining cleared agricultural land (agricultural edge) and three adjoining established eucalypt plantations (plantation edge). The extent of edge influence on woodland microclimate is estimated using transects into woodland interiors in both winter and summer, and gradients in microclimate variables are interpreted using relationships with woodland structural attributes. We aimed to increase current minimal knowledge of temperate woodland microclimates and, more specifically, to address the questions: (a) do woodland edge microclimates differ between edge types (agricultural versus plantation)? (b) does the extent of edge influence in woodlands vary by edge type? and (c) what factors most influence woodland microclimate, and are these notably different from more dense forest types?

2. Materials and methods

2.1. Study area

Study sites were located in the Dergholm region, Victoria, south-eastern Australia (37°22′S, 141°13′E). The region has a Mediterranean climate characterised by warm summers and cool winters. Mean monthly minimum temperatures range from 5 °C (June) to 12 °C (January), and mean monthly maximum temperatures from 12 °C (June) to 28 °C (January). Mean annual rainfall is 643 mm, falling mostly in winter (June–August).

The landscape is noticeably flat (mean elevation of 147 m above sea level, 'asl'). It is characterised by dunes and sandy rises that developed from aeolian deposition after retraction of an inland sea during the Pleistocene (Baxter and Robinson, 2001). Soils are classified as deep podosols under the Australian Soil Classification System (Isbell, 2002).

The dominant land use is agriculture (mostly dryland pastures), which covers 81% of the Dergholm region (Baxter and Robinson, 2001). Native vegetation is the next significant land use, occupying 16% of the region (Baxter and Robinson, 2001). Over the past 10 years, 5% of pre-existing agricultural land has been converted to blue gum (*Eucalyptus globulus* ssp. *globulus* Labill.) plantations, and this area was recently expected to double by 2030 (Clifton et al., 2006).

Native vegetation is predominantly heathy woodlands containing species typically associated with low fertility soils (Specht and Rayson, 1957). *Eucalyptus arenacea* (Marginson and Ladiges) and *Eucalyptus baxteri* Benth. are the dominant overstorey trees with a sparse PFC cover of less than 30%, and a variable height of 10–30 m (Specht, 1981). A mid-canopy layer is absent. The understorey is a diverse heath layer to 1 m height and dominated by *Leptospermum myrsinoides* Schltdl., which can have up to four times as much biomass as the next dominant species (Jones, 1968).

2.2. Experimental design

Our study involved six woodlands representing two edge types that were interspersed across an area of 25 km radius. The woodlands were fragments of size 100–500 ha, at elevations between 134 and 187 m asl. All had similar management histories with little or no stock grazing and more than 10 years since the last prescribed (low intensity) fire. Fragmentation occurred in the previous 50–100 years when the region was developed for agriculture. Three of the woodlands were adjoined by broad acre grazing land ('agricultural edge'), and the other three adjoined by blue gum plantations ('plantation edge'). Plantations were established between 1998 and 2000 (i.e. age 7–9 years at study commencement), and had reached maximum height (of ca. 18 m) and canopy closure. Woodland and plantation trees were separated by a 25 m firebreak; this is a common practice in plantation management, and our sites were representative of woodland/plantation edges in these landscapes. All edges faced north—this orientation was chosen to maximise incoming radiation and wind energy as indicated by pre-study analysis of solar angles and wind data from regional weather stations. Plantation or agricultural land extended for at least 1 km to the north of the associated woodland edge type.

2.3. Microclimate measurements

Effects of edge type (agricultural, plantation) on woodland edge microclimate were examined using six 'fixed' weather stations located at the northern edge of each fragment (0 m) directly beneath the canopy of a woodland tree (*E. arenacea*), and at least 500 m from east-, west- or south-facing edges. Weather stations were equipped with HOBO temperature, relative humidity, photosynthetically active radiation (PAR), and wind speed and direction sensors connected to a HOBO datalogger (Onset Computer Corporation, MA, USA). Temperature and relative humidity sensors were housed inside a HOBO solar radiation shield (152 mm × 213 mm × 188 mm) at 1.5 m height, and PAR and wind speed/direction sensors were mounted on the same post at 1.8 m height. Weather stations logged continuously from 31 March 2007 to 31 March 2008 recording values every 10 min (and every 10 s during transect measurements, as below). Microclimate sensors from the different fixed stations were calibrated against each other at the start and end of logging using linear regression.

The extent of edge influence on woodland microclimate was examined in winter and summer along north-south transects using a separate 'roving' weather station equipped with the same set of microclimate sensors as the fixed weather stations. An exception was PAR at 1.8 m height, which was estimated from hemispherical photos using WINPHOT v 5.0 (Hans ter Steege, Netherlands).

Transects were repeatedly sampled at nine distances from the edge (0, 10, 20, 30, 40, 50, 75, 100 and 150 m), with intervals between distances reflecting an assumption that microclimate gradients would be steepest near the edge (Didham and Lawton, 1999). At each woodland, a fixed weather station (as above) continuously measured microclimate at the edge (0 m) to provide reference con-