Paddock-scale water use in a 'belt and alley' system with oil mallee trees

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Abstract

The incorporation of perennial plants into farming systems is now widely acknowledged as a viable option to control the spread of dryland salinity in south-western Australia. One of the proposed perennial inclusions is oil mallee trees, which can be incorporated spatially as belts of trees with alleys of traditional agricultural activity in between. Several studies have investigated water use of single trees, or single belts of trees. In this study we investigate water use at the paddock scale, where belts of trees with crowns approximately 16 m wide and 66 m apart were established in a paddock of approximately 1000 m by 750 m. An adjacent paddock, without oil mallees, was used as a control. Simultaneous measurements of water use were made with the Eddy Covariance method in both paddocks, for periods November 23, 2005 to January 12, 2006, May 25 to October 18, 2006, and April 4, 2007 to April 14, 2008. Results indicate that oil mallees occupying around 20% of the landscape can extract 40-70 mm more water per year at the paddock scale than sown pasture or wheat crops. This compares with lucerne, occupying 100% of the landscape, removing 50-100 mm extra water over 3 years. Oil mallees show promise for landscape de-watering at the paddock scale, but modelling will be necessary to determine the impact of belts of trees on groundwater recharge.

Keywords

Agroforestry, landscape-scale, evapotranspiration.

Introduction

Recent research into prevention of dryland salinity has concentrated on the incorporation of perennials into farming systems (Dunin and Passioura 2006). Perennial pastures such as lucerne, and belts of trees such as oil mallees, have been of particular interest because of their potential to be readily incorporated into farming systems in southern Australia (Latta and Lyons 2006; Ward et al 2006; Wildy et al. 2004a). The contribution of belts of trees to the water balance at the landscape level can be difficult to determine. Individual trees can be readily measured with the sap flow technique (Burgess et al 2001), and with a few more assumptions, these results can be scaled up to represent a tree belt (White et al. 2002; Wildy et al. 2004b). However, scaling these results up to a landscape level, with many tree belts, is fraught with difficulty.

Eddy Correlation (EC) is a micrometeorological technique which is commonly applied to extensive areas of vegetation to measure carbon and energy fluxes, and therefore appears promising for measuring evapotranspiration (ET) for belt and alley systems. It relies on accurate and rapid (20 times per second) measurement of atmospheric CO_2 and H_2O concentrations, and simultaneous measurement of the vertical wind speed. The technique is often used to determine carbon and water balances of native or managed forests (eg Wilson et al. 2001), and can also be readily applied to crops and pastures (Denmead et al. 1996).

In this paper we use the EC technique to monitor water use at paddock to landscape scale in a 'belt and alley' farming system in south-western Australia, and compare these measurements with a traditional agricultural landscape containing only annual plants.

Methods

Site details

The site was located on a farm at 32?53’S, 117?47’E, near Tincurrin, 200 km south-east of Perth. Two paddocks were selected on shallow gravelly duplex soils, with a loamy sand A horizon of 10-15 cm depth overlying a gravelly sandy clay. The first paddock (the ‘oil mallee’ paddock) was about 1000 m by 750 m, and contained 9 belts of oil mallees planted in 2003 in an E-W orientation, with a distance of approximately 66 m between belts (Figure 1). The second paddock (the ‘control’ paddock) of similar dimensions contained no trees until seedlings at the same spacing as the first paddock were planted in August 2007. Rainfall during the trial was obtained from an automatic weather station located in the oil mallee paddock, maintained by DAFWA since 1997. Average long-term rainfall at Dudinin, 12 km east of the site, is 345 mm, of which 244 mm falls in the May-October period.

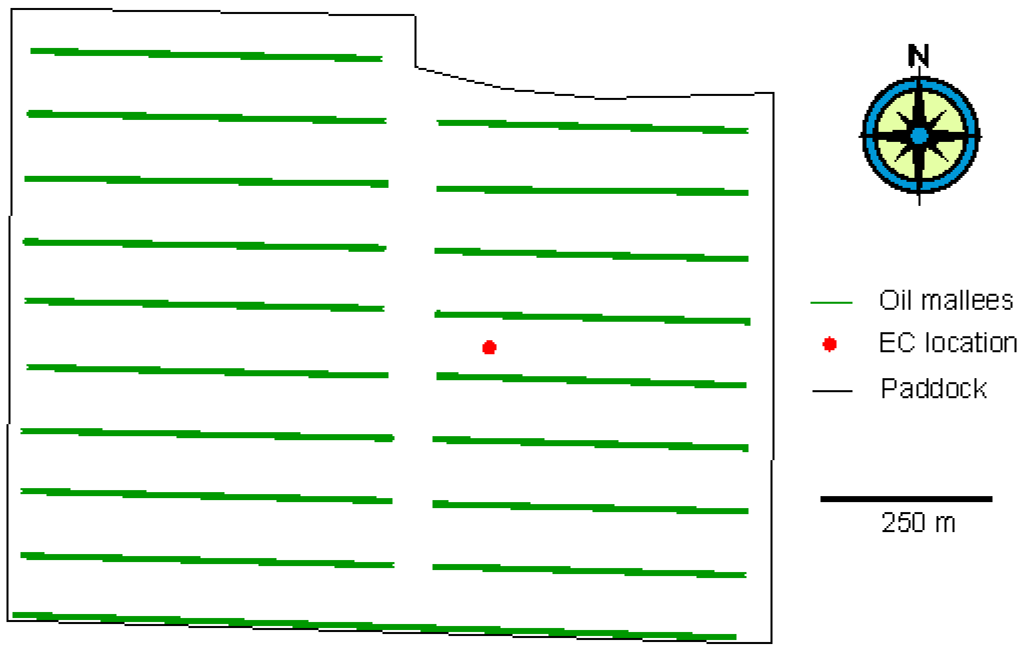

Figure 1. Oil mallee paddock layout.

Eddy Correlation

One Eddy Correlation unit was installed in each paddock. Each unit consisted of a R3-50 sonic anemometer (Gill Instruments, UK), and a LICOR LI-7500 open-path infra-red gas analyser. Raw data was collected at a frequency of 20 Hz, and subsequently analysed in 2-hour time periods with EdiRe 4.2 software (University of Edinburgh). Solar panels and a battery bank were used to maintain power to the units.

EC measurements were conducted for periods: November 23, 2005 – January12, 2006; May 25 – July 3, 2006; July 13 – August 29, 2006; September 5 – October 18, 2006; and April 4, 2007 to April 15, 2008. Gaps in the data were filled by using average ET values for three days each side of the gap. Average tree height was approximately 2 m in November 2005, 3 m in October 2006, and 4 m in November 2007. Measurement height in the oil mallee paddock was 3.7 m until July 3 2006, 5.4 m until April 2007, and 6.0 m for subsequent measurements. Measurement height was 1.7 m in the control paddock.

Results

In the 2005/06 summer, despite a relatively short period of measurement, ET from the oil mallee paddock was greater than from the control paddock. ET from both paddocks was similar in magnitude to rainfall for the period, and substantially less than potential ET (Figure 2).

Early in the growing season of 2006 (May-June), ET from the control paddock was slightly greater than from the oil mallee paddock (Figure 2). Dry conditions early in the measurement period resulted in ET rates from both paddocks being substantially lower than potential ET, until a large rainfall event on June 28. ET rates for both paddocks subsequently increased to close to potential ET rate for the period in July and August, in response to near-average rainfall. On about September 15, water stress caused ET rate in both paddocks to fall below potential ET. After September 15, ET rate was maintained about 0.1 mm/day higher in the oil mallee paddock than in the control paddock. For the period of measurement between May and October 2006, total ET from both paddocks was greater than rainfall, indicating use of water received prior to the measurement period.

For the third period of measurement indicated in Figure 2 (April 2007 to April 2008), water use by the annual crop was very similar in magnitude to rainfall received at the site. Seasonal water use patterns followed those described previously, with ET being close to potential rates through the winter and spring, but substantially lower than potential ET during summer and autumn. Also as observed previously, ET from the control paddock was slightly higher than from the oil mallee paddock for the winter months, but this was reversed at other times of the year. Over the full 12-month period, water use from the oil mallee paddock was approximately 75 mm more than water use from the control paddock, and the same amount more than rainfall. This indicates that the trees are 'mining' deep soil water, although no soil water measurements are available at this site to confirm this conclusion.

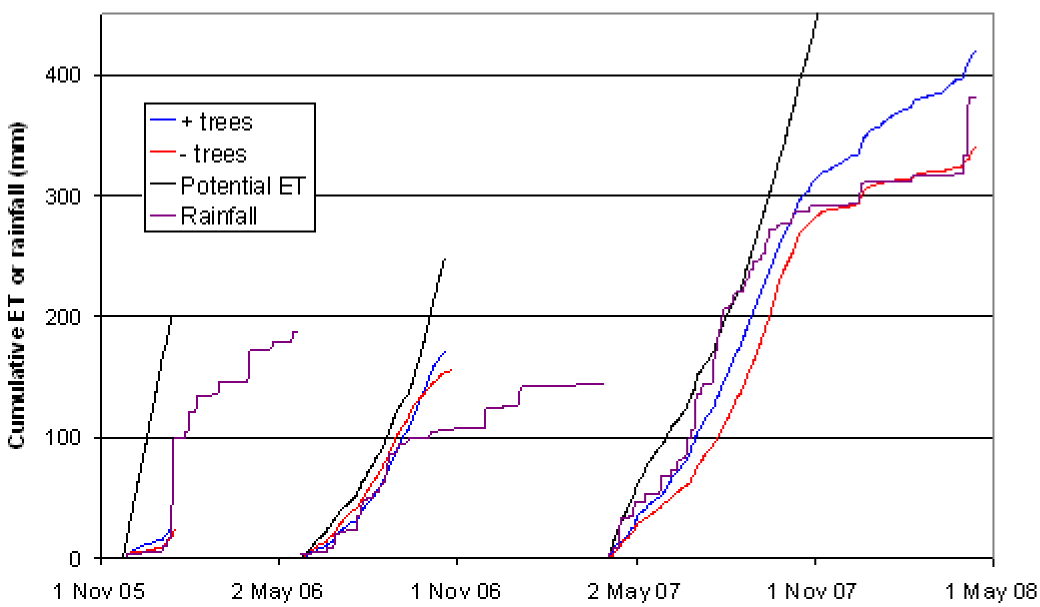

Figure 2. Cumulative water use, potential ET and rainfall for three periods of measurement between November 2005 and April 2008. Note that the rainfall record is continuous, but re-set to zero at the commencement of each period of EC measurement.

Discussion

Oil mallees represent one of the few woody perennial options for drier regions of the southern Australian wheat belt. The most usual form of incorporation into farming systems is as narrow belts of 2-4 trees wide, separated by alleys of 50-150 m. Many farmers base the alley width on convenient multiples of machinery widths, so oil mallees fit neatly into controlled traffic farming systems as well.

In the current study, oil mallees were planted in 4-row belts separated by 66 m, giving a total coverage of around 20% of the paddock, which is slightly higher than the average level of coverage in the region. In this arrangement, the estimated extra water use for 2006/07 was around 40 mm, with a further 75 mm for the 2007/08 season. In these soils, lucerne (the most attractive herbaceous perennial option for the region) would be expected to generate a buffer of about 90 mm after three years (Ward *et al*. 2006). Although we have no estimates of oil mallee water extraction at this site in other years, its performance during the measurement periods was comparable to that expected for lucerne, despite oil mallees only occupying about 20% of the paddock.

Carter *et al.* (2005) and Wildy *et al.* (2004b) used sap flow techniques to measure oil mallee ET of 2-3 mm/day (based on tree crown area) in December, in the absence of groundwater. Assuming coverage of 20% of the landscape, this equates to 0.4-0.6 mm/day at the landscape scale. In our measurements, the difference in total ET between the oil mallee paddock and the control paddock (i.e. the amount of ET attributable to the trees) during December was 6.5 mm (0.21 mm/day) in 2005, and 7.6 mm (0.25 mm/day) in 2007, which is considerably lower than previous estimates based on sap flow. It is possible that scaling measurements from single trees or tree belts to landscape scale might overestimate the impact of trees, but further research will be necessary to confirm this. Nevertheless, results presented here confirm that oil mallees can play a role in salinity control.

Acknowledgements

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