Trees and groundwater on the water-limited Eyre Peninsula: an ecohydrological perspective

submitted by

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Declaration of originality

I certify that this thesis does not incorporate, without acknowledgement, any material previously submitted for a degree or diploma in any other university; and that to the best of my knowledge and belief does not contain any material previously published or written by another person, except where due reference is made in the text.

The contribution for the authorship of the three published journal papers which are presented in this thesis as Chapters 2, 3 and 4 are declared to be as follows:

- **Chapter 2**: Water use strategies of two co-occurring tree species in a semi-arid karst environment (Swaffer 70 %, Holland 5 %, Doody 5 %, Li 15 %, Hutson 5 %).
- **Chapter 3**: Rainfall partitioning across two co-occurring, morphologically distinct tree species in a semi-arid environment (Swaffer 85 %, Holland 5 %, Doody 5 %, Hutson 5 %).
- **Chapter 4**: Comparing ecophysiological traits and evapotranspiration of an invasive exotic, *Pinus halepensis* in native woodland over a karst aquifer (Swaffer 90 %, Holland 10 %).

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Abstract

This thesis investigated the ecohydrological linkages between native and exotic tree species and karstic groundwater systems on Eyre Peninsula, South Australia. It focuses on two issues of global importance: the declining status of fresh water resources in water-limited environments and the rate of evapotranspiration from native and non-native trees encroaching across groundwater recharge areas. The work focussed on karstic groundwater systems, a geological setting where the water flux dynamics from the surface through to groundwater is a complex process involving storage in the unsaturated zone and diffuse and preferential recharge pathways. This geological complexity and the processes associated with this behaviour are not well understood, despite karst aquifers often being the source of drinking water supplies. As a result, uncertainty regarding the ecohydrological processes in this environmental setting remains large.

In addition to the complex nature of the karst substrate, the presence of vegetation growing above the groundwater lens will further influence recharge and discharge dynamics. Water use by trees, as well as the partitioning of precipitation into interception, stemflow and throughfall, was considered to be an important ecohydrological process affecting this groundwater system.

This study examined whether groundwater level decline could be attributed to changes in land cover, reflecting differences in evapotranspiration rates and pathways of water flux across morphologically distinct, locally common tree species. Pre-European settlement the region was characterised by a grassy woodland dominated by Allocasuarina *verticillata* (Lam.) L. Johnson (drooping sheoak). Since the establishment and subsequent cessation of grazing across

groundwater recharge areas, *Eucalyptus diversifolia* ssp. *diversifolia* Bonpl. (coastal white mallee) has expanded in range. Furthermore, the non-native *Pinus halepensis* Mill. (Aleppo pine), originally planted as a wind-break, has since naturalised and invaded significant areas of the rocky, shallow, calcrete soils often characteristic of karstic systems. Invasion by an aggressive exotic plant species into this water-limited environments was commonly believed to further exacerbate water scarcity issues.

Fundamentally, this thesis seeks to address concerns regarding the effect native trees, or encroachment by exotic trees, exerts over groundwater flux in a water-limited environment. The belief that the vegetation will detrimentally affect the groundwater charge rates inevitably attracts debate regarding the ability of active management of vegetation to improve water yield.

I applied both plot-scale and remotely-sensed methodologies to examine total evapotranspiration (*ET*) flux, and used these to construct a water balance for the three tree species in question, as well as for a grassland site. Water use strategies and ecophysiological characteristics were examined using leaf water potential and soil matric potential, and twig water sources were traced using the stable isotopes of water. The funnelling of water from canopies via tree surfaces to enhance infiltrate around the base of tree boles was explored as a mechanism though which soil water content could sustain transpiration during dry periods. Global literature suggested that variability in methodological approach significantly affected the reported results, which I demonstrated using two years of rainfall partitioning data.

The results of this study indicated that *ET* losses from native vegetation associations were equivalent to long term precipitation. Despite a shallow groundwater depth of < 5 m, use of groundwater to sustain transpiration requirements was not clearly demonstrated by the studied tree species, suggesting that while recharge will be reduced by the presence of these trees, *ET* was most likely supported by soil water stores rather than groundwater extraction. The reliance on soil moisture, rather than groundwater, was further supported by actual *ET* remaining well below (one third of) potential *ET*, therefore a significant constraint was evident on the system. However, the encroachment of the invasive *Pinus halepensis* was considered likely to have contributed to declining groundwater levels, based on higher rates of sap flux per unit sapwood area compared to the native species. Comparison of *ET* rates before and after removal of *P. halepensis* suggested an annual water saving of ~ 50 mm; however it was recommended more than two years of post-removal data be used to assess the likelihood of realising long term water savings.

Irrespective of stand and morphological differences, the water use characteristics of the native *E. diversifolia* and *A. verticillata* were remarkably similar , demonstrating the evolutionary capacity of these species to maximise the use of the available precipitation. Furthermore, rainfall channelled as stemflow is believed to play an important ecohydrological role in this environment. Infiltration directly adjacent tree root systems provides a water store which can be used during times of precipitation deficit. In addition, I suggest that the water holding capacity of porous geological substrate has played an important role in buffering inter- and intra-annual rainfall variability and needs to be considered when characterising karstic groundwater systems.

The findings described in this thesis add to our knowledge of evapotranspiration rates of vegetation in semi-arid systems. I have demonstrated the value of using both plot scale field investigation and remotely sensed data to address important knowledge gaps and improve the management of regionally significant groundwater supplies. The results of this research are expected to inform water resource policy as competition for fresh water increases, expected to intensify following predicted climate change scenarios.