# Soil Water and Nitrogen Dynamics of Farming Systems on the upper Eyre Peninsula, South Australia.

A thesis submitted in fulfilment of the degree of Doctor of Philosophy in the School of Earth and Environmental Sciences at the University of Adelaide.

Discipline of Soil and Land Systems
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July 2005

**Dedicated to the memory of my father, Ian Leigh Adcock**

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# Abstract

In the semi-arid Mediterranean-type environments of southern Australia, soil and water resources largely determine crop productivity and ultimately the sustainability of farming systems within the region. The development of sustainable farming systems is a constantly evolving process, of which cropping sequences (rotations) are an essential component. This thesis focused on two important soil resources, soil water and nitrogen, and studied the effects of different crop sequences on the dynamic of these resources within current farming systems practiced on the upper Eyre Peninsula of South Australia.

The hypothesis tested was that: *continuous cropping may alter N dynamics but will not necessarily alter water use efficiency in semi-arid Mediterranean-type environments*. Continuous cropping altered N-dynamics; increases in inorganic N were dependent on the inclusion of a legume in the cropping sequence. Associated with the increase in inorganic N supply was a decrease in WUE by the subsequent wheat crop. Overall, estimates of water use efficiency, a common index of the sustainability of farming systems, in this study concur with reported values for the semi-arid Murray-Mallee region of southern Australia and other semi-arid environments worldwide.

Soil water balance and determination of WUE for a series of crop sequences in this thesis suggests that the adoption of continuous cropping may increase WUE and confer a yield benefit compared to crop sequences including a legume component in this environment. No differences in total water use (ET) at anthesis or maturity were measured for wheat regardless of the previous crop. Soil evaporation ($E_s$) was significantly affected by crop canopy development, measured as LAI from tillering until anthesis in 2002, however total seasonal $E_s$ did not differ between crop sequences. Indeed in environments with infrequent rainfall, such as the upper Eyre Peninsula, soil evaporation may be water-limited rather than energy limited and the potential benefits from greater LAI and reduced $E_s$ are less.

Greater shoot dry matter production and LAI due to an enhanced inorganic N supply for wheat after legumes, and to a lesser degree wheat after canola, relative to continuous cereal crop sequences resulted in increases in WUE calculated at

anthesis, as reported by others. Nonetheless the increase in WUE was not sustained due to limitations on available soil water capacity caused by soil physical and chemical constraints. Access to more soil water at depth (>0.8m) through additional root growth was unavailable due to soil chemical limitations. More importantly, the amount of plant available water within the 'effective rooting depth' (0-0.8m) was significantly reduced when soil physical factors were accounted for using the *integral water capacity* (IWC) concept. The difference between the magnitude of the plant available water capacity and the integral water capacity was approximately 90mm within the 'effective rooting depth' when measured at field capacity, suggesting that the ability of the soil to store water and buffer against periodic water deficit was severely limited. The IWC concept offers a method of evaluating the physical quality of soils and the limitations that these physical properties, *viz.* aeration, soil strength and hydraulic conductivity, impose on the water supply capacity of the soil.

The inability of the soil to maintain a constant supply of water to satisfy maximal transpiration efficiency combined with large amounts of N resulted in 'haying off', and reduced grain yields. A strong negative linear relationship was established between WUE of grain production by wheat and increasing soil $NO_3$-N at sowing in 2000 and 2002, which conflicts with results from experiments in semi-arid Mediterranean climates in other regions of the world where applications of N increased water use efficiency of grain.

Estimates of proportional dependence on $N_2$ fixation ($\%N_{dfa}$) for annual medics and vetch from this study (43-80%) are comparable to others for environments in southern Australia (< 450mm average annual rainfall). Such estimates of fixation are considered low (<65%) to adequate (65-80%). Nevertheless, the amount of plant available N present at sowing for subsequent wheat crops, and the occurrence of 'haying off', suggests that WUE is not N-limited *per se*, as implied by some reports, but constrained by the capacity of a soil to balance the co-limiting factors of water and nitrogen.

# Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or any other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by an other person, except where due reference has been made in the text.

I give my consent to this copy of my thesis, when deposited in the University library, being made available for photocopying.

Damien Adcock
May 2005

# Acknowledgements

I would like to thank all my supervisors Dr. Ann McNeill, Dr. Cameron Grant, Professor David Coventry and Dr. Robert Holloway for their advice and guidance throughout the course of this project. I am indebted to my principal supervisors: Annie for her constant support and friendship, and Cam for his insightful direction and encouragement.

In particular, I wish to thank Matt and Mignon Dunn and family for their hospitality and friendship and providing the experimental site. I am especially grateful to Pennelopy Day for field and technical assistance and her efforts maintaining the site during my intermission. I would also like to thank the staff from the Minnipa Agricultural Centre for their assistance during the project, in particular Jon Hancock and Shane and Samantha Doudle.

I would like to offer a special note of appreciation to Dr. Murray Unkovich for keeping me focused and reminding me what a thesis is all about.

I would like to also thank Laurence Jassogne for her skilled assistance with formatting.

I am obliged to the Grains Research and Development Corporation for funding this project, which was part of the Eyre Peninsula Farming Systems initiative. I am also thankful to the A.W. Howard Memorial Trust for funding to attend the 11$^{th}$ Nitrogen Worksop in France and the K.P. Barley Trust for other funding.

Finally, I would like to thank Caroline for her constant patience, support, encouragement and understanding throughout.