Benchmarking wheat water-use efficiency in Tasmania

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Summary

- This factsheet reports on desktop modeling studies to benchmark wheat water-use efficiency (WUE) and to explore the sensitivity of WUE to changes in management practice.
- WUE in the high rainfall zone can be extremely variable, as a result of environmental and agronomic constraints to grain production that limit yield potential [1, 2].
- Potential WUE, which takes into account losses due to runoff and drainage, had a maximum value of around 20 kg/ha.mm and was variable as a result of constraints of climate, soil attributes and water availability.
- At most sites there was a gap of 58% to 100% between attainable and potential WUE, which could be addressed by improved crop management. Modelled scenarios showed that yield, WUE and economic returns could be improved by applying additional N fertiliser with strategic irrigation, to avoid co-limitation [3] of these inputs.
- In high rainfall cropping areas such as Tasmania, N supply is a key driver of yield and hence WUE.
- Validation of the modelled scenarios and further field trials will be required to better understand the complexities of yield formation and efficient use of inputs in Tasmania.

Background

- Emerging developments in Tasmanian grain cropping such as the expansion of low pressure overhead irrigators and increased access to low-cost, plentiful irrigation sources in some areas will have a strong influence on WUE.
- Estimates of WUE that are based on grain yield per the combined amount of rainfall plus irrigation do not account for stored soil moisture, drainage or runoff events that can be frequent in high rainfall environments. As a result, WUE may be over-estimated. An alternative approach is to estimate WUE as grain yield per the combined amount of surface evaporation, transpiration, drainage and runoff. Direct measurement of these different components to quantify 'actual' WUE is difficult and desktop modelling is used instead. This approach can distinguish between 'attainable' WUE, which is limited by crop management e.g. nitrogen fertiliser, and 'potential' WUE, which is determined by climate and is free of nutrient and biological constraints.
- Management and yield data for 34 wheat trials were used to configure and validate the APSIM farming system model. Model output for key water balance elements were used to estimate 'attainable' and potential WUE. Further model scenarios were run to explore the response of WUE to nitrogen and irrigation management.

Results and discussion

Benchmark WUE

- The performance of the model to predict grain yield was acceptable across a range of environment and management systems. Maximum potential WUE was determined to be around 20 kg/ha.mm (Figure 1). Furthermore, there was substantial variability in potential WUE and a significant gap between attainable and potential WUE in the majority of environments (Figure 1).
- There was a trend for WUE to increase with decreasing N stress, which indicated that nitrogen supply and demand dynamics were an important driver of WUE in Tasmania (Figure 2). In a wet year, N supply will be a key driver of yield and WUE in Tasmania. The importance of N in Tasmania is also supported by the gap between potential and attainable WUE at some sites (Figure 1).

WUE sensitivity to nitrogen and water supply

- Increasing the irrigation by 60 mm resulted in an average yield gain of 602 kg/ha and an increase in WUE of 0.4 kg/ha.mm of the control, with 15/30 years generating both an economic yield gain and an increase in WUE (Table 1). A further increase in irrigation by 120 mm led to a small increase in average yield but had no effect on average WUE. The frequency of seasons with gains in both yield and WUE declined to 8. There are larger gains in WUE achieved from irrigation in drier years.

- Increasing the total N rate from 70 kg N/ha (control) to 140 N/ha (unchanged irrigation of 20 mm), resulted in yield gains of 437 and 660 kg/ha, respectively. Corresponding gains in WUE were 0.6 and 0.9 kg/ha.mm. The frequency of gains in both yield and WUE ranged from 17/30 (+70 kg N/ha) to 13/30 (+140 kg N/ha).
- Increasing both irrigation and applied N resulted in much larger and more consistent gains in both yield and WUE. For example, average yield and WUE gains of 2119 kg/ha and 1.9 kg/ha.mm were reached with an additional 120 mm irrigation and 140 kg N/ha of fertiliser with positive gains in both occurring in 22/30 years.

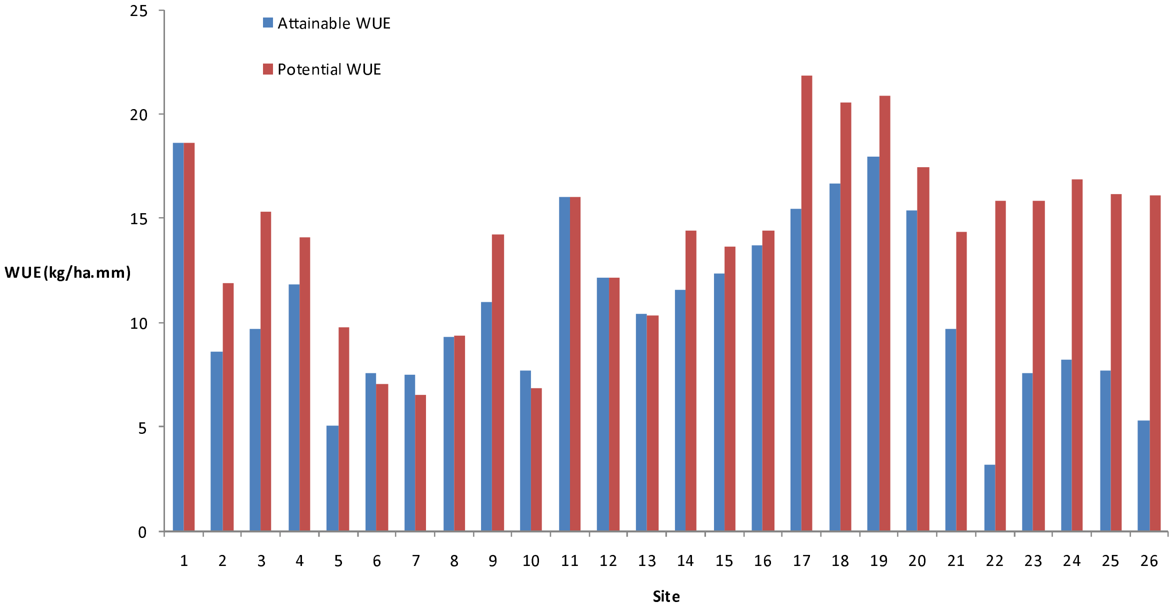

Figure 1. Simulated attainable and potential WUE for a subset of the benchmark dataset

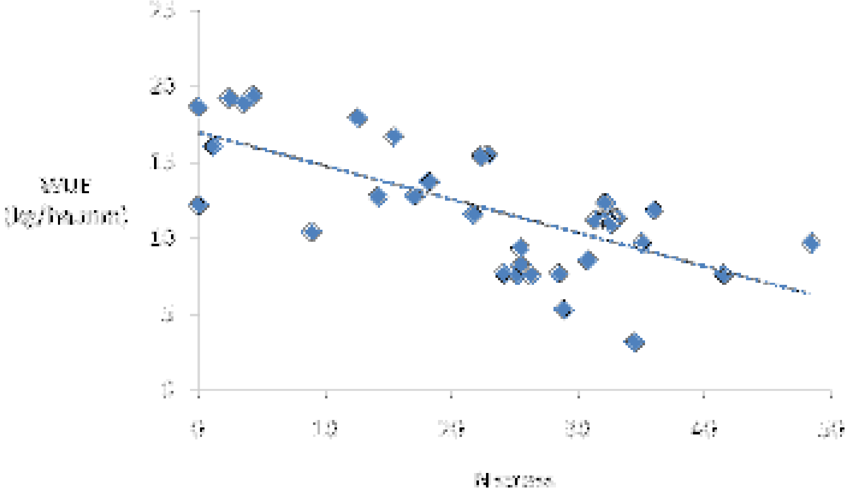

Figure 2. Accumulated seasonal crop N stress versus WUE for the benchmark dataset

Table 1. WUE and yield response to irrigation and N treatments across the period from 1980 to 2010.

Irrigation (mm)	N (kg/ha)	Average yield change (kg/ha)	Years with yield gain	Years with economic yield gain	Average WUE change (kg/ha.mm)	Years with WUE gain	Years with economic WUE gain
Additional irrigation							
60	0	602	20	15	0.4	15	15
120	0	817	20	8	0.4	13	8
Additional N							
0	70	437	28	17	0.6	28	17
0	140	660	27	13	0.9	23	13
Additional irrigation + N							
120	70	1577	30	14	1.3	25	14
120	140	2119	30	22	1.9	30	22

Methods

Benchmarking WUE

Management and yield data for 34 wheat field trials undertaken in Tasmania from 1982 to 2009 were used to configure the APSIM farming system model. Sowing dates of the wheat (cvs. Mackellar or Tennant) field trials ranged from May to September and around 25 kg N/ha was applied at seeding and 50 kg N/ha as a topdressing. Around half of the field trials received between 24 to 60 mm of irrigation; two received a maximum of 160 mm and the remainder were rainfed. Model soil parameters were chosen to represent the prevailing conditions at each site and long-term climate data was sourced from the Australian Bureau of Meteorology. Once satisfied that the model was reliably simulating wheat yield across the sites, APSIM model output for key water balance elements were then used to estimate 'attainable 'and 'potential' WUE [grain yield / (Surface Evaporation + Transpiration + Drainage + Runoff)]. Potential WUE was determined by climate and was free of nutrient and biological constraints. Attainable WUE is additionally constrained by nitrogen supply.

WUE sensitivity to nitrogen and water supply

Further model scenarios were run to explore the response of WUE to irrigation and nitrogen management practices and the potential to close the attainable versus potential WUE 'gap'. Analysis was based on a field trial undertaken in the 2009–10 season at Cressy in northern Tasmania. The control treatment was sown on 18 May 2009 to Mackellar wheat with 23 kg N/ha and 5 mm irrigation. Two 23 kg N/ha applications of urea were applied as topdressings (i.e. total N applied of 70 kg N/ha) plus an extra 15 mm of irrigation in November (i.e. total irrigation of 20 mm). A range of additional scenarios were configured covering different irrigation rates (60 and 120 mm), N rates (70 and 140 kg N/ha) and various combinations of N and irrigation rates (Table 1). All model scenarios were run over the 30 years from 1980–2010 to explore the impact of seasonal climate variability. Economic cost-benefit analyses of the scenarios were based on a feed wheat grain price of $200/t, with costs of $145/ML for water plus delivery and $1.05/kg N fertiliser. Treatments were considered economic when the extra revenue gained from yield increases exceeded the additional input costs.

Acknowledgements

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References

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