Identifying farm-scale opportunities to improve WUE: A nationally-coordinated systems approach.

Summary
This project provided farming system science and simulation support and a national co-ordination and communication role to the network of 16 regional grower groups funded within the National Water Use Efficiency (WUE) Initiative. The aim was to assist groups to achieve the initiative’s goal of a 10% increase in the WUE of their farming systems. Together, WUE increases well above the 10% target (often 20–60%) were demonstrated from a range of pre- and in-crop management practices and combinations of these. Evidence of significant on-farm adoption has been documented during the initiative, and the better-informed growers and advisers are an important legacy for continued practice change from the initiative.

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taken as a recommendation for their use.

Conclusions
Theme 1: Summer fallow management
1. Strict summer fallow weed control conserves water (mean 37mm) and soil nitrogen (N) (44kg/ha) and reduces impacts of
disease carry-over, generating 60% increase in WUE and an average $5.60 return on each dollar invested.
2. Maintaining groundcover over summer (70%-2.0t/ha) protects the soil surface and improves rainfall infiltration and water
storage. Heavy stubble loads (5t/ha) can also reduce evaporation in autumn for early sowing opportunities.
3. Sheep do most damage with their mouths, not hooves. Removal of cover by overgrazing, rather than soil trampling, has the
biggest effect on water storage.

Theme 2: Break crops and crop sequence
4. Break crops play an important role in managing weeds, diseases and N, to ensure healthy crops capture resources efficiently.
5. Break crops can be profitable if whole-of sequence effects on water, N, diseases and weeds are accounted for and flexible approaches, including green and brown manures and hay-cutting (especially for legumes), are considered.

Theme 3: Division and distribution of water use
6. Sowing early with appropriate varieties to maintain optimum flowering time is necessary to capitalise on the stored summer water and N using good fallow management.
7. If sowing early, it is important to modify the agronomy, including disease management, plant density and N management, to avoid excessive early biomass production and preserve water for use during critical periods. Average crop yield increases of 0.8t/ha have been achieved, and farm yields of 11–46% predicted.
8. In the high rainfall zone where water can be adequate or excessive, N and disease management must be optimised for higher yield potential. Managing barley yellow dwarf virus (BYDV) in early sown crops generated 20–25% yield, and the upper leaves should be protected to ensure high potential is achieved.

Theme 4: Managing variable and hostile soils
9. Identifying and ameliorating subsoil constraints to growth can significantly increase the capture, storage and effective use of subsoil water, and can increase yield and WUE.
10. On variable soils, significant increases in yield and WUE can be obtained by varying the N applied i.e. either increasing N on deep sands with higher yield potential and lower fertility, or reducing N on heavier swale soils with lower yield potential and high fertility.

Recommendations
Our results demonstrate that the best outcomes are likely to arise from the synergies of better management at a number of stages throughout the cropping cycle. Specific recommendations adjusted according to site and soil-type would be to:

1. Benchmark performance according to developed guidelines to consider the scope for improvement.
2. Identify yield potential of specific paddocks based on soil characteristics (depth, plant available water capacity (PAWC)) and seasonal rainfall.
3. Consider the options to ameliorate or manage variable and hostile subsoils for improved productivity.
4. Develop crop sequences to manage weed, disease and N cycles according to the paddock characteristics. Consider low-input, flexible approaches (green or brown manures or hay cutting with legumes) along with higher input high value break crops (canola, chickpeas, lentils).
5. Adopt a strict summer weed control policy.
6. Maintain residue cover at 70% or above throughout summer by avoiding overgrazing.
7. Sow early with suitable varieties to target the optimal flowering window - consider slower-maturing wheat sown early to start the sowing program to capture whole-of program benefits.
8. Be mindful of the impact of wider rows (>25cm) on yield potential - consider yield loss versus operational benefits.
9. Manage the crop canopy to ensure sufficient water remains for critical periods (density, row spacing, deferred N), and protect the flag leaf to ensure grain-filling.
10. Match N inputs to the potential of soil and season.

Outcomes
Economic outcomes:
The potential for improvements in productivity and WUE well above the 10% target were demonstrated experimentally from a range of innovations and their combinations including better summer fallow weed control (60%), inclusion of break crops (16–83%), earlier sowing of appropriate varieties (21–33%), matching N supply to soil type on variable Mallee soils (up to 91%), disease control in high rainfall areas (20–25%), amelioration of subsoil constraints (ripping, gypsum, spading, deep manuring - 20–80%). Importantly, the value of combining innovations to capture synergies for productivity was demonstrated. For example, it was shown experimentally (at 20 sites across the regions, and with simulation) that combined better summer fallow weed control with the earlier sowing of longer-season wheat varieties with packages of better agronomy (row spacing, N and disease management) could lead to 11–46% increase in farm-scale wheat yield. Several growers and advisers across the
southern region adopted this approach with their clients in 2011 and 2012 with significant success. It is estimated conservatively that achieving the initiative goal of 10% would add half a billion dollars per year to the value of Australian grain production, and in many cases the project demonstrated strategies that exceed that target.

Environmental outcomes:
Long, medium and short-term management practices improve the capture, storage and use of water within the cropping system. The efficient use of water and nutrients demonstrated by several of the innovations in the initiative will reduce the likelihood they will be lost to the environment by run-off or leaching. Several groups investigated specific amelioration of acid, sodic, and non-wetting soils, improving water infiltration, crop growth and the long-term structure of the soil. Better use of break crops also reduced the need for excessive use of fungicides and herbicides in the cereal phases to control pests, diseases and weeds. Recommendations for better managing weeds, stubble and stock in the summer fallow to maintain surface cover will also improve infiltration, reduce runoff and wind and water erosion. Across the initiative, better capture, storage and use of water inevitably ties the productivity improvements (above) to reduced risk of environmental damage.

Social outcomes:
This project served to strengthen the capacity, confidence and links between the network of grower groups involved in the initiative. The revelation of the significant opportunities to improve productivity in sustainable and profitable ways using practices developed and demonstrated in the initiative was an important tonic through the early years of the initiative which coincided with the millennium drought. The capacity building with growers and advisers is a legacy that will drive continued practice change to maintain the prosperity of rural communities.

Achievements/Benefits
In summary, the team of agronomists, plant physiologists and modellers from across CSIRO’s Agriculture Flagship led a coordinated national effort with 16 collaborating grower groups to deliver RD&E with demonstrated adoption and profound ongoing impact for the productivity and sustainability of the Australian grains industry. It provided farming system science and simulation support to the group network within the National WUE Initiative to assist them to achieve the initiative goal of a 10% increase in the WUE of their farming systems. This was achieved by providing support and assistance to:

(1) Understand and use consistent approaches to benchmark the WUE of crops and systems.
(2) Develop and execute sound experiments with consistent design and measurement protocols.
(3) Sample and analyse critical soil and plant samples to understand impacts of interventions.
(4) Use pre-experimental crop and systems modelling to identify opportunities to improve WUE.
(5) Apply crop simulation models to extrapolate experimental results across different regions and to whole-farm scale, and
(6) Communicate results across groups (annual meetings and newsletters) to capture benefits of group learning.

Approach:
This task was managed by organising the interventions proposed by the 16 groups into four themes of research based on the practice they were targeting. This allowed the groups from different regions working on similar themes to see how the interventions affected WUE in different regions, and also to understand how interventions from different themes interacted at the whole-farm scale. The themes also acted as a focus for the CSIRO team to target experimental and simulation effort. In each theme the team assisted individual groups to develop sound experimental approaches using pre-experimental modelling scenarios, and helped them interpret results, gather necessary data to parameterise simulation models, and also used simulation approaches to scale up predicted impacts of interventions to the whole-farm scale. Throughout the initiative growers and advisers were also testing the ideas on their own farms and with clients providing a direct pathway for adoption. Significant achievements within each of the four themes are considered below.

Theme 1: Fallow management (managing stubble, weeds and stock in the summer fallow)
In 2009/10, an analysis of the potential benefits of good fallow management (weeds, stubble and stock) at 40 sites throughout Australia was completed, communicated and published. Also, the unifying concept of ‘pulse paradigm’ to predict the likely storage of fallow rainfall was published. The study suggested significant potential to capture benefit in southern...
Australia from stored summer rainfall though the increase in WUE varied from 10% (0.1t/ha) in the northern Western Australia (WA) wheat belt, to 100% (2t/ha) in central west New South Wales (NSW). A review and simulation study that suggested livestock would have little impact on crop production in no-till or conventional tillage (CT) systems was also published. There was wide communication to regional groups and the broader industry on how management of weeds, stubble and livestock can influence productivity and WUE. Over the course of the project, the groups subsequently conducted 20 field experiments in six different regions, which validated all of the predictions that had been made. Better capture of summer fallow rainfall by better managing weeds increased water and N stored at sowing by an average of 37mm and 44kgN/ha, generating an increase in yield of 0.85t/ha (0.2–1.7t/ha) and WUE of 60%. The work had immediate, widespread and ongoing impact across the industry. Mr Bill Long, consultant and GRDC Panel member, stated: “Farmers no longer debate the benefits and costs of summer weed control”.

Theme 2: Division and distribution of water-use/in-crop canopy management (row spacing, grazing, N, fungicides etc)

In 2011/12, the focus was shifted to ‘in-crop’ management interventions to build on the impact of the summer fallow management message, as earlier sowing was often required to capture benefits from stored water. A newsletter with articles from regional groups working in this area was prepared and distributed and focused discussions on this topic were held at the Perth workshop (2011). Specific experiments with three groups in 2011/2012 (Central West, FarmLink and Southern Farming Systems [SFS]) were designed and coordinated to demonstrate the benefit of sowing early with modified agronomy. It was demonstrated experimentally and with simulation that an increase of 11 to 46% in farm-scale wheat yield and WUE was possible by combining good summer fallow management with early sowing and modified management of slow-maturing wheats. At Temora, yield increases of 0.8 and 1.9t/ha were demonstrated in experiments and farm yield increases of 31% predicated over current practice. The approach was adopted by several growers and advisers from 2011–2013, with significant success.

Theme 3: Break crops and crop sequencing

Several groups investigated the impact of break crops on productivity and WUE. These groups were supported in experimental design, sampling and analysis to ensure these longer-term three-year rotation experiments were completed successfully. For example, the work with the Birchip Cropping Group (BCC) at Hopetoun showed that including a break crop in a sequence could be at least as profitable as continuous wheat, and in some cases substantially more profitable. Options of legumes for brown or green manure and hay along with higher input canola were compared. A vetch break crop increased the WUE of the following two wheat crops by 16 and 83%, relative to wheat on wheat, and the canola grain, vetch hay and pea hay, followed by wheat, were as profitable as continuous wheat. Remaining flexible about the break crop end use was an important aspect for success. Mallee Sustainable Farming Systems (MSFS) also demonstrated significant N (pasture) and Rhizoctonia control (canola) benefits from breaks in the crop sequence. The GRDC Crop Sequence Initiative was developed during this period and some work was integrated into that larger focussed initiative.

Theme 4: Managing variable or hostile soils

A number of different groups investigated the impact of managing soils with subsoil constraints by either ameliorating the soil (gypsum, subsoil manuring, mouldboard and spading) or with variable rate N input (on Mallee soils). The increases in WUE achieved in these experiments were 15 to 54% with gypsum (in the South East Premium Wheat Growers Association (SEPWA) WA), 28% with subsoil manuring (SFS, Victoria [VIC]), and 20 to 80% with mouldboard and spading. Variable rate N application on variable Mallee soils: reducing rates on swale clays and increasing rates on deep sands increased WUE on dunes by up to 91% (MSFS). Simulation studies by the CSIRO team related to this work indicated significant promise across seasons to improve profitability and productivity by varying N application in this way.

Whole-farm integration

An important message from the initiative was the synergy that can be achieved by integrating several practice changes across the themes and how this influences whole-farm productivity. A modelling study was published in 2010 that predicted significant benefits from combining break crops, no-till, summer weed control and early sowing, but no large impacts individually. Subsequently, the experiments and modelling confirmed that adopting a strict summer fallow weed control policy, rather than grazing summer weeds, scaled up to a $74/ha benefit across mixed farms in Temora (NSW) and Hopetoun (VIC). Likewise, adopting an early sowing strategy using later-maturing wheats to start the sowing program earlier scaled up to an 11 to 46% farm-wide wheat yield increase. A study on ‘adaptive crop choice’ with Upper North Group in South Australia...
(SA) considered the merits of selecting specific crop and pasture options for paddocks based on conditions at the start of the season (the date of the break, starting plant-available water, current price levels) and paddock history, rather than strategic management with set rotations. The study in that area showed that for risk averse growers, tactical management had value, while for those willing to risk some upside loss in good years (e.g. insufficient N or higher canola prices) strategic management was marginally more profitable in the longer term. Therefore, the attitude of growers to risk influenced the preferred management pattern.

**Consistency, co-ordination and communication**

Sixteen individual WUE and benchmarking master classes with regional agronomy groups, presented summaries, newsletters and a booklet providing a summary of simple guidelines on how to use WUE benchmarks with worked examples for all groups to allow the accumulated data on the effects of interventions to be compiled were completed and presented in Hobart (2012) and Canberra (2013) and for use in the Ground Cover Supplement. National meetings (Canberra 2009, Melbourne 2010, Perth 2011, Hobart 2012, Canberra 2013) were convened to provide a forum for groups to present and discuss their progress and to understand how their work on specific interventions fitted within overall efforts of the GRDC investment to improve crop and system WUE. Presentations were made available to all groups on the initiative website or via Dropbox. Four initiative newsletters on benchmarking (November 2009), fallow management (March 2010) and in-crop (canopy) management (March 2011) and the effects of interventions at the whole-farm scale (March 2012) have been prepared and distributed. A GRDC Ground Cover Supplement was prepared summarising a range of work in the initiative and published in March-April 2013.

In addition to the experimental and simulation activities outlined above, the CSIRO team was engaged in an enormous amount of communication, presentation and publication activities throughout the initiative, including field days, GRDC updates, grower group updates, consultant client meetings and bus trips. These assisted initially to set directions for research and then to communicate clear messages from the various themes of work. The close collaboration and embedded scientists within several of the regional groups further strengthened the flow of information within the initiative, and from it to the wider industry.

**Other research**

During the course of the initiative a number of other research opportunities were identified, some of which have already been developed into new project areas.

1. Value of break crops: The project results demonstrated that break crops can be profitable even in traditionally risky areas (e.g. work in Mallee by MSFS and Birchip) if a full account of the system benefits (N, weeds, diseases, water) are considered over several years. These early results from WUE were expanded within the wider Crop Sequencing Initiative.

2. Early sowing: The impressive yield and WUE benefits identified from the combination of good summer fallow management and early sowing of appropriate varieties has been developed into a new project.

3. Stubble initiative: the new GRDC productivity in Retained Stubble Initiative will provide an opportunity for the specific constraints to production in stubble-retained systems to be addressed. These cover a wide range of issues including N, disease, and weed management, and some will extend work initiated within the WUE initiative and within the same network of grower groups.

4. Higher rainfall zone (HRZ) initiative - The groups operating in the HRZ identified a much larger ‘yield gap’ between potential yield and grower yield during the course of the project, and this often related to soil constraints, waterlogging, N or disease management. The focus for these systems should be to use (i.e. transpire) more of the available water by ensuring other inputs are available in a timely way to capture the yield potential. A specific initiative targeting varieties, management, and greater water use in the HRZ should be developed.

5. Genotype x management interactions: This project focused on the synergies between pre- and in-crop management with suitable varieties as the hallmark of improvements to productivity and WUE. GRDC has embraced this philosophy through the closer scrutiny of management at National Variety Trials (NVT) sites and development of variety specific management.

Facilitating more ‘system synergy’ type projects that combine management and variety development for future farming
systems should be a priority.

**Additional information**


Thomas DT, Finlayson J, Moore AD, Robertson MJ (2010). Profitability of grazing crop stubbles may be overestimated by using the metabolisable energy intake from the stubble. *Animal Production Science* 50, 699-704


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