# Economic performance and system water-use-efficiency of farming systems

**Lindsay Bell[1], Andrew Zull[2], Darren Aisthorpe[2]**
[1] CSIRO Agriculture and Food
[2] Department of Agriculture and Fisheries

***Research Questions:*** *Can systems performance be improved by modifying farming systems in the northern grains region? | What is the impact on system WUE ($ gross margin return per mm of system water use)?*

## Key findings

1. Differences of $204-670/year were found between systems across sites.
2. Cropping intensity is the major factor driving good/poor economic performance.
3. A system water use efficiency of $2.50 of crop income/mm of rainfall over the cropping sequence is achievable and could be used to benchmark current farming systems.

## Background

Leading farmers in Australia's northern grains region perform well in terms of achieving the yield potential of individual crops. However, the performance of the overall system is harder to measure and less frequently well considered. Analysis suggests that fewer than one third of crop sequences achieve more than 80% of their potential water use efficiency despite having adequate nitrogen fertiliser inputs (Hochman *et al.* 2014). The key factors appear not to be related to in-crop agronomy but to the impact of crop rotations and are thought to relate to issues occurring across the crop sequence such as poor weed management, disease and pest losses, sub-optimal fallow management and cropping frequency. Similarly, farming systems are threatened by the emerging challenges of increasing herbicide resistance, declining soil fertility and increasing soil-borne pathogens, all of which require responses to maintain total system productivity. Questions are emerging about how systems should evolve to integrate practices that: maximise capture and utilisation of rainfall particularly when using high-value, low-residue crops; reduce costs of production and the likelihood of climate-induced risk; respond to declining chemical, physical and biological fertility; improve crop nutrition and synchrony of nutrient supply; suppress or manage crop pathogen populations; and reduce weed populations and slow the onset, prevalence and impact of herbicide resistance.

Because of the multi-faceted nature of these challenges, an important need is for a farming systems research approach that develops an understanding of how various practices or interventions come together, quantifies synergies or trade-offs and shows how these interventions impact on whole-of-system productivity, risk, economic performance and sustainability of farming systems. In this research we used the key metric of 'system water use efficiency' (WUE) to compare system productivity or profitability per mm of rain across environments and cropping systems. Importantly, this differs from commonly used 'crop water use efficiency' as it captures multiple years, with different crops, and accounts for both rainfall capture and loss during the fallow over a sequence of crops, the differences in the inputs required, as well as the productivity of different crops which may be influenced both positively, or negatively, by previous crops in the sequence or rotation. Hence, we have evaluated the system WUE as the $ gross margin return per mm of system water use (i.e. rain minus the change in soil water content) over the period of interest.

$$\text{System WUE } (\$\ GM/mm) = \frac{\sum\{(\text{yield} \times \text{price}) - \text{variable costs}\}}{(\sum rain + \Delta\, Soil\ water)}$$

## What was done

Experiments were established at seven locations; Pampas near Toowoomba (referred to as Core site with 38 systems) and six regional centres in Queensland (Emerald, Billa Billa, Mungindi) and northern New South Wales (Spring Ridge, Narrabri and Trangie) where 6-9 locally relevant systems are being studied. Across these experiments the farming systems differed in strategies that modify crop intensity, crop choice and fertiliser input approach. These different farming system strategies are not predetermined and hence play out differently in different locations, based on the environmental (climate and soil) conditions at that location.

1. **Baseline** approximates current best management practice in each district against which each of the system modifications are compared. It involves only dominant crops used in the district; sowing on a moderate soil water threshold (i.e. 50-60% full profile) to approximate moderately conservative crop intensities (often 0.75-1 crop per year); and fertilising to median crop yield potential.
2. **Higher crop intensity** aims to increase the proportion of rainfall transpired and reduce unproductive losses by increasing the proportion of time that crops are growing; this is implemented by reducing the soil water threshold required to trigger a planting opportunity (e.g. 30% full profile) so that cropping intensity is increased relative to the *Baseline.*
3. **Lower crop intensity** aims to minimise risk by only sowing crops when plant available soil water approaches full (i.e. >80% full), and higher value crops are used when possible. This requires longer fallows and will lower crop intensity relative to the *Baseline.*
4. **Higher legume frequency** aims for every second crop to be a legume across the crop sequence using high biomass legumes (e.g. faba bean) when possible.
5. **Higher crop diversity** uses a greater set of crops with the aim of managing soil-borne pathogens and weed herbicide resistance risk through crop rotations. This is implemented by growing 50% of crops resistant to root lesion nematodes (preferably two in a row) and two alternative crops are required before the same crop is grown in the crop sequence.
6. **Higher nutrient supply** increases the fertiliser budget for each crop based on 90% of yield potential rather than the *Baseline* of 50% of yield potential.

## System water use efficiency

Over the 3.5 years of experiments conducted for each system, data has been collected on the grain yields of crops, the total inputs of fertilisers, seed, herbicides and other pesticides, and operations. This has allowed the calculation of the accumulated income and gross margins for each of the cropping systems deployed at each location. Consistent prices for each commodity (10-year average adjusted for inflation) and inputs across locations were used to avoid introducing discrepancies in the data (Table 1). Grain yields were corrected to 12% moisture to account for variable harvest moistures.

**Table 1. Commodity prices (10-year average) for each crop grown across the farming systems experiments.**

| Crop | $/t grain# |
|---|---|
| Barley | 218 |
| Wheat (durum and APH) | 269 |
| Canola | 503 |
| Chickpea | 504 |
| Faba bean | 382 |
| Field pea | 350 |
| Sorghum | 221 |
| Maize | 281 |
| Mungbean | 667 |
| Sunflower | 700 |
| Cotton | 1090 ($480/bale lint) |

#farm gate price with grading and additional harvesting costs already deducted.

Prices for inputs of fertilisers, herbicides, other pesticides and seed were based on market prices at purchase for each input. Costs for operations differed by crop to reflect different contract rates or machinery requirements. It should be noted we have not attempted to correct for overhead or other fixed costs associated with the farming enterprise; these are likely to vary significantly from farm to farm and region to region.

## Results

As would be expected the total income and gross margins varied substantially across all sites, owing to the difference in rainfall, and hence crop productivity, and input costs required. There are large cost differences incurred between sites, due to differences in starting nutrient levels and weed status, which greatly influence the gross margin outcome between sites. For this reason, we focus mainly on comparing the economic outcomes between systems at the same site.

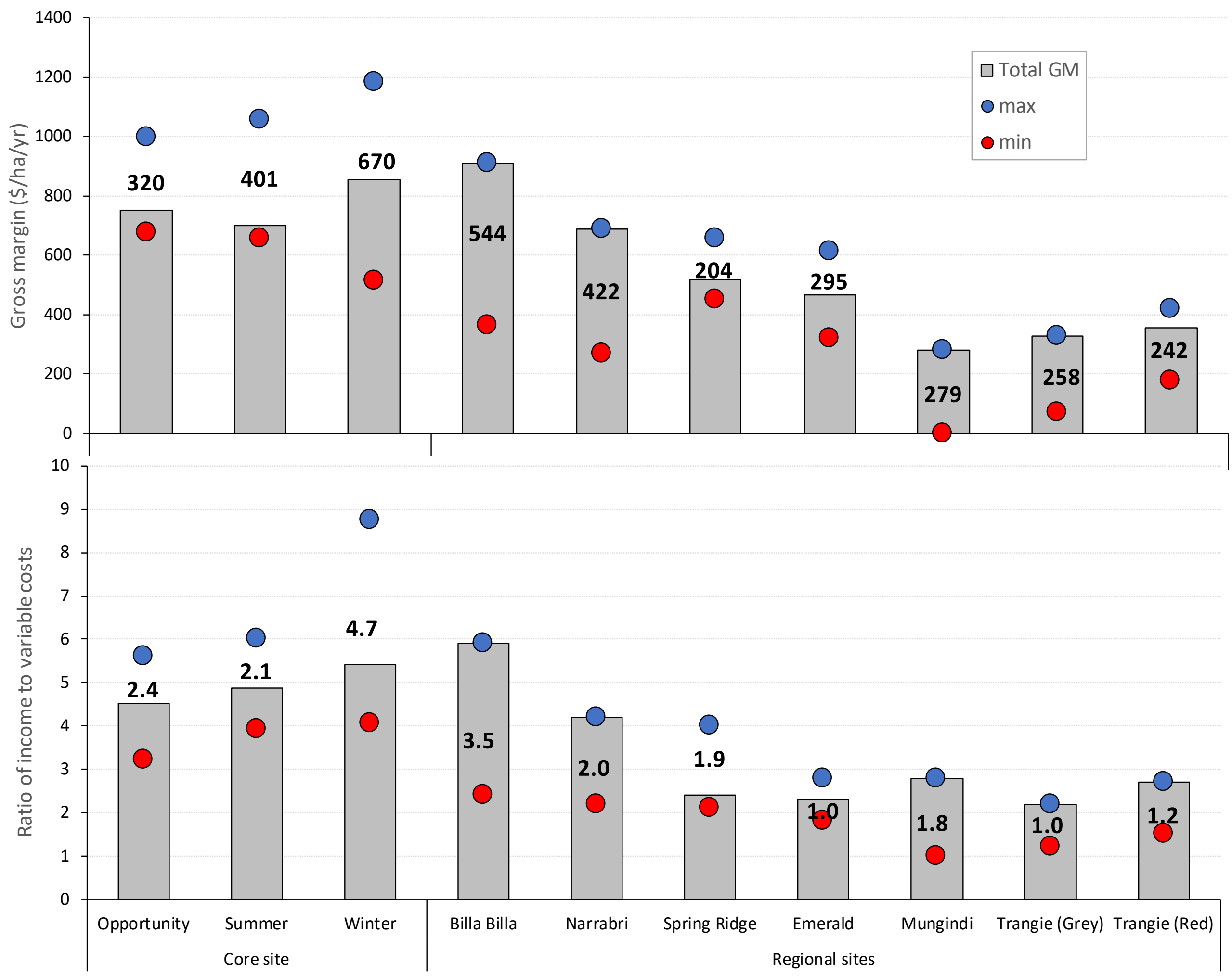


**Figure 1. Range in system gross margin ($/ha/yr) and ratio of income to variable costs between the best and the worst performing farming systems, compared to the *Baseline* across 8 farming systems experimental sites.**

Within each experimental comparison there was a significant gap between the best and the worst cropping system (Figure 1). The gap was highest at the core site in the winter rotation systems ($670/ha/yr) and lowest at Spring Ridge ($204/ha/yr). Similarly large gaps were observed in the return on variable cost ratios across the sites (1.0–4.7 difference), though the systems that were the best/worst for this metric were not necessarily the same. Overall, this highlights that there is a large difference in the profitability of farming systems within a particular situation. The best (or worst) system at each location was also not consistent. At most regional sites (except Emerald), the *Baseline* cropping system (designed to replicate current best management practice in a district) performed the best or as well as any altered system. At Emerald, the *Higher legume* and *Higher soil fertility* systems performed the best, $150/ha/yr higher than the *Baseline*. Amongst the Core site systems, the gross margin returns of the *Baseline* systems was exceeded by systems with *Higher crop diversity* or *Higher legume* by $120-$380 per year over the experimental period.

While there are several interesting differences between different farming systems at each experimental location, here we examine across the full range of sites how modifications to the farming system that were common across several sites (i.e. *Higher nutrient supply*, *Higher legume*, *Higher crop diversity*, *Higher crop intensity*, *Lower crop intensity*) have influenced the economic performance compared to the *Baseline* at each site. This was done by calculating the system WUE ($ GM/mm) in order to take out climatic influences and presented as a proportion of that achieved in the *Baseline* (Figure 2). This shows that systems employing the *Higher legume* and *Higher nutrient supply* systems were able to achieve similar system WUE to the *Baselines* at most sites. However, *Higher crop diversity* systems had highly variable impacts on system WUE, some sites

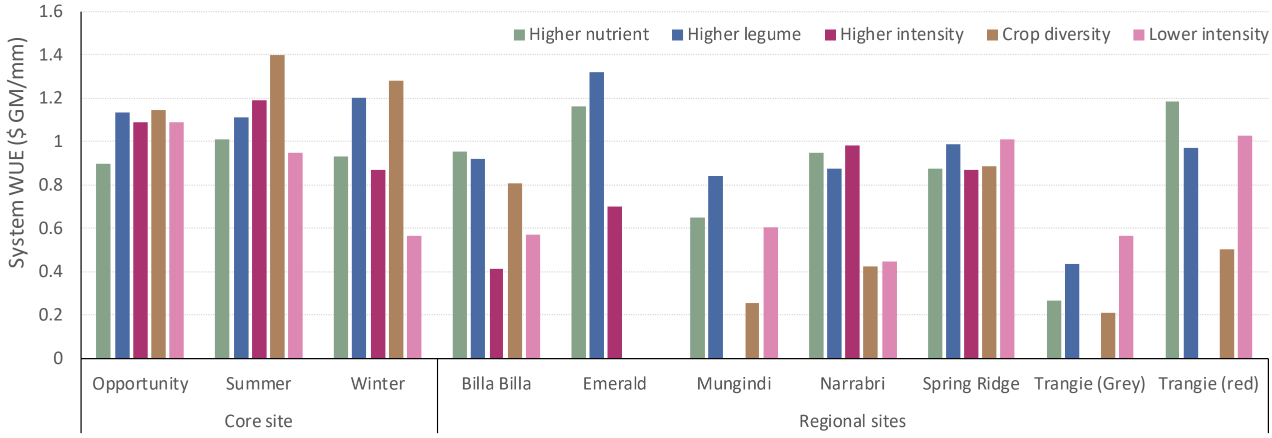


**Figure 2. Relative system water use efficiency (i.e. $ GM/mm) of modifying farming systems compared to the *Baseline* at five regional sites and under three different seasonal crops at the Core site (Pampas).**

increasing while other sites incurring a large cost. At the most favourable environments (Pampas, Spring Ridge and Narrabri), *Higher crop intensity* was able to maintain similar or slightly higher system WUE, however, there was a large cost from this strategy at other locations. Similarly, *Lower crop intensity* systems also reduced system WUE at several sites, but others achieved similarly to the *Baseline*.

## Implications for growers

The economic performance of the farming system integrates many of the various factors that may influence their short and long-term productivity (water use efficiency, nutrient inputs and balance, yield responses to crop rotation). Across all farming systems sites, several of the modified farming systems could achieve similar or even greater profits, however this was not consistent across all sites. That is, in many cases there are options to address particular challenges (e.g. soil-borne diseases or weeds, nutrient run-down) that can be profitable. However, in some locations the options seem much more limited, particularly where risky climatic conditions (or challenging soils) limit the reliability of alternative crops in the farming system. The results here provide a snapshot in time over only a 3.5 year period. The longer term impacts of some of these farming systems strategies may yet to be fully realised and hence, some consideration of these results against this longer-term view is also required.

## Acknowledgements

This research was conducted as part of Grains Research and Development Corporation funded projects CSA00050 and DAQ00192. We thank all the contributing field and farm staff for their hard work and participating farmers and advisors hosting these experimental sites.

## References

Hochman Z, Prestwidge D and Carberry PS (2014). Crop sequences in Australia's northern grain zone are less agronomically efficient than the sum of their parts. Agricultural Systems 129, 124-132.

Core site 2017.