Through the looking glass: relative performance of farming systems of the future

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Abstract
Farming systems of the future need to evolve to be more resilient to a range of emerging challenges to their long-term sustainability and profitability. This research has examined how changing some of the strategies to address some of these impacts on the performance of farming systems in Australia's summer-dominant cropping regions. We conducted a set of farming system experiments for five years to examine how altering decisions based on soil water available at planting, crop choice in rotations, and fertiliser input strategies impacted a range of performance indicators. There were significant differences in system profitability, with systems ranging in gross margins of > $300/ha/yr and return on variable costs by 2-fold at most sites. No system modifications consistently increased system performance but cropping intensity or the soil water threshold required to trigger sowing of crops was the most influential decision on system performance.

Keywords: pathogen, water, nitrogen, break crops, fallow, economics, WUE

Introduction

Farming systems are facing numerous challenges to maintain their long-term sustainability and profitability. Farming systems need to evolve to be more resilient to changing climatic conditions with increasing rainfall variability, declining soil fertility and function, increasing soil-borne pathogens, increasing prevalence of herbicide resistance and problem weeds. There are questions about how different farming system approaches will impact various farming system elements. These questions include: how can we maximise the capture and utilisation of rainfall? How do we reduce the risk of crop failure? How can we suppress or manage crop pathogen populations or weeds and slow the onset or prevalence of herbicide-resistant weed populations? How do we maintain the soils capacity to provide adequate nutrients to crops when they need them? How do we reduce the reliance or costs of external inputs? How do we minimise our demand on labour and overhead operating costs? All these questions are those that challenge the decision making of farmers. However, because of the multi-faceted nature of these challenges, a farming systems approach is required to understand how various practices or interventions come together and quantify synergies or trade-offs. There is also a need to understand how these interventions may impact the whole-of-system productivity, risk, economic performance, and sustainability of farming systems.

The paper reports on a set of long-term farming systems experiment conducted over five years across Australia's summer-dominant rainfall zone. Farming systems in this region are particularly complex, with a broad range of potential crops with a range of sowing windows in summer and winter, different soil water requirements for these crops, and the capacity to store soil water during fallows for subsequent crops. Hence, farmers have a complex set of decisions that drive the farming system, with diverse management approaches being used depending on soil and climatic environment. We established experiments comparing different system 'strategies' with associated decision-making rules designed to address critical current and emerging issues for farming systems to monitor how these impacted a diverse range of performance indicators.

Methods

Systems experiments and rationale

We established experiments in 2015 at seven locations; a core experimental site at Pampas near Toowoomba (38 systems) and six regional centres across central and southern Qld (Emerald, Billa Billa, Mungindi) and northern NSW (Spring Ridge, Narrabri and Trangie) each comparing 6-9 locally relevant systems. Together, this constituted 85 systems × sites combinations that were monitored for five years (2015 to 2020). A common set of system treatments were implemented across each regional site. At the same time, the core experiment also investigated interactions between these systems for a variety of crop rotations represented across the northern grains zone (summer crop- and winter crop-dominated or opportunistic involving both summer and winter crop options). A local baseline treatment (designed to represent local best practice) was compared against a set of modified farming system treatments at each site. These treatments involved altering the decision-making strategies or rules that allow the farming system to respond to the climatic and soil conditions it faces and the crop suite and management relevant at each location (outlined below). Hence, the system treatments induce different crop sequences across locations, but these are based on a common approach or rationale.

In this paper, we focus on those systems deployed across multiple sites.

a) ***Baseline*** –approximates the current best practise in a region, involving sowing crops when moderate levels of soil water have been reached (i.e. 50-60% of plant-available water (PAW)) with a limited set of only main crops used (e.g. sorghum, wheat, chickpea) and fertiliser inputs budgeted to meet demands of median crop yield predictions for that sowing time and soil water status.
b) ***High nutrient supply*** **–**replicates the *Baseline* except that fertiliser inputs are budgeted to meet crop yield predictions for the 90th percentile for that sowing time and soil water status.
c) ***High legume frequency*** **–**aims to achieve at least 50% of crops grown are legumes, and preference is given to increased biomass, and N fixation legumes are used (*e.g.* fababean, lupin, field pea).
d) ***Crop diversity*** **–**tests using a greater range of crops in rotations to manage disease threats and herbicide resistance. For example, over 50% of crops are resistant to root-lesion nematodes (*Pratylenchus thornei*), crop species are not repeated within two years, and crop choices should allow rotation of in-crop herbicide mode of action (*e.g*. rotating broad-leaf and cereals).
e) ***High crop intensity*** **–**involves sowing crops on a lower soil water threshold to increase the proportion of time that crops are growing and reducing time in fallow. In some cases, this involved adding additional crops to capitalise on double-crop opportunities (*e.g.* mungbeans).
f) ***Low crop intensity*** **–**involves sowing crops only when PAW approaches maximum storage (i.e. > 80%) requiring longer fallows, but higher value crops (*e.g*. dryland cotton) are preferred to capitalise on the stored water.

Over the life of these experiments, we have measured a range of attributes, including soil profile water and mineral nitrogen dynamics, crop productivity, nutrient removal and utilisation, soil-borne disease inoculum loads, and production inputs. Using this data, we have calculated a range of performance indicators, including profitability, risk, resource-use-efficiency, nutrient balance, pathogen populations, soil function, pesticide inputs and load, labour and machinery operation requirements. Here we present just a selection of these to illustrate the impact of some of these farming system changes and decisions.

Results

The decision making framework established for each farming system strategy has produced divergent choices in crop types and sequences grown, cropping intensities (or the number of crops grown), and fertiliser and other inputs at each of the sites. It is notable that these choices, and hence the effects that have resulted, are not consistent across these experiments due to differences in their climate and weather experienced, viable crop options available and soil fertility status and paddock history. Nonetheless, together there are several trends that are particularly evident across sites.

First, there was an extensive range in gross margin within any one site between the best and worst system; exceeding over $200/ha/yr at most sites. Similarly, a wide range in return on variable costs (ROVC) was found, often varying by more than 2-fold within the site.

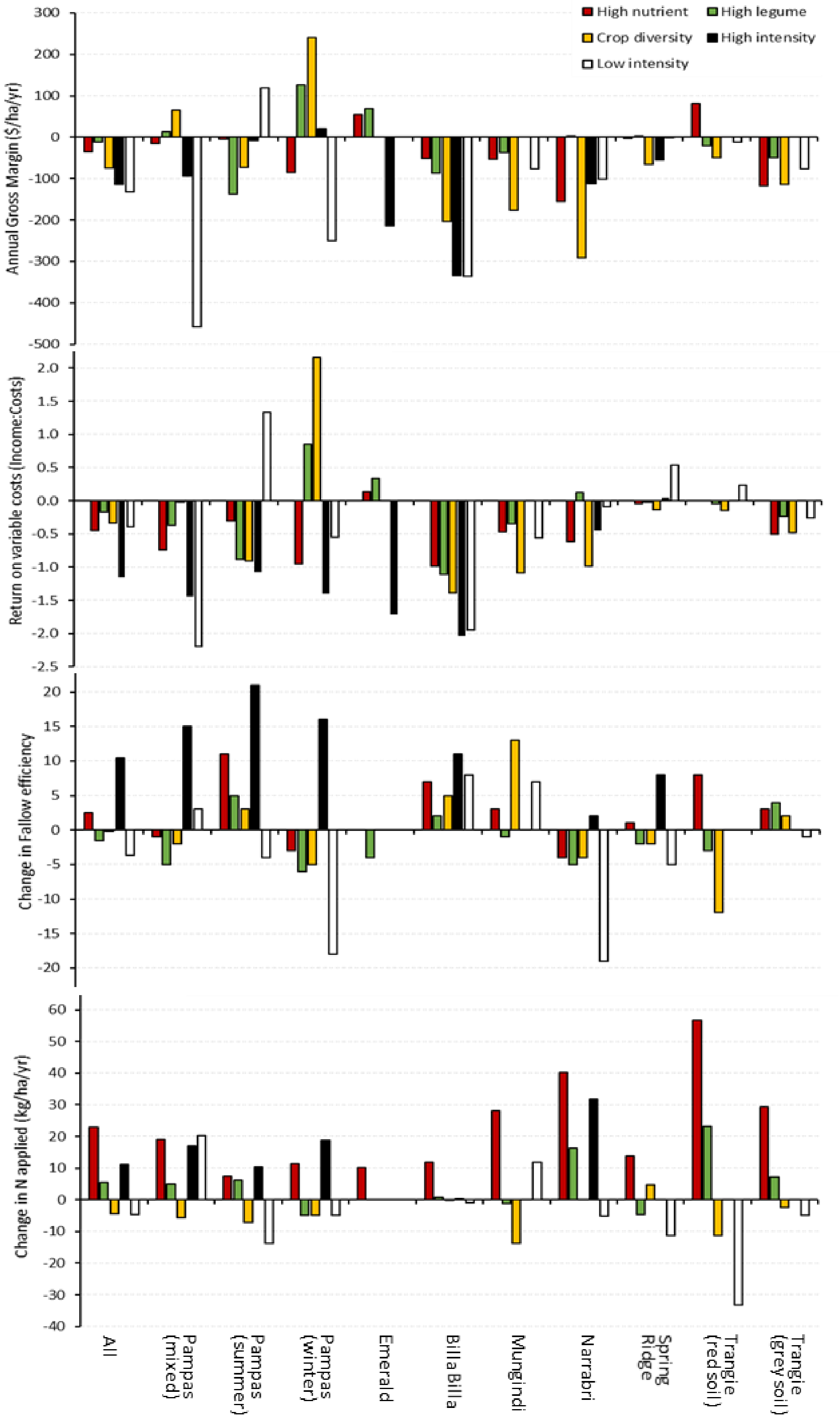

Figure 1. Differences in selected system performance indicators after five years between the baseline farming system and modified system strategies implemented over ten experimental sites distributed across the sub-tropical grain production region.

Second, only rarely did any modified farming systems achieve significantly higher gross margins than the *Baseline* deployed at each site. When averaged across all site comparisons, the intensity of the farming system has had the most influence on profitability, producing $114/ha/yr and $132/ha/yr lower returns from the *Higher* and *Lower* intensity systems, respectively. Higher intensity systems often incurred significantly higher variable costs and inputs, and hence lower ROVC. While increasing crop intensity often increased fallow efficiency and rainfall capture, this was often not used most efficiently to produce profitable crops (see Erbacher et al. 2021). *Lower intensity* systems often reduced the efficiency of fallow rainfall accumulation due to longer fallows with lower ground cover, and not always were the subsequent crops sufficiently profitable to compensate for this.

The *High nutrient* and *Higher legume* strategies had only slightly lower reductions on the gross margin on average ($-35/ha/yr and $-15/ha/yr, respectively). This lower margin was attributable to the higher inputs of fertiliser in the *High nutrient* strategy. With dry seasonal conditions predominating across these experimental years, only two crops had a significant yield response to higher fertiliser inputs. These two cases were the two locations where the *High nutrient* strategy increased gross margin and achieved equal ROVC, indicating that this strategy may have resulted in the more favourable outcomes over the long term with more favourable seasonal conditions. A somewhat surprising result was that the *high legume* systems increased fertiliser input requirements rather than reduce them. This increased fertiliser input requirement could be due to the significant depletion of soil mineral N and high yielding crops exporting large amounts of N from the system (see Baird et al. 2021). The *High legume* systems also often incurred higher variable production costs (e.g. pesticide costs) and reduced efficiency of fallows due to providing less persistent ground cover.

Finally, increasing *crop diversity* as a strategy to manage biotic threats had highly variable outcomes across sites, but on average, it achieved a $74/ha/yr lower gross margin. Many of these systems saw a reduction in the presence of populations of important diseases (e.g. root-lesion nematodes, crown rot). However, they also had a higher diversity of herbicides used, demonstrating that there are often risks and potential losses when system responses to these threats are required.

Conclusion

This research has demonstrated that farming systems decisions such as the soil water required for sowing and crop choice are critical drivers of profitability. These can result in large differences in gross margin and return on input costs. Hence, understanding the implications of these decisions on multiple aspects of the farming system is critical. The intensity of the farming system is the proportion of time when crops are growing, and the associated reliance on in-crop *versus* soil water accumulated during fallows is a significant driver of many performance indicators. Therefore, understanding soil water availability and factors influencing its accumulation and utilisation (e.g. ground cover) is the vital information required to make better decisions that ultimately result in improved system profitability over the long term.

References

Baird J, et al. (2021). Cropping intensity and crop choice influence long-term mineral N cycling and balance within north-east farming systems. *In* Proceedings of the 20th Australian Agronomy Conference, 17-21 October 2021, Toowoomba, QLD.

Erbacher A, et al. (2021). Water-use-efficiency is improved by storing more water before planting. *In* Proceedings of the 20th Australian Agronomy Conference, Toowoomba, 17-21 October 2021.