Understanding the risk and return of intensifying a rotation with opportunity crops.

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Abstract

Debate exists around the design of crop rotations in the northern grain's region. Increased intensity by the inclusion of more crops and fewer fallows has demonstrated increased returns. The adoption of opportunistic sequences has highlighted the value of flexibility, while the more conservative fixed rotation with long fallows has demonstrated greater resilience. Can the best attributes of these different systems be combined to improve returns without increasing risk in this variable environment?

A simulation study was used to assess different rule-based triggers with the aim of reducing the risk of crop failures while cautiously increasing cropping intensity. Strict rules based on soil water at planting increased cropping intensity, improved average annual sequence returns (by 28%) while increasing the risk of negative gross margins by only 3%.

Keywords

Rotation, crop-intensity, decision rules,

Introduction

The northern grains zone of eastern Australia lies to the west of the Great Dividing Range and extends from central Queensland in the north to central NSW in its south. The general climate is subtropical with a summer rainfall dominance that decreases from the north (80:20) to the south (60:40). Annual rainfall declines from the east (750mm) to the west (350mm) and the area is characterised by a variable climate, with high evaporation and high intensity rainfall events (Webb et al., 2007). The dominant grain producing soils are self-mulching clays with an average plant available water capacity (PAWC) of 182mm to a depth of 1.8m (Hochman et al., 2001).

The construction of rotations generally follows a hierarchy of decisions that are tempered by the environment, the personal preferences of the farmer, their risk profile, existing weed, disease and pathogen burdens and historic management decisions, current markets and prices. From an individual crop perspective, the value of stored soil water and the risk and return associated with its availability have been well documented (Angus et al., 1980; Moore et al., 2011; Whish et al., 2007). Despite this work, Hochman,(2014) highlighted the high yield gap for individual crops within the region and suggested inefficiencies within the sequences would extend this gap. The use of fallows between crops to capture and store rainfall and ensure reliable yields at the individual crop level (Hunt and Kirkegaard, 2011; Thomas et al., 2007) has been identified as an area of inefficiency (Hochman et al., 2014; Rodriguez et al., 2014) and provides the opportunity to increase cropping intensity.

However, the trade-off with increasing intensity is an increase in yield variability, resulting in an increase in the number of failed and unprofitable crops. This work looks to test decisions based on environmental triggers to opportunistically increase intensity when soil water resources are plentiful, with the aim of increasing profit while minimising the risk of unprofitable crops.

Methods

Rotation design

Building on previous, participatory research and simulation studies (Hochman et al., 2020; Whish et al., 2019), interviews with local grower and consultant focus groups were used to identify feasible cropping rotations. Follow up discussions focused on flexible phases within the rotations identified practical areas to increase cropping intensity. Easily measured practical decision rules were created and tested within the modelling scenarios.

Modelling

The rotational sequences (Table 1) were created using the active-graph rotation (Rodriguez et al., 2011) and manager2 modules within APSIM (Holzworth et al., 2014) that allows alternative rotation paths (flows) dependent on the resources within the system to select alternative crops (state). The simulations of all crop rotations were phased, to ensure each year of the rotation was exposed to each year of the climate record (1956-2017).

Environments

The rotational sequences were applied to six different environments across the northern grains region; however, only data for Billabilla' Balanced conservative rotation will be presented.

Table 1. Description of low and high intensity rotations where all crops are sown every year and opportunistic crop rotation, where some crops are only grown when soil water exceeds a minimum threshold (underline).

Rotation Intensity	Winter		Balanced - conservative		Balanced - aggressive	
	Crops	/yr	Crops	/yr	Crops	/yr
Low	xW|xx|xCh|xx	0.5	Sx|xCh|xW|xx	0.75	Sx|xW|xx	0.66
High	xW|xW|xCh|xW	1.0	Sx|xCh|xW|Mgx	1.0	SCh|xW|Mgx	1.33
Opport.	xW|x<u>W</u>|xCh|x<u>W</u>	0.5-1.0	Sx|xCh|xW|<u>Mg</u>x	0.75-1.0	S<u>Ch</u>|xW|<u>Mg</u>x	0.66-1.33
					S<u>Ch</u>|xW|xx	0.66-1.0

W= Wheat, Ch = Chickpea, Mg = Mungbean, x= 6 month fallow.

Economic analysis parameters

Sequence annual gross margin ($/ha/yr) was calculated using simulated outputs of grain yield, N requirements and number of weed germination events during fallows, using the equation below(Whish et al., 2019). These assumed long-term average grain prices and current variable input prices for each crop (Table 2).

$$GM_{seq}(\$/\text{ha/yr}) = \frac{\sum\{(\text{Grain yield} \times \text{price}) - (\text{kg N} \times 1.3) - (sprays \times 17) - \text{variable costs} - \text{harvest costs}\}}{no.of\ years}$$

Crops were considered as failed if the yield was less than the threshold (Table 2) and in this case harvesting costs were not included. Machinery costs were based on an owner-operated production system; therefore, fuel, oil, repairs and maintenance (FORM) costs were included in the variable costs.

Table 2. Ten year average prices and variable costs used in gross margins for crop sequences

Crop	Average price ($/t)[#]	Harvest cost ($/ha)	Variable costs ($/ha)	Failed Crop (kg/ha)
Wheat	264	40	175	500
Sorghum	225	55	218	800
Chickpea	569	45	284	340
Mungbean	710	55	276	300

[#]*farm gate price with grading & additional harvesting costs already deducted*

Results

The results highlight that the balanced-conservative low intensity rotation with a cropping frequency of 0.75 had the lowest mean annual gross margin, but was the least risky with 8% of the crops having a negative gross margin (Figure1a). The high intensity treatment (crop intensity of 1) increased the mean annual gross margin by $66/ha, but nearly doubled the chance of having a negative gross margin. The opportunity approach of using soil water to target a decision achieved the best mean annual gross margin while only increasing the risk of a failed crop by 3% compared to the low intensity treatment.

In the lowest 20% of gross margins (worst 20%) the high intensity rotations returned the highest gross margin identifying under variable conditions sometimes the decision not to plant comes at a cost (Figure 1b).

If drainage and runoff are considered environmental indicators both the opportunistic and high intensity strategies performed equally and reduced losses compared to the conservative low intensity approach that was the leakiest (Figure1c).

The return on investment is a good indicator of how much it cost to achieve an annual gross margin. In this case the failed crops of the high intensity strategy, reduce the net benefit to below 1 while the opportunity cropping approach performed better than 1:1 (Figure 1d).

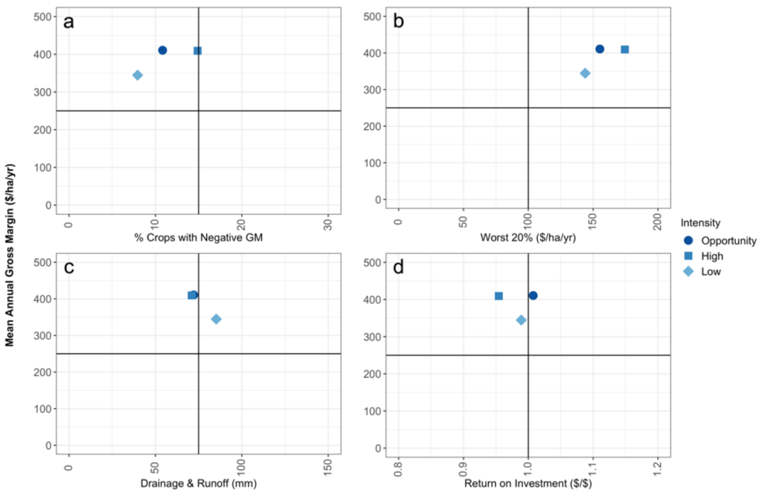

Figure 1. The trade-off between mean annual gross margin and (a) the percentage of crops that generated a negative or $0 Gross margin. (b) Worst 20%, as the gross margins from the 20th percentile of seasons. (c) Loss of water through drainage and runoff. (d) Mean annual return on investment. For the Balanced conservative rotations at Billabilla.

Table 3 Contribution to mean annual gross margin of each crop

Crops	Low Sx|xCh|xW|xx 0.75/crop/yr ($/yr)	High Sx|xCh|xW|Mgx 1.0/crop/yr ($/yr)	Opportunity Sx|xCh|xW|Mgx 0.75-1.0/crop/yr ($/yr)
Sorghum	101	73	83
Chickpea	157	156	156
Wheat	72	79	78
Mungbean	-	88	105
Total	330	396	422
Crops/year	0.75	1	0.93

Breaking the sequences down to their individual crop phases, highlights how the opportunity cropping rules benefit the sequence (Table 3). The opportunity cropping rotation had 7% fewer crops than the high intensity sequence; however, choosing not to plant in these situations increased the average annual sorghum return by $10/ha/year and mungbean by $17/ha/year. Showing that sowing fewer, well-resourced crops is a more profitable approach, compared to only increasing cropping intensity.

Conclusion

These results highlight the importance of a balanced approach when modifying cropping sequences and the importance of understanding the trade-offs and costs of changing cropping intensity. Matching sequence intensity to the environment and including flexibility to minimise risk are key to structuring the rotation. For the balanced conservative rotation at Billbilla having a rigorous pre sowing decision point ensured the opportunistic double crop (mungbean) was significantly more profitable, reducing mungbean failures increased the profitability of the following sorghum crop. Because, failed crops reduce the availability of resources and reduce the returns over the whole sequence.

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