Short and long-term profitability of different farming systems - southern Qld

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Key words

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Take home message

- Farming system decisions – crop choice and soil water required for sowing can have a large influence on system profitability over the short and long-term; differences of >$100/ha/yr occur regularly.
- Systems involving alternative crop types can not only help manage biotic threats (e.g., diseases and weeds) but also be profitable compared with conventional systems.
- While the last 6 years have presented a diverse range of seasons, this period in general has not favoured alternative farming systems compared to the Baseline.
- Simulated predictions of relative profitability of the systems generally correspond well with those calculated from experimental data over the same period.

Introduction

The northern farming systems project has been examining how different farming system strategies impact on various aspects of the farming system since 2015. Across a diverse range of production environments, we have tested the impacts of changing:

A. the mix of crops grown by increasing the frequency of legumes or diversifying crop choices to provide disease breaks, or

B. the intensity of the cropping system by either increasing it by reducing the soil water threshold to sow more crops or by reducing it and only growing higher profit crops once the soil profile is full; and

C. the supply of nutrients provided to crops.

Despite now collecting over 6 years of data on each of these different farming strategies, the full range of climatic conditions that are experienced across the region have not been captured. In particular, most sites have experienced extremely dry periods over the past 6 years, which is likely to bias or favour some particular farming systems. Simulation modelling can be useful to help explore how the different farming strategies might perform over the longer-term and under a range of climatic conditions. In this paper we compare APSIM predictions of system profitability over the long term with those for the period 2015-2020. This paper reports specifically on results from the two sites in southern Qld at Billa Billa (Western Downs, near Goondiwindi) and Pampas (Eastern Darling Downs near Brookstead).

System simulations and estimates of profitability

The different farming systems were simulated from 1957 to 2021 using APSIM. Soils used in simulations were those characterised at each location, and long-term climate data was sourced from the closest meteorological station. For each farming system at each location, the simulation was provided a list of crops (prioritised), their sowing window, and minimum soil water required to allow them to be sown. An example of the rules dictating crop choices at both sites are outlined in Table 1; each site varies in the crop choices, their sowing dates and soil water thresholds but the general rules dictating crop choice were constant.

Table 1. Rules associated with crop choice, crops available and their plant-available water threshold required to be sown in the Baseline and 3 modified farming systems at Trangie red and grey soil sites. * indicates that crop not included at that site in that system

System	Crop choice rules	Crops	Soil water threshold (mm PAW)	
			Pampas (PAWC = 250 mm)	Billa Billa (PAWC = 180 mm)
Baseline	No more than 3 winter cereals or sorghum in a row	Wheat	150	90
		Chickpea	150	90
		Barley	150	90
		Sorghum	150	120
	≥2 yrs between chickpea	Mungbean	100	*
High legume frequency	*As above +* Legume every second crop	*As above +*		
		Fababean	150	120
		Fieldpea	150	*
		Soybean	200	*
		Mungbean		80
Higher crop diversity	*As in Baseline +* ≥1 yr break after any crop ≥50% crops nematode resistant	*As above +*		
		Canola	200	150
		Sunflower	150	90
		Millet	120	100
		Maize	200	*
		Cotton	200	150
		Fieldpea		90
Higher crop intensity	*As in baseline*	Wheat	100	50
		Chickpea	100	50
		Barley	100	50
		Sorghum	100	100
		Mungbean	70	70
		Fababean	*	90
Lower crop intensity	*As in baseline*	Wheat	200	150
		Chickpea	200	*
		Barley	200	150
		Sorghum	200	150
		Mungbean	150	*
		Cotton	200	*
		Millet Cover crop		50

Revenue, costs and gross margin for each crop were calculated using predicted grain yields and estimates of crop protection, non-N fertilisers and operational costs for each crop (see Table 2). Fertiliser inputs were simulated dynamically based on a crop budget targeting a median yield (N fertiliser was costed at $1.30/kg N), and fallow herbicide applications ($15/ha/spray) were also predicted using the model based on the number of germination events that occurred.

Table 2. Assumed prices (10-year average, farm gate after grading/bagging/drying) and variable costs for inputs and operations (e.g., seed, pesticides, starter fertilisers, sowing, spraying) and harvest costs (for viable yields only) for each crop simulated.

Crop	Price ($/t product)	Variable crop Costs ($/ha)	Harvest costs ($/ha)
Wheat	269	175	40
Durum	335	175	40
Barley	218	175	40
Chickpea	504	284	45
Sorghum	221	221	55
Mungbean	667	276	55
Faba bean	382	341	40
Field pea	382	341	40
Canola	503	351	70
Soybean	607	305	55
Sunflower	1052	365	55
Maize	250	218	55
Millet	564	350	70
Cotton	1800[A]	774	280

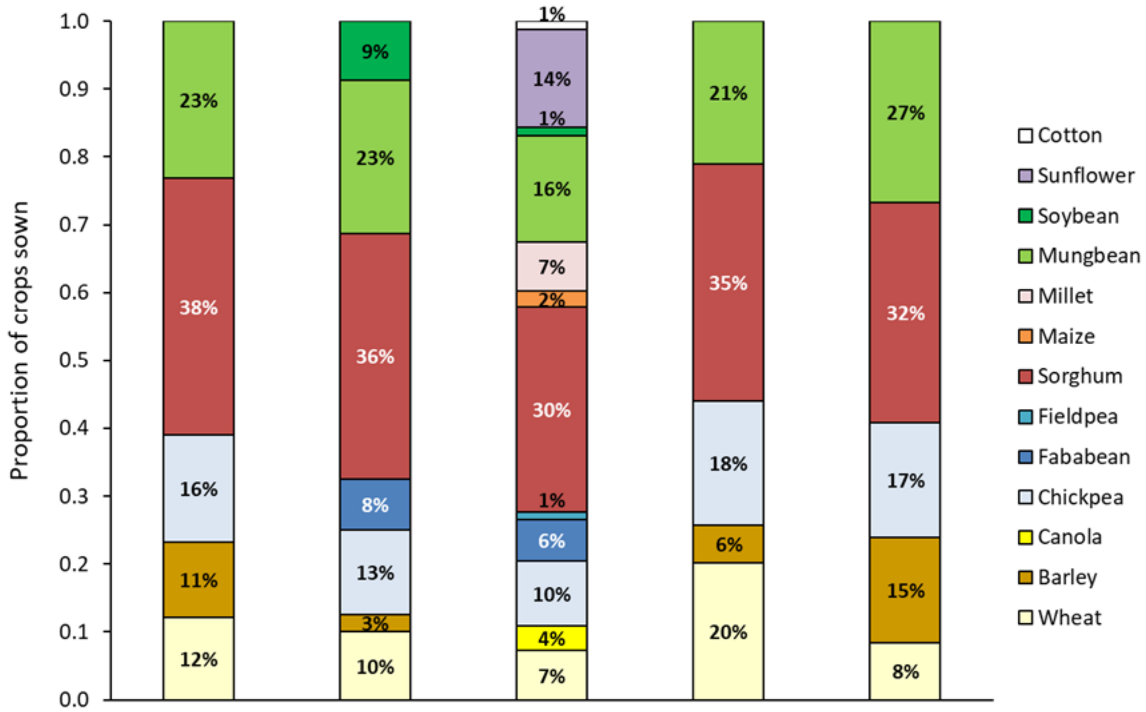
A – Calculated on total harvest assuming 45% cotton lint turnout and 55% seed.

Because of the dynamic nature and range of different crops across these simulations, we generated only a single crop sequence over the simulated period. To allow analysis of the climate-induced variability, we aggregated the system gross margins over sequential 6-year; for example, from 1957-1962, 1958-1963 and so on. Hence, we were able to compare what the simulations predicted would occur during the experimental period of 2015-2020 at Pampas and 2016-2021 at Billa Billa compared to more than 50 other 6-year periods. This allows us to examine how this period compared with longer-term conditions. We were also able to compare the relative performance of the different simulated systems over this period compared to their relative performance from our experimental data. Differences in how costs were calculated, with simulations assuming a set crop input cost, meant there was always a difference in the actual gross margins estimated from the model compared to the actual costs attributed in the experiments.

Crop sequences & frequencies amongst simulated systems

The simulation rules imposed (Table 1) resulted in some clear changes in the frequency and types of crops grown in the farming systems (Figures 1 and 2).

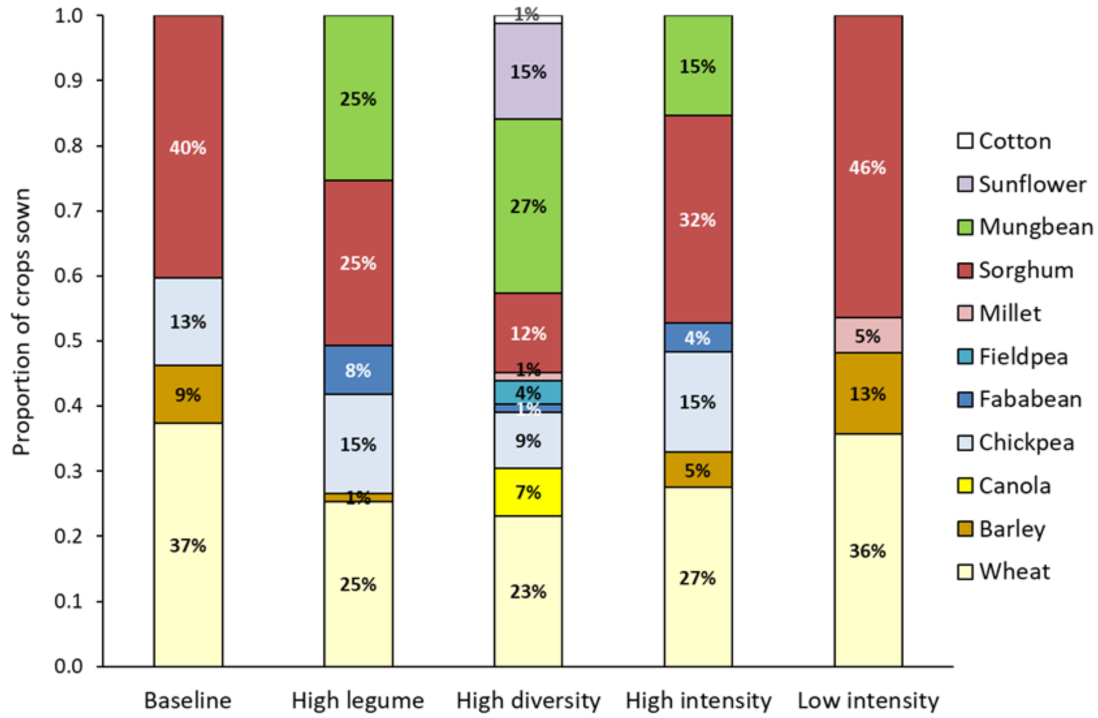
At the Pampas site, the *Higher legume* system resulted in some additional soybean crops and fababean replacing barley in the crop sequence (Figure 1). The *Higher crop diversity* system saw a drop in both legume and cereal frequency and less winter crops grown. Oilseeds increased to 20% of the crops grown - canola replacing barley and sunflowers replacing sorghum. Millet also often substituted for mungbean as a summer double-crop and maize occasionally replaced sorghum. The *Higher intensity* strategy (*i.e.,* lower soil water thresholds to sow crops) saw an increase in crop frequency by about 0.4 crops/yr (i.e., an additional 24 crops over the 60 year simulation), but the mix of crops was fairly similar to the *Baseline*. The *Lower intensity* system (*i.e.,* a higher soil water threshold to sow crops) saw the crop frequency drop by 0.2 crops/yr – less than might be expected; the proportion of different crops also remained fairly stable except early-sown barley often replaced wheat.



	Baseline	High legume	High diversity	High intensity	Low intensity
Crops/yr	**1.27**	**1.24**	**1.29**	**1.69**	**1.10**
% Winter	39	33	28	44	41
% Cereal	61	49	47	61	56
% Legume	39	51	34	39	44
% Oilseeds	0	0	19	0	0

Figure 1. Cropping intensity (crops/yr) and the proportion of different crops simulated under different farming system strategies at Pampas over the long-term.

At the Billa Billa site, the *Higher legume* system with the addition of mungbean crops as an option, saw them now constitute ¼ of crops sown, replacing sorghum but also allowing an increase in crop intensity (Figure 2). Fababean crops also replaced barley in the crop sequence (Figure 2). The *Higher crop diversity* system less winter crops grown, with an increase in summer opportunity crops (mainly mungbean). The frequency of sorghum also dropped, replaced by mungbean, sunflower and occasional crops of millet or cotton. Canola was also incorporated often instead of barley, and field pea replaced chickpea occasionally. The *Higher intensity* strategy (*i.e.,* lower soil water thresholds to sow crops) saw an increase in crop frequency by about 0.3 crops/yr (i.e., from 1.04 to 1.35 crops per year), mainly due to the incorporation of mungbean double crop as an option. The *Lower intensity* system (*i.e.,* a higher soil water threshold to sow crops) saw the crop frequency drop by 0.2 crops/yr and this included just cereal crops with chickpea not amongst the crop choices in this scenario.



Crops/yr	**1.04**	**1.20**	**1.23**	**1.35**	**0.82**
% Winter	56	48	44	46	51
% Cereal	87	52	37	65	100
% Legume	13	48	40	35	0
% Oilseeds	0	0	23	0	0

Figure 2. Cropping intensity (crops/yr) and the proportion of different crops simulated under different farming system strategies at Billa Billa over the long-term.

Long-term predictions of system profitability

Figure 3 shows the range in average annual gross margin predicted over all the 5-year periods between 1957 and 2020 amongst the 4 different farming systems at both sites. These are arranged from the lowest to the highest to show the distribution of these predictions as a result of climate variability (note prices are held constant at 10-year average values).

At both sites, the *Higher intensity* system (grey circles) frequently exceeds the profit generated in either the *Baseline* or *Low intensity* systems, particularly under more favourable conditions. However, the *Higher intensity* system produces the lowest returns in the lower profit periods, particularly at Pampas. On the other hand, the *Low intensity* system (white circles) performs relatively well compared to *Baseline* and *Higher intensity* systems under the lower production and profit periods, exceeding them around 40% of the time.

The systems that alter the mix of crop (either *Higher legume* frequency or *higher crop diversity*) are predicted to generate higher profits reliably at both sites. In general, they achieve similar potential profits to the other systems in the lower profitability periods but potentially offer significant upside under more favourable conditions. In particular, these systems were able to offer a broader range of crop options to make use of seasonal rainfall and hence was more able to make use of additional crop opportunities when they occurred.

At the Pampas site the predicted returns over the experimental period (2015-2020) were in the lowest 10% of occurrences in all systems. Based on these predictions this indicates that we would expect relatively small differences in profit amongst the systems over this period and the lower intensity system may be more favoured relative to the other systems as a result.

In contrast the period of 2016-2021 at Billa Billa, was predicted to represent a median outcome (i.e., 50th percentile) amongst the longer-term conditions in both the *Baseline* and *High intensity* systems. The *Low intensity* system ranked about the lowest third of periods, while the *High Legume* and *Higher diversity* systems over this period ranked about the 25th percentile and 15th percentile, respectively.

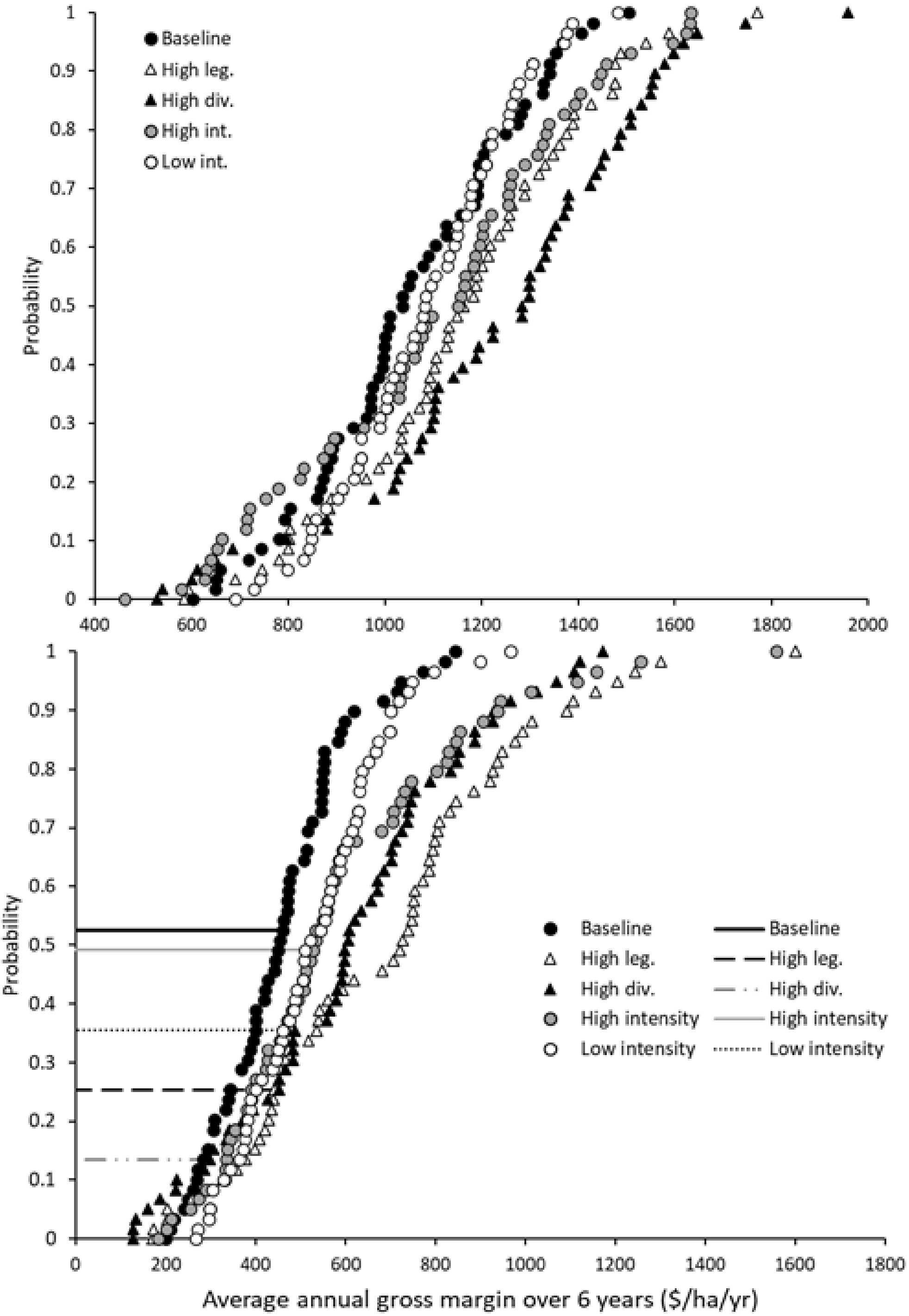


Figure 3. Distribution of simulated gross margins (average of 6-years) over 60 years period (1957-2020) of different farming systems strategies at Pampas (top) and Billa Billa (bottom). Each dot indicates the outcome of a 5-year period and the lines indicate the predicted GM for the 2015-2021 period.

Short-term (experimental period) relative to the long-term

When the relative returns achieved from the various systems over the same 6-year period are compared to the *Baseline* system, this shows that the modified farming systems frequently produce higher average returns (Figure 4). At both sites, the *Higher diversity* systems produced higher returns 85% of the time, *Higher legume* systems 70% of the time, *Higher and lower intensity* systems about 60-70% of the time. However, particularly at the Pampas site, the different intensity systems also had significantly lower profit in some periods.

When just comparing the modelled differences between the *Baseline* and the various other systems over the experimental period (indicated by the larger symbols in Fig 3), the predictions at Pampas were that the *higher intensity* system was predicted to be about $150/ha/yr behind, the *higher legume* system was predicted to be $70/ha/yr ahead of the *Baseline,* while the other two systems achieved similar gross-margins over that period (within $40/ha/yr). These predictions align very closely with the observed differences in calculated gross margins calculated over the same period using the experimental data (indicated with the vertical lines). The only exception is that experimentally the *Low intensity* has performed worse compared to the *Baseline* than was predicted by the model.

At Billa Billa, the *Low intensity* and *Higher intensity* systems in the experiments have generated significantly lower returns compared to the *Baseline*, much lower than was predicted by the model simulations. Experiments have had several failed (negative gross margin crops) that were not sown in the model simulations and hence subsequent crops then also performed better. On the other hand, the predictions of the relative profit for the *Higher legume* and *Higher diversity* systems compared to the *Baseline* align reasonably well with the observed experimental outcomes over the experimental period – showing that much better performance might be expected under a different experimental period.

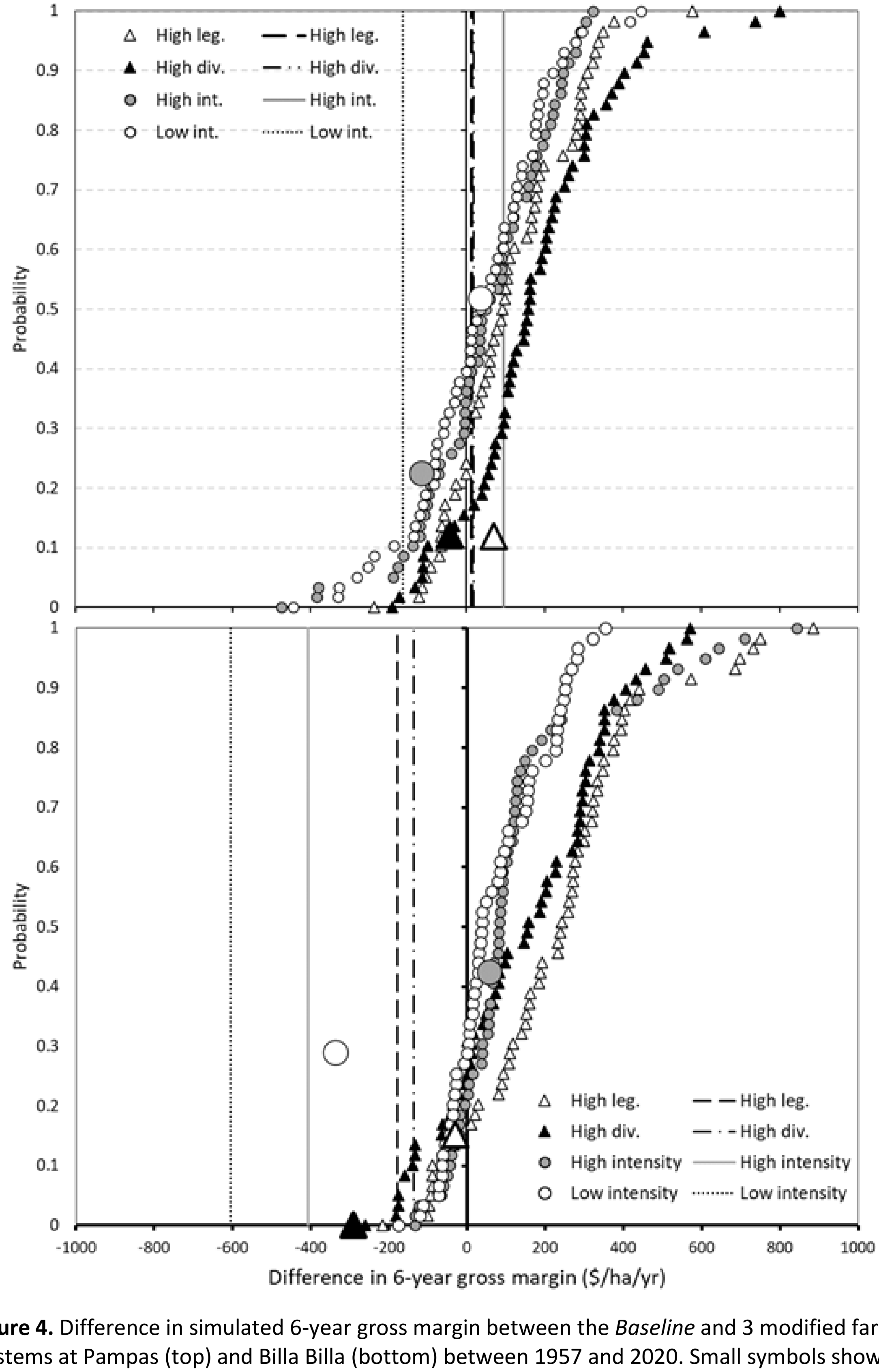


Figure 4. Difference in simulated 6-year gross margin between the *Baseline* and 3 modified farming systems at Pampas (top) and Billa Billa (bottom) between 1957 and 2020. Small symbols show the difference in annual returns over the distribution of the 54 different 6-year periods, the large symbols indicate the difference for a simulation of just the period of 2015-2020, and the vertical lines indicate the differences measured in our experiments over this same period. Negative values indicate the alternative system has produced a lower GM than the *Baseline*, and vice versa.

Conclusions

Farming strategies or systems need to consider resilience and relative performance across the full range of likely climate variability. While our experimental work has captured a range of seasons, the modelling here adds further insight into how the various farming system strategies might perform over the long-term. The modelling predictions of the relative differences over the past 6 years correspond well with our experimental data over the same period. While some of the alternative systems have not proved to be advantageous and in some cases worse over this experimental period, the long-term analysis suggests there is potential to make use of a greater diversity of crops which could add significant upside under more favourable growing seasons. Further examination of the influence of price variability and risk on these findings is required to understand how robust different strategies are, and the key factors that might influence this.

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