Executive summary

Key messages

- Successful grazing of crops requires planning from the outset of the season to reduce crop yield losses (eg. sow earlier) and maximise livestock productivity (eg. change operation timings to suit, increase number of twin bearing animals).
- Adequate cropped area was important for significant change to farm profit. The rule of thumb is >60% cropped to ensure adequate feed for meaningful change to livestock production.
- Sowing crops earlier saw yield increases that often outweighed the marginal yield declines from grazing and provided feed earlier in the season.
- Increasing livestock production, by moving to twin bearing ewes to capitalise on the additional feed available, increased farm profitability. The increased fecundity of ewes and number of lambs increased the DSE carried on the property, providing an alternative strategy to buying more stock to match feed availability.

Background

Mixed farm systems across southern Australia have significant opportunities to increase efficiencies by integrating livestock and crop operations. Over the course of the Grain and Graze project, thinking about how crops can best be grazed has shifted from marketing it as a 'free lunch', to a strategic system decision (Creelman et al, 2015). A key reason for not grazing crops is the cost to production in reduced yields. To increase profitability with grazing crops, there needs to be at least one of the following.

i. Reduced crop yield losses from grazing
ii. Increased livestock productivity

Modelling was undertaken as part of Grain and Graze 3 to ascertain the impact of grazing crops across the whole of the farm. This modelling for Victoria and South Australia focused on reducing crop yield losses from grazing by sowing early to maximise crop recovery time. Farms in Western Australia focused on optimising livestock production from grazing crops and sowing earlier to reduce yield loss and increase early feed.

Experiential learning in complex systems, such as farming, is difficult because of the time lag between actions and outcomes as well as the blurred feedback from variables such as weather (McCown et al, 2012). Trials and demonstrations provide valuable data to help understand the dynamics and best practice for grazing crops, however they are limited in feeding-back on long term implications and some of the secondary effects of changes in the system. Whole farm models are helpful in providing insights to the later.

Models were set up for three farms in Western Australia (Moora, Katanning and Esperance), two farms in south west Victoria (Inverleigh and Penshurst) and two farms in South Australia (Kapunda and Minnipa) (figure 1). Model farms were based on typical farms for those regions. Models were simulated with a combination of APSIM, GrassGro and GrazFeed. Farm outputs were copied into a Excel-based farm system with relevant prices and Monte Carlo simulations run to predict farm profitability and risk. Farm structure and outputs being verified by local consultants and researchers. See appendix 1 for more information on the model set up.

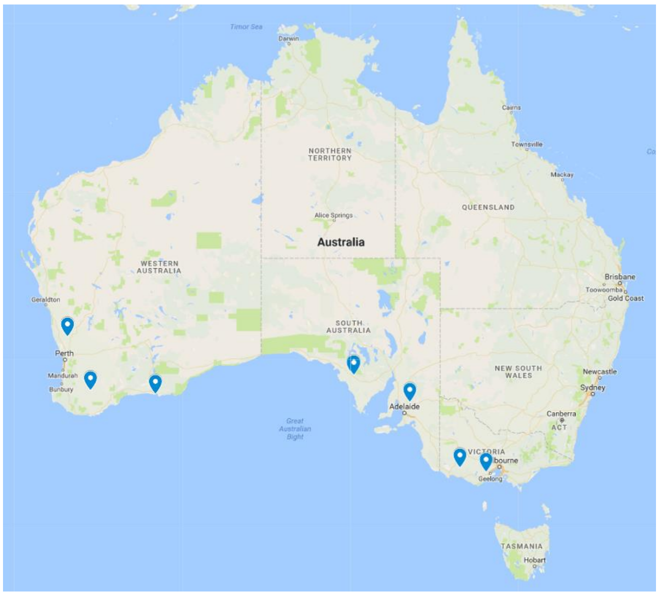

Figure 1. Modelled farm locations. From left to right: Moora, Katanning, Esperance, Minnipa, Kapunda, Penshurst, Inverleigh.

Differences in grazing crops across agro-ecological zones

The diversity of farming contexts across southern Australia influences management decisions and the effectiveness of practices. Farm models ranged from high rainfall (eg. Esperance and Penshurst) to low rainfall (eg. Minnipa); from self-replacing merino flocks, to first-cross sheep flocks and trade steers. Table 1 gives an overview of enterprise mixes, with more details given in the appendix for each chapter.

Table 1. Enterprise mix of each farm

		Crops		**Livestock**	
Western Australia	**Esperance**	Wheat Barley Canola	3200 ha	Trade steers Self-replacing Merinos First cross Merino x Suffolk	800 ha
	Katanning	Wheat Barley Oats Canola	1500 ha	Self-replacing Merinos	1000 ha
	Moora	Wheat Barley Oats Canola	1750 ha	Self-replacing Merinos	750 ha
South Australia	**Kapunda**	Wheat (milling & durum) Barley Canola	650 ha	Self-replacing Merinos First cross Merino x Suffolk	1850 ha
	Minnipa	Wheat Field peas Canola	1300 ha	Self-replacing Merinos	440 ha
Victoria	**Inverleigh**	Wheat Barley Canola	240 ha	Prime lambs Self replacing Merinos First cross Merino x Suffolk	900 ha

	Penshurst	Wheat Barley Canola	110 ha	Vealers Prime lambs Self replacing Merinos First cross Merino x Suffolk	935 ha

The enterprise mix, rainfall and livestock classes were key drivers in how much difference grazing crops made to the businesses' bottom lines.

- Farms with minimal crop area (e.g. Inverleigh and Penshurst) were restricted to short periods of grazing crops with select animal classes. This limited the potential for increases in farm profit from grazing crops. As a rule of thumb, if crop made up >60% of the farmed area, grazing crops had the potential to significantly change farm profits.
- Low rainfall areas typically had lower net farm profits, so the gains made through reducing supplementary feeding, increasing yield from sowing earlier and selling more animals slightly heavier saw significant proportional increases in farm profits (e.g. Minnipa compared to Penshurst in table 2).
- High value animals that made additional gains by grazing crops helped overcome the cost to crop yields of grazing crops e.g. grazing crop with twin bearing ewes rather than single and twin bearers saw greater returns.

Table 2. Changes to farm profit with different grazing scenarios. 'Median net farm profit' is where no crops were grazed and acts as the baseline for comparison.

		Average annual rainfall (mm)	Median net farm profit ($/ha)	Change in median whole farm profit (%)			
				Normal sowing	**Early sowing**		
				1. Crops grazed	2. Crops grazed	3. S+TB ewes grazing crops	4. TB ewes grazing crops
Western Australia	**Esperance**	572	$500	-16	19[#]	5	9
	Katanning	419	$192	1	54[§]	51	62
	Moora	418	$250	-16	2*	-3	19
				1. Crops grazed	2. Crops ungrazed	3. Crops grazed by ewes	4. Crops grazed by ewes with more stock
South Australia	**Kapunda**	373	$187	6	5	3	-
	Minnipa	314	$70	-15	94	101	97
Victoria	**Inverleigh**	558	$358	2	5	7	8
	Penshurst	726	$474	1	2	2	-

[#]Ewes grazed barley

[§]Ewes grazed barley and oats

**Hoggets grazed all crops*

- Insufficient grazing opportunity to increase stock number

Drivers of changes to farm profits

Grazing crops involves a trade-off between crop yield reductions from grazing and increased livestock performance. For farm profitability to be improved with grazing crops, either yield penalties have to be eliminated and/or the benefit to livestock maximised to recoup the cost. The premise for the modelling was to quantify how grazing crops impacts different areas of a whole farm system, and the risk involved. The following three sub-sections summarise the key factors at play in the modelled farms. Location specific reports are available on the Grain and Graze 3 website that give more detail on the ***extent*** of changes with grazing crops. Table 3 below only conveys the ***reliability*** of change rather than the magnitude.

Table 3. Reliability of change in production at modelled farm locations under the four different scenarios (see table 2 for scenarios). White gaps represent no change. NB: this table does not indicate the magnitude of change. See individual farm reports and the comments in following sections for details on the amount of change.

- Increased >75% of the time
- Increased 50-75% of the time
- Decreased 50-75% of the time
- Decreased >75% of the time

		Crop GM				**Livestock GM**				**Lambing %**			
	Scenario:	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Western Australia	Esperance	Decreased >75%	Increased >75%	Increased 50-75%	Increased 50-75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%
	Katanning	Decreased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%
	Moora	Decreased >75%	Decreased >75%	Decreased >75%	Decreased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%
South Australia	Kapunda	Decreased 50-75%	Increased >75%	Decreased 50-75%		Increased >75%		Increased >75%		Increased >75%		Increased >75%	
	Minnipa	Decreased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%		Increased >75%	Increased >75%	Increased >75%		Increased >75%	Increased >75%
Victoria	Inverleigh	Decreased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%		Increased >75%	Increased >75%	Increased >75%		Increased >75%	Increased >75%
	Penshurst	Decreased 50-75%	Increased >75%	Increased >75%		Increased >75%		Increased >75%		Increased >75%		Increased >75%	

		Lamb sale weight				**Hogget Wool cut**				**Supp. feeding**			
	Scenario:	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Western Australia	Esperance	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Increased >75%	Decreased >75%	Decreased >75%	Decreased >75%	Decreased >75%
	Katanning	Decreased >75%	Decreased >75%	Decreased >75%	Decreased >75%	Decreased 50-75%	Decreased 50-75%	Decreased 50-75%	Decreased >75%	Decreased >75%	Decreased >75%	Decreased >75%	Increased 50-75%
	Moora	Decreased 50-75%	Increased >75%	Decreased 50-75%	Decreased >75%	Increased >75%	Increased 50-75%	Increased >75%	Increased >75%	Decreased >75%	Decreased 50-75%	Decreased >75%	Decreased >75%
South Australia	Kapunda	Increased >75%		Increased >75%		Increased >75%		Increased >75%		Decreased >75%		Decreased >75%	
	Minnipa	Increased >75%		Increased >75%	Increased >75%	Increased >75%		Increased >75%	Increased >75%	Increased >75%		Decreased >75%	Decreased >75%
Victoria	Inverleigh	Increased 50-75%		Increased >75%	Increased >75%	Increased 50-75%		Increased 50-75%	Increased 50-75%	Decreased 50-75%		Decreased 50-75%	Decreased 50-75%
	Penshurst	Increased >75%		Increased >75%		Increased >75%		Increased >75%		Increased 50-75%		Decreased 50-75%	

1. Changes to crop yield

Grazing crops generally reduced yields. There were no strong trends of grazing lowering high yields more than poor yields, i.e. crops responding differently when grazed in good or bad years. Work in recent years has advocated for earlier sowing dates to lengthen the growing season and yield potential, whilst being mindful of the proximity of crop flowering and frost risk (Hunt et al. 2016).

- When crops were sown 'normally' and grazed, whole farm profit differed from the baseline by -15% to +6% across the seven location (table 2).
- When crops were sown earlier with longer season varieties, whole farm profits differed from the baseline by +2% to +101% (table 2).

Profit declines with grazing normally sown crops signified that yield penalties from grazing were greater than the benefit to livestock. Crop gross margin (GM) declines were consistent across all the sites when crops were sown normally and grazed, as seen in table 3 (scenario 1 under Crop GM).

Moora was the exception, with small (-$16 to -$77/ha) but consistent crop yield declines across all the scenarios. It is possible crops were sown too early at Moora, showing that early sowing is not a silver bullet approach to avoiding yield losses and still requires sound agronomy.

Minnipa did especially well with sowing crops earlier – with a 46% increase in crop gross margin from sowing earlier and not grazing. Even when early sown crops were grazed, crop gross margin increased from $189 to $255 (35%). Increase in crop income was a large part of the significant increases in farm profit at Minnipa seen in table 2, the other being wool production that will be discussed in the following section.

Notably, the locations in table 2 that recorded significant increases in farm profits were all >60% cropped land. More crop area also meant more stubbles for lambs to graze which was a key supplementary feed saving in many of the systems.

2. Increasing animal production

Animal production increased across all the farm locations with the provision of high value feed in the form of crops. Farms with more cropped area to graze increased livestock production considerably more than farms that were livestock dominant. Both south-west Victorian farms were >75% pasture by area and only grazed cereals, limiting capacity to graze crops. This was seen in the small changes to livestock performance and ultimately farm profit (table 2).

a. Lambing percentage

Lambing percentage improved consistently across the farms (table 3), although the extent of change varied considerably. Proximity to grazing crops was an important factor, with strong links between extra ewe body condition at lambing and increased in lambing percentage. Lifetime wool (2011) records the relationship as being linear, with every increase of 1 condition score resulting in a 20% increase in lambing percentage. Generally, ewes came off crop one to two weeks before lambing and were 0.1 to 0.6 of a condition score higher (most common increase was 0.2CS). According to the Lifetime Wool rule, lambing should have increased around 2% to 12% which it roughly did. Sometimes the increase was more (e.g. Katanning: 16% increase in lambing from +0.6CS), and sometimes it was less (e.g. Penshurst: 1.1% increase in lambing from +0.1CS)

The WA farms were set up to maximise the return on grazing crops by value adding livestock – in this case changing the flock from a mix of single and twin bearing ewes (60% and 40% respectively), to 100% twin bearing ewes. As shown in table 2, these scenarios were the most profitable for the WA farms, with increases in lambing percentages of 42- 62%.

Shifting to twin bearing ewes increased the DSE carried on the property. While a lactating ewe with a single lamb has a DSE rating of 2.5, a lactating ewe with twins is 3.4. In addition to the increased energy requirements of the ewes to produce twins, total feed requirement of lambs also greatly increased with around a 50% increase in the number of lambs turned off compared to the baseline. This did meant that some livestock performance indicators declined (e.g. Katanning in table 3). Effectively, moving to twin bearing ewes achieved the same effect as the Victorian scenarios where the flock size was increased to adjust for the extra grazing area with crops, but without having to purchase more stock.

b. Sale weight

Lamb sale weight generally increased across the farms. Greatest gains were seen where lambs grazed stubble over summer, provided there were adequate stubbles available. As mentioned previously, the additional lambs born increased grazing pressure and meant weight gains were not always as high as might be expected. This was especially the case in WA where ewes were switched to twin bearers.

At Katanning, lamb sale weights were consistently lower when grazing crop than the baseline, (table 3). The difference though was generally only 100 g/hd or less. The exception was in scenario 4 (twin bearing ewes) where lambs were born slightly lighter and there was more feed demand; in that instance lambs sold around 550 g/hd lighter. The same was true for Moora. The difference with Moora was in scenario 2, hoggets grazed barley and oats while ewes remained on pasture, hence the increase in lamb sale weight in table 2.

Esperance was the only farm with cattle grazing crop, with weight gains ranging from 7.2 kg/hd (normal sowing, later grazing), to 9.7 kg/hd (early sowing, earlier grazing).

The prices used in the model are based historic CPI adjusted values from June 2003 to December 2016; if the very high livestock prices experienced in 2016/17 were used, then grazing crops would have appeared even more favourable.

c. Wool cut

Wool cut did not change drastically across most of the farms. Minnipa had the greatest change in wool cut, with increases across all the grazing scenarios. Hogget wool cut increased on average 301 g CFW/hd across the grazing scenarios (± 9 g CFW/hd), representing considerable increase in wool income of +$4.17 per hogget. The consistent increase in wool cut, coupled with increased crop income as discussed previous, explains the doubling of Minnipa farm profit recorded in table 2.

3. Reducing supplementary feed costs

Supplementary feeding was generally reduced, often substantially so, with grazing crops and stubbles. The extent of feed savings depended on the reliance on feeding out to begin with. For instance, at Penshurst where feed was relatively reliable year-round, grazing crops only reduced supplementary feeding across the sheep flocks by 1.04 t (normal sowing and later grazing) and 7.03 t (early sowing and earlier grazing). At the other end of the spectrum was Esperance which had very high supplementary feeding at the baseline, both to finish trade steers at a target weight as well as maintaining ewes and finish lambs over summer. Putting young stock on stubbles significantly reduced the sheep feed requirements, and the high value feed in the wheat grazed by steers reduced their finishing feed ration. In the best performing scenario, grazing crops at Esperance saved on average 202.8 t per year, equating to $47,861 (scenario 3).

Concluding remarks

- More condition at lambing lead to higher lambing percentages
- Increased lambing percentage increases the number of twins. More and smaller lambs sometimes meant lower lamb performance and increased feed demand, but an overall increase in farm profitability.
- Shifting flocks to twin bearers was less risky than increasing flock size to capitalise on extra feed in season. Increasing flock size to capitalise extra feed came with the down-side risk of having to increase supplementary feeding to maintain animals in a bad year
- Sowing crops early saw significant increases in yields (even when shifting to feed varieties from milling) that diluted the impact of grazing yield penalties

- Where possible the model was altered to maximise outputs and capitalise on opportunities, but a real system would be more responsive to seasons and prices (e.g. holding on to stock or selling early depending on feed availability).

References

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Appendix 1 – Model set up

APSIM and GrassGro models were run from 1963 to 2015 with the first 27 years excluded to eliminate the effect of initial conditions in the model. This meant leaving 25 years of simulated data was used to inform the farm system.

A feed budget monitored how long feed would last/how much will be available after grazing. This then fed back into APSIM to inform the defoliation rules (ie. how much crop biomass remains after grazing).

The models are driven by Data Drill SILO rainfall, and soil parameters based on representative APSoil characterisations.

Key production indicators are used to inform an excel farm model. Inputs were entered as percentiles (10, 50 and 90) to enable Monte Carlo simulation using the Excel plug-in, @risk. Simulations were run 5000 times and inputs had correlation values specified so they behaved more realistically in the excel model (see Appendix 2). Indicators used were:

Crop

- Historic prices
- Yields

Livestock

- Historic prices
- Number of stock
- Lambing percentage
- Sale weights
- Wool cut
- Maintenance feeding
- Finishing feeding

Stocking rate was based on feedback from local advisors and farmers. Where stock number was increased to match increases in grazing area across the year, stocking rate was calculated as follows.

If:

- 500 ha barley is grazed for 2 weeks, or 4% of the year, and
- 250 ha oats are grazed for 1 week, or 2% of the year

Spread out over the whole year, it gives an extra 24 ha for grazing, giving a cumulative 774 ha for the sheep. With a base stocking rate of 2250 ewes or 3 ewe/ha, the extra area from grazing oats and barley means an increase in stocking rate to 2322 ewes to maintain the same stocking rate of 3 ewes/ha.

Appendix 2 - Correlations

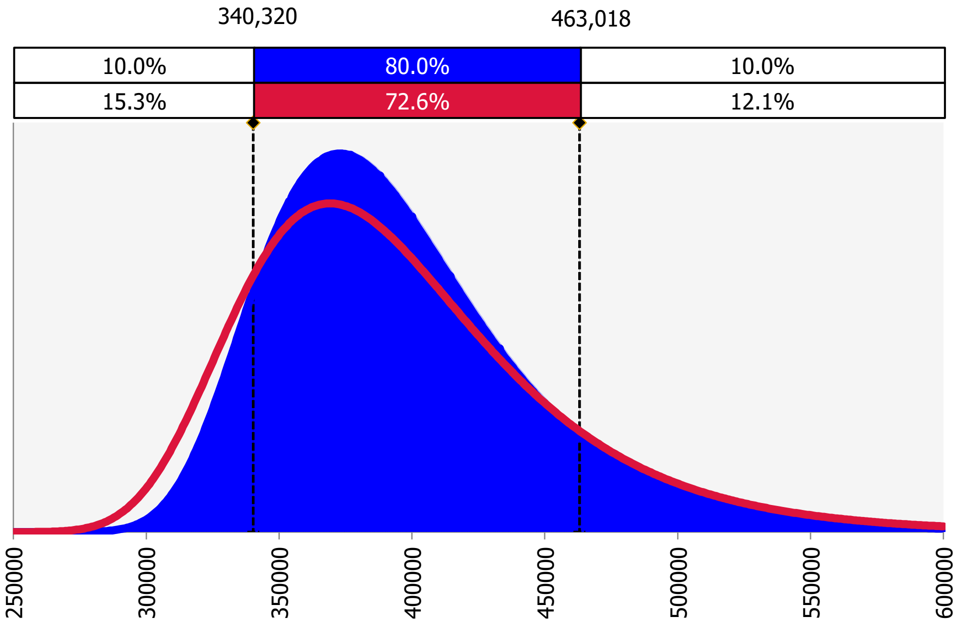
Nothing happens in isolation in a system – everything is interconnected and dependent on other factors. Consequently, often when an output in one area is high, another will also be high, or conversely will be low. For instance, if it is a good spring, there is likely to be a lot of feed around, with heavier turn-off weights, less supplementary feeding and higher crop yields.

Modelling farm systems requires specifying values for important parameters (eg. Lambing percentages, sale weights, crop yields). Without specifying how these change in relation to one another, the model is free to combine them in ways that are inconsistent with the reality.

This inadvertently dilutes the risk portrayed by the model, because it won't show bad years as being bad across all areas of production, and good years as being good across all areas. Figure 1 illustrates the difference to crop income.

The blue curve shows income from a sheep operation WITHOUT correlations, the red curve shows it WITH correlations.

- Median income stayed the same ($399,363)
- Both the lowest 10% and the highest 10% of values are moves out by more than $9,000. That is, there is more chance of getting a value lower than the median and more chance of getting it higher than the median.



The Monte Carlo simulation program, @Risk, enables correlations to be specified for inputs to ensure the model moves in a realistic way. The following table of correlation coefficients provides a guide for dryland mix farming systems. Correlations are based on APSIM and GrassGro data sets that were run for 25 years.

	Lambing	CFA weight	Surplus ewe sale weight	Wether sale weight	Wool cut (ewes)	Wool cut (lambs)	Supp feed (ewe maintenance)	Supp feed (lamb maintenance)
Lambing	1.0							
CFA weight	0.6	1.0						
Surplus ewe sale weight	0.5	0.7	1.0					
Wether sale weight	0.7	0.6	0.7	1.0				
Wool cut (ewes)	0.7	0.7	0.6	0.7	1.0			
Wool cut (lambs)	0.6	0.7	0.7	0.6	0.7	1.0		
Supp feed (ewe maintenance)	-0.4	-0.8	-0.8	-0.9	-0.6	-0.7	1.0	
Supp feed (lamb maintenance)	-0.5	-0.7	-0.8	-0.8	-0.6	-0.7	0.9	1.0

	Wheat yield	Barley yield	Canola yield
Wheat yield	1		
Barley yield	0.7	1	
Canola yield	0.7	0.7	1