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A financial analysis of the effect of the mix of crop and sheep enterprises on the risk profile of dryland farms in south-eastern Australia

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Abstract

This study analyses the financial risk faced by representative mixed-enterprise farm businesses in four regions of south-eastern Australia. It uses discrete stochastic programming to optimise the ten-year cash flow margins produced by these farms operating three different farming systems. Monte Carlo analysis is used to produce a risk profile for each scenario, derived from multiple runs of this optimised model, randomised for commodity prices and decadal growing season rainfall since 1920.

This analysis shows that the performance of the enterprise mixes at each site is characterised more by the level of variability of possible outcomes than by the mean values of financial outputs. It demonstrates that relying on mean values for climate and prices disguises the considerable risks involved with cropping in this area. Diversification into a Merino sheep enterprise marginally reduced the probability of financial loss at all sites.

This study emphasises the fact that the variability, or risk, associated with all scenarios far exceeds the likely change in cash margins due to innovation and good management. It further shows that farm managers should give a higher priority to adopting innovations which reduce costs, rather than increase productivity, in order to reduce risk.

Further analysis shows that the current static measures of financial performance (gross margins, profit and cash margins) do not characterise the risk-adjusted performance of the various farming systems and almost certainly result in a flawed specification of best-practice farm management in south-eastern Australia.

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Introduction

Dryland farming systems are suffering a systemic failure in SE Australia. Many farms in the area have experienced a negative cash flow from their farming operations for at least the five years prior to 2008 (Lagura and Ronan 2009). This failure is likely to have arisen from an inability to increase productivity (ABARE 2009) at a rate equivalent to input cost inflation (Reserve Bank of Australia, August 2009), and to the concurrent inability to reduce costs due to the rigidity of the cost structures in most farming businesses. The additional impact of the recent prolonged period of low incomes due to serious drought has exacerbated these effects, as has the falling real commodity prices and higher currency exchange rate following the international financial crisis.

This study examines the hypothesis that more resilient and profitable business structures can be developed for these farm businesses using the business process modelling (BPM) methodology imported from non-farming industries (Boehlje et al. 2000). These structures would need to be able to deal with the considerable variability of incomes and costs experienced in the region.

In order to develop these business structures it would be necessary to test them on a range of typical farms in each study area. This can only be done practically by modelling different management systems for the whole farm business for these farms over a number of years in order to capture the effects of the normal year to year variability for each region. There is substantial expert opinion that such simulation is both impractical and unlikely to succeed (Dillon 1979; Hardaker et al. 1998; McCown et al. 2006), despite the success of business process modelling in non-farm businesses in recent times (Jeston and Nelis 2007; Smith 2007).

Pioneering work on whole farm bio-economic modelling in Western Australia has flourished since the late 1980s with the development of MIDAS (Morrison et al., 1986; Kingwell and Pannell, 1987). In order to deal with weather and price variability and farmers' attitudes to income risks, which are fundamental characteristics of dryland farming, a *Model of an Uncertain Dryland Agricultural System* (MUDAS) was developed (Kingwell, 1987; Kingwell et al., 1990; Kingwell et al., 1993; Kingwell, 1994). It is a discrete stochastic version of MIDAS which did not deal with risk, (DAWA no date).

MUDAS defines multiple discrete season types with options for tactical adjustments in each. Tactical adjustments are made in each season type according to weather conditions before sowing. These adjustments have carry-over effects on costs, yields and responses to inputs in subsequent years. MUDAS captures inter-year effects while determining optimal enterprise mixes for crop/livestock systems over time. (DAWA no date).

A successful farm simulation must model the effect of the sequence of the input cycles (seasons) on cash flow and resulting cash surplus or deficit (Antle and Capalbo 2001; Hutchings 2008; Mokany 2009). This occurs because of the many interactions which occur during the farming process. For example a particular enterprise in different areas can interact with different seasonal conditions to produce outputs at different prices. Consequently whole farm models should be run for a number of combinations of seasons in order to estimate this effect on probable future performance.

This study aims to provide a more complete understanding of the financial uncertainty facing farm decision-makers in the rain-fed agricultural regions of south-eastern Australia. It overcomes many of the limitations of previous studies because:

This model reflects current best agronomic, farm management and financial practices in use by leading farm managers and their consultants.

All financial analysis is based on full costing, with separate whole-farm budgets prepared for each scenario, which overcomes the limitations of partial costing evident in the majority of past analyses.

Time (and the accompanying variability) are incorporated by building these budgets over ten-year intervals which are drawn from actual historical rainfall and price records.

These simulations allow for the sequential nature of farm businesses by accumulating, rather than averaging, farm financial output.

The model uses standard business reporting KPIs (key performance indicators).

In summary this analysis estimates the effect that climate and price have on the operating bank balance of representative farms in four regions of south-eastern Australia at each of three farming systems.

Method

Model description

A model (MS&A Farm Wizard®) was developed by the author (Hutchings) for Mike Stephens and Associates (MS&A), a leading Agricultural Consultancy firm, to facilitate farm management planning for their clients. The Farm Wizard is a whole-farm model simulating a full range of business and financial KPIs over a three-year period. Separate and detailed budgets are prepared for each paddock, using flexible crop and pasture sequences and planned livestock numbers and enterprises. The paddock results are then accumulated into whole-farm physical and financial forecasts. All physical and financial inputs can be varied so that the model can be used to simulate the medium-term effects on the farm bank balance of most tactical and strategic changes in management applied at any level from the individual paddock to the whole farm.

This paper utilises an updated version of this model which incorporates improved yield and stocking rate estimates, driven by growing season rainfall (GSR). Crop yields are simulated using the French and Schultz (1984) method, as modified by Oliver et al (2009). These crop yield simulations correlate well (R^2>0.88) with long-term farm records in the region (Hutchings 2009a). Stocking rates are also calculated using this modified growing season rainfall and compare well with simulations using the CSIRO Grassgo® pasture model. Grassgo® has been verified and its predictions proven robust in a variety of localities (Donnelly et al. 2002)

From the outset it must be stressed that the results for each site are specific to the representative (and largely generic) farms utilised in the analysis; in the opinion of the district consultants the subject farms are typical of well-managed, single-family farms in each area and the capital and management structures have been standardised to reflect best practice operations for that area.

The farms are located in four regions selected to reflect the high and low rainfall extremes of the mixed-farming areas of south-eastern Australia. These regions are the South-west Slopes and Riverina regions of New South Wales and the Mallee and Western Districts of Victoria.

Farming systems

The farming systems were standardised to give approximately 30%, 60% and 90% of the total area cropped, with a typical ten percent of the area being set aside for road, buildings and other infrastructure. The 90% crop system farms the total arable area, and is thus referred to as 100% crop.

The rotational sequences were considered by consultants in each area to be optimal for that crop/pasture mix (see Table 1). Each phase of each rotation was present in equal areas each year on each farm. This multi-paddock approach removed any bias in farm performance due to unequal seasonal effects on rotational components. Annual pasture was used in each analysis because Grassgro analysis showed it to be more cost-effective at all sites in these rotations. It is worth noting that issues of topography and water-logging limit the percentage cropped at the South-west Slopes and Western Victorian sites to less than 100%.

Farm sizes were set at values which the local consultants felt were typical of efficiently run single family farms. Thus the area of the Mallee and Riverina farms was set at 2000 ha each, and the Western Victorian and South-west Slopes farms were each 800 ha.

A commonly used financial benchmark, EBIT (Earnings Before Interest and Tax), is used as the basic component of the reporting function of this model. EBIT includes all the cash costs mentioned above, including living costs and is a more accurate measure of whole-farm performance than gross margins. Interest and income tax were calculated on the annual accumulating cash balance.

Table 1: Crop/pasture rotations at each site for each farming system

Agricultural consultants in each region were asked to provide the best practice rotations for each enterprise mix. The pasture was standardised as annual sub-clover and grasses as the production from this mix equalled or exceeded the production from perennials over the lifetime of the short rotation with crop in the Grassgro simulations, and was less costly.

Rotations used in different scenarios for each location

SW Slopes Rotations	**100% crop**	**60% crop**	**30% crop**
Year 1	TT canola	TT canola	TT canola
Year 2	Wheat	Wheat	Wheat
Year 3	Barley	Triticale + clover	Triticale + clover
Year 4	Lupins	Annual pasture yr 1	Annual pasture yr 1
Year 5	Wheat	Annual pasture	Annual pasture
Year 6		Annual pasture final	Annual pasture
Year 7 to 9			Annual pasture final

Riverina Rotations	**100% crop**	**60% crop**	**30% crop**
Year 1	Wheat	Wheat	Wheat
Year 2	Wheat	Wheat	Wheat
Year 3	Barley	Barley + clover	Barley + clover
Year 4	Long fallow	Annual pasture	Annual pasture
Year 5 to 8			Annual pasture (3 years)
Year 9			Fallow

Western Vic Rotations	**100% crop**	**60% crop**	**30% crop**
Year 1	Canola	Canola	Canola
Year 2	Wheat	Wheat	Wheat
Year 3	Barley	Barley + clover	Barley + clover
Year 4		Annual pasture yr 1	Annual pasture yr 1
Year 5		Annual pasture	Annual pasture
Year 6 to 8			Annual pasture
Year 9			Annual pasture final

Mallee Rotations	**100% crop**	**60% crop**	**30% crop**
Year 1	Canola	Wheat	Wheat
Year 2	Wheat	Wheat	Barley + clover
Year 3	Wheat	Barley + clover	Annual pasture yr 1
Year 4	Barley	Annual pasture yr 1	Annual pasture
Year 5	Lentils/Field peas	Annual pasture	Annual pasture final
Year 6		Fallow	Fallow

Table 2 shows median budget EBITs for each scenario. These were extracted from the static model for median (decile 5) GSR and prices, and demonstrate typical inputs into the dynamic model. They do not include interest or income tax costs, as these are calculated using accumulated annual totals.

Table 2: EBIT statements for all scenarios, median values

	Riverina			Mallee		
	30% crop	60% crop	100% crop	30% crop	60% crop	100% crop
Crop income	425,908	689,282	884,239	176,500	505,085	639,786
Other income	22,394	22,394	22,394	22,394	22,394	22,394
Non-farm	8,962	8,962	8,962	8,962	8,962	8,962
Total	**457,263**	**720,637**	**915,595**	**207,855**	**536,441**	**671,142**
Sheep gross margin	295,995	128,477		295,995	128,477	
Total income	**753,258**	**849,114**	**915,595**	**503,850**	**664,917**	**671,142**
Costs						
Crop	114,570	228,522	282,776	68,100	202,828	285,679
Pasture	87,400	26,600	0	85,750	24,850	0
Machinery	50,000	82,600	82,600	62,000	73,000	84,600
Overheads	58,095	58,095	58,095	64,490	64,490	64,490
Personal costs and super	7,000	7,000	7,000	7,000	7,000	7,000
Capital	52,065	56,750	57,465	58,725	58,725	61,065
Total	**369,130**	**459,567**	**487,936**	**346,065**	**430,893**	**502,834**
Margin	*384,128*	*389,547*	*427,659*	*157,785*	*234,024*	*168,308*

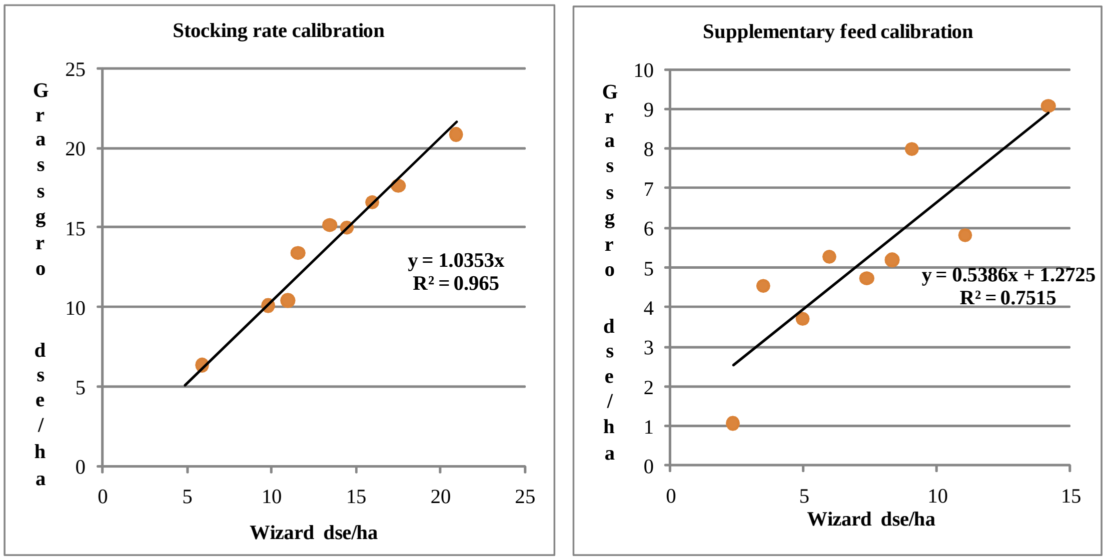
	W. Victoria			SW Slopes		
	30% crop	60% crop	100% crop	30% crop	60% crop	100% crop
Crop income	226,935	401,135	634,608	229,604	431,692	665,830
Other income	22,394	22,394	22,394	14,689	14,689	14,689
Non-farm	8,962	8,962	8,962	8,962	8,962	8,962
Total	**258,291**	**432,490**	**665,963**	**253,255**	**455,342**	**689,480**
Sheep gross margin	295,995	128,477		237,604	113,620	
Total income	**554,286**	**560,967**	**665,963**	**490,859**	**568,962**	**689,480**
Costs						
Crop	66,344	117,527	193,241	63,169	124,702	209,816
Pasture	34,160	20,300	0	38,304	20,520	0
Machinery	49,500	57,500	66,500	39,523	61,817	71,546
Overheads	34,200	34,200	34,200	69,607	69,607	69,607
Personal costs and super	7,000	7,000	7,000	7,000	7,000	7,000
Capital	38,052	43,290	44,640	47,493	51,691	50,515
Total	**229,256**	**279,817**	**345,581**	**265,096**	**335,337**	**408,484**
Margin	*325,030*	*281,150*	*320,383*	*225,763*	*233,624*	*280,996*

Sheep enterprise budgets

A self-replacing Merino flock was used to represent the livestock component of the rotation, as this enterprise is present on about 80% of farms in the region (Villano et al. 2010). In contrast to the crop enterprises almost all sheep enterprise costs are variable; that is they relate to the number of sheep, which are the unit of production. Income for the sheep enterprise is more stable due to the fact that best management practice recommends that sheep are fed a supplementary ration sufficient to maintain a relatively stable level of meat and wool production (Curnow 2010). Thus the important variable components of a sheep budget are the number and type of sheep and the amount of supplement used.

The CSIRO Grassgro® model was developed to estimate the level of these variables over time for any site in Australia. (Donnelly et al. 2002). The predictions for both annual energy production (expressed as dry sheep equivalents/ha, see Figure 1) and supplementary feed requirements for the last 30 years were calibrated using Grassgro and gave good fits over a wide range of rainfalls and stocking rates.

Figure 1: Calibration of stocking rate and supplementary feed requirements



The discrepancy in the supplementary feed requirements at low stocking rates is explained by the fact that the Grassgro model only simulates the energy yield for the annual pasture component, whereas the model used in this study allows for contributions (green feed and stubble) from the cropping component of the rotation (Kirkegaard et al. 2008; Mulholland and Coombe 1979).

Fixed and capital costs

Fixed costs include some fuel, labour and repairs, plus all administration, depreciation and finance costs. To develop more representative whole-farm budgets the actual fixed costs for each site are adjusted for each scenario, because these costs are as variable as production costs on any farm (Hutchings et al. 2010). Interest and income tax costs were calculated annually on the accumulating cash flow.

Capital costs also vary between farms, and reflect the current program of capital purchases, which is determined by enterprise mix and management preferences. In this study a typical machinery inventory was developed for each farm reflecting the absolute area cropped and the number of sheep in the flock for each scenario. Annual capital costs were then set to equal the annual first-year depreciation (at twelve percent), based on the assumption that a sustainable farm business needs to maintain its working assets at current levels.

Labour costs were also adjusted to reflect the work-loads resulting from each scenario: the farmer was assumed to be able to farm 400 ha of crop and 5,500 dry sheep equivalents

(DSE). Additional labour was charged at $25/hour proportionally when the workload exceeded these levels.

Living costs are also classified as capital costs, and these have been standardised at $55,000 per farm, plus an additional $7,000 in benefits extracted from the farm accounts. This reflects the current typical value used by consultants (MS&A). Income tax was estimated using the standard five-year averaging system used by most farm businesses.

Commodity prices

Price percentiles for all commodities were prepared from weekly market prices (port basis) for the period beginning January 1st, 2000. This period was chosen to reflect current market conditions. Because the sampling period was relatively short and covered a period of low inflation these prices were not adjusted for inflation. Further, because the price series for some commodities were not available their price was set using the historical relationship with wheat prices (see Table 3).

The price percentiles used do not reflect the current extreme prices for sheep and lamb, because these occurred outside the sample period.

Table 3: Decile prices for all enterprises, (average of weekly market prices 2000 - 2009) *

	Crop grain price percentiles $/tonne									
Crop	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	***100%***
Canola	300	334	367	401	434	468	501	535	568	602
Wheat	140	166	191	217	242	268	293	319	344	370
Triticale *	125	148	171	193	216	239	262	284	307	330
Oats *	110	131	152	173	194	216	237	258	279	300
Lupins *	160	192	224	257	289	321	353	386	418	450
Fieldpeas *	180	210	240	270	300	330	360	390	420	450
Barley *	130	149	168	187	206	224	243	262	281	300

* Infered from historical price relationship to wheat

Sheep **	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	***100%***
Ewes - CFA	17.80	31.42	36.40	39.40	41.90	43.90	45.98	48.55	51.70	64.30
Ewes	19.58	34.56	40.04	43.34	46.09	48.29	50.58	53.40	56.87	70.73
Ewes 1-2yo	24.48	43.20	50.05	54.18	57.61	60.36	63.22	66.75	71.09	88.41
Ewes <1yo	37.42	31.42	36.40	39.40	41.90	43.90	45.98	48.55	51.70	64.30
Wethers	22.98	32.61	38.07	42.60	45.65	47.91	50.30	53.16	56.20	78.00
Wethers 1-2yo	22.98	32.61	38.07	42.60	45.65	47.91	50.30	53.16	56.20	78.00
Wethers <1yo	37.42	31.42	36.40	39.40	41.90	43.90	45.98	48.55	51.70	64.30
Ram lambs < 1 yo *	22.98	32.61	38.07	42.60	45.65	47.91	50.30	53.16	56.20	78.00
Rams 1-2 yo *	22.98	32.61	38.07	42.60	45.65	47.91	50.30	53.16	56.20	78.00
Rams *	27.58	39.13	45.68	51.12	54.78	57.49	60.35	63.79	67.44	93.60
Ewe lambs	37.42	31.42	36.40	39.40	41.90	43.90	45.98	48.55	51.70	64.30
Wether lambs	38.80	57.58	68.40	73.42	77.10	80.36	83.37	86.68	94.89	130.50

* Infered from historical relationships to other prices in the series

	Merino wool price percentiles c/kg **									
Wool	**10%**	**20%**	**30%**	**40%**	**50%**	**60%**	**70%**	**80%**	**90%**	***100%***
Ewes - CFA	375	387	396	411	426	449	476	493	518	660
Ewes	395	408	417	433	448	472	501	519	545	694
Ewes 1-2yo	395	408	417	433	448	472	501	519	545	694
Ewes <1yo	434	448	458	476	493	520	551	570	600	764
Wethers	355	367	375	390	403	425	451	467	491	625
Wethers 1-2yo	375	387	396	411	426	449	476	493	518	660
Wethers <1yo	434	448	458	476	493	520	551	570	600	764
Ram lambs < 1 yo	415	428	437	455	470	496	526	544	573	729
Rams 1-2 yo	355	367	375	390	403	425	451	467	491	625
Rams	355	367	375	390	403	425	451	467	491	625
Ewe lambs	454	469	479	498	515	543	576	596	627	799
Wether lambs	454	469	479	498	515	543	576	596	627	799

** Adjusted for normal variation in micron and yield

Optimising sheep numbers

Crop income is determined by yield, and crop variable costs are relatively constant once the rotation is selected (Table 1). The main controllable management variable on a mixed farm is therefore the number of breeding sheep which are run. This is set by the manager on the basis of history and experience, and changes relatively slowly, because of the long-term costs of breeding for performance and of re-building numbers after sales. This study uses discrete stochastic programming (*What's Best®) (Lindo 2009)* to optimise DSE numbers in order to maximise the whole-farm EBIT over any chosen decadal GSR sequence. This process optimises the ten-year stocking rate in response to calculated supplementary feed costs, the value of sale sheep and wool and the cost of additional labour. For example, too high a stocking rate would lower the decadal margin by increasing feed and labour costs; a stocking rate below optimum would have low costs but also a sub-optimal income over the ten-year period.

The results of this optimisation (Table 4) show that,as the cost of grain and therefore feed cost falls, then the optimum stocking rate rises, averaged over all decades. As a result, in all decades, sheep margins would tend to increase at the same time that crop income is falling, which would account for some of the stabilising effect of sheep on whole-farm income on these mixed farming enterprises.

Conversely, Table 4 shows that the optimum stocking rate increases as sheep and wool prices rise as would be expected. The optimum stocking rate for any decade and location is therefore sensitive to price and GSR.

Table 4: Effect of climate and price on optimum stocking rate
(results averaged by price percentiles for crop and sheep)

Crop price percentile					**Sheep price percentile**				
Riverina	**30% crop**		**60% crop**		**Riverina**	**30% crop**		**60% crop**	
Crop price percentile	Opt Dse/ha	Supplement fed dse/ha *	Opt Dse/ha	Supplement fed dse/ha *	Sheep price percentile	Opt Dse/ha	Supplement fed dse/ha *	Opt Dse/ha	Supplement fed dse/ha *
10%	7.24	2.82	5.72	2.38	10%	4.51	1.23	3.78	2.38
50%	5.28	1.04	3.89	0.87	50%	5.88	1.55	4.46	0.87
100%	4.51	0.78	3.32	0.34	100%	6.64	1.86	4.69	0.34
Mallee	**30% crop**		**60% crop**		**Mallee**	**30% crop**		**60% crop**	
Crop price percentile	Opt Dse/ha	Supplement fed dse/ha	Opt Dse/ha	Supplement fed dse/ha	Sheep price percentile	Opt Dse/ha	Supplement fed dse/ha	Opt Dse/ha	Supplement fed dse/ha
10%	8.92	3.14	5.31	1.64	10%	5.68	0.56	3.39	0.75
50%	5.07	0.54	3.53	0.65	50%	6.82	1.34	3.96	0.51
100%	4.56	0.31	3.21	0.29	100%	8.08	2.43	4.70	1.32
W. Victoria	30% crop		60% crop		**W. Victoria**	**30% crop**		**60% crop**	
Crop price percentile	Opt Dse/ha	Supplement fed dse/ha	Opt Dse/ha	Supplement fed dse/ha	Sheep price percentile	Opt Dse/ha	Supplement fed dse/ha	Opt Dse/ha	Supplement fed dse/ha
10%	17.67	0.83	17.07	0.25	10%	17.04	0.20	16.40	0.85
50%	17.04	0.20	16.46	0.86	50%	17.04	0.20	16.46	0.25
100%	17.04	0.20	16.40	0.24	100%	17.67	0.83	17.07	0.25
SW Slopes	30% crop		60% crop		**SW Slopes**	**30% crop**		**60% crop**	
Crop price percentile	Opt Dse/ha	Supplement fed dse/ha	Opt Dse/ha	Supplement fed dse/ha	Sheep price percentile	Opt Dse/ha	Supplement fed dse/ha	Opt Dse/ha	Supplement fed dse/ha
10%	11.43	1.58	13.74	2.57	10%	8.35	1.55	9.61	1.86
50%	8.65	1.48	9.96	1.75	50%	9.11	0.63	10.73	1.08
100%	8.02	0.43	9.10	0.60	100%	10.63	1.30	12.46	1.99

*** Supplement fed is expressed in energy units, where one dse = 3262 mJ/year.**

Estimating risk

Risk is here defined as the variation in outputs resulting from random and uncontrolled variation in inputs.

A subset of this definition (Richardson et al. 2000) is that risk is the probability of loss, and this was also investigated.

In this study the key output is the change in the accumulated decadal cash margin, which is equivalent to the change in the farm bank account.

In each simulation price percentiles for all commodities (Table 3), and the starting year of any decade between 1920 and 2000 were varied randomly for 1,000 runs using the *@Risk®* add-in to Microsoft Excel 2007® (Palisade 2009). There was no significant correlation between the crop and livestock price percentiles. However sheep and wool prices were significantly correlated ($r^2 = 0.58$) and this was allowed for in the simulation. This process generated four reports which were each calculated for all scenarios:

1. The effect of climate and price on cash margins
2. The range (maximum to minimum values) of cash margins.
3. The cumulative distribution function (CDF) of cash margins,
4. The probability of loss, ie negative cash margin values.

Results and Discussion

Risk is the defining feature of Australian agriculture (Chambers and Quiggin 2000).

Whilst this statement is accepted as fact, very few analyses have attempted to quantify the financial risk facing dryland farmers in mixed-farming systems in eastern Australia (Pannell 2006; Stone and Hoffman 2004). Whilst using data for the same representative set of farm businesses as the previous papers, this study extends the scope of the analysis to deal with the full range of climatic variability since 1920, and captures the effect of price on farm financial performance using historical prices for the current decade (Hutchings 2009a; Hutchings 2009b)

The Monte Carlo analysis randomised inputs for multiple optimised runs to produce a risk profile (CDF) for each scenario, based only on variations in prices and climate. There are limitations to this approach, which will inevitably under-estimate the risk faced by farmers for the following reasons:

1. The optimisation of stocking rates for each simulation presumes a degree of prescience on the part of the manager. Whilst long-term experience and district practice do tend to produce stocking rates near the values calculated, these may not vary as much as estimated in response to seasonal changes.
2. The use of one set of price assumptions, although random, for each decade must reduce the measured variability. However this should be countered by the use of multiple runs at random price combinations, which should give a representative indication of the effect of price changes over time.
3. The occurrence of rare events with large consequences on cash flows (such as mice, plague locusts, disease, frost, floods and financial crises, to name a few un-insurable events from the current year alone) would also increase the level of cash flow variability, particularly downside risk, above the level estimated. Estimates of the effect of climate change suggest that such events may become more common in the future (Peck and Adams 2010).
4. The assumption of best-practice management would also tend to reduce the range of output values. In particular the assumption of a one-family business, when the average is 1.9 families per farm (O'Callaghan 1999), would mean that this analysis could

significantly under-estimate the costs on many farms. As a result many farms would have a higher risk of loss than the farms used in this analysis.

5. This model does not allow for the effects of total or partial crop failure (ie GSR deciles less than 1), which has been experienced several times at the Mallee and Riverina sites in the past decade and may occur in the current year due to recent flooding.
6. Other external sources of risk, including legal, regulatory, technical failure, health and other personal issues, which can all have a considerable impact on financial performance are excluded from this analysis (Krause 2009).

For all these reasons the analysis is based on the assumption of the achievement of 75% of potential productivity, which is consistent with the levels achieved over time by good farm managers (Hutchings 2009a; O'Callaghan 1999). The farms chosen for this analysis are only representative and the performance of many, particularly larger, farm businesses or businesses with higher equity, may improve on these outcomes.

The four most pertinent measures of risk faced by farmers in the study area are discussed separately.

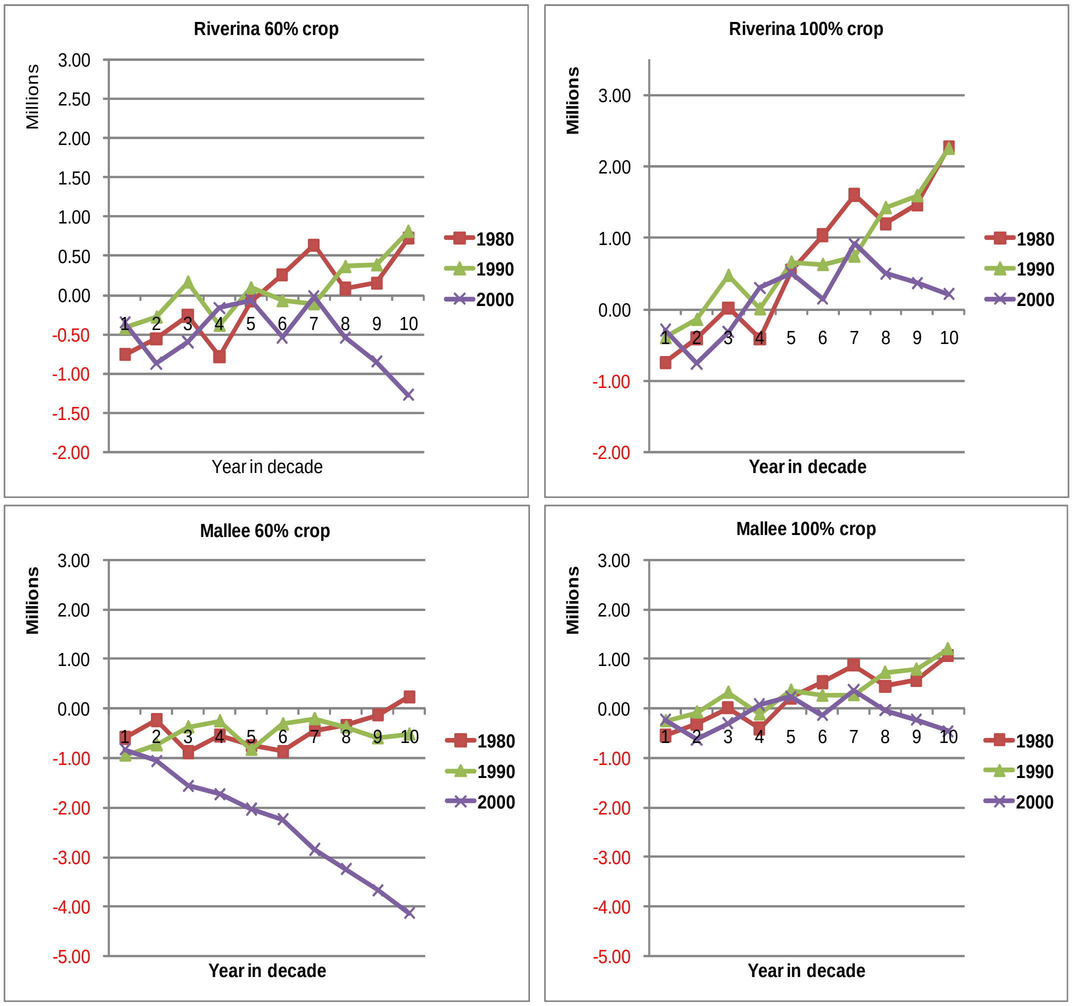
Cash margins

The simulated long-term cash margin represents change in the bank balance over the decade. Cash flow was chosen as the indicator of choice for farm financial performance, because it is the only measure which contains all costs.

Output from the discrete stochastic programming used in the simulation can be used to show the simulated cash flows for chosen decades. Cash flows for the 60% crop and 100% crop systems at the Riverina and Mallee sites provide examples of the cumulative consequences of weather sequences over the three most recent decades (Figure 2).

In all scenarios except Western Victoria the effect of the varying climate in the different decades was marked, with the period from 2000-2009 showing the effect of the long period of drought in that decade. The reason for the lack of variability at the Western Victorian site was that rainfall was capped at approximately 390 mm/yr because of water-logging occurring in the high clay-content soils. This cap, and the relatively high GSR values at the lower GSR deciles, effectively reduced the rainfall variability and therefore the variability of cash flows over each decade at this site.

Figure 2: Median cash flows, 75% WUE, selected recent decades for the Riverina and Mallee sites



Variability between decades increased with the cost base of the site (Table 5). This cost base can be indicated by the cost to income ratio (CIR), which measures total cash costs as a percentage of total returns, and therefore measures the static cash margin of each business. Both the South-west Slopes and Mallee sites, which show the highest CIR, generated the greatest loss in the recent dry decade beginning in 2000. The performance of each site in each of the three decades closely approximates the results for these areas according to consultants experience.

The decadal cash flow sequences shown in Figure 2 confirm the large effect of climate on farm performance and the sensitivity of high-cost businesses to potential loss following periods of drought over a limited number of decades. A more complete risk analysis, including a longer time period and commodity price range was undertaken to quantify this effect.

Table 5: Relationship between cost to income ratio (CIR) and the risk of loss

	Riverina	Mallee	W. Victoria	SW Slopes
30 % crop				
CIR *	72%	89%	75%	82%
Risk of loss	7%	66%	37%	88%
			R^2 =	***0.78***
				$p<0.1$
60 % crop				
CIR *	63%	78%	67%	78%
Risk of loss	30%	45%	20%	67%
			R^2 =	***0.82***
				$p<0.05$
100 % crop				
CIR *	58%	85%	63%	72%
Risk of loss	30%	48%	27%	81%
			R^2 =	***0.48***
				NS

* Derived from static model

* CIR = total cash costs/total cash income

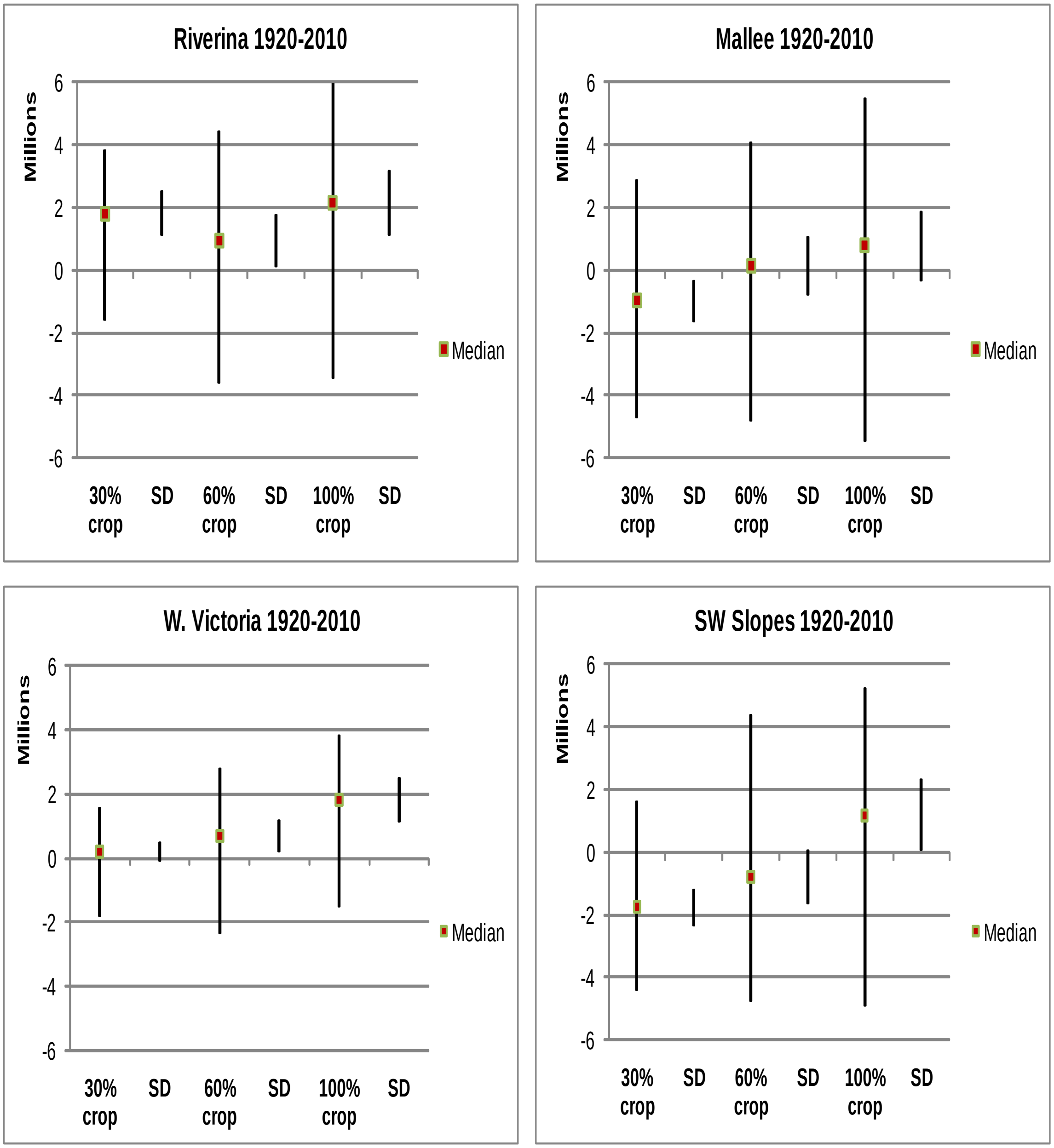
Range of cash margins

The range of possible decadal cash margins is an important measure and is easily understood. Figure 3 shows the range and standard deviations around the median decadal cash margin for each scenario and confirms the shape and range of results shown in the corresponding CDF curves. This representation also shows the skew in each distribution as inequalities in the range about the median values; it is notable that the skew indicates more downside than upside risk for most scenarios and tends to be greater for the 100% cropping system at all sites, confirming the downside risk inherent in the current intensive cropping systems.

In addition to this skew, both the variability and range of results (Table 6) increases with the level of cropping at all sites. This confirms the riskiness of cropping and the value of sheep in reducing risk in the dryland farming systems in the study area.

The range in the decadal cash margins values for each scenario closely mirrors the climatic variability, expressed as the standard deviation of the GSR (Table 7).

Figure 3: Range of cash margins* for 75% grazing potential, 75% cropping potential



Cash margin = ending cash balance - opening cash balance

This range in values emphasises the fact that the variability, or risk, associated with all scenarios far exceeds the likely change in cash margins due to innovation and good management.

Table 6: Characteristics of the distribution of decadal cash margin ($millions)

	Riverina			Mallee		
	30% crop	60% crop	100% crop	30% crop	60% crop	100% crop
Minimum	-2.17	-3.39	-4.28	-4.44	-5.09	-6.34
Maximum	5.01	4.57	5.56	2.92	4.00	4.81
Range	*7.18*	*7.96*	*9.84*	*7.37*	*9.09*	*11.15*
Range in SD units	*6.71*	*4.80*	*4.55*	*6.05*	*5.09*	*4.78*
Mean	1.51	0.89	1.21	-0.56	0.10	-0.08
Median	1.43	0.93	1.38	-0.45	0.18	0.11
Std Deviation	1.07	1.66	2.16	1.22	1.79	2.33
Skewness	0.19	-0.13	-0.17	-0.21	-0.22	-0.22

	W. Victoria			SW Slopes		
	30% crop	60% crop	100% crop	30% crop	60% crop	100% crop
Minimum	-0.17	-1.62	-2.46	-4.38	-4.55	-5.53
Maximum	4.38	3.01	3.17	2.93	4.34	3.66
Range	*4.54*	*4.63*	*5.63*	*7.32*	*8.89*	*9.19*
Range in SD units	*6.39*	*5.11*	*3.88*	*6.41*	*5.24*	*4.88*
Mean	1.71	0.84	1.03	-1.40	-0.69	-1.70
Median	1.69	0.91	1.09	-1.47	-0.73	-1.77
Std Deviation	0.71	0.91	1.45	1.14	1.70	1.88
Skewness	0.29	-0.14	-0.33	0.39	0.31	0.40

Cumulative distribution functions (CDF)

CDFs give the probability that any level of decadal cash margin will not be exceeded (Figure 4). Each curve is a linear representation of a skewed normal probability distribution, which can be characterised by the following features:

1. The slope of the curve, which is determined by the range of the values of the decadal cash margin it represents (Table 6).
2. The point of maximum loss, which is the nearest approach to the X-axis.
3. The Y-axis intercept, which reflects the probability of negative decadal cash margins for that scenario.

Each of these features is a response to separate factors in the operating environment.

The slope of the curve is determined by the range in values of the decadal cash margin, which is determined by the climatic variability, as discussed above (Table 7). This range is greatest for the 100% crop system, and is reduced in proportion to the grazed area; the curve for the 30% crop system shows the least slope, and the 100% crop system the greatest slope.

Table 7: Relationship between range of cash margins and climatic variability.

	Riverina	Mallee	W. Victoria	SW Slopes	R^2	
30 % crop						
Range *	7.18	7.37	4.54	7.32		
SD (GSR)**	27%	34%	23%	32%	*0.84*	*p<0.05*
60 % crop						
	Riverina	Mallee	W. Victoria	SW Slopes	R^2	
Range *	7.96	9.09	4.63	8.89		
SD (GSR)**	27%	34%	23%	32%	*0.92*	*p<0.01*
100 % crop						
	Riverina	Mallee	W. Victoria	SW Slopes	R^2	
Range *	9.84	11.15	5.63	9.19		
SD (GSR)**	27%	34%	23%	32%	*0.85*	*p<0.05*

* Range of decadal cash margins ($ millions)

** Standard deviation of growing season rainfall (% of median)

The point of maximum loss is determined by the fixed costs of each scenario, as shown in Table 2 and Table 8. The fixed costs were determined separately for each scenario and are the sum of the variable, fixed and capital costs which are not linked the income for that scenario. These costs, when subtracted from the income, determine the margin. The maximum loss occurs when the margin is the least; at this point the loss is therefore closest to the fixed costs.

The maximum loss is least for the systems including the greatest area of pasture, or sheep, because:

1. The pasture area replaces the crop area, and the sheep enterprise it supports has lower costs than the crop enterprise (Table 8).
2. The optimum stocking rate, or number of sheep, supported for each grazing scenario, tends to rise as the grain price, and therefore the cost of supplementary feed falls (Table 4). Therefore the sheep margin tends to be highest when the crop margin is the lowest. Sheep therefore effectively reduce the maximum loss incurred by any mixed enterprise system, in proportion the area grazed; the 30% crop system shows less loss than the 60% crop system, which is again less than the high losses experienced by the 100% system (Table 8).

The relative risk profile of the systems at each site is determined by both the maximum loss and the slope of the curve from that point, and therefore reflects the influence of the level of fixed costs of the farming system and the climatic variability of the site.

Table 8: Correlations between farming system fixed costs and probabilities of decadal cash margins ($ millions)

	Riverina			Mallee		
	30% crop	60% crop	100% crop	30% crop	60% crop	100% crop
Fixed costs *	-0.369	-0.460	-0.488	-0.346	-0.431	-0.503
Cash margin values (correlated with fixed costs)						
Minimum	-2.048	-4.010	-4.284	-4.429	-4.701	-6.335
R2 (Fixed Costs)	*99%*	*p<0.01*		*91%*	*p<0.01*	
5% probability	-0.099	-1.943	-2.492	-2.812	-3.106	-4.058
R2 (Fixed Costs)	*100%*	*p<0.01*		*94%*	*p<0.01*	

	W. Victoria			SW Slopes		
	30% crop	60% crop	100% crop	30% crop	60% crop	100% crop
Fixed costs *	-0.229	-0.280	-0.346	-0.265	-0.335	-0.408
Cash margin values (correlated with fixed costs)						
Minimum	-0.166	-1.621	-2.455	-3.980	-4.679	-5.532
R2 (Fixed Costs)	*97%*	*p<0.01*		*100%*	*p<0.01*	
5% probability	0.575	-0.679	-1.674	-2.998	-3.099	-4.432
R2 (Fixed Costs)	*99%*	*p<0.01*		*90%*	*p<0.01*	

* Fixed costs are costs which do not vary with output, and include most crop and pasture producton costs.
The costs shown were used to generate the site-specific budgets used in this analysis, minus the sheep gross margin..

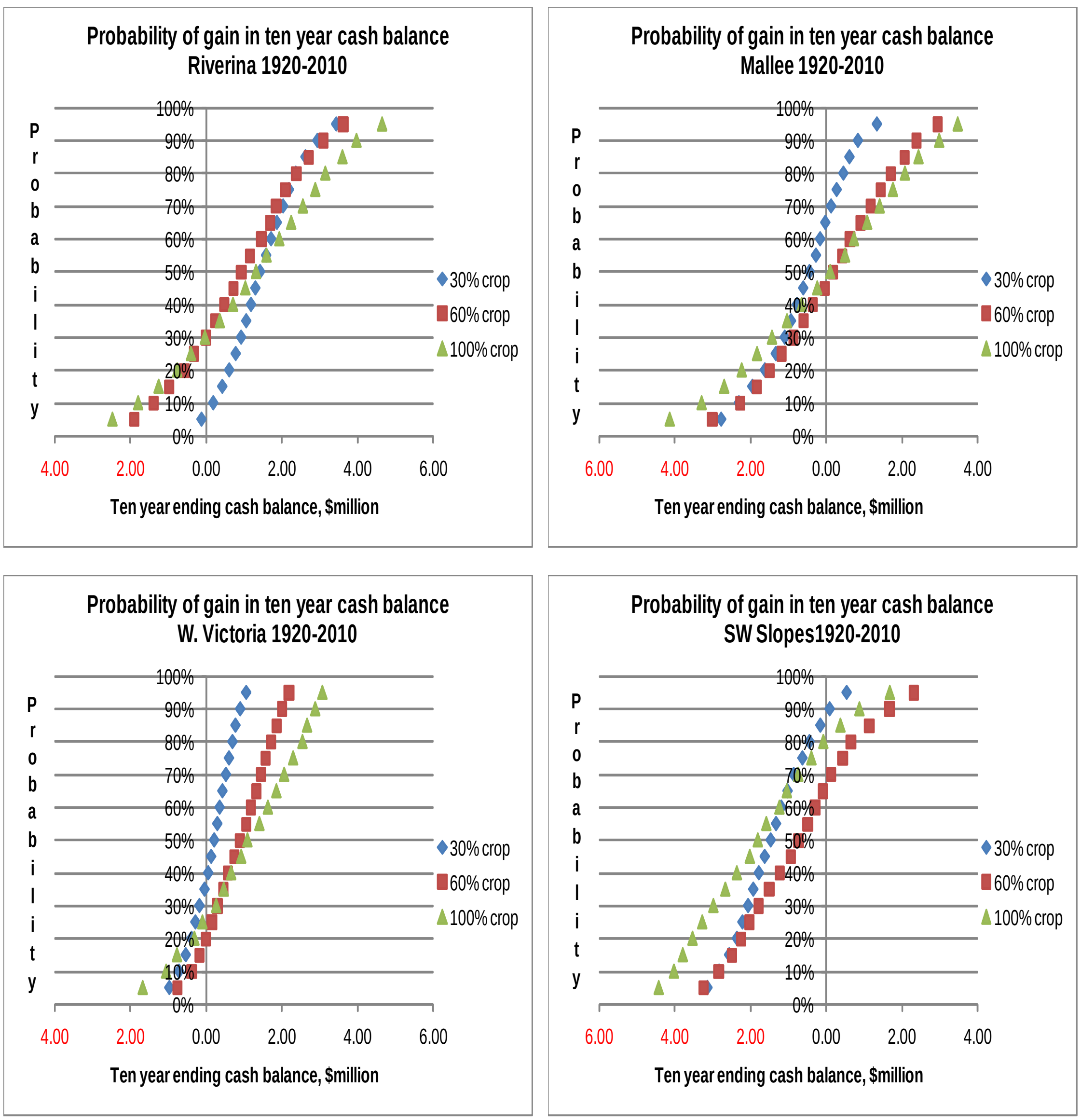
The Y-axis intercept is the point at which the income for each scenario equals the costs; any point to the left of the intercept is therefore a loss. This intercept defines the accumulated decadal risk of loss for each scenario. The intercept on the Y-axis is determined by both the maximum loss, which defines the location of the curve on the X-axis, and by the slope from that point, which is determined by climatic variability. The greater the slope the higher will be the Y-axis intercept, which determines the risk of loss. If follows that the systems with the lowest risk of loss will have very low costs and high variability; that is they will have incomes which respond positively to climatic variation.

For any scenario total costs determine the downside risk, and variability determines the upside potential for long-term cash margins.

Figure 4 shows that there are major differences between the productivity of the underlying rotations, due to interactions between climate, crop sequences, prices and cost structure, which explains the variation in the distributions between sites. The CDFs are therefore independent and specific to each scenario; their relative position is set by their maximum loss, or the nearest approach to the X-axis. In particular the relative position of the 60% and 100% crop systems is set by the point of maximum loss. Both these systems show greater margins under more favourable conditions than the 30% crop system.

The margins generated by the 30% crop options in the high-cost sites of the Mallee and South-west Slopes (Table 7) were insufficient to meet the costs for a large proportion of the risk profile. This contrasts with the low-cost sites in the Riverina and Western Victorian where the 30% crop margins were positive over nearly the entire range of probable cash margins. At all sites this system shows lower margins under more favourable conditions than the 60% and 100% crop systems, because the sheep enterprise margins are less variable than the crop margins and are therefore less responsive to favourable conditions.

Figure 4: CDFs for three systems at four locations, grazing and crop yield potentials at 75%

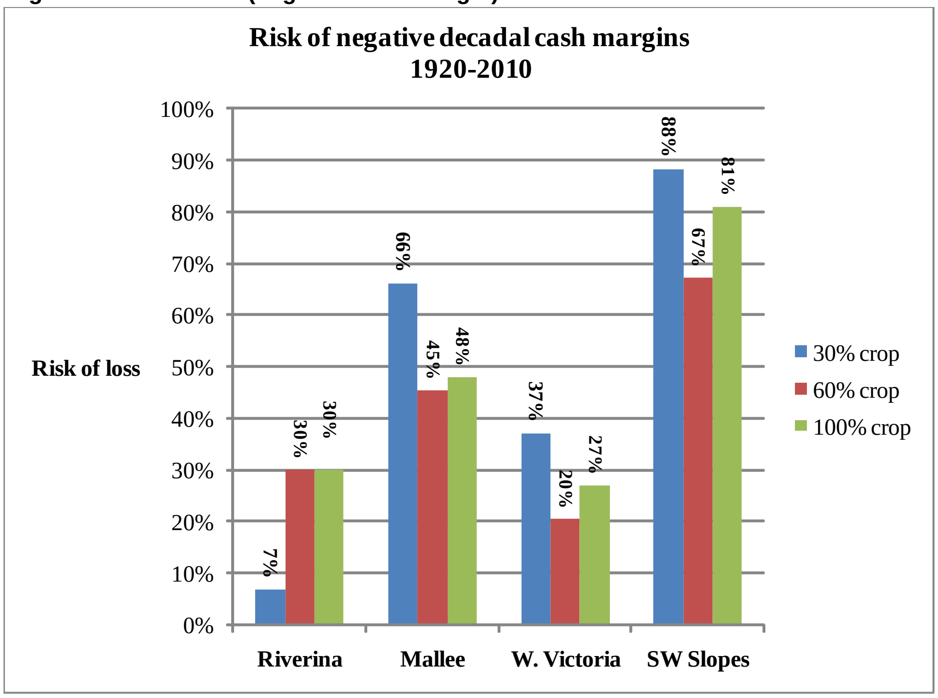


Risk of loss

This is another measure of risk used in policy analysis (Richardson et al. 2000). It is a subset of the information contained in the CDFs above, but can be used to simplify their message.

Figure 5 shows the proportion of negative cash margins generated by the 1,000 simulation runs for each scenario. It reflects the Y-intercept of the CDF, and confirms the points made above concerning CDFs. It particularly shows the relative riskiness of the South-west Slope site; a 67-88% risk of loss across all farming systems after ten years of operation should be enough to either discourage further investment, or force a change in the production system.

Figure 5: Risk of loss (negative cash margin)



At all sites the continuous cropping (100% crop) system generated losses over the decades with a probability of between 30% (Riverina) and 81% (SW Slopes) (Figure 4). This risk of loss is exceeded by the 30% crop system in the Mallee and Southwest Slopes, due to the higher fixed costs of the 30% crop system at these sites.

Risks as high as these should deter most farmers using these systems; the fact that many farmers have moved towards increasing the area cropped in the near past (ABARE 2009) suggests that they may be unaware of the downside risks involved. This is possible, as many farm and extension decisions are made on the basis of either gross margins, or annual budgets based on average yields (Bamberry et al. 1997).

Figure 5 also confirms that the 60% crop system shows equal (Riverina) or lower risk of loss than 100% cropping. It is doubtful that a 20% or greater chance of making a loss is acceptable over ten years, especially when this under-estimates the likely level of risks from all sources. The fact that the risk of loss for each scenario could represent the cumulative result of ten years work must be considered when evaluating these graphs. It is reasonable to assume that most individuals would have a much lower tolerance to risk over a ten-year cycle than for any one year. For this reason, in the long term, the risk of loss becomes relatively more important than the probability of high returns.

Because the risk of loss is largely determined by the total fixed costs for each scenario (Table 8), it seems logical that farm managers and R&D planners should give priority to developing systems that minimise costs over those systems which attempt to increase production, especially when this model already assumes maximum attainable water-limited productivity.

Comparison of risk-adjusted and conventional indices of financial performance

Figure 6 compares the output of four financial indices of farm business performance; gross margin, profit and cash margin are standard business indices. These three measures are calculated for median years (decile 5 GSR) and prices (50^{th} percentile for all commodities). The fourth (bottom) lines in Figure 6 show the effect of risk on the cumulative decadal cash margins. This measure reflects the median value from 1000 runs of the optimised model with randomised GSR and prices for each location and farming system.

The conventional static measures of farm business performance, comprising average gross margins, profit and cash flow, indicate financial performance improves with increase in the area cropped in all sites except the Mallee, where both profit and cash margin are lower for the 100% than for the 60% crop system.

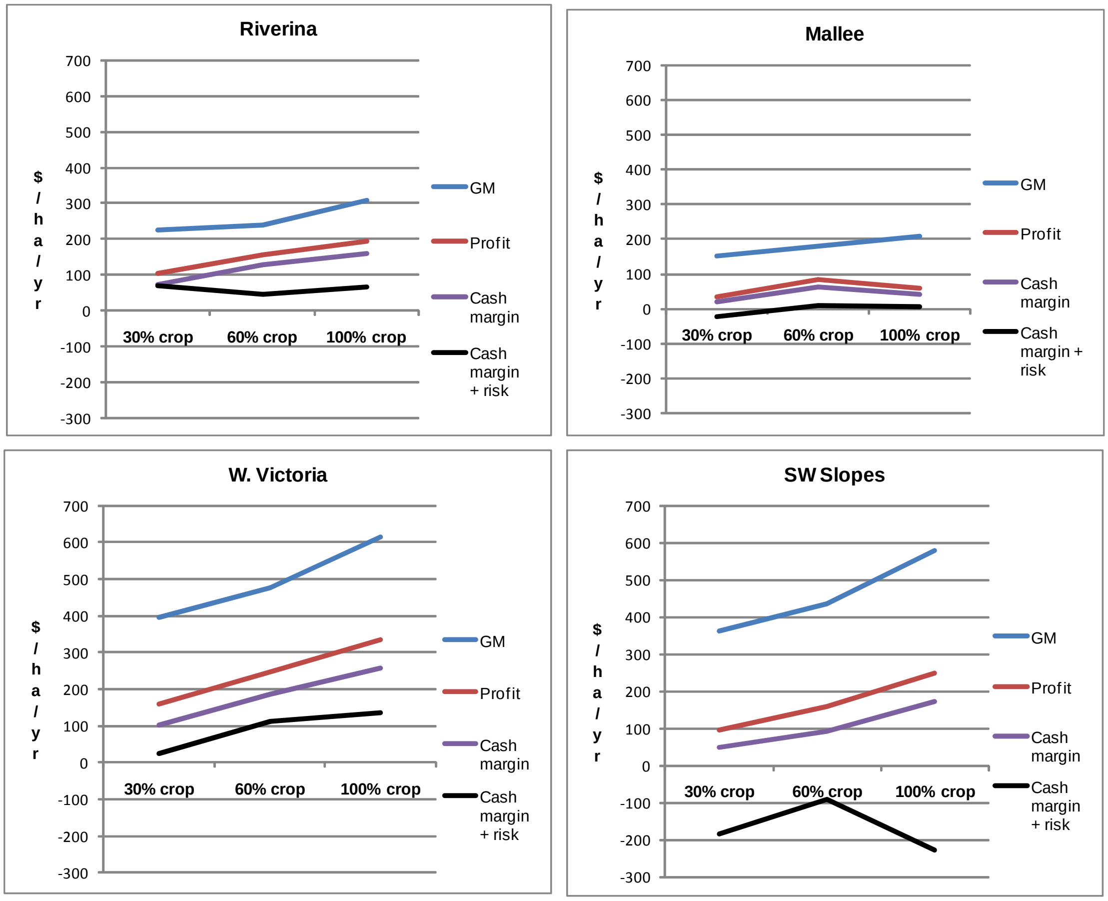
Risk-adjusted cash margins, as reported in this analysis, are the only measure which shows the long-term, cumulative effects of the enterprise mix on the bank balance, taken at median (50^{th} percentile) risk. This is the only measure which shows the cumulative effects of profits and losses on the long-term cash balances. However even this measure fails to show the full downside potential of the different enterprises, because it is limited to the median value and does not reflect the range of possible financial outcomes.

The median risk-adjusted margins show a negative divergence from the linear trend of the other indices at all sites. This divergence is most marked for the South-west Slopes site, where strong positive static indices revert to significant losses when adjusted for risk. At all sites, except for Western Victoria, the risk-adjusted cash margins are near to or less than zero.

This comparison of conventional and risk-adjusted measures of financial performance demonstrates that conventional indices could encourage the use of non-optimal and more risky farming systems. These findings question the value of these static KPIs and demonstrate that single point (average) measurements of mixed farming systems are unlikely to satisfactorily characterise their skewed and variable distributions.

This finding strongly suggests that current best management practice recommendations may be flawed, and result in the adoption of loss-making innovations.

Figure 6: Comparison of financial indices, median prices and GSR, $/ha/yr *



Gross margin =(income - variable costs)
Profit = gross margin - fixed costs (including depreciation)
Cash margin = profit - capital costs (asset purchase, living costs and income tax) + depreciation
} three-year averages derived from Business Process Model
Cash margin + risk = median probability decadal cash margin - from 1000 runs of optimised model

Conclusion

Risk has always been accepted as an important component of farm business performance, but, as discussed in the introduction, there have been few published attempts to quantify its effects on farm businesses in Australia. Agriculture seems unique in this respect; most other non-rural businesses have systems and resources designed to manage risk, as evidenced by the size of the risk management industry outside agriculture (Schroeder 2008). This study aims to define financial risk so that agricultural businesses can be properly compared with other sectors of the economy, and appropriate risk management responses identified.

Risk and the farming system

The farming systems described here are comparable only in their use of the land resource; the actual combination of crop, fallow and livestock enterprises is specific to each site (Table 1), but selected to be representative and reflect best practice management for that region.

The following generalisations can be drawn from the analysis:

1. The cash flow variability increases with the area cropped at all sites.
2. The size and risk of losses generated by the 100% cropping enterprises exceeds most scenarios which include grazing enterprises.
3. The inclusion of a Merino sheep enterprise at 60% of the farm area significantly reduces the risk of loss at all but the Riverina site.

On all sites the 60% crop option offers lower or equal probabilities of negative margins than continuous cropping. This occurs despite the fact that the normal management benchmarks, based on average prices and GSR, consistently favour the highest possible percentage of crop in the enterprise mix (Figure 6). This difference arises largely because this analysis is based on accumulated margins, so that losses are additive and are compounded at the current interest rate, mirroring the effect of losses on the farm bank account. This results in a negative bias to the results, which favours giving priority to systems which reduce the frequency of loss-making years.

Implications for management and policy

This analysis demonstrates the overwhelming impact of risk on farm performance in the study area. It emphasises the critical importance of including all costs in any assessment of any innovation, and evaluating each innovation over a wide variety of cultural, climatic and price conditions. Using margins based on partial budgets and average inputs can, and has, led to the promotion and adoption of loss-making innovations (Hutchings et al. 2010) and suggests that the specifications for current best practice management, which is based on such static measurements, may need revision. The compounding effect of losses (and profits) on cash flow can amplify the effects of any innovation; it is therefore important to evaluate any innovation over long periods. It is even more important to accumulate rather than average the annual output. Accumulated returns sum and compound the effects of all the variability experienced by the business over the measurement period and are ideal for evaluating the impact of long-term risk on farm viability. Furthermore accumulating returns simulates the effect on the farmer's bank balance, which is an important determinant of management behaviour.

The range of possible cash margins dwarfs the scale of likely agronomic treatment effects on cash flow. This emphasises the importance of including an assessment of resilience, or stability, especially under less favourable conditions, when evaluating any management innovation. This analysis shows that innovations need to be assessed on their ability to reduce costs rather than to increase income, especially when the farms are achieving near the maximum practical water-limited productivity.

The current practice of providing farmers with data averaged over a period hides this variability, which, given the size of the risks farmers face, could be more significant information than the average. This is particularly relevant when faced with an innovation with a relatively low cost/benefit ratio, as is normal in agriculture. If, for example, a new variety increases average yields by five percent, the cash benefit in a low yield year may be negligible. Furthermore the larger cash benefit in a good year can be eroded by income tax of up to 32%.

This discussion has focussed on financial management, but risk also affects investment. It could be argued that the level of risk described in this study may discourage investment in agriculture. Alternatively, understanding the level of risk involved may result in a change in investment patterns and concepts of best management practice, enabling the industry to become more competitive with other sectors of the economy.

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