

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 alternative farming systems. Monte Carlo simulation 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 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 on 60% of the area 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. This analysis shows that innovations need to be assessed more on their ability to reduce costs rather than to increase income, especially when the farms are achieving near the maximum practical water-limited productivity.

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.

Keywords: Farm management, financial risk, climate risk, price risk, variability.

Introduction

The failure of agricultural economics to successfully model whole-farm systems in south-eastern Australia is a failure of theory to follow practice, a conclusion confirmed by many authors over a considerable period (Cacho et al. 1999; Carberry 2004; Dillon 1979; Makeham and Malcolm 2002; Malcolm 2004; Stone and Hoffman 2004; Thompson et al. 1996). There are few published analyses in the academic literature which demonstrate knowledge of the full range of production, financial and management information relevant to the farming process (Hutchings 2008; Sadras et al. 2003; Thompson et al. 1996). This implies a voluntary isolation from the skills and knowledge contributed by all the essential component disciplines. As early as 1939 Schultz discussed the '*capture*' of the study of farm management by theoretical economists, as illustrated by the positioning of economics as the over-riding discipline for all aspects of farm management, as claimed by Malcolm (2004). This isolation caused the increasing prominence of theory over practice (Cacho et al. 1999; Dillon 1979; Just 2003; McCown 2001; McCown et al. 2006; McCown and Parton 2006b; Stone and Hoffman 2004) to the extent that McCown et al. (2006) concluded that theoretical models of farm practice had never been relevant and could not be relevant, a conclusion mirroring Dillon (1979), who stated that the study of farm management was based on '*logically attractive but largely inapplicable theory'*.

Just (2003) continued in the same vein when he wrote '*I am pessimistic* [for the survival of the study of farm management] *if agricultural economics research continues on the same roads it has been travelling'*.

The lack of communication between agricultural economists and the production and management disciplines has also resulted in a lack of access to essential data from these sources, which constrained the analytical process and further removed it from reality (Just 2003; Martin and Woodford 2003). This caused a concentration on data derived from statistical correlations to explain essential components of the function of the farm business (Dillon 1979; Richardson et al. 2000), an approach that resulted in analyses which, being determined by the limitations of the statistical techniques available, resulted in a general over-simplification of the problems being analysed (Antle and Capalbo 2001; Bellotti 2008; Just 2003; Malcolm 2004; Schultz 1939). Most analyses concentrate on partial analysis, either as single enterprises or gross margins, without including these as components of the whole-farm system. This inevitably resulted in partial understanding of the processes in question (Just 2003; Malcolm 2004; Stone and Hoffman 2004).

In addition, Schultz (1939) and others since (Bellotti 2008; Cacho et al. 1999; Castle and Becker 1964; Harwood et al. 1999; Keating and McCown 2001; LeRossignol 2003; Lien 2003; Malcolm 2004; McCown 2001; McCown et al. 2006; McCown and Parton 2006b; Officer and Anderson 1968; Pannell et al. 2000; Sadras et al. 2003; Shapiro 1990; Stone and Hoffman 2004), have stressed the importance of including both time and variability in the analysis of farm management processes. In the past this has presented theoreticians with a seemingly intractable problem: how to account for all possible combinations of inputs in order to present all possible outcomes for an extended time period. This can be overcome by replacing many of the values of the variable inputs in an analysis with values derived from the manager's expectations (Boehlje et al. 2000; McCarthy and Thompson 2007): that is, they replace ranges in the values of inputs with *expected* or *feasible* values (derived from either experience, judgement or prejudice) in order to be able to limit the number of solutions which have to be assessed (Janssen and Ittersum 2007; Just 2003; Lien 2003; Pannell 2006; Schultz 1939). This approach has the advantage that it includes the farm manager in the analytical process, resulting in a participative approach which is seen as integral to the credibility of the analytical output (Keating and McCown 2001; Martin and Woodford 2003; Stone and Hoffman 2004). This method is made reasonable by the generally relatively flat bio-economic response curves, noted by Pannell (2006) and Stone and Hoffman (2004), and which therefore removes the need for extreme precision (Albright and Winston 2005; Lien 2003; Makeham and Malcolm 2002; Pannell 2006; Stone and Hoffman 2004).

A successful farm simulation must also allow for 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), and incorporate 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 different 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.

The above discussion has shown that farm production is a sequential process understood by farmers, and as a result should be easily represented and transparent to the farming community at both the tactical and strategic levels (Carberry 2004; Stone and Hoffman 2004), in spite of their relative lack of mathematical (Kahn et al. 2008) and accounting skills (Malcolm 2004). Most farmers are familiar with the concept of cash flow from budgeting (Bamberry et al. 1997) and net worth (from loan applications) and are therefore able to understand the important financial measures (KPIs) at both the tactical and strategic levels. Despite this, farm management analysis has historically relied heavily on partial financial analysis, such as gross margins. There are many such examples (Adamson et al. 2007; Hajkowicz and Young 2005; Kaine and Tozer 2005; Keating and McCown 2001; Lien 2003; Lilley and Moore 2008; Musshoff and Hirschauer 2007; Pannell et al. 2004; Robertson et al. 2004; Schilizzi and Kingwell 1999; Scott et al. 2000; Warn et al. 2000) including the output of the popular APSIM (Keating et al. 2003) and Grassgro® (Donnelly et al. 2002) models.

These examples were chosen because they all failed to define the content of their financial calculations. Only net worth contains all the information related to each farm business available to the farm manager. Refereed studies which contain analyses of cash flow or net worth are rare (Sadras et al. 2003; Thompson et al. 1996), even though this is the standard legal end-point of all commercial financial balance sheets.

It is important that these key performance indicators (KPIs) are sufficient to measure and differentiate farm performance. Studies in Australia (Beever and McCarthy 2003), the United States (Gloy and LaDue 2003; Harwood et al. 1999; Jones et al. 2006; Just 2003; Mishra et al. 1999; Mishra and El-Osta 2001; Purdy et al. 1997) and Europe (Poppe and van Meiji 2004) show that successful farm businesses have common characteristics, such as scale, low relative costs and appropriate management skills which generate larger surpluses. These surveys also confirmed that standard measures of business performance, such as profit and cash flow, can be applied to farm business analysis (Just 2003; Klose and Outlaw 2005).

This study aims to provide a more complete understanding of the 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:

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

2. All financial analysis is based on full costing, with separate whole-farm budgets prepared for each scenario.
3. Time (and the accompanying variability) is incorporated by building these budgets over ten-year intervals which are drawn from actual historical rainfall and price records.
4. These simulations allow for the sequential nature of farm businesses by accumulating, rather than averaging, farm financial output.
5. The model uses standard business reporting KPIs.

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

Method

Model description

The base model (MS&A Farm Wizard®) was developed by the author 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. The physical and financial inputs can be varied so that the model can be used to simulate the medium-term impacts on the farm bank balance of most tactical and strategic management changes.

The results for each site are specific to the representative (and largely generic) farms utilised in the analysis. In the opinion of the MS&A 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.

Farming systems

The study 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.

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 roads, buildings and other infrastructure. The 90% crop system farms the total arable area, and is thus referred to as 100% crop, to indicate that this system did not incorporate any grazing component.

The rotational sequences applied were considered by consultants in each area to be usual for that crop/pasture mix (see Table 1). In the analysis, 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 in area.

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 considered a more accurate measure of whole-farm performance than gross margins.

Table 2 shows median budget EBITs for each scenario. These were extracted from the static model for median 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.

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. This model showed a consistently lower feed requirement at low stocking rates than that calculated by Grassgro®. This was 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 that part of fuel, labour and repair costs not related to the production process, 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 (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 12 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, unassisted, 400 ha of crop and 5,500 dry sheep equivalents (DSE). Additional labour was charged at $25/hour 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 to cover items, such as fuel, electricity, private telephone usage and rations, 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 from 1st January 2000 to 31st December, 2009. This period was chosen because it should reflect recent 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.

Crop enterprise returns

Growing season rainfall (GSR) deciles were calculated using monthly rainfall records for each site since 1920, as supplied by the Australian Bureau of Meteorology. Crop yields were estimated using the French-Schultz model, modified to include stored moisture and capped according to soil type (Oliver et al. 2009). This method resulted in modelled yields that were correlated highly ($r^2 > 0.88$, $p < 0.001$) with 20 years of actual whole-farm records for wheat and canola in the Riverina and Southwest Slopes districts of NSW (Hutchings 2009b). In this method GSR includes estimates of moisture stored from autumn rainfall, so that:

$$GSR = ((Rf_{(aut)} \cdot 0.3) + Rf_{(grow)}) \qquad (1)$$

$$Yield = (GSR - e) \cdot (WUE/1000) \qquad (2)$$

in tonnes per hectare, where GSR < *cap* and

GSR = growing season rainfall

$Rf_{(aut)}$ = rainfall between January 1st and March 31st on any year.

$Rf_{(grow)}$ = rainfall during the growing season, beginning on April 1st and ending at or soon after the end of October.

e is a factor, referred to as evaporation, which is specific to various crops and soil types.

WUE (water-use efficiency) is a crop-specific measure of yield in kg/mm GSR.

cap is a cap on GSR, and therefore on yield, specific to soils type and area, described by Oliver et al. (2009). There is a paucity of data on the relationship between yield and waterlogging, which will vary with a number of factors, such as saturation of the profile, and soil type.

The income, $\$I_c$, for all crops is the product of yield, area (*ha)* and price ($\$P_c$), ie

$$\$I_c = Yield \cdot ha \cdot \$P_c \qquad (3)$$

The EBIT for each crop and pasture (i.e. excluding sheep enterprises) is therefore the income minus all costs, $\$C_c$, including labour, specific to each crop, site and year:

$EBIT_{c,s,y} = \$I_{c,s,y} - \$C_{c,s,y}$ where $c_1, c_2\ c_n$ are the crop and pasture enterprises at each site (4)

The total EBIT for all crop and pasture enterprises (*j),* for each ten-year scenario, *EBITC*, is therefore the sum of the separate EBITs for each crop and pasture.

$$EBITC = \sum_{c} \sum_{s} \sum_{y} EBIT_{c,s,y} \qquad (5)$$

EBITC, as defined here, contains all the fixed and capital costs for the farm business; only the costs related to the number of sheep, which by definition are variable costs, remain to be calculated.

Sheep enterprise returns

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. The results of the optimisation (Table 4) show that, as the cost of grain and therefore feed cost falls, 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.

Available pasture energy yield in mJ/year ($Prodn_{s,y}$), for any site, *s*, and year, *y*, was calculated from growing season rainfall. Figure 1 shows the calibration graphs for the Southwest Slopes and Mallee sites. The value of the calibration factor *a* (the mm of GSR required to run one dse/ha/yr) was lower at sites with shorter growing seasons; in other words green feed was available for less time at sites with the same rainfall. The potential stocking rate (dse/ha) at that site could then be calculated from the number of dse, $N_{(s,y)}$, that could potentially be carried in any year at that site.

$N_{(s,y)} = GSR / a_s$ where a_s is the mm of GSR/DSE specific to site s. (6)

The number of dse carried in any year was optimised ($Nopt_s$) using discrete stochastic programming analysis, (*What's Best®) (Lindo 2009)* to give the maximum total financial return over any selected decade. This optimum number of dse was constrained by the cost of both supplementary feed, *Feed $*, and the cost of labour, L$, which were calculated as follows:

a. Feed costs

Any feed energy demand in excess of energy supplied from the pasture and crops, $Prodn_{(s,y)}$, has to be met from feed energy supplements. The size of this energy supplement, as determined by Grassgro®, was found to be a function of the energy deficit at each site, expressed in dse units.

$Feed_{(s,y)} = b_s \cdot (D_{(s,y)} - Prodn_{(s,y)})$, $(D_{(s,y)} - Prodn_{(s,y)}) > 0$ (7)

b_s is a calibration factor, which was found to be constant at 1.4 for all sites, suggesting that the actual feed requirement was 40% greater than the theoretical energy deficit.

The cost of the ration, $Feed\$_{(s,y)}$ can be calculated from this energy demand.

$Feed\$_{(s,y)} = (Feed_{(s,y)} / RE) \cdot RP$ (8)

Where *RE* is the energy content of the ration per kilogram, and *RP* is the ration price per kilogram, set by the price of the components grains, selected from the grain price matrix shown in Table 3. A supplementary ration of wheat grain was used, reflecting the most common farmer practice.

b. Labour costs

The labour requirement for each scenario will differ. Interviews with MS&A agricultural consultants in the study areas suggested that one person could manage 5,500 dse (*Lsheep)* and 400 ha (*Lcrop)* per year*.* The total labour demand could therefore be scaled and totalled from these assumptions, so that if the scaled labour requirement was greater than one person-year the cost of additional labour for the sheep enterprise was subtracted from the sheep gross margin, given a labour cost per hour, *Lcost*, of $25/hour. If the total additional labour cost for crop and sheep enterprises exceeded $42,000, then this value was used, representing the cost of a full-time employee. The crop area, C_s hectares, varied between scenarios. The cost of additional labour, $L\$_{(s,y)}$, can be calculated as follows:

$L\$_{(s,y)} = (((Nopt_s - L_{sheep})/L_{sheep}) + ((C_s - L_{crop}) / (L_{crop})) - 1) \cdot L_{cost} \cdot 2000$ (9)

Subject to: $0 < L\$_{(s,y)} < \$42{,}000$

The net sheep gross margin (*Sheep$)* for any scenario was calculated from the product of the dse numbers and the gross margin in $/dse, GM_s, and subtracting the cost of supplementary feed and labour:

$Sheep\$_{(s,y)} = (Nopt_s \,.\, GM_s) - Feed\$_{(s,y)} - L\$_{(s,y)}$ (10)

This equation shows the optimum sheep numbers for any decade are determined by the costs of feed and labour. It is convenient to express these values in terms of $ per dse as follows***:***

Z_S = 10 years' earnings per dse, S, before costs of feed & labour ($/dse)

Z_F = cost per year for full feed supply to support one dse, F ($/dse)

Z_L = 10 years' cost per dse of hired labour, L, ($/dse)

Given the *Z* values in (9) the questions of "best" constant numbers of sheep dse's ($Nopt_s$) and hired labour (*L*) can be answered by simultaneously solving the following five equations:

Maximise $Z_S X_S - Z_F X_{F1} - Z_F X_{F2} - \ldots - Z_F X_{F10} - Z_L X_L$ (11)

Subject to:

$X_S - X_{Fy} \leq Prodn_y$ (dse) (y = 1,10)

$X_S - X_L \leq R_{max}$ (dse)

$X_L \leq L_{max}$ (dse)

and all $X \geq 0$ (dse)

Where the variables are

X_S the number of sheep dse's (*S*) carried on the farm

X_{Fy} the number of Feed dse's (F_y) required on the farm in year y (y = 1,10)

X_L the number of additional dse's of hired labour required on the farm

and constraint limits are

P_y the number of pasture dse's produced on the farm in year y (y = 1,10)

R_{max} the max number of sheep dse's manageable by the owner alone

L_{max} the max number of additional dse's manageable by hired labour alone

This can be written more compactly where matrix coefficients are $\boldsymbol{a_{i,j}}$ in the ranges of ***i***=1,12 and ***j***=1,12 as:

$$\text{Max} \sum_{j=1}^{12} Z_{13,j} X_{14,j} \quad \text{s.t.} \qquad (12)$$

$$\sum_{j=1}^{12} a_{i,j} X_{14,j} \leq RHS_i \text{ (for } i\text{=1,12), and all}$$

$$X_{14,j} \geq 0$$

This model is configured for discrete stochastic programming by virtue of its capacity to solve for optimal sheep dse numbers, $Nopt_s$, given 10-year (decadal) sequences of pasture productivity (P_y dse) values that are randomly generated from long historical rainfall records.

Once $Nopt_s$ is known the gross margin for the sheep enterprise, *Sheep$*, can be calculated (from equation 8):

The whole-farm EBIT for any site and year, $EBIT_{(s,y)}$, is the sum of the EBIT for pasture and crop (from equation 3) and the net sheep gross margin:

$EBIT_{(s,y)} = EBITC_{(s,y)} + Sheep\$_{(s,y)}$ (13)

The EBITs for each year (*n*) of the chosen decade were accumulated, and interest (*Int)* and income tax (*Tax*) calculated annually on the annual closing balances (*Clbal*), to produce the cash flow (*CF*). The cash flow is cumulative, and the ending value can only be calculated when all previous years are included:

$CF = (Clbal_{(n-1)} + EBIT_{(n)} + Tax_{(n-1)}) \,.\, (1+Int)$

where *Int* = 8.5% (14)

The cash margin (*CM*), or net change in the cash flow over the decade, was calculated by subtracting the opening from the closing balance.

$CM = CF_{(n=10)} - Clbal_{(n=0)}$ (15)

In this study the opening balance (equal to the $Clbal_{(n=0)}$) , for each scenario was calculated at 70% equity for the continuous crop systems, and 75% and 80% for the 60% crop and 30% crop systems respectively. These are representative values reflecting the National Australia Bank database of regional farm accounts (NAB Agribusiness 2009).

Estimating risk

Risk is 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, and

4. the probability of loss, i.e. native cash margin values.

Results and Discussion

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

This statement is accepted as fact, yet 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). This study deals 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 generated 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 a fixed combination of commodity prices for each chosen decade must reduce the measured variability. This should be countered by the use of multiple runs at random price combinations, which, when combined, should give a representative indication of the effect of price changes on the risk profile for any scenario 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 last 12 months 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 underestimate 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, which has been experienced several times at the Mallee and Riverina sites in the past decade.
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 that good farm managers achieve a maximum of 75% of potential water-limited productivity (Hutchings 2009a; Kingwell 2011; O'Callaghan 1999). This level of water-use efficiency actually achieved by farmers seems to be relatively constant for all developed agricultures (Cassman 1999; Sadras and Angus 2006).

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.

Decadal cash flow

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 shows that the cash flows for each scenario vary considerably in each decade. The 100% crop system is the most affected by the prolonged drought of the decade beginning in the year 2000; the 60% crop system, which incorporates a grazing component, was less affected at each site. The Mallee site was less profitable than the Riverina site in all scenarios, due both to lower yields and higher costs.

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 deciles, effectively truncated the rainfall variability and therefore reduced the variability of cash flows over each decade at this site.

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.

Range of cash margins

Table 6 shows the range and standard deviations for the decadal cash margin for each scenario and the range of results shown in the corresponding CDF curves. This representation also shows that these cash margins are skewed and that the skew indicates more downside than upside risk for most scenarios, confirming the downside risk inherent in the current intensive cropping systems. This skew may be partially caused by the fact that positive cash flows are taxed at up to 34% in any year, while losses accumulate and are charged interest at 8.5% per annum on the annual account balance.

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).

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.

Cumulative distribution functions (CDF)

CDFs give the probability that any level of decadal cash margin will not be exceeded (Figure 3). Each curve is a representation of a skewed probability distribution, which can be characterised by the following features:

1. The point of maximum loss, which is the nearest approach to the X-axis, and which locates the distribution on this axis (Table 5).
2. The slope of the curve, which is determined by the range of the values of the decadal cash margin it represents (Table 6).
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 many separate factors in the operating environment.

The slope of the curve is unique to each farming system and is determined by the range in values of the decadal cash margin. This range is closely correlated with the climatic variability at each site (Table 7). This range is greatest for the 100% crop system, and decreases in proportion to the grazed area. The point of maximum loss is determined by the fixed costs for each scenario. Table 5 shows the close correlation between the total fixed costs and the minimum decadal cash margin for each scenario.

The maximum loss, or the level of fixed costs, is least for the systems that have 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 decreases, 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 to 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.

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 variability.

Figure 3 shows that there are major differences between the productivity of the underlying rotations, due to these interactions between climate, crop sequences, prices and cost structure, which explain the variation in the distributions between sites.

The incomes 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 upside potential 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.

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 4 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 the relative riskiness of the South-west Slope site; a 67-88% risk of loss across the three farming systems after ten years of operation should be enough to either discourage further investment, or force a change in the production system.

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 lower margins 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 4 also confirms that the 60% crop system shows equal (Riverina) or lower risk of loss than 100% cropping. Despite this 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, including one-off events. The fact that the risk of loss for each scenario could represent the cumulative result of ten year's 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, 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 incorporates the maximum water-limited productivity historically achieved by good farmers.

Comparison of risk-adjusted and conventional indices of financial performance

Figure 5 compares the output of three standard financial indices of farm business performance: gross margin, profit and cash margin. These three static measures are calculated for average GSR and prices. The fourth index in Figure 5 shows the effect of risk on the cumulative decadal cash margins. This measure reflects the average value from the type of probabilistic cash-flow analysis presented in this paper.

The conventional static measures of farm business performance, comprising average gross margins, profit and cash flow, indicate that 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 show the long-term, cumulative effects of the enterprise mix on the bank balance. The risk-adjusted cash margins shown in Figure 4 measure the average change in the cumulative decadal cash margin values (as defined in equation 12) for 1000 runs of the model for each scenario. This measure fails to show the full downside potential of the different enterprises, because it shows only the average value, which does not reflect the range of possible financial outcomes, or the negative skew of the distributions.

These average risk-adjusted margins show a negative divergence from the linear trend of the other indices at all sites, which occurs because the annual losses accumulate over each decadal sequence for each scenario, reflecting the dynamics of a bank balance. This divergence is most marked for the South-west Slopes site, where strong positive static indices, calculated for average prices and yields, revert to significant losses when adjusted for such losses. 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 financial indices 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.

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 financial performance 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, allowing appropriate risk management responses to be developed.

Risk and the farming system

The farming systems described here are similar only in their use of the land resource; the actual combination of crop, fallow and livestock enterprises is specific to each site (Table 1), and selected to represent 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% cropping 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 5). This difference arises largely because the analysis presented in the paper 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 are 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 could be more significant information than the average, given the size of the risks farmers face. This is particularly relevant with innovations with relatively low cost/benefit ratios, 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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Appendix

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 in the Grassgro simulations equalled or exceeded the production from perennials over the lifetime of the short rotation with crops, 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. 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	62,674	22,589		48,778	11,172	
Total income	**519,937**	**743,226**	**915,595**	**256,633**	**547,613**	**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	*150,807*	*283,659*	*427,659*	*-89,432*	*116,720*	*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	47,558	55,173		43,204	20,660	
Total income	**305,849**	**487,663**	**665,963**	**296,459**	**476,002**	**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	*76,593*	*207,846*	*320,383*	*31,362*	*140,665*	*280,996*

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

Table 4. Effect of 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.**

Table 5. Correlations between farming system fixed costs and the minimum decadal cash margins.

($ millions)

	Riverina			**Mallee**		
Farming system	**30% crop**	**60% crop**	**100% crop**	**30% crop**	**60% crop**	**100% crop**
Fixed costs *	-3.705	-4.002	-6.465	-5.835	-5.511	-6.733
<u>Cash margin values (correlated with fixed costs)</u>						
Minimum decadal cash margins	-2.048	-4.010	-4.284	-4.429	-4.701	-6.335
R^2 (Fixed Costs)	*67%*	*NS*		*92%*	*p<0.01*	

	W. Victoria			**SW Slopes**		
Farming system	**30% crop**	**60% crop**	**100% crop**	**30% crop**	**60% crop**	**100% crop**
Fixed costs *	-2.418	-2.432	-4.651	-4.357	-4.510	-7.293
<u>Cash margin values (correlated with fixed costs)</u>						
Minimum decadal cash margins	-0.166	-1.621	-2.455	-3.980	-4.679	-5.532
R^2 (Fixed Costs)	*78%*	*p<0.1*		*91%*	*p<0.01*	

* Fixed costs are costs which do not vary with output, including most crop and pasture costs.

The costs shown were used to generate the site-specific budgets used in this analysis.

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

Table 7. Correlations between range of cash margins and climatic variability.

	Riverina	Mallee	W. Victoria	SW Slopes	R^2	
30 % crop						
Range *	7.98	7.98	3.97	6.15		
SD (GSR)**	27%	34%	23%	32%	*65%*	*p<0.1*
60 % crop						
Range *	8.45	8.94	4.91	8.71		
SD (GSR)**	27%	34%	23%	32%	*86%*	*p<0.01*
100 % crop						
Range *	11.06	11.90	6.44	9.93		
SD (GSR)**	27%	34%	23%	32%	*80%*	*p<0.05*

* Range of decadal cash margins ($ millions)

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

Figure 1. Calibration of stocking rate and supplementary feed requirements

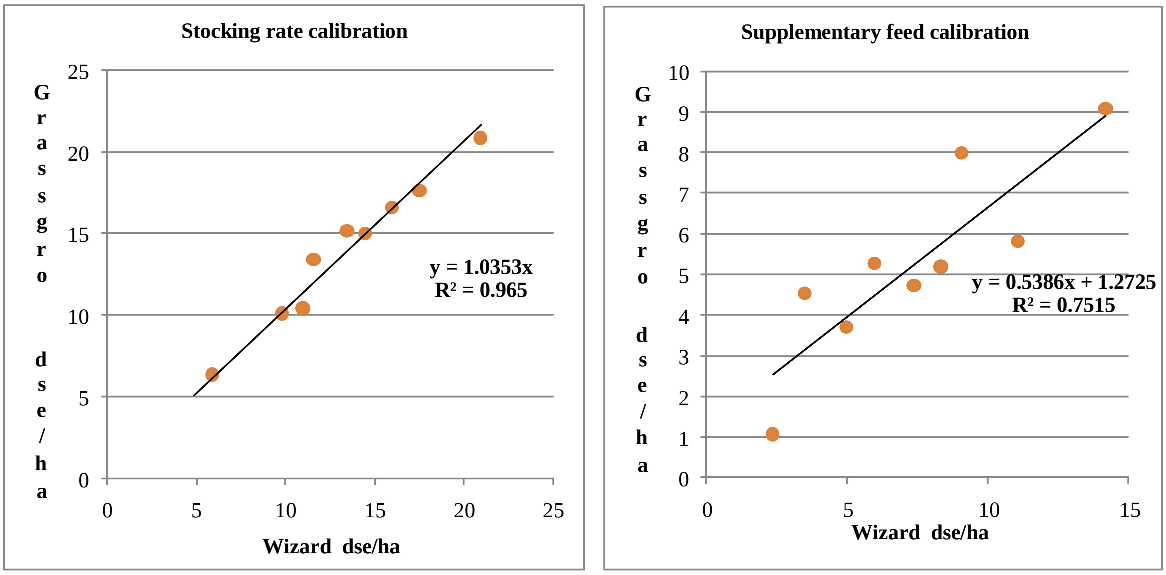


Figure 2: Median cumulative cash flows, 75% WUE, selected recent decades for the Riverina and Mallee sites

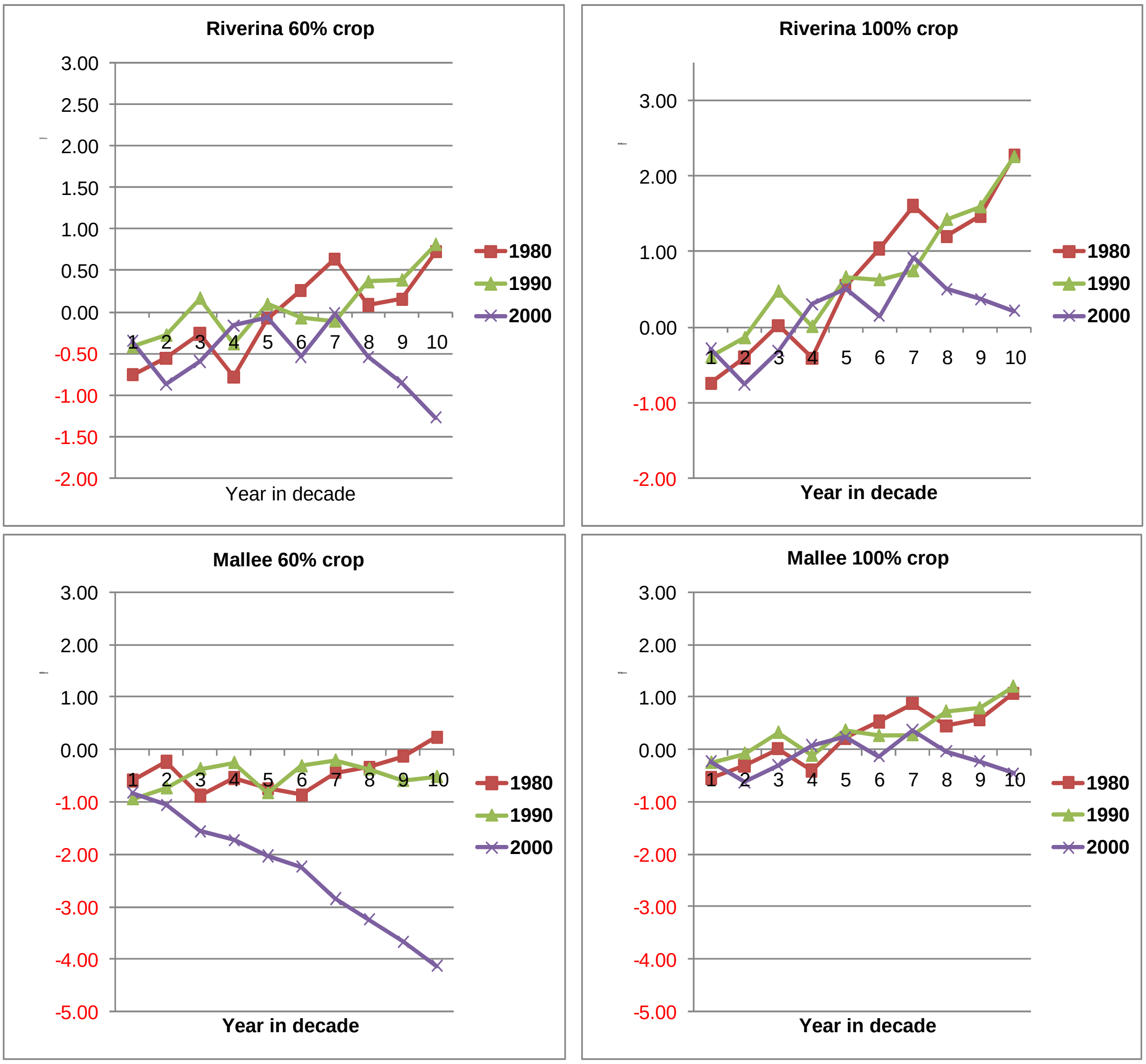


Figure 3: Risk profiles (CDF) for each scenario

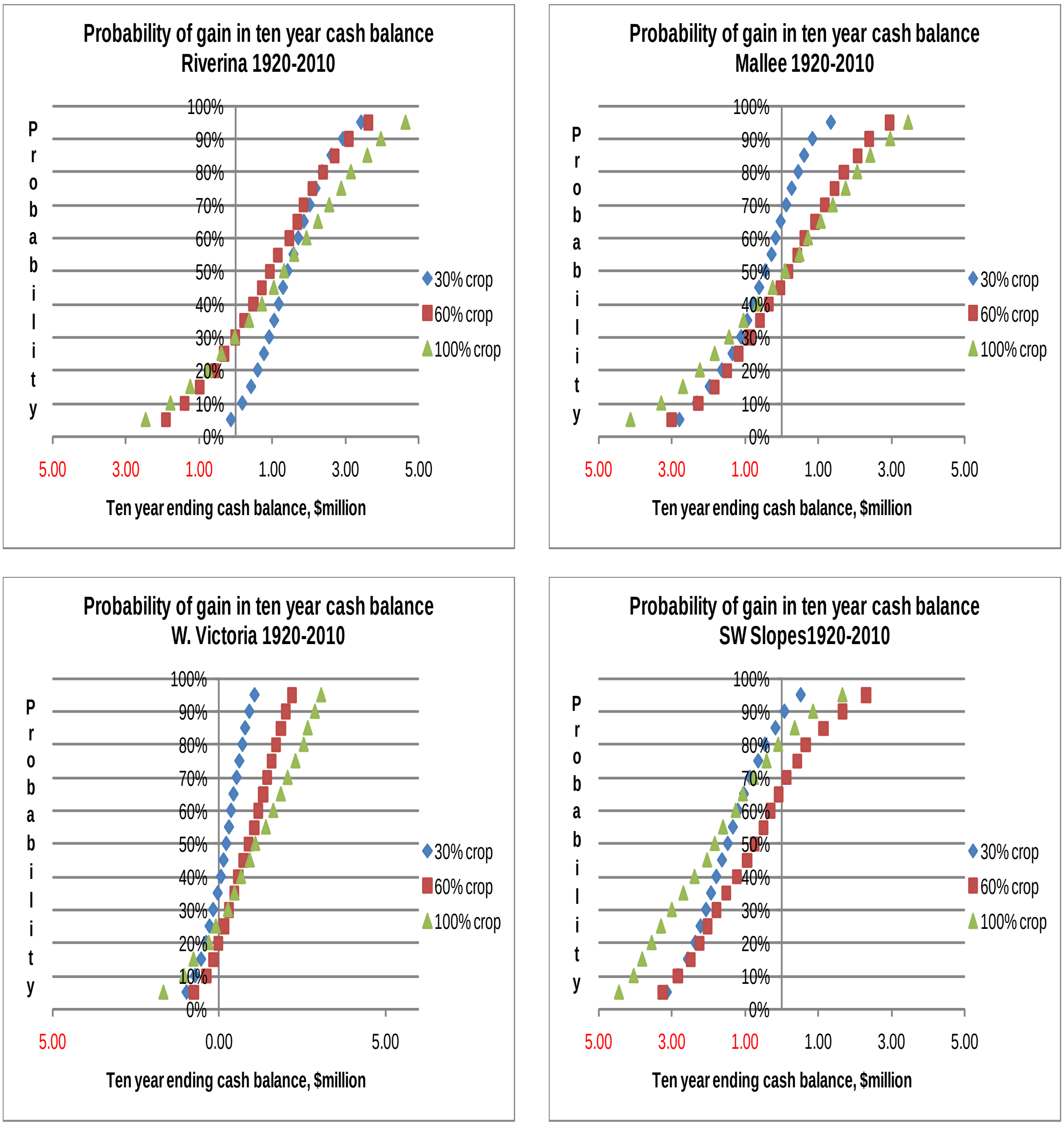


Figure 4. Risk of loss, i.e. negative decadal cash margin

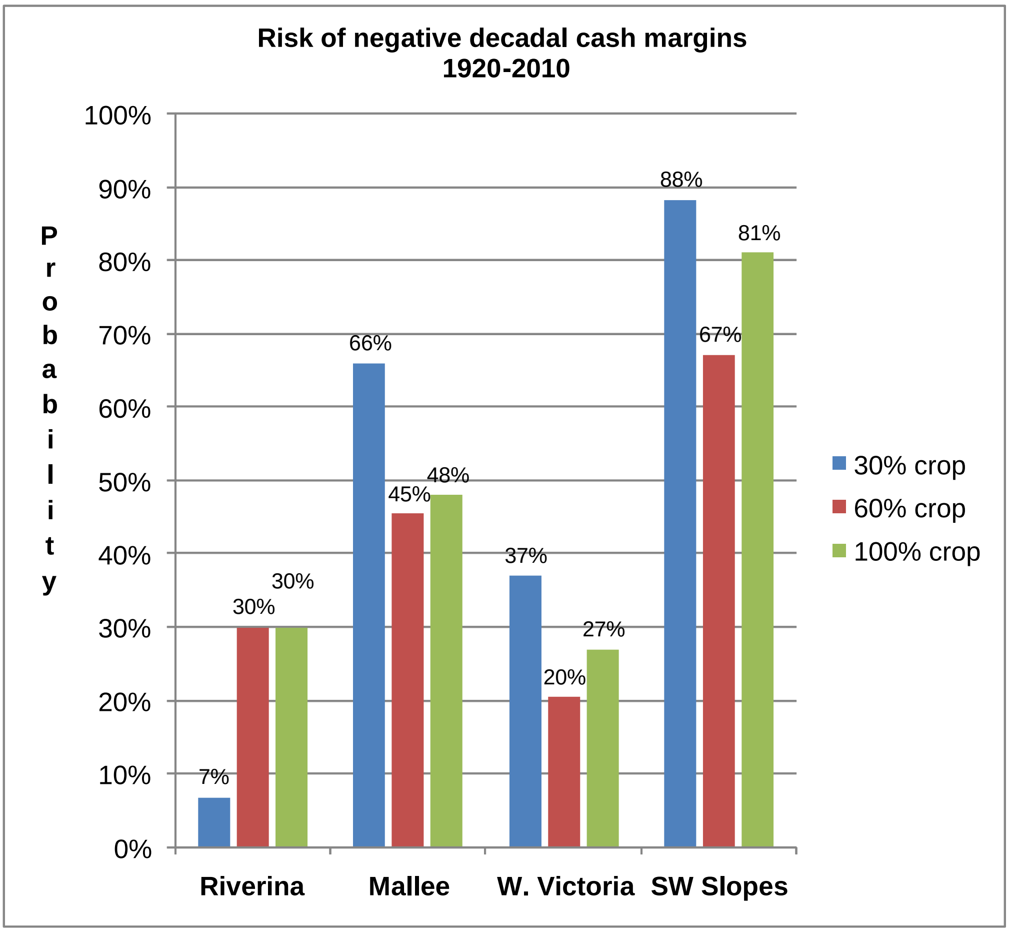
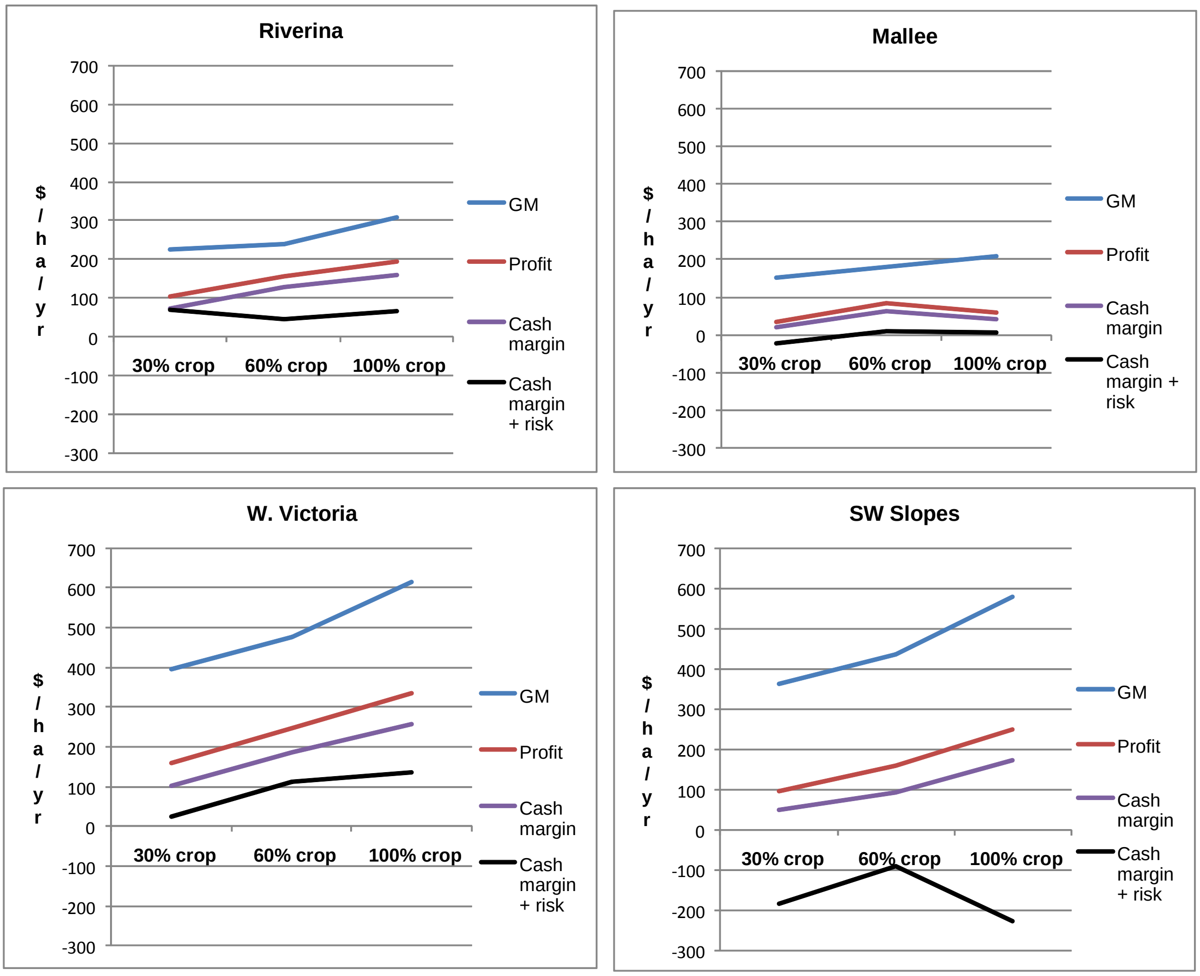


Figure 5. Comparison of financial indices, median prices and GSR, $/ha/yr *



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
Cash margin + risk = median probability decadal cash margin

} three-year averages derived from Business Process Model
- from 1000 runs of optimised model