A FRAMEWORK FOR MODELLING WHOLE-FARM FINANCIAL RISK

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Abstract

We consider the limitations of optimisation analyses that ignore farm-level financial risks arising from combinations of high fixed costs, including debt burdens and highly variable local weather and prices. A sequential multivariate analysis method is used to compute cumulative distribution functions of decadal whole-farm cash balances for a farm facing highly variable prices and weather, and a level of opening debt. This enables direct probabilistic projections of long-term whole-farm financial viability typical of the Coolamon area in New South Wales. We contrast this with a partial-budgeting linear programming study using average annual prices and weather for the same farm. Our focus is on the effects of varying sheep stocking rates, given different pasture compositions in rotation with cropping under weather and price variations over time and different levels of starting debt. We show how best practice recommendations based on partial costing might mislead by ignoring the powerful cumulative effects of input variability and compounding debts. Increasing production, often already near the achievable water-limited potential, can be of far lower priority than reducing costs and lowering heavy debt burdens. We demonstrate that whole-farm financial risk profiles of a farm's options provide a richer, more meaningful basis for sound advice.

Keywords: Farm management, Financial risk, Perennial pastures, Rainfed mixed farming, Weather and price variations

1. Introduction

High risk is a defining feature of Australian agriculture (Chambers and Quiggin, 2000). Risk is also commonly accepted as an important determinant of business performance in other industries. A successful business must be able to identify, quantify and act to minimise risk. The ability of a farm business to respond to risk can determine the difference between subsequent success or failure. Despite the fact that Australian farms are exposed to much greater levels of financial risk than their competitors (OECD-FAO, 2011), there is a notable absence of analyses that include and quantify the effects of production and price risk and farm debt on farm financial performance. Consequently, Australian farm managers have been forced to rely on experience, intuition and judgment to manage risk (McCarthy and Thompson, 2007).

All sectors of the agricultural industry have been encouraged to choose systems which maximise performance, in the belief that increasing production (grain yields or stocking rates), and therefore income, is the most effective route to resilience. In large part this was justified by the ever-declining terms of trade experienced by Australian farmers over the past 4-5 decades. Resilience, however, is defined as the capacity to recover from the impacts of variability, or risk. Resilience can therefore only be evaluated over time, with analysis involving the cumulative response to multiple levels, or sets, of inputs, which define multiple states of nature. Conventional analyses, which use average inputs to describe a system incorporating only one state of nature, cannot test for resilience because they do not include the effects of time, or variability. Consequently, risk is often ignored by most conventional methods of farm analysis.

Productivity improvement only results in increased resilience when the cost to income ratio, and variability of income, are low. This was the case in Australia for a large part of the past century, when productivity growth exceeded cost inflation. This situation changed with the advent of modern agricultural systems which achieve high water-use efficiencies. As a result productivity plateaued in the late 1990s (Hughes *et al*., 2011; Sheng *et al*., 2011), and since then the yield variability of dryland farming systems has risen and approaches the variability of growing season rainfall (Kingwell, 2011; Lobell *et al*., 2009). In the same period total farm costs have increased by approximately 40%, which has reduced margins to low or negative levels (O'Dea, 2009; O'Donnell, 2011). This, when coupled with the long period of drought in the 2000s, has resulted in an exponential increase in farm debt (Reserve Bank, 2009).

Marshall (2014) reported that calls for release of up-to-date figures on Australia's rural debt problem have been stonewalled by banks for fear that the flood of red ink surrounding many of their clients could badly erode lenders' own balance sheets. Powell and Scott (2011) illustrate the wide variations in net income of a representative irrigated farm in northern NSW due to variations in input and product prices, while noting the associated financial risks of failing occasionally to meet interest payments on typical debt burdens. Malcolm and Sinnett (2014) distinguished farm business risk, arising from price and yield variations, and financial risk defined as the probability of failing to service farm debts.

There is a need for greater awareness of farm financial risk management by farmers and advisors across the country. It is important that more resilient farming systems are developed in the near future. By definition, such systems must be 'cash flow positive' in the long term, and have significantly greater upside prospects than downside risks. Businesses in other industries, most of which face lower risks than agriculture, have long monitored their financial risks routinely, recognising these in their forward planning. These examples show why it is important for analyses by agricultural advisors to include full, long-term, financial risk profiles based on accurate and complete whole-farm costs. Farming systems which are profitable at low debt levels may be unprofitable when the farm has significant debt, or is exposed to high income variability.

The present paper describes an application of the simulation model, Sequential Multivariate Analysis (SMA) by Hutchings (2013), with examples drawn from Hutchings *et al*. (2014), to illustrate the need to include all costs and level of debt. Results are compared with those of the Coolamon linear programming (LP) study documented by Bathgate *et al*. (2010). The Coolamon LP model used long-run average productivity levels and prices in the Coolamon district of southern New South Wales (Lat -34.817, Long 147.198, Alt 247m). It assumed average monthly rainfalls, average crop, pasture and sheep production, and average input costs and output prices for a representative dryland farm. The Coolamon LP was run on the industry benchmark MIDAS platform (Kingwell and Pannell, 1987). That analysis showed some management practices, specifically the inclusion of perennial pastures species, to be more 'profitable' than an enterprise without perennials. The present study will show that extra care is required in stating the conditions that would have to hold for this to be true. By including weather and price variations and all costs, results of the different pasture options can be presented simply in probabilistic terms.

2. An application of Sequential Multivariate Analysis (SMA)

The SMA model is designed to dynamically account for impacts of variations in growing season rainfall (GSR), and commodity prices, for financial outcomes of dryland crop and grazing enterprises in virtually any location in the winter rainfall areas of south-eastern Australia.

The SMA process is composed of three stages:

a) Financial and physical data for the representative farm were used in the whole-farm model of Hutchings *et al*. (2014). Rainfall data for 1950-2007 for the Coolamon area were sourced from the Bureau of Meteorology (BOM, 2013). These provide the relevant long-run local basis for sampling sequences of growing season rainfalls on which variations in crop yields could be based after adjusting the water-use efficiencies (Oliver *et al*. 2009) to match the long run average-year yields given in Bathgate *et al*. (2010). Weekly percentiles of commodity prices (Mike Stephens & Associates, 2011) in the decade from 2000 to 2010 were used to provide a matrix for sampling price variations.

b) Decadal sequences of historic growing season rainfall for the Coolamon area were randomly selected and the GrassGro® model (Donnelly *et al*. 2002) used to simulate monthly energy production from the different pasture types for each pasture option listed in the Coolamon LP model. Combinations of price percentiles for the crop and livestock commodities from the farm were from randomly drawn weekly market price percentiles in the period 2000 to 2010. This selection maintained the only significant correlation among these commodity prices (i.e., for sheep and wool, $r^2 = 0.58$).
c) The output from this process was used to develop cumulative distribution functions (CDFs) of decadal cash margins (the ten-year change in the cumulative ending cash balance, including income tax and interest). A description of this process is given by Hutchings and Nordblom (2011). These CDFs quantify the risk profiles for the Coolamon farm. The median profit could then be compared with the output from the Coolamon LP model.

Data for these comparisons are sourced from Bathgate *et al*.(2010). That report details the inputs and outputs from the Coolamon LP, to study the impacts of different combinations of pasture species on the economic output of a typical farm located at Coolamon in southern

New South Wales, Australia. The Coolamon LP model is one example of an application of MIDAS, and does not necessarily reflect the wider capabilities of that family of whole-farm models (Kingwell and Pannell, 1987).

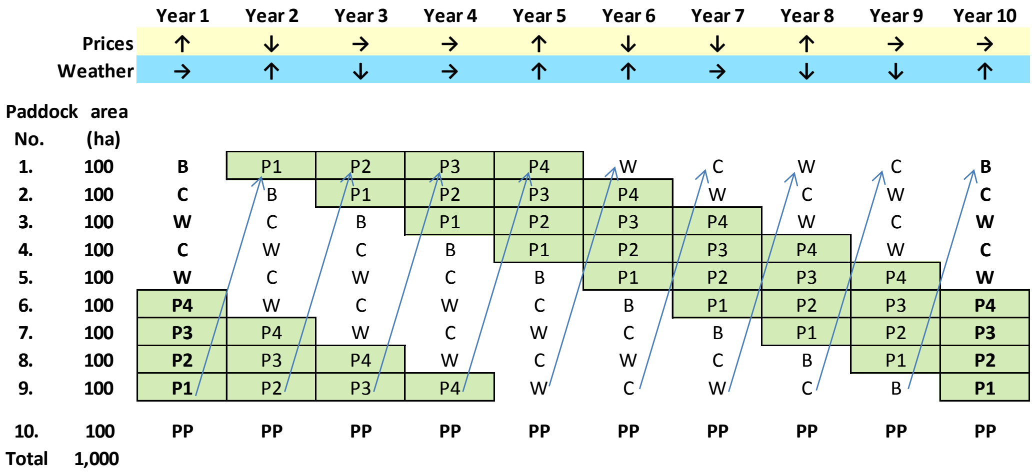
The Coolamon LP was designed to test the impact of different suites of pasture species (Pasture Options) on the profits of a representative Coolamon farm. However, it provides a limited, partial outlook that ignores major cost items as well as any risks due to large year to year variations in prices and growing conditions. These missing cost items and risks are treated explicitly in the present analysis. Importantly, SMA generated the cumulative distributions of ending decadal cash balances to allow direct probabilistic comparisons of the financial consequences of different options for pasture composition and stocking rates given specified levels of opening debt.

3. Fully-phased crop-pasture rotations

The illustrations we give here focus on questions of best strategy, in economic terms, for sheep stocking rates and mixtures of pasture and cropping areas in the Coolamon area, under the influence of different equity levels. Underlying yearly tactical purchase decisions on feed and fertiliser, and decisions on re-sowing (when there is poor establishment of the previous year’s under-sown pasture), depending on the particular sequence of weather, are computed within each decade. It is assumed that five cropping elements of a crop-pasture rotation across the arable land (wheat, canola, wheat, canola, and low-seed-rate barley to allow under-sowing lucerne and other pasture species), are followed by four years of pasture grazing (P1 to P4). Each of the nine elements of the nine-year land use rotation is present in a paddock of equal size each year; thus all land-use elements are affected by the same weather sequence as it varies from year to year (Figures 1 and 2).

A ten-year sequence of growing season rainfalls was used from each decade randomly drawn from the 1950 to 2007 period (i.e., decades beginning in 1951, 1998, 1965, etc.) were combined by SMA with randomly-drawn weekly price sets from the decade of 2001 to 2010.

Following the 9-year rotation, land use of each paddock in year 1 would return to that paddock in year 10. However, the price and weather conditions in year 10 are likely to be different to those which held in year 1. Of course, the economic outcomes will vary between years as weather affects biological production, and prices affect production input costs and output sale values. Each step of the 9-year crop-pasture rotation is represented each year among the 9 paddocks on this farm. In any particular year, the weather and prices of that year determine the economic outcomes.



Paddock No.	area (ha)	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Prices		↑	↓	→	→	↑	↓	↓	↑	→	→
Weather		→	↑	↓	→	↑	↑	→	↓	↓	↑
1.	100	B	P1	P2	P3	P4	W	C	W	C	B
2.	100	C	B	P1	P2	P3	P4	W	C	W	C
3.	100	W	C	B	P1	P2	P3	P4	W	C	W
4.	100	C	W	C	B	P1	P2	P3	P4	W	C
5.	100	W	C	W	C	B	P1	P2	P3	P4	W
6.	100	P4	W	C	W	C	B	P1	P2	P3	P4
7.	100	P3	P4	W	C	W	C	B	P1	P2	P3
8.	100	P2	P3	P4	W	C	W	C	B	P1	P2
9.	100	P1	P2	P3	P4	W	C	W	C	B	P1
10.	100	PP	PP	PP	PP	PP	PP	PP	PP	PP	PP
Total	1,000										

Figure 1. Example of crop / pasture rotation over nine paddocks with variable weather and prices, where B= low seed rate barley (*Hordeum vulgare*) under-sown with pasture species, P1-P4 is a four-year pasture grazing phase, W= wheat (*Triticum aestivum*), C= canola (*Brassica napus*), PP= permanent pasture. Note: ↑, →, ↓ symbolise good, medium, poor.

We adopted the same five pasture options and their proportions of four species of pasture plants as defined in the Coolamon LP results (Figure 2). Option 1, representing sown annual pasture plants, such as subterranean (sub) clover, which re-seed themselves each year, is in greatest contrast to the other four options, which are predominantly comprised of perennial species, with lucerne most heavily represented. In the SMA model we assumed both the annual and perennial species are established by under-sowing their seed with the low-seed-rate barley, to provide four years of grazing in the pasture phase preceding (and following) the five-year cropping phase of the rotation.

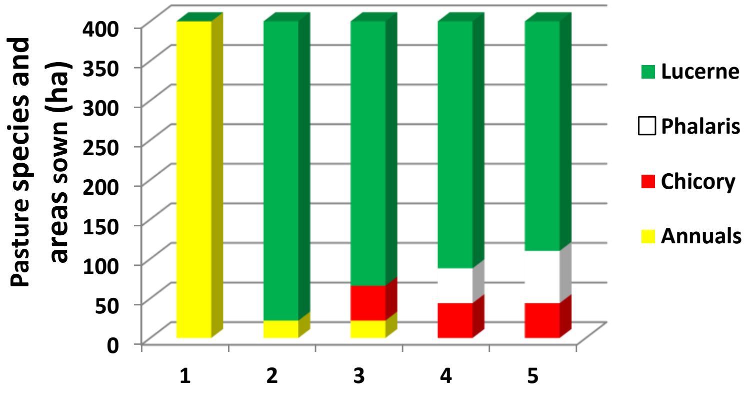


Figure 2. Options for a four-year pasture phase (P1- P4) in rotation with the 5-crop sequence. The annual species here is assumed to be subterranean clover (*Trifolium subterraneum*), and the perennials are Lucerne (*Medicago sativa*), Phalaris (*Phalaris aquatica*) and Chicory (*Cichorium intybus*).

4. Supplementary feed requirements due to weather: a function of stocking rate

We consider a range of sheep stocking rates on this farm given the quantities and qualities of grazing from the cropped paddocks, including summer grazing of stubbles and weeds, can vary greatly from year to year. The lowest stocking rate of 5 dse/ha (1 dse = 1 dry sheep equivalent) would leave a large amount of home-grown forage unused in most years. At the other extreme of maintaining 20 dse per ha, a shortfall in home-grown grazing will require the farmer to feed sheep, which can be very expensive.

The flock structure assumed here is based on a Merino ewe flock breeding its own replacements, joined to Merino rams. The 5 and 6 year-old ewes are joined to meat breed rams to produce prime lambs. All male lambs are sold as prime lamb, with the Merino lambs growing at 180 g/day, and the crossbred lambs growing at 250g/day, values which are typical for this type of enterprise. All lambs are sold to produce a 20kg carcass. Male crossbred lambs are not shorn. Ewes produce 5.5kg/head of 20 micron wool. Both micron and wool cut vary with the age of ewe and lamb. Weaning percentage is 91%, taken from the original MIDAS analysis.

Even in the most favourable years for home-grown pasture, such a high stocking rate would require some feed purchases (Figure 3). The amount of feed required to be purchased in a median year rises from near zero with stocking at 5 dse/ha to about 750 tonnes at 20 dse/ha (Figure 3). A decile-1 (very dry) year with stocking of 20 dse/ha, would mean a high pasture deficit, calling for purchase of about 2,250 tonnes of feed; a situation which approaches that of a feedlot (Figure 3). In such a scenario, the downside risk of the farm enterprise is greatly increased. Of course real farming systems will be more flexible, able to de-stock or find feed sources off farm, etc. The model allows us to compare results of such narrow strategies as holding to a 10 or 15 or 20 dse/ha stocking rate through best and worst of conditions; not every possible, practical way of dodging such conditions.

We assume in the SMA model that production per head does not vary in a drought, with all stock assumed to follow the *LifetimeWool* recommendations for bodyweight, ie maintained at condition-score 3, falling to 2.5 in autumn, and rising before lambing (Young, 2007). While this is difficult to manage, leading sheep producers actively aim to meet these criteria, using feedlotting when necessary. The model does not allow for higher production per head in better seasons, except to adjust the cost of the supplementary feed according to the Grassgro simulation of feed supply for that season, which does give rise to some non-linear responses. Such non-linearity is masked by the extreme variability in rainfall and prices over each decadal simulation.

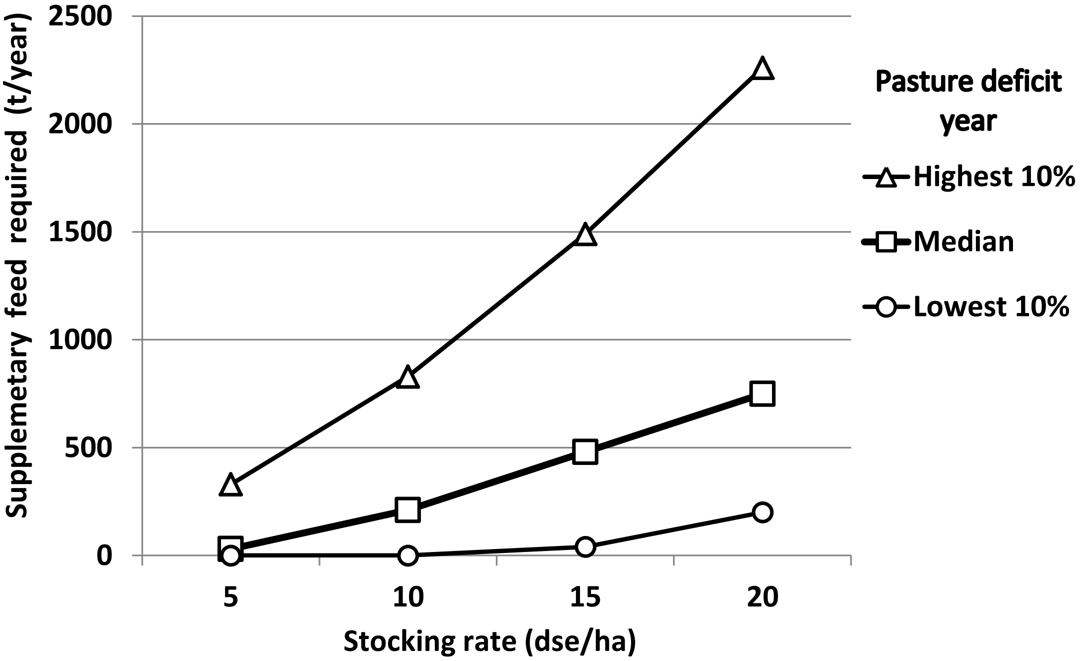


Figure 3. Calculated supplementary feed requirements (whole wheat grain) for pasture Option 5, at various stocking rates (dse/ha of pasture) in high, median and low pasture-deficit years (i.e., dry, normal and wet years, respectively). Requirements increase with stocking rate and pasture deficits due to dry years or poor establishment

Supplementary feed in SMA is adjusted on a monthly basis to meet the deficits. The energy demand is calculated for the above flock. The energy supply uses Grassgro simulations; both supply and demand are calculated on a monthly basis, and summed for each year of the chosen decade. The deficit is supplied using high protein wheat, priced at the price percentile used for the crop enterprise. The SMA model assumes a 70% utilisation efficiency (approx. 8.4 kg grain/kg gain) which correlates well (r^2=0.85 to 0.95) with Grassgro simulations. The model does not allow for selling at non-optimum weights, assuming that lightweight lambs will be placed in a feedlot, which is necessary in most years with spring lambing, in order to reach target bodyweights. In this model the crop stubble is kept free of green growth, in order to conserve summer rainfall, as is now the common practice. This means that the major contribution to feed-on-offer from crops comes from winter grazing, which is now also common practice. The feed available from this source is considered equal to that produced by annual pasture for each year, up to mid-July, taken from Grassgro, so that there is almost no contribution from crops in years with late sowings.

5. Comparing the Coolamon LP and SMA models

Figure 4 compares the profits presented in Bathgate *et al*. (2010) with the true profits calculated for an average decade and median prices, by the SMA model. It must be stressed that the Coolamon LP profit contains calculated opportunity costs and depreciation which are not cash costs; that is, the use of the term profit is incorrect. Figure 4 shows a consistent ranking of the financial results given the different methods of calculation, the variation in sale lamb prices and the difference in the costs included. Nevertheless, profit estimates in the Coolamon LP report are considerably higher than those with the SMA analysis.

The SMA output shown in Figure 4 was modified to estimate true profit levels, including 2014 costs, and depreciation based on the value of the assumed $544,700 in machinery operated by the farm. In addition, this profit includes accumulated interest costs over the chosen decade, which began in 1955. This decade was picked because it appears as the decade closest to the median weather and price outcome in the Monte Carlo analyses, as used by the SMA model.

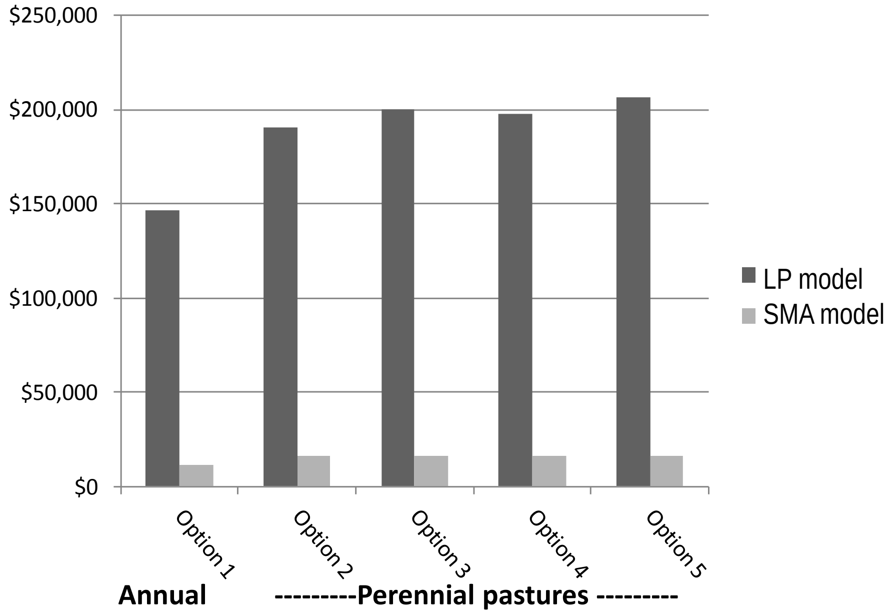


Figure 4. Comparison of average annual profits of the Coolamon LP and SMA analyses. Results of the two models are highly correlated: r^2=0.97

The commodity prices used in the SMA analysis for Figure 4 were fixed at median (decile 5) levels and all costs were inflated over the chosen decade at 3% per annum, compounded. The opening bank balance used in the SMA analysis was adjusted to $40,000 credit balance to match the Coolamon LP; that is, opening with greater than 100% equity.

These changes resulted in model outputs which were highly correlated (r^2=0.97, Figure 4) with those of the LP model, but indicate the latter underestimated the costs of a representative farm in the area by about $180,000 per year. This underestimation can be identified as the Coolamon LP model's omission of $90,000 in annual fixed costs and $72,000 in living costs, as well as pasture costs and interest on debt. Both models showed the profits for the perennial systems were similarly ranked, and 30-40% more profitable than the annual system. Consequently, it is likely that the lower profit for the annual pastures is significant, but by a very small margin.

6. Whole-farm risk profiles for different pasture systems by SMA

Assuming 80% starting equity; interest on the borrowed capital can be a substantial cost; see Figure 5 for the farm with Option 5 pastures. Accumulated debt reduces the bottom-line decadal cash balance (Figure 6) by the amounts shown.

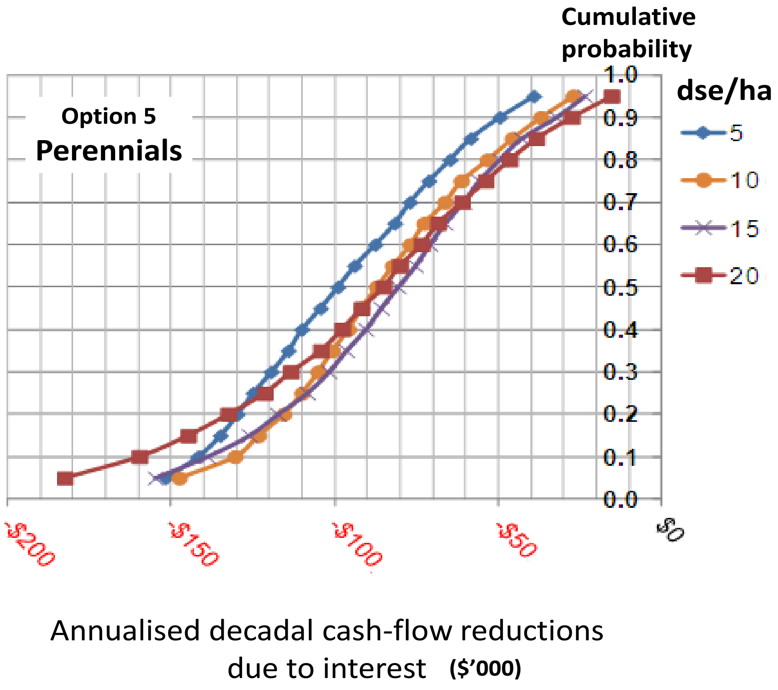


Figure 5. Annualised decadal interest distributions paid at a range of stocking rates, with pasture Option 5 and 80% starting equity. Note high interest with 5 dse/ha due to low use of available resources; and greater downside risk due to feed costs with 20 dse/ha in poor years.

The CDFs for each system, at a range of stocking rates (5 to 20 dse/ha), are shown in Figure 6. These curves confirm that the annual system (Option 1) is less profitable at any stocking rate than the perennial systems. The annual system is more variable, especially at higher stocking rates, due to the extreme level of supplementary feeding required due to the lower productivity of this system.

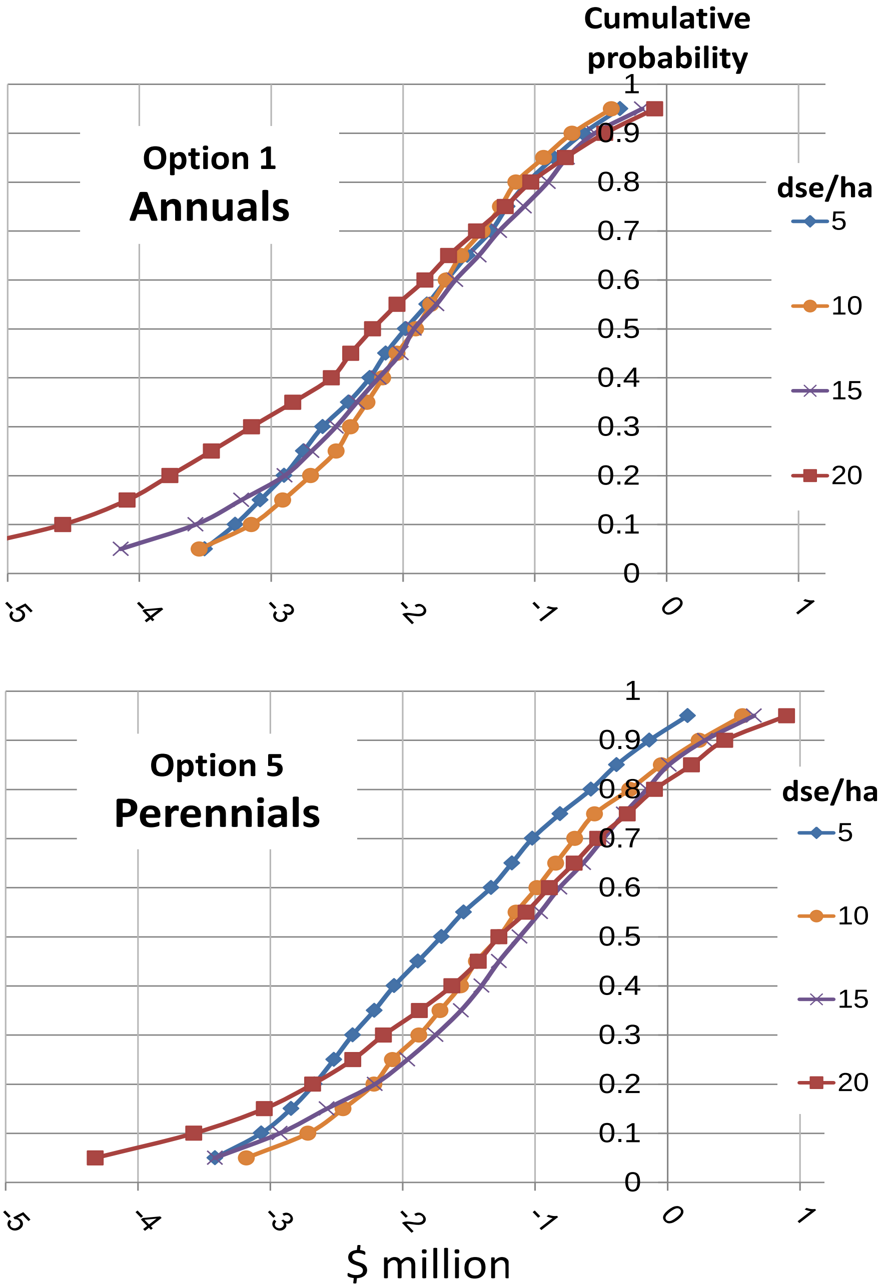


Figure 6. Whole-farm decadal cash margin CDFs (as risk profiles) for pasture Option 1 (annuals) and Option 5 (lucerne and other perennials) at four stocking rates, given starting equity at 80%.

It is doubtful that there are significant differences in risk profiles among the perennial pasture Options 2 to 5 in Figure 6. This should not be surprising, as the perennial Options are all chiefly composed of lucerne, with minor components of phalaris and chicory (Figure 2). Furthermore, the monthly productivities of phalaris and chicory are similar to those of lucerne. However, the inclusion of alternative perennial species may be motivated by non-financial reasons such as to increase groundcover, or utilised on soil types where lucerne is not well adapted (Casburn *et al.* 2014). Of course, in other districts, alternative perennial species may be better adapted than lucerne.

The early grazing is calculated by GrassGro® for each species, with the contribution of crop grazing taken to be equal to annual pasture germinating at the same time. There is no allowance for green growth in stubbles. Together this leaves little room for variation in carrying capacity, or supplementary feed requirements, between the different perennial pasture systems for a given year.

In Figure 6, the cumulative distribution functions for the highest stocking rate (20 dse/ha) indicate the greatest levels of downside risk. For example, in the case of Option 1 (with annual pastures), decadal cash deficits may exceed \$5M. The case of 15 dse/ha with annual pastures indicates possible downside losses of \$4M; almost as risky as the highest stocking rate. Notice the stocking rates of 5 and 10 dse/ha have similar median cash balances.

With perennial pasture Option 5, the 15 dse/ha stocking rate appears to offer the highest median (50% probability) decadal cash margins. The 10 dse/ha stocking gives results nearly as good. The 20 dse/ha rate exhibits the widest range of decadal cash margins, from the highest and lowest benefits. The 5 dse/ha rate with Option 5 appears to give the worst results in all but the poorest 20% of decades, where only the 20 dse/ha rate does worse.   Notice how the impacts of interest costs for Option 5 (Figure 5) are reflected in decadal cash margins for Option 5 (Figure 6).

In Figure 6, cumulative distributions of decadal cash margins each cover a large range of losses, but only low probabilities of positive outcomes. How can this be the case where farmers are good at agronomic and animal husbandry practices and use contemporary equipment and facilities? Part of the reason is the farm debt burden carried by typical farms in the region; assumed to be 20% of equity here (i.e., the farmer owns 80% equity).

7. Stocking rate response curves for the different systems

The SMA model allows the stocking rate to be adjusted, and recalculates the supplementary feed demand and cost, and pasture costs, accordingly. These changes are reflected in the cash flow for any one year, and are incorporated into the resulting decadal cash margin over time, as shown in Figure 7. The maximum, median and minimum decadal cash margins for each stocking rate (5, 10, 15 and 20 dse/ha) can be extracted from these curves and used to develop the response surfaces for each pasture option, as shown in Figure 7.

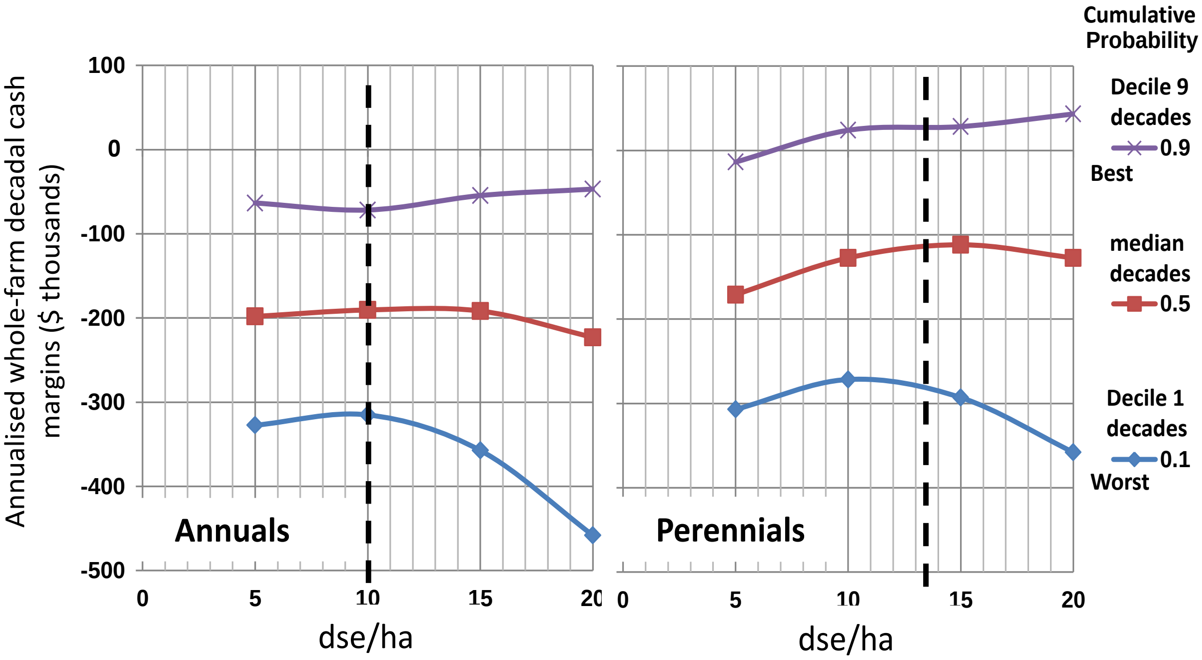


Figure 7. Stocking rate response curves as annualised whole-farm decadal cash margins for two pasture options, As in Figure 6, pasture Option 1 (annuals) and Option 5 (lucerne and other perennials) at four stocking rates, given opening equity at 80%. Decile 9 decades have good weather and prices; decile 5 decades (median) and decile 1 decades have poor weather and prices.

The data points in Figure 7 are the decadal cash margins divided by 10, to give an average annual output more aligned to the annualised reporting in the Coolamon LP model. There are several outstanding features of these curves:

a. They all show substantial annual losses for the whole-farm systems they represent. The annual pasture system (Option 1) shows the highest median losses, of about $200,000 annually. All the perennial systems show median annual losses of slightly more than $100,000 at the most profitable stocking rate.

These losses arise from

- Including the higher fixed and capital costs omitted by the Coolamon LP model.
- The compounding effects of the resulting losses due to the effects of weather and price risk contained in the SMA model.

b. The response curves appear very flat; that is, there seems to be a relatively minor effect of stocking rate on median margins at this scale.

c. The apparent maximum median stocking rates for each pasture option indicated by the SMA analysis seem to be marginally higher than those calculated by the Coolamon LP, as shown by the vertical dotted lines in Figure 6. However, because these response curves are so flat, there is little to be gained by moving to this higher SMA maximum, which would always incur higher costs

d. The results are highly variable; that is the differences between the maximum (highest 10%) and minimum (lowest 10%) average decadal cash margins are much larger and more variable than indicated by the median result.

e. The apparent optimum median stocking rates for all pasture options approximate the optimum values indicated in Bathgate *et al*. (2010, Table 16).

The characteristics of the median may oversimplify the interpretation of these curves, because a farmer using these results as a basis of setting an ideal stocking rate would have little confidence that they would be correct for any one year in the future. In fact the downside risk, as shown by the minimum curves, indicate that it would be prudent to be conservative in setting the optimum stocking rates, when the returns from funds invested in higher stocking rates may be much more profitably invested elsewhere both on and off-farm.

The apparently flat median curves in Figure 7 need to be explained, as this outcome contradicts current extension messages on stocking rate selection.

At the median (50%) level, marginal increases in average annualised decadal cash margins are apparent at the whole-farm level up to a stocking rate of 15 dse/ha, and then decline with 20 dse/ha. The upside prospects, in the decile-9 (best) decades, show a low positive marginal return above 10 dse/ha. In the decile-1 (worst) decades, downside risks decrease in the 5 to 10 dse/ha range and begin to increase at stocking rates between 10 and 15 dse/ha. It therefore seems the most prudent stocking rate would lie closer to 10 dse/ha than 15 dse/ha; this conclusion strikes a balance between maximising income and minimising the risk of loss. However, this outcome has to be put in the context of large and unsustainable losses for the whole farm, when starting at only 80% equity at any stocking rate, and demonstrates the hazzard of making decisions based on marginal analysis alone.

Another reason for the apparently flat response to increasing stocking rate is that every increase in stocking rate in the model results in increased costs, which reduce the marginal response. To understand this it is necessary to explain the structure of the model.

In the SMA model, as used for this analysis, all crop costs, sheep variable costs per head, fixed costs and capital costs remain constant (except for inflation at 3% p.a.) between years. The only factors which change with stocking rate are the cost of supplementary feed, and the cost of phosphate fertiliser applied to pasture. The latter is a minimal cost, as it only involves an additional 0.8 kg phosphate per dse/ha, or $2.92 per dse each year.

The final reason for the flat response curves in Figure 7 is that the interest charge on debt is more than twice as high (7%) as that paid on credit balances (3%). For this reason, debt compounds faster than credit, amplifying the negative bias already apparent in these accounts. Income tax can further increase this bias, because it removes up to 34% of profits before capital and living costs; however, tax is negligible in the predominantly loss-making accounts developed in this study.

The effect of compounding interest was illustrated by Figure 5, which shows the average annual interest paid for each stocking rate for pasture Option 5. That figure emphasises how the highest stocking rate, 20 dse/ha, is associated with the greatest downside risk because it requires more supplementary feed in the poorest seasons, giving it higher costs and lower net income than the lower stocking rates. Notice that the median interest paid is almost identical for all stocking rates above 5 dse/ha. This emphasises that they have very similar long-term levels of debt, which confirms the likelihood of very flat returns across this range of stocking rates.

The lowest stocking rate (5 dse/ha) is less productive, as it leaves unused much of the available grazing resource across a wide range of medium to good years, and provides less income to defray fixed costs. This is reflected in higher interest on debts in those years than under the other stocking rates for pasture option 5. Once again this outcome is reflected in the stocking rate curves of Figure 7.

8. Gross margin risk profiles for sheep enterprises

The main cost associated with increasing the stocking rate is the increase in supplementary feed required to match the resulting increased monthly feed deficits, as illustrated in Figure 3. The median amount of feed required per year increases with stocking rate, but the median requirement is dwarfed by the variability, which also increases with stocking rate. Consequently, the downside risk for sheep gross margins also increases with stocking rate. This is significant because downside risk is associated with losses, and losses accumulate over time in the cash flow. This is also demonstrated by the CDF curves for sheep enterprise gross margins in Figure 8.

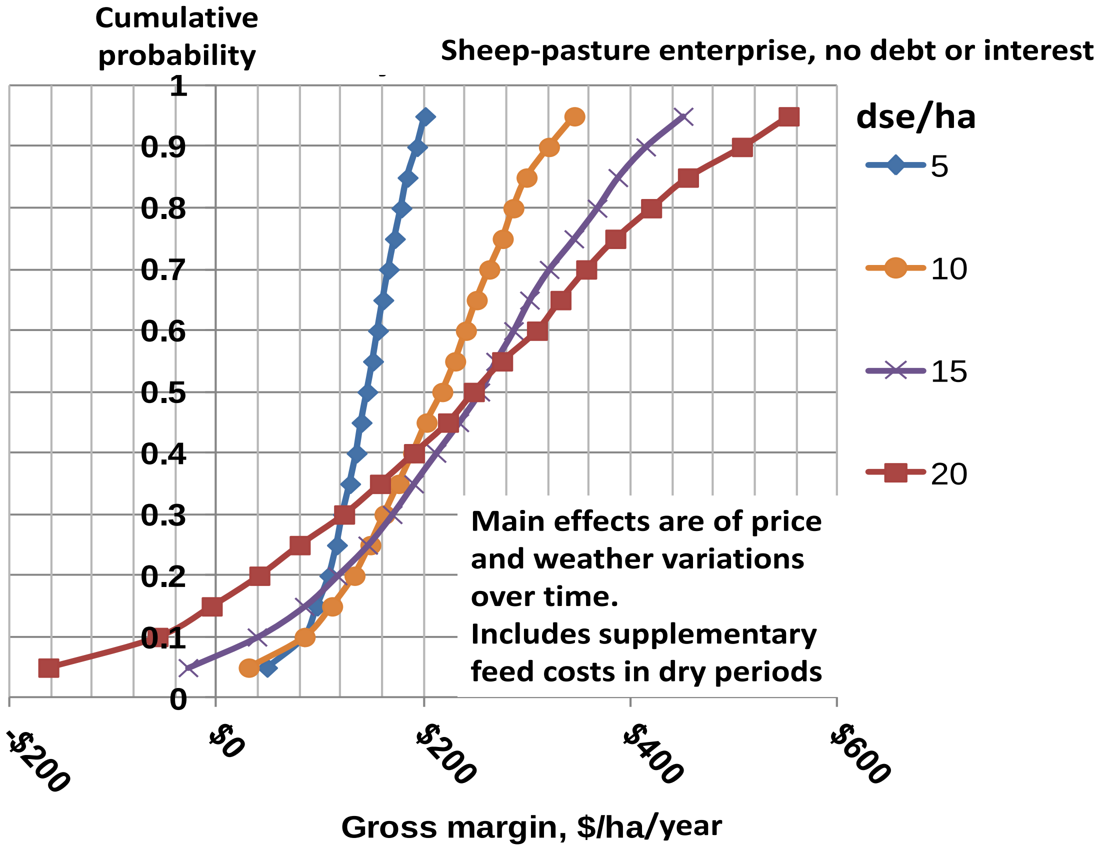


Figure 8. Annualised decadal risk profiles for sheep enterprise gross margins at a range of stocking rates for pasture Option 5.

The CDF curves for each enterprise gross margin in Figure 8 include the supplementary feed, and pasture costs. The slope of each CDF curve decreases with stocking rate. Consequently, the higher stocking rates are more variable (that is they have a wider range of decadal margins) than the lower stocking rates, and are therefore more sensitive to risk. Furthermore, with the exception of the lowest (5 dse/ha) curve, the other curves tend to aggregate between the 20% and 50% probability levels, which explains why the median stocking rate response curves in Figure 7 tend to be flatter than expected, and why the variability is so large at the highest stocking rate.

These gross margin curves do not include the debt burden or other costs of the whole farm. Neither do the gross margin curves reflect the diversification benefits which accrue from combining both the crop and sheep enterprises. Such benefits can result from the fact that the sheep enterprise benefits from low crop prices, which reduce the feed costs. The sheep also benefit from grazing the green crops in winter and the stubbles in summer and autumn. Consequently, sheep gross margins tend to increase when cropping margins are reduced. These benefits are captured by the CDF profiles for the whole-farm decadal cash margin.

9. Effects of debt on whole-farm risks of financial loss

The impact of interest costs on long-term margins will vary with the level of debt, or equity in the farm. This can be modelled (Figure 9), and shows that there is a monotonic negative shift of the CDF profile with every reduction in equity (increase in debt). On average a 20% decrease in equity resulted in a $115,000 reduction in annual cash margin. This margin is more than double the interest on the increase in debt ($51,870), associated with a 20% loss of equity ($741,000). This indicates debt was increasing and compounding over the decade of cash flow simulation. The effect of this growing debt level was sufficient to increase the risk of loss from less than 50% with no debt, to 100% at 60% equity; that is, a shift from a marginal level of farm viability to a certainty of increasing and unsustainable debt.

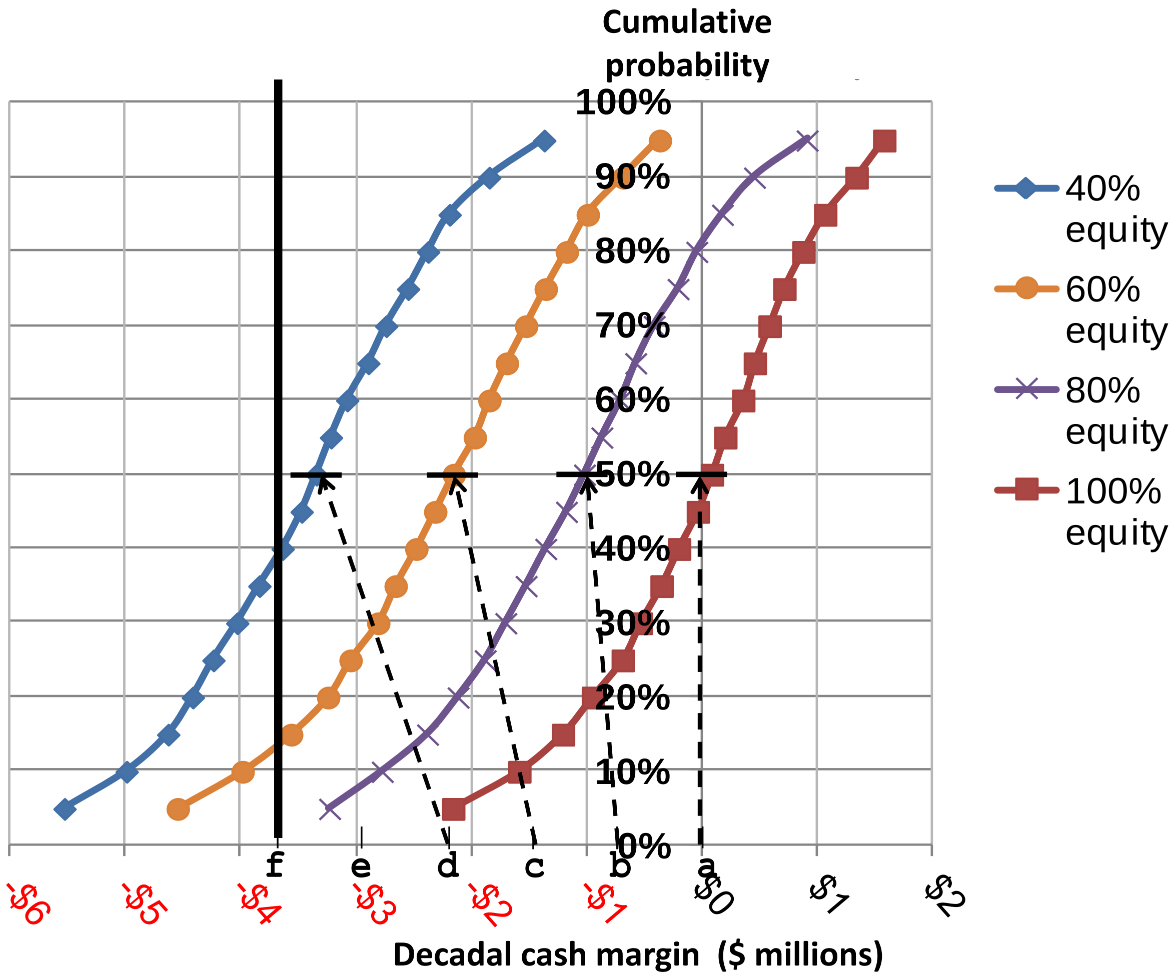


Figure 9. Cumulative distributions of decadal cash margins for different starting debt levels with pasture Option 5. Values **a**, **b**, **c** and **d** are the starting levels of equity corresponding, respectively, to the ending decadal cash margin CDFs labelled 100%, 80%, 60% and 40% equity. Value **f** marks the point where decadal cash margin indicates 100% loss of equity.

It is notable that the average equity level for farms in the area, according to the National Australia Bank database, was 73% in 2007 and has decreased significantly since then (ABARE, 2012). This analysis supports the point that many farms, given the levels of production and price risk associated with mixed farming practices in the region, have large and unsustainable debt levels, which cannot be relieved by better agronomic management alone. It is reasonable to conclude that the high debt levels, which characterise current farm businesses, reflect compounding losses resulting from high risk and low margins. Notice for 100% starting equity, the lowest point on the CDF (Figure 9) is very near **d**; that is, a new opening equity of 40%.

The SMA model calculates the equity position at the end of each decade. However the only component of equity which was considered likely to have changed was the bank balance, ie the cash flow. It is certainly the only variable under the control of the farmer. For this reason all reports focus on the change in cashflow, which, by definition, parallels the change in equity.

Equity in livestock was not considered, as livestock are considered to be trading stock, not capital. However the value of the livestock component is small compared with the investment in land and machinery, which are both included. The model looked at the long-term steady state implications of different stocking rates, rather than the cost of transitioning between them, so that the comparisons are valid, especially as the change in cashflow contains all the costs, including labour, capital and living costs, associated with the change in the stocking intensity. The various scenarios can be considered to represent valid comparisons between different farms in the same region.

10. Conclusions

Though highly correlated, the financial outputs, or direct comparison of profits from the LP and SMA models, were vastly different in scale. The outputs from the Coolamon LP model are presented as profits, but contain non-standard component costs, when compared to the costs included in the more accurate SMA profit calculations. We have illustrated how farming systems, which are profitable at low debt levels may be unprofitable when the farm has significant debt, or is exposed to high income variability. Surprisingly, a farm business starting at full 100% equity, with no debts, is still at risk of sinking into debt if faced with a sequence of bad seasons combined with low prices.

The SMA analysis confirms the importance of including all costs in farm business analysis. Partial costing, such as used by the Coolamon LP model, can provide misleading messages to farm managers, except for those few whose businesses are free of debt. It is obvious that the relatively small benefits from changing pasture management practices, which were the outcome of this analysis, are of limited importance when seen against the background of large and accumulating debt, which is characteristic of many farms in the Southwest Slopes region of New South Wales (Hutchings, 2013).

Dynamic systems analysis is critical to all high-risk businesses, like farming, and has the potential to change research priorities and to better qualify best practice farm management advice with respect to debt. This study illustrates the possibility that it is the absence of such information which has allowed the promotion of farming systems that lack the necessary resilience to cope with the inherently high levels of variability. In contrast, the dynamic analysis provided by the SMA model shows that the single-point optimum outcomes suggested by the Coolamon LP model fail to render an appreciation of the risks associated with rainfed mixed farming in this area. While the Coolamon LP pointed to optimum stocking rates, it failed to show that there is little loss in margin, but a substantial reduction in risk, at lower stocking rates. This is demonstrated in comparing the distributions of 10, 15 and 20 DSE/ha stocking rate outcomes in Figures 7, 8 and 9.

This more holistic interpretation could have considerable impact on better understanding of the risks in running the higher stocking rates compared with alternative investments either on or off-farm. This information questions the current extension emphasis on production and therefore questions the formulation of best practice messages, made without regard to the risks faced by farmers in different circumstances with regard to equity.

Our analysis supports the point that many farms, given the levels of production and price risk associated with mixed farming practices in the region, have large and unsustainable debt levels, which cannot be relieved by better agronomic management alone. It challenges the common use of the term profit to describe a partial calculation of benefits from a change in part of a farming system while assuming all other determinants and costs of sustaining and modulating such benefits can be ignored yet remain present and constant. Such a partial analysis, using average conditions, can be a misleading basis for advice. We have demonstrated that whole-farm financial risk profiles of a farm's options provide a richer, more meaningful basis for sound advice.

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