Financial risk analysis of lucerne pasture establishment: Under-sowing vs Direct sowing

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ABSTRACT

Over the past 80 years an unresolved issue in rain-fed crop-pasture rotations by scientists and farm advisors has been whether to recommend sowing a perennial pasture either alone or with a cereal cover crop. Researchers and agronomists have typically advocated sowing pastures alone to improve pasture productivity, but a large proportion of farmers continue to sow pastures under a cover crop suggesting a perceived financial advantage with the latter establishment method. Whether there is a real financial benefit of establishing pastures under a cover crop presents a practical Farm Financial Risk problem. Our study is based on four years of field experiment results (2008 to 2012) along a 200 km transect running north and south of Wagga Wagga, New South Wales, Australia. Analysis of these results with information on local weather and price variations using "The Intensive Farming (IF) model" (Hutchings *et al*, 2016), suggests the following: (1) sowing the pasture alone is a more reliable method of establishing lucerne (*Medicago sativa* L.) pasture than sowing under a cover-crop; and (2) the additional costs of sowing a lucerne pasture alone are met in the majority of years by its increased productivity compared with pastures sown with cover-crops. Comparing median decadal cash balance values for pastures with stocking rates of 10, 15 and 20 dse/ha, our results show an advantage with direct-sowing for farms with high equity. Farms with low equity may not be helped by agronomic improvements, but find it best to focus on reducing debts.

Keywords

South-eastern Australia, Rain-fed crop-pasture rotations, *Medicago sativa* L., Perennial pastures, Weather and price variations, Pasture establishment efficacy and cost, Farm financial risk analysis, Decadal cash balances.

PLAN OF THE PAPER

1. With a focus on comparing pasture establishment methods, the paper briefly describes the logic and sources of information used to capture numbers required for a simulation model to estimate pasture and crop growth in response to varying rainfall conditions from year to year for the study location. Additionally, interactions in sheep nutrition requirements that can be met by

grazing pastures and crop residues each season, with shortfalls met by supplementary feed, are specified.

2.   The paper describes the integration of the varying streams of pasture and crop yields, and supplementary feeds, from the simulation model above in an accounting model that adds a stream of relevant commodity price variations to produce a mixed stream of data for risk analysis of the farm's financial bottom line. Random draws from these data are carried out in 'Monte Carlo' simulations, which also consider the influence of specified levels of initial debt on the farm's bottom line. Choices of fixed stocking rates of sheep numbers on the farm's total pasture area (i.e., 5, 10, 15 and 20 dse/ha) serve as key parameters for simulation runs.

3.   The paper Illustrates the steps in an example risk analysis, discussing the results and their implications for the financial stability of the farm. The results are presented as risk profiles in the form of cumulative distribution functions, which summarise the probabilities of attaining particular decadal cash balances. These show the likelihoods of negative versus positive financial results in the long run. The whole range of yield and price variations as well as the initial level of farm debt, are taken into account in the process.

Introduction

We consider the financial risks in the performance of rain-fed perennial (Lucerne) pastures sown with, or directly following, the final crop in a cropping sequence. Four-year perennial pasture phases followed by five-year cropping phases (or other combinations), are common in south-eastern New South Wales (NSW) Australia. Comparisons of these pasture establishment methods have been the subjects of a number of studies. Among the recent studies are Dear *et al*. 2010; McCormick *et al*. 2012a: 2012b; 2014; Li *et al*. 2014; Swan *et al*.). McCormick *et al*., (2014) highlighted the scanty attention previously given to economic considerations around this question, observing:

> "More than a dozen experiments over the past 80 years, excluding the many field experiments that were never published as well as studies internationally, have attempted to measure the effect of cover-crops on pasture establishment. However, despite relatively consistent messages about reduced pasture performance due to competition from the cover-crop, farmers in the mixed-farming zone of south-eastern Australia continue to rely on the practice as a method of establishing their pastures. Reasons for this non-adoption of research findings may be an ineffective campaign over

several generations to extend insights from the research or, **more likely, that the agronomy-focused experiments have failed to address the issue of farm finance and the complex problem of balancing the needs and opportunities of multiple crop–livestock enterprises within the one farm.**" (bold emphasis added)

The present paper represents perhaps the first attempt to assess the financial factors associated with different approaches to pasture establishment. New statistical analyses of field trials are presented. These form part of the basis for whole-farm modelling that takes account of weather and price variations for our analysis of financial risks at given equity levels.

Our statistical analysis of pasture productivity for its first grazing years is based on measured pasture characteristics and crop responses under several treatments and a range of weather conditions from 2008 to 2012. The present study uses these results, combined with wider information on long-term sequences of weather, to simulate distributions of rain-fed cropping / pasture production, combined with economic and financial risk analyses using simulated price series, to produce distributions of the change in net cash flows over 10-year sequences.

METHODS

At Yerong Creek in the mixed farming zone of south eastern NSW, a sequence of three experiments were sown commencing in 2008, 2009 and 2010 in adjacent fields (Li *et al*., 2014). These trials were aimed, among other things, to quantify the factors determining pasture productivity in the first year of grazing.

Six large-scale, on-farm participatory experiments were sown using farmers' own labour and machinery at two further locations, as follows: in 2009, three of these participatory experiments were sown in the Ariah Park area and one at Brocklesby (respectively 120 km north and 55 km south west of Yerong Creek); in 2010 one further participatory experiment was commenced at Ariah Park, and one at Brocklesby (Swan *et al*., 2014).

While annual rainfalls at these locations were well below long term averages in 2008 and 2009, they were 200mm above average in 2010.   These trials provided cover-crop wheat grain yield in the year of sowing and pasture dry matter yield measures at points in time beginning in autumn of the year following sowing. This captured the pasture productivity in the first full year of

grazing and in subsequent years. In some cases, measurements of four-year sequences were captured.

Data on soil types and chemical properties (pH and effective cation exchange capacity) were available for the different sites. Monthly weather (rainfall) data were available for many of the trial sites. Use was also made of monthly rainfall data available from the Australian Bureau of Meteorology (BOM) for the various locations spanning the experimental period for the respective field trials.

Measures of above-ground biomass, botanical composition and persistence observed in field trials of lucerne pastures, sown alone or with a cover-crop, helped provide the basis for simulation of pasture establishment success over many seasons, sampling the long-run monthly rainfalls for the location over the 1950-2010 period.

Details on statistical analysis based on the field trials are presented here with plots of observed vs simulated pasture dry matter yields in the first year of grazing following the establishment year, followed by financial simulation results.

Data from these sources were combined in regression analyses for estimation of effects of weather, cover crop and pasture sowing rates and dates, and soil factors in pasture productivity, in pastures either sown alone or with a cover-crop. This permits building upon the trial results using multiple decades of weather and price data for simulations capturing a wider range of probabilities.

A regression equation was developed predicting the dry matter yields of pastures either sown alone or with a cover-crop in the first year of grazing:

DM = -3666+(GSR*3.13)+(SRf2*2.08)+(Na*4155)+(pH*1923)-
   (Day*106.6)+IF(Usow="Y",-335,0)+IF(Dir="Y",805,0) $r^2 = 0.86$ n=42
Where:

   DM (kg/ha) = total available above-ground biomass in the first grazing
         year; that is, the calendar year following the first summer,
         when under-sown lucerne is in its second year of growth.
   GSR   = growing season rainfall for the establishment year (p<0.001)
   SRf2   = Jan-March rainfall in summer following establishment (p<0.001)
   Na   = concentration of exchangeable sodium, ppm (p<0.001)

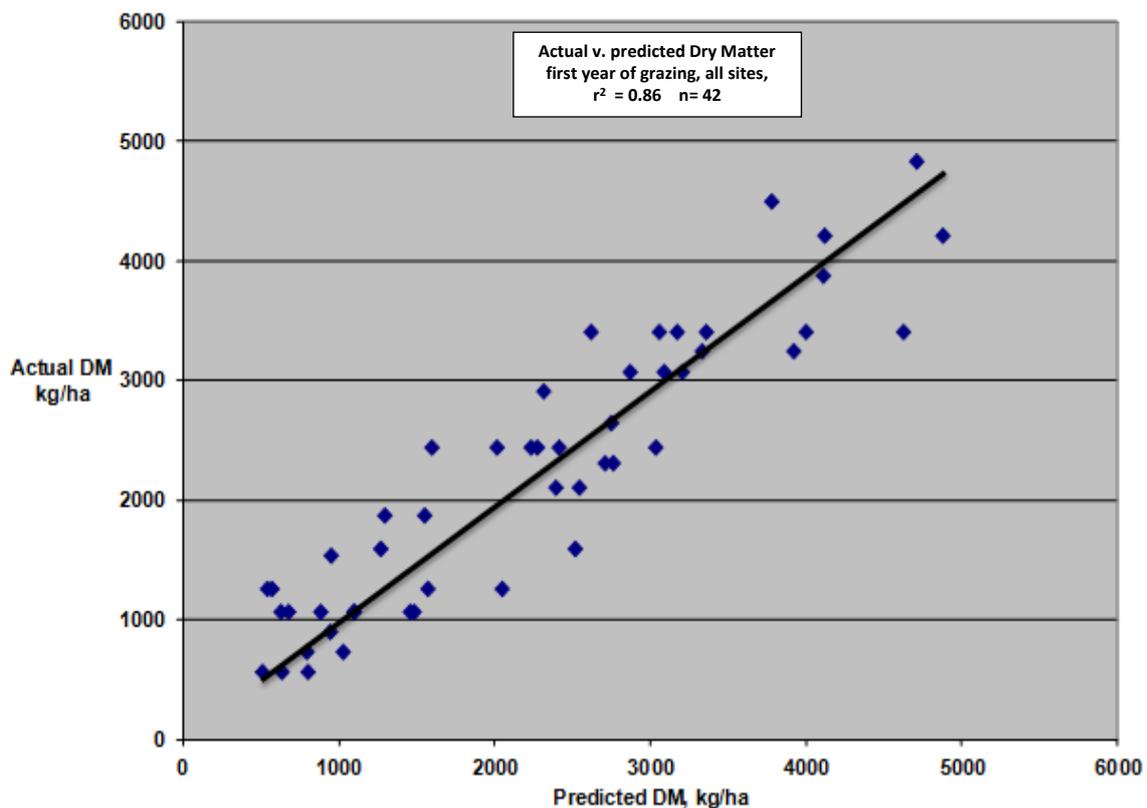**pH**   = soil pH (0-10cm, $CaCl_2$) (p<0.1)

Day   = sowing date expressed as number of days after May 1st (p<0.1)

Usow = lucerne sown with a cover crop (p<0.001)

Dir   = lucerne sown alone

RESULTS

Results of the above regression equation (combining both sowing methods) are illustrated in Figure 1.
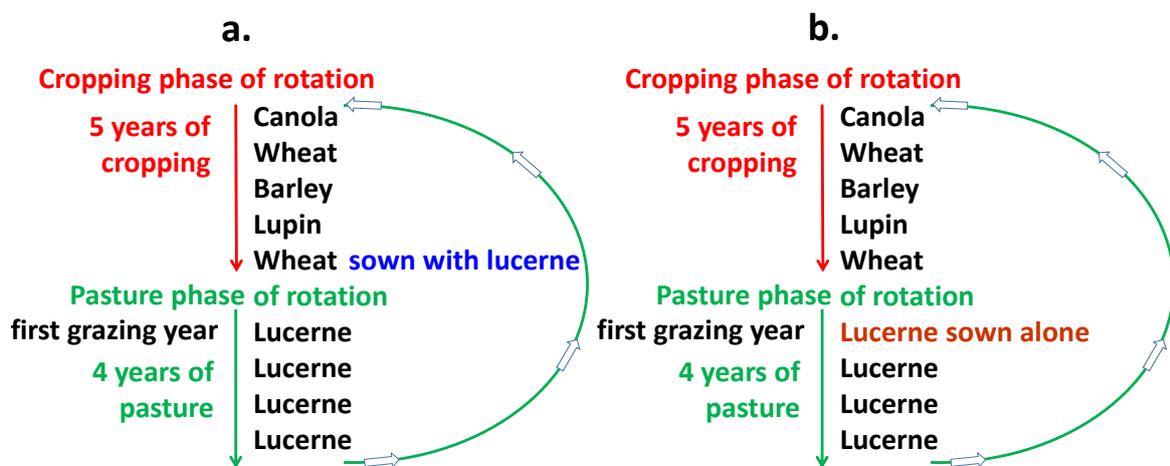

Actual v. predicted Dry Matter first year of grazing, all sites, r^2 = 0.86   n= 42

Figure 1. *Comparison of observed and predicted pasture dry matter yields in the first year of grazing.*

Our analysis assumes a mixed (crop/livestock) system on a 1,000 ha farm in the Coolamon region of NSW, detailed further in Hutchings *et al*. (2014). It assumes the farm is divided into nine paddocks managed with a rotation of five years of cropping followed by four years of pasture. All nine elements of the rotation are assumed present on paddocks of equal size on the farm each year, moving to the next paddock each year according to the sequence given. That is, each

element of this nine-year rotation is present in one of the farm's paddocks each year (Figure 2).

Variations on this sequence are common in the mixed farming systems of the study area. Over the long term, with changes in costs and prices, and with technical advances, or emergence of new problems such as pests, these patterns are expected to change. Rodriguez *et al.* (2011) showed how plasticity (adaptability) can be a desirable characteristic in farming systems operating in highly variable environments. At seven of nine locations across southern Australia, Moore (2014) found the most profitable farming systems included some perennial pasture, but no one species or land use system predominated.

a.

Cropping phase of rotation

5 years of cropping | Canola
Wheat
Barley
Lupin
Wheat **sown with lucerne**

Pasture phase of rotation

first grazing year | Lucerne
4 years of pasture | Lucerne
Lucerne
Lucerne

b.

Cropping phase of rotation

5 years of cropping | Canola
Wheat
Barley
Lupin
Wheat

Pasture phase of rotation

first grazing year | Lucerne sown alone
4 years of pasture | Lucerne
Lucerne
Lucerne

Figure 2. The rotation of a five-year cropping sequence with a four-year pasture phase. Two methods of Lucerne establishment are indicated to illustrate the contrasts in their timing: **a.** where the final crop in the sequence is sown with Lucerne; and **b.** where lucerne is sown alone following the final crop in the rotation.

Pasture dry matter yield (DM kg/ha lucerne + other species) in the first grazing year was simulated with the regression model shown above to capture the effects of rainfall, sowing date and soil characteristics from the field trial. Energy yield of a pasture in its succeeding (2nd, 3rd and 4th) grazing years was calculated with *Grassgro* (Donnelly et al., 2002). Each dot in Figure 3 represents the total of calculated nutrient energy in that calendar year from grazing the farm's four pasture paddocks of different maturities: one paddock in its 1st grazing year, one in its 2nd, one in its 3rd and one in its final (4th) year of grazing.
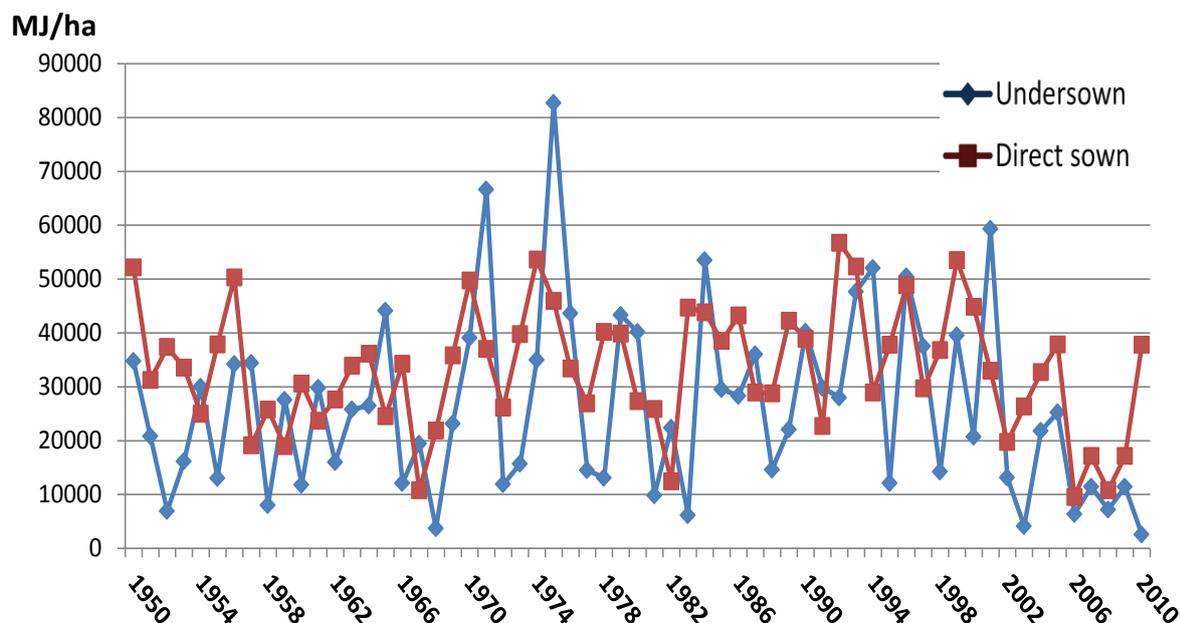
Figure 3. Comparisons of annual energy yield of lucerne pastures sown alone or with a cover crop.

These results indicate that lucerne sowing alone yielded higher digestible energy production than under a cover crop in 40 out of 60 years, based on the actual 1950-2010 rainfall record at Coolamon, NSW.

Sowing lucerne alone costs $204/ha compared to only $55/ha in additional costs for sowing lucerne with a cover-crop, which is the final crop in the rotation. Reasoning that the crop establishment costs are already committed, simply adding the lucerne seed at sowing may be regarded as the 'lowest cost' way to establish a pasture.

Effect of stocking rate on supplementary feed costs
1950-2010
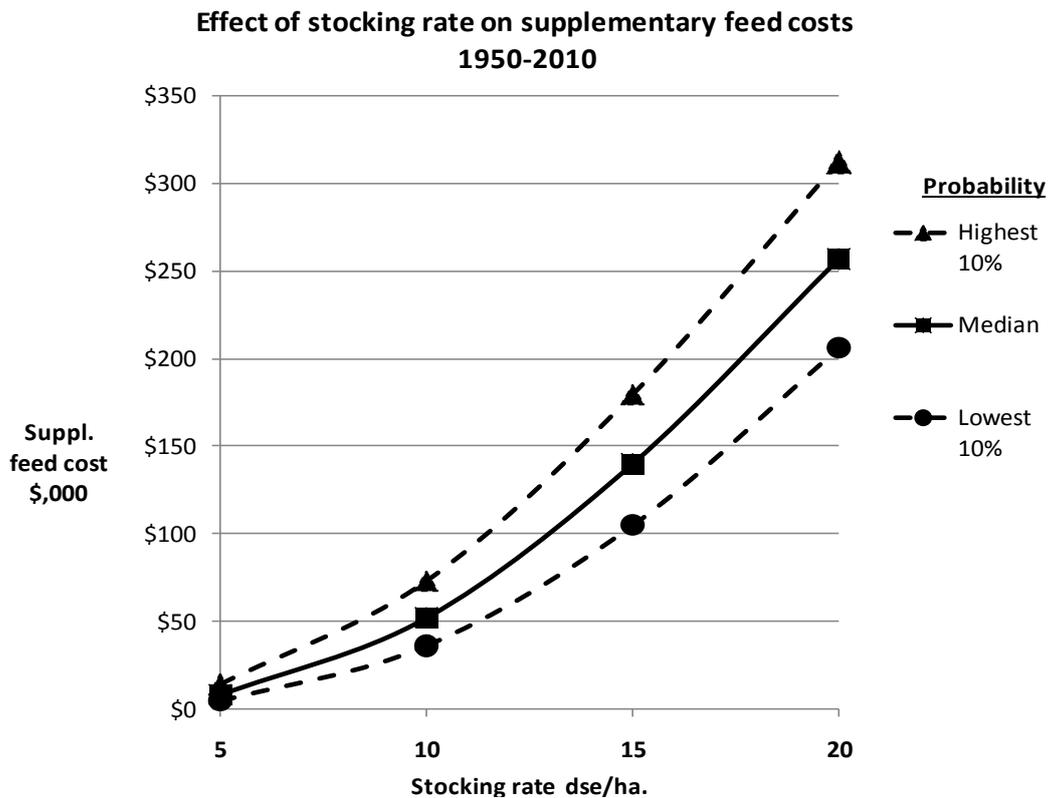
Figure 4. Supplementary feed costs with lucerne pastures sown alone.

Our simulation accounts for lucerne establishment failure by assuming pasture in a particular paddock in a particular year will revert to annual vegetation for the remainder of its pasture phase.

Supplementary feeding costs are minimal at low stocking rates because the pasture produces sufficient energy. In contrast, at a high stocking rate (20 dse/ha), supplementary feeding will be required in most years, with larger amounts in poor years.

The field trial methods and analyses of biological response data above provide one of the keys for understanding and mitigating some of the financial risks in mixed rain-fed crop-livestock systems. The importance of going beyond typical gross margin calculations in farmers decision making has been highlighted earlier by Hutchings and others: they showed how including weather and price risks and all costs allows comparison of farm financial risk profiles for different management decisions in terms of probability distributions of long-term

(decadal) whole farm cash margins (Hutchings, 2013; Hutchings *et al*. 2014, 2016; Nordblom *et al*. 2015).

The present paper illustrates an application of this approach to the conundrum of how best to establish a rain-fed perennial lucerne pasture under the local conditions of our study area in south-eastern New South Wales. First, we consider some ways of defining economic and financial condition of a farm .

For a given enterprise, subtracting its annual variable costs for a year from its annual gross income gives us a measure called its gross margin for the year. Given year to year variations in prices and growing conditions, gross margins will fluctuate over time. Typically, average yields and average costs are assumed for gross margin calculations for the average year. The implication often suggested is that this can represent the economic situation of a farm. This is the normal method used by managers and research personnel to evaluate management changes, which makes no allowance for fixed and capital costs, cost inflation, accumulation of debt, or variability from any source.
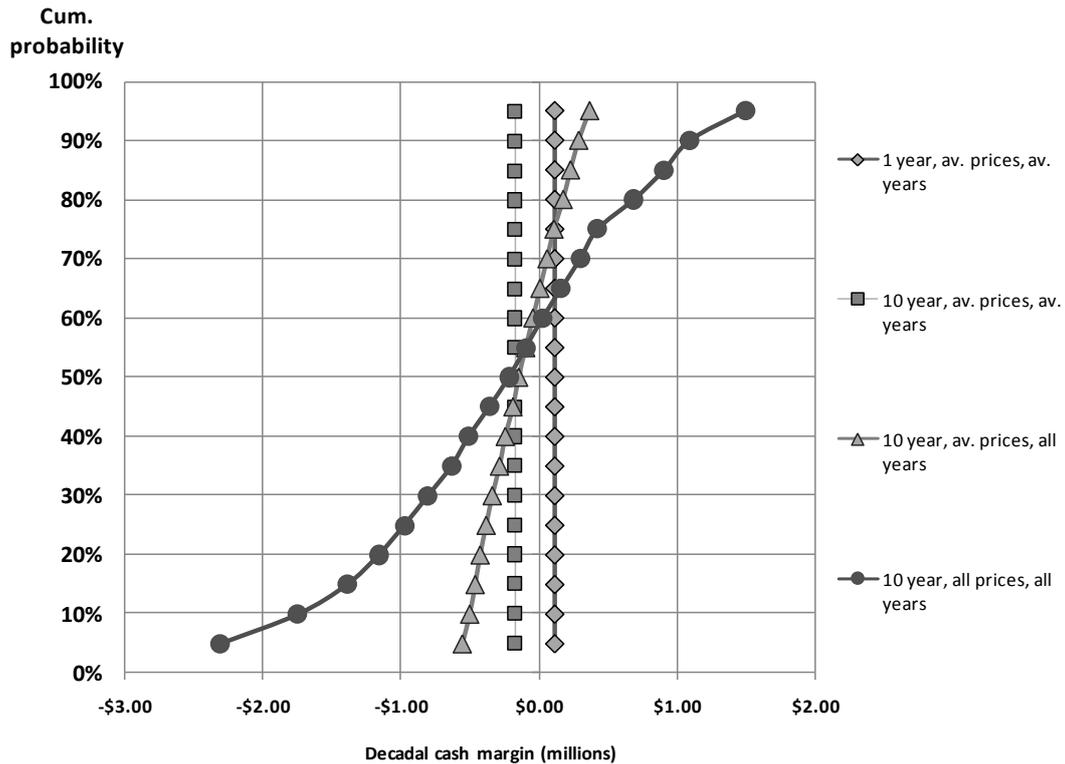
However, cost inflation and accumulation of debt (or surplus) over a 10 year period can place the same farm in a negative (or positive) financial position. An example is given in Figure 5, (borrowed from Hutchings *et al*. 2016). Further, allowing for price variations, rather than averages, allows for the probabilities of different financial outcomes. Finally, adding the effects of all costs and variable growing conditions from year to year in a dynamic analysis completes (in Figure 5) the probabilistic 'risk profile' for a particular management option. This can be compared with the risk profiles of other management options.

We have used terms such as 'annual gross margin' here and 'decadal cash margin' earlier without defining them. Brief descriptions of these terms are needed:

Subtracting a farm's annual variable costs from the farm's annual gross income gives us the measure of the farm's annual gross margin. But these annual variable costs account for only 30 to 40% of total costs.

Subtracting from the annual gross margin the farm's 'fixed and capital costs' (40-50% of all costs), 'living costs' (5-15% of all costs) and 'tax & cumulative interest costs' (0-25% of all costs) gives us the measure called 'annual cash flow'.

Cash margin estimates for static and dynamic analysis

Legend:
- 1 year, av. prices, av. years
- 10 year, av. prices, av. years
- 10 year, av. prices, all years
- 10 year, all prices, all years

Figure 5. Risk profiles for the cash margin under a range of scenarios at 80% equity (after Hutchings *et al*., 2016).

The measure called 'decadal cash margin' is the farm's cash balance at the end of year 10, minus the opening cash balance at the beginning of the decade. With variations in growing conditions and in prices within and among decades, there have been and will likely continue to be, variations in 'decadal cash margins' for any farm over time.

Given the availability of multiple decades of weather data for many locations, it is possible to simulate yield responses of crops and pastures to random weather sequences. These, combined with random price sequences for farm inputs and products, allow simulation of distributions of 'decadal cash margins' for a farm configured for different production plans. For example, the long-term results with a plan to maintain a particular sheep stocking level on the farm may be compared with long term results with a different stocking rate. The median 'decadal cash margin' from a thousand 'runs' simulating the financial consequences of a particular configuration of a farming system can usefully be compared with that of other configurations. For example, see Figure 6.
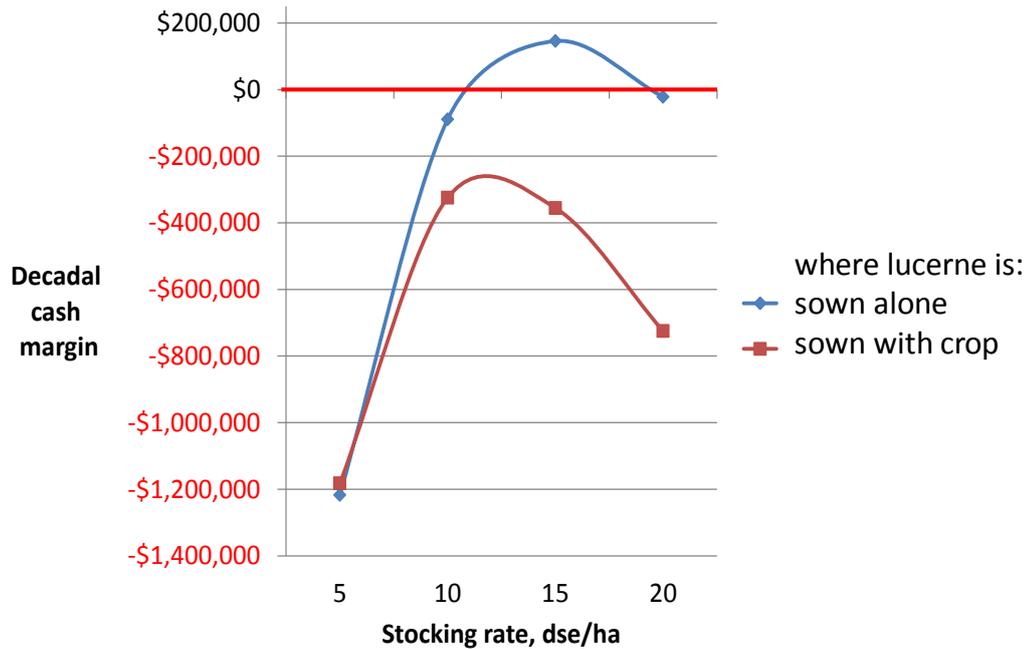
Figure 6. Median effects of pasture establishment methods and stocking rates on whole-farm decadal cash margins, given opening equity of 80%.

Notice the best median 10-year (decadal) whole-farm cash margin observed is less than $200,000 (Figure 6). Because the decadal cash margins account for all costs they can present a less optimistic picture than simple annual gross margins, which account for only 30-40 % of costs.

It is clear in Figure 6 that pasture sowing method and stocking rates influence the median outcomes for farm finances in terms of ending cash margins. In terms of median long-run cash margins, lucerne establishment by sowing alone dominated cover cropped scenarios at stocking rates of 10, 15 and 20 dse/ha. The low stocking rate of only 5 dse/ha did poorly with either sowing method, offering the lowest chances of improving decadal cash margins.

The peak median cash margin for pastures sown with a crop is around 12 dse/ha, while that with pastures sown alone is about 15 dse/ha. The difference equates to an extra 1,200 dse, which generate sufficient additional income to deliver positive median decadal cash margins. This reflects, in financial terms, the effects of higher carrying capacity with the often-higher, more stable, energy yields of pastures sown alone than those sown with a crop, as illustrated in Figure 3.

We use the term 'equity' to express the proportion of the farm's total assets remaining at a point in time after all farm debts are subtracted. Farm debts are

commonly 20% or more of total farm assets in the study area. This why we have used examples in which beginning or opening 'equity' is assumed at 80%. This is an important consideration because debt accumulates over time due to the compounding of interest.
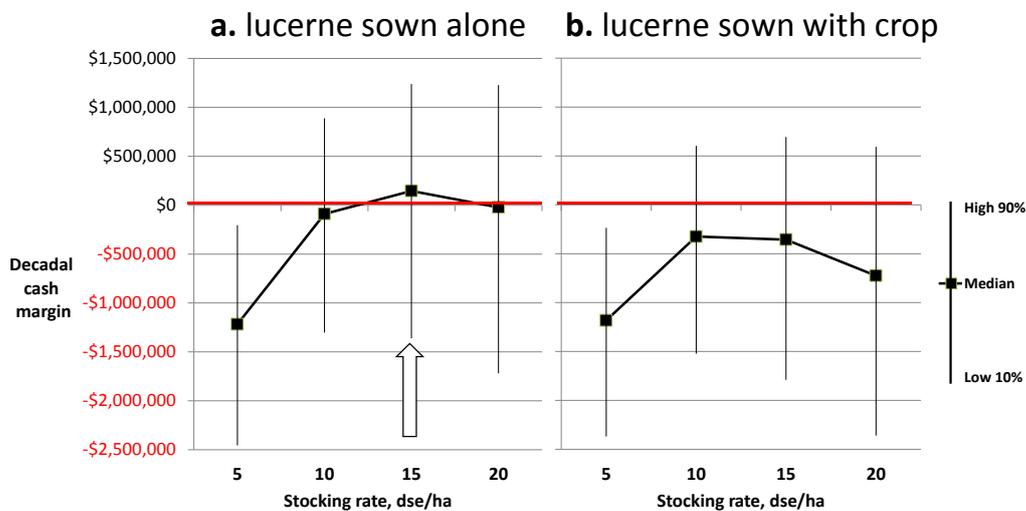
Figure 7. Effects on whole-farm decadal cash margins with lucerne sown either a) alone or b) with a cover crop and under different stocking rates, given opening equity of 80%.

The arrow in Figure 7a points to the simulated distribution of decadal cash margins for pasture sown alone and stocked at 15 dse/ha. This corresponds to the cumulative distribution function for the 80% opening equity level in Figure 8.

It is clear in Figure 7 that both pasture sowing method and stocking rates influence not only the median outcomes for farm finances, but also the ranges of likely outcomes. In the cases of the two 5 dse/ha treatments, there is little difference due to sowing method in their poor prospects for positive decadal cash margins.

In other cases, not only do the ranges largely overlap, but also reveal different degrees in risks of loss and gain (Figure 7). For example, consider the declining lower tails in the 10, 15 and 20 dse/ha sequence of stocking rates for pastures sown with a crop while the upper ends of the 10 and 20 dse/ha distributions reach similar maximal decadal cash margins: around $600,000. This illustrates a case where the 10 dse/ha system has a higher median cash margin and is relatively more stable than that with 20 dse/ha.

Similar comparisons are invited for the case of lucerne sown alone (Figure 7a), where the 10 dse/ha rate again is relatively less risky than that with 20 dse/ha.

Equity levels also have a major influence on farm financial outcomes (Figure 8). Pastures sown alone and stocked at 15 dse/ha showed the highest positive median probability of improved long-run cash margins (Figure 7a), assuming 80% opening equity. When expressed in probabilistic terms, the vertical range of variations in Figure 7 becomes the horizontal range in Figure 8. Likewise, at the 80% equity level, a positive median decadal cash margin and 58% chance of surplus and long term gains is indicated in Figure 8.
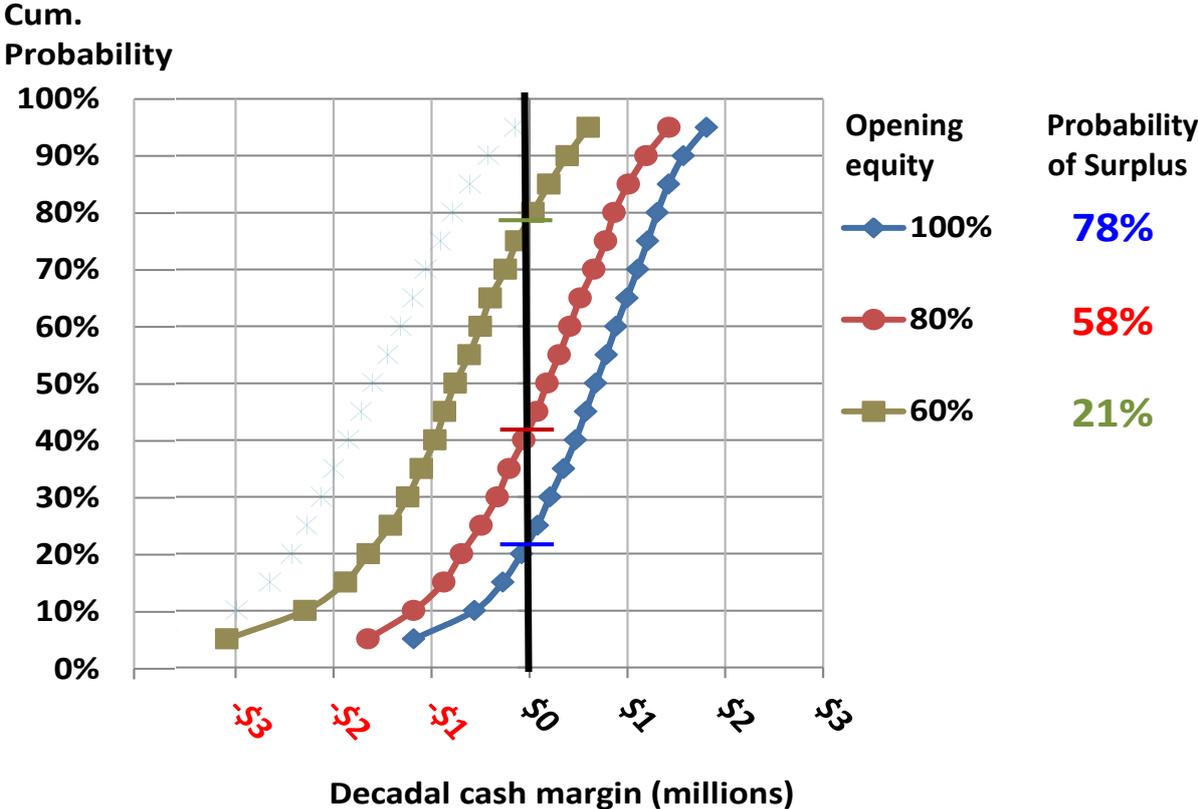
Figure 8. Effects of opening equity on distributions of decadal ending cash balances with lucerne pastures sown alone, and stocking rates of 15 dse/ha

At 100% equity, however, the same 15 dse/ha treatment indicated a 78% chance of viability and improving long-run cash margins further. In sharp contrast is the case of 60% equity, where the same treatment showed a 79% chance of non-viability and further reduced long-run cash margins.

CONCLUSIONS

1. The number of seasons sampled in field plots was limited, but greater than in most previous agronomy studies and included observations in both poor

and good rainfall years. Also, the geographic span of the field trials referenced in this study was limited along the 200 km north-south transect from Ariah Park to Yerong Creek and Brocklesby. Along that transect also is Coolamon, the location of the representative 1,000 ha farm modelled for this study. The soils, and long-run weather records for that location were used for modelling crop and pasture yield variations for the risk model. Likewise, the crop-livestock system and budget details for that area were important elements in the financial model, which further required relevant international commodity price series variations (for fuel, fertiliser, grain crops, lambs and wool).

2. A decadal cash margin accounting model integrated with a stochastic (jointly-distributed random) yield and price series generator were used as described by Hutchings *et al*. 2016.   Integrating the varying streams of pasture and crop yields and prices allowed thousands of iterations of the combined model to compare the effects of different management decisions (i.e., fixed stocking rates) and conditions (opening equity levels) for meaningful risk analyses. In Hutchings *et al*. (2016) such results are compared with those from common, simple gross margin analyses that assume average prices and yields for a single year, ignoring the farm debt level and the powerful effects of risk factors and time with cumulating debt. Here we focus on risk analysis of the farm's financial bottom line.

3. We summarised implications for financial stability of a farm in the study area. These results were presented as risk profiles in the form of cumulative distribution functions. Probabilities of attaining stability or growth in levels of decadal cash margins are then accurately visualised.

4. The conundrum of how best to establish a rain-fed lucerne pasture has been approached in this study from the perspective of determining the approach which most reliably delivers the best financial outcomes for a single location in south-eastern New South Wales. We used observed pasture response data from field trials which measured growth conditions along a transect reaching 60 km north to 140 km south in the 2008-2012 period.

5. Our results indicate a more probable financial advantage to the farm business from sowing rain-fed Lucerne pasture alone without a cover crop, if the farm is not deeply in debt. Given this caveat, we cannot reject the recommendations from agronomy experiments run over many decades in

the region, in favour of direct sowing, (Moodie, 1936 ; Smith and Argyle, 1964; Cregan, 1985; Dear, 1989). The conundrum is in the question of why sowing of lucerne with crops remains such a popular technique among farmers.

6. In this region, rain-fed farming is a gambler's game (Malcom *et al*. 2005). The jackpot for establishing a lucerne pasture by sowing with a crop is the occasion where weather conditions result in both a high-yielding crop and a well-established and persistent pasture. Combined with the notion that this is the lowest-cost way to establish a pasture, such an occasion is perhaps most memorable. Though same calendar year may be the first year of grazing for two lucerne paddocks, the one sown along with a crop was sown a year earlier than the pasture sown alone, and often under different weather conditions. We included this consideration in our regression model on pasture dry matter yields in the first year of grazing (Figure 1.). Visual comparisons of pasture productivity of these two sowing options, even in adjacent paddocks, are always confounded. In a given year one option can appear to give the best results and in another year the reverse may be seen.

7. Advice to farmers based on average years, average prices and gross margins (as in Figure 5), can be very misleading; it can mask the wide range of whole-farm outcomes possible due to price and yield variations and the effects of debt on viability (illustrated in Figure 8). Chasing higher production alone can drive farmers into unsustainable debt.

8. In the study area, where equity in farm business is typically low and technical productivity in the field is typically good, it may often be more important to find ways of **reducing costs** than increasing production. Cost reduction has positive effects on cash surpluses in all years.

References

Dear, B.S., Casburn, G.R., Li, G.D., Walker, J., Bowden, P., Hayes, R.C. (2010). *A survey of the use of perennial pastures as part of the pasture-crop rotation in the mixed farming zone of southern New South Wales*. In Future Farm Industries CRC Technical Report 3, Perth, WA: Future Farm Industries Technical Report 3, Future Farm Industries CRC. Download at: http://www.futurefarmonline.com.au/publications/Technical%20Reports/Technical_Reports

Dear, B.S. (1989). Establishment of subterranean clover under direct drilled cereal crops. In '*Agronomyin a Mediterranean Environment. Proceedings of the 5th Australian Agronomy Conference'.* Perth, W. Aust. (The Australian Society of Agronomy) Available at: www.regional.org.au/au/asa/1989/contributed/pasture/p-03.htm

Cregan, P.D. (1985). Managing the seedling for establishment. In *'Pasture renovation. Proceedings Grasslands Society of Victoria 26th Annual Conference'*. Melbourne, Vic. pp. 41–46. (Grasslands Society of Victoria)

Donnelly, J. R., Freer, M., Salmon, L., Moore, A. D., Simpson, R. J., Dove, H., & Bolger, T. P. (2002). Evolution of the GRAZPLAN decision support tools and adoption by the grazing industry in temperate Australia. *Agricultural Systems*, 74, 115-119.

Hutchings, T.R. (2013). "*Managing financial risk on dryland farms in SE Australia*". PhD Thesis, Charles Sturt University, Wagga Wagga, NSW 2650, Australia. Available on-line at: http://purl.umn.edu/204434

Hutchings, T.R., Nordblom, T., Hayes, R., Li, G.D. (2014). *Financial risk modelling with long-run weather and price variations: Effects of pasture options on the financial performance of a representative dryland farm at Coolamon, NSW, comparing results of average-year linear programming and sequential multivariate analysis (SMA).* Future Farm Industries CRC Technical Report 14-Economic Analysis. 46pp. ISBN: 978-0-9925425-1-1 Available on-line at: http://www.futurefarmonline.com.au/publications/Technical%20Reports/Technical_Reports or   http://ssrn.com/abstract=2495186

Hutchings, T., Nordblom, T., Hayes, R., Li, G.D., Finlayson, J. (2016). *A framework for modelling financial risk in Southern Australia: the intensive farming (IF) model*. Contributed paper, 60th annual conference of the Australian Agricultural & Resource Economics Society, Canberra, ACT 2-5 Feb, 2016. Forthcoming on-line at AgeconSearch

Li, G.D., Hayes, R.C., McCormick J.I., Gardner, M.J., Sandral, G.A., Dear, B.S. (2014). Time of sowing and the presence of a cover-crop determine the productivity and persistence of perennial pastures in mixed farming systems. *Crop and Pasture Science* 65(10): 988–1001. http://dx.doi.org/10.1071/CP13447

Malcolm, L.R., Makeham, J. P., Wright, V. (2005). The Farming Game, Agricultural Management and Marketing. (2nd ed.). Cambridge University Press, Melbourne

McCormick, J.I., Hayes, R.C., Li, G.D. and Norton, M.R. (2014). A review of pasture establishment by under-sowing with special reference to the mixed farming zone of south-eastern Australia. *Crop and Pasture Science* 65(10): 956 -972. http://dx.doi.org/10.1071/CP14049

McCormick, J., Li, G., Hayes, R., Casburn, G., Gardner, M., Sandral, G., Peoples, M., Swan, T. (2012a) A survey of farmer practice on the establishment, duration and production of pastures in the mixed farming zone of southern New South Wales. In "Capturing opportunities and Overcoming Obstacles in Australian Agronomy" *Proceedings of the 16th Australian Agronomy Conference*, 15-18 October, Armidale, NSW. Australian Society of Agronomy. http://www.regional.org.au/au/asa/2012/pastures/8077_mccormickji.htm

McCormick, J., Hayes, R., Li, G., Nordblom, T., Casburn, G., Hutchings, T., Moore, A.D., Zurcher, E., Peoples, M., Swan, T. (2012b). To under-sow or not? A decision support tool to determine the most profitable method of pasture establishment. In: I Yunusa editor(s). *Capturing Opportunities and Overcoming Obstacles in Australian Agronomy. Proceedings of the 16th Australian Agronomy Conference*: 14 - 18/10/2012; Armidale, NSW. http://www.regional.org.au/au/asa/2012/pastures/8079_mccormickji.htm

Moodie, A.W.S. (1936). Sowing lucerne with wheat. *The Agricultural Gazette of New South Wales* 47, 419.

Moore, A.D. (2014). The case for and against perennial forages in the Australian sheep–wheat zone: modelling livestock production, business risk and environmental interactions. *Animal Production Science*, 54: 2029–2041. http://dx.doi.org/10.1071/AN14613

Nordblom T.L., Hutchings, T.R., Hayes, R.C., Li, G.D. (2015). *A Framework for Modelling Whole-Farm Financial Risk*. Selected paper, 59th AARES Annual Conference, Rotorua, New Zealand, 10-13 Feb 2015. Available on-line at: http://purl.umn.edu/202581

Rodriguez, D., deVoil, P., Power, B., Cox, H., Crimp, S. and Meinke H. (2011). The intrinsic plasticity of farm businesses and their resilience to change. An Australian example. *Field Crops Research* 124: 157–170. http://dx.doi.org/10.1016/j.fcr.2011.02.012

Smith, J.A.C., Argyle, D.B. (1964) Establishing wheatbelt pastures—don't use a cover-crop. *Journal of Agriculture Western Australia* 5, 134.

Swan, A.D., Peoples, M.B., Hayes, R.C., Li, G.D., Casburn, G.R., McCormick, J.I. and Dear, B.S. (2014). Farmer experience with perennial pastures in the mixed farming areas of southern New South Wales: on-farm participatory research investigating pasture establishment with cover-cropping. *Crop and Pasture Science* 65 (10): 973-987. http://dx.doi.org/10.1071/CP13448