A Stochastic Analysis of Selected Drought Preparedness Strategies in NSW

by

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Paper presented to the 39th Annual Conference of the Australian Agricultural Economics Society, University of Western Australia, Nedlands, 13–16 February 1995.

Abstract

Since July 1993, the financial and risk effects of drought management strategies for farmers have been the subject of a study by CARE (UNE), NSW Agriculture and the WADA. In this study the relative effectiveness of investing in different forms of reserves (including IEDs/FMBs and feed) is being evaluated in a whole-farm stochastic budgeting framework. The approach is to simulate the post-tax financial performance of regionally-based farm models under alternative investment scenarios over a 4-year sequence of random climatic events. The parameters of the models and their functional relationships are derived from historical records and consensus group data.

In this paper, some preliminary findings are presented and discussed. These findings are interpreted in terms of both their farm management and policy implications. Attention is also given to the strengths and weaknesses of the modelling technology and the benefits of the consensus group approach. It is noted that benefits are also derived simply from the process of conducting drought research in that it encourages farmers and policy makers to carefully consider the range of issues associated with drought management.

Keywords: drought preparedness, consensus data, strategic reserves, IEDs, RISKFARM.

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* The opinions and views expressed in this paper are those of the authors and may not reflect the policy of NSW Agriculture or the NSW Government.

Introduction

In July 1993, the Centre for Agricultural and Resource Economics (CARE) at the University of New England, Armidale received funding for a two year project entitled 'Analysing Drought Strategies to Enhance Farm Financial Viability'. Funding was provided jointly by the Land and Water Resources Research & Development Corporation (LWRRDC) and the Rural Industries Research and Development Corporation (RIRDC), under the LWRRDC National Climate Variability R&D Program. In this paper, the findings of one part of the project are presented and discussed.

The research was, and is, being undertaken as a collaborative effort between CARE, NSW Agriculture and WA Agriculture. Researchers investigated the financial implications of specific drought management strategies, as well as more general risk management strategies, in several farming systems in NSW and WA. The approach was to examine options for strategic investment in reserves to assist in managing through periods of drought, while accounting for other common risks in the operating environment.

Computerised decision support tools provided the means of analysing the financial implications of the drought strategies. The RISKFARM model (Milham 1992; Milham *et al.* 1993), which was developed within CARE, was used in NSW. For the WA cropping systems, the MUDAS (Kingwell, Morrison and Bathgate 1990) and TACT (Robinson and Albrecht 1994) models developed by WA Agriculture were used in conjunction with RISKFARM.

There were three main issues addressed in the project. First, the limited availability and use of analytical methods tailored to analyse the financial implications of specific drought risk management strategies. Second, the lack of guiding applications and understanding of the financial outcomes of alternative drought management strategies and, third, the lack of training materials relating to the financial implications of drought risk management strategies.

Although the project focused on drought management, the analysis also encompassed risk management in the broader sense. Traditional drought management strategies include tactical and strategic responses, such as the timing of farm operations, hand feeding of stock, irrigation of crops, management of stock numbers and cropping area decisions. However, there are other risk management tools which can help maintain farm financial viability during periods of poor cash flow. For example, Kaine *et al.* (1993) suggested that the maintenance of a cash buffer

fund, such as an Income Equalisation Deposit (IED), could have a substantial beneficial impact upon the long-term financial performance of the farm.

Strategic Reserves

The project focus was on the stochastic simulation of the whole-farm impacts of strategic investment in reserves. A farmer can hold various types of reserves, such as financial investments, physical commodities and productivity and herd reserves. Financial reserves can be held in both off-farm and on-farm forms. In this project, investment in IEDs was selected to represent the strategy of holding financial reserves, however there are other possible investment options, such as cash or securities.

The purchase of a silo for the storage of feed grain was selected to represent the holding of physical reserves. Other physical reserves such as water or stocks of cash inputs could also be held. A conservative stocking strategy, which is an indirect form of maintaining pasture reserves, was also modelled.

It is also possible to hold productivity reserves such as soil fertility or drought tolerant crop varieties, however these were not investigated in the NSW work.

Modelling Drought Using RISKFARM

A key aim in this study was to investigate the financial and risk effects of drought while allowing for variation in economic and biological parameters. This task was approached using the RISKFARM model which utilises the @RISK software. RISKFARM is a whole-farm stochastic budgeting program, which allows uncertainty to be represented through probability distributions for selected variables in the operating environment and captures risk by generating probability distributions for nominated financial outcomes.

RISKFARM uses a combination of physical and financial data provided by farmers/farm advisers to assess the financial and risk effects of alternative farm and non-farm production and investment decisions. The model may also be used to examine the effects of using specific financial options such as IEDs. RISKFARM emphasises the medium-term to allow comparison of alternative management strategies and financial structures, rather than evaluating the impacts

of intra-year tactical decisions. Annual reports are generated for a 5-year model horizon and include year-end profit and loss statement, cash flow statements, balance sheets and various financial ratios.

Stochastic variables in RISKFARM include product yields and prices, expenses, interest rates and livestock production parameters such as death and weaning rates. Future, and therefore uncertain, interest rates and prices are selected from either normal distributions based on linear regressions using historical data or subjective probability distributions. (At present, some of these distributions are based on national data, however the scope for using regional data is being investigated.) Weaning rates, death rates and yields are selected from triangular distributions specified by the farmer/farm adviser. The model allows for livestock, pasture and cropping enterprises. Although the biological effects of climate cannot be modelled directly, they can be captured indirectly by making assumptions about yield and price distributions.

@RISK simulations were run using Monte Carlo sampling in which variates were randomly sampled from the probability distributions specified in the model to compute risk profiles for critical outcomes (Reutlinger 1970; Milham 1992). Using this method, iterative simulations allowed the construction of cumulative distribution functions (CDFs) for the outcomes of interest.

In order to model a drought in the RISKFARM program significant adaptations had to be made to the base model. Sections were added to cover drought feeding requirements, agistment and transport costs, and livestock selling arrangements. Probabilistic rainfall indices, which determine the climatic conditions prevailing at critical decision times, were also incorporated. These indices were formulated using data from the AUSTRALIAN RAINMAN program (Clewett *et al* 1994). This program provides the average annual rainfall and standard deviation of that rainfall for a large number of regions based on 100 years of rainfall data. Information on the probability of drought occurring in the various regions was also extracted from RAINMAN. Taxation provisions were also given sophisticated treatment, in particular the use of IEDs and livestock elections which can now be analysed precisely and rigorously.

While RISKFARM is not a bio-economic model, the model structure is consistent with the findings of the Working Group on Drought Policy who identified a need to integrate the issues of climate, livestock, pasture and cropping into whole-farm planning, and a need to develop commercial decision support packages that are accessible to farmers and that will give them strategies to follow (Kingma 1994).

The stochastic budgeting approach using RISKFARM and the @RISK software had a number of advantages. First, it enabled the calculation of the probability of achieving a particular financial outcome while explicitly accounting for risk. Where appropriate, historical data or subjective expectations could be used to describe the distribution. Second, the range of probability distributions that could be used to describe risky variables is very diverse and RISKFARM allowed easy transition between alternative distributional parameters and forms. Third, there was considerable scope for determining which uncertain variables were having the largest impact upon total risk. Finally, model output was simple to interpret in the graphical formats given.

Specifying drought as a random climatic event formed the basis of the approach. The concept was to commence the simulations with the farm business in a long-run 'equilibrium' position and then subject it to a 4-year sequence of random climatic events with automated responses. A drought occurred whenever the rainfall index sampled below a predetermined value. This climate index approach enabled farm financial performance under the alternative strategies to be simulated over a large number of possible sequences of climatic events. It thus provided more information than simply analysing the impact of a particular drought event.

This approach did make it difficult to investigate financial performance during and after a specific drought event. If desired, however, this type of information could be gained by examining the data on each individual iteration of the simulation and finding an iteration in which a drought was selected in the year required.

The Consensus Group Approach

It is easy, but perhaps dangerous to be prescriptive about drought management strategies. Each farm has individual characteristics and each farmer has a unique attitude to risk and these characteristics and risk attitudes can alter the sets of options open to different farmers in otherwise homogenous farming environments. In addition, attitudes to risk can vary over time. It is thus preferable to canvas the alternative drought management options and provide neutral, non-prescriptive comment on their respective performance under various assumed conditions. Of course, if a particular strategy or set of strategies are found to be clearly superior under a wide range of conditions, then it would be difficult to avoid the conclusion (and recommendation) that, as a general rule, that strategy should be followed.

The approach taken in this project was to examine several farming systems in different regions of NSW and WA. In NSW the regions were; the Western Division, Central West, Hunter Valley, Liverpool Plains and Northern Tablelands, and in WA; the Eastern Wheatbelt, Woolbelt and Great Southern Region. A model farm was constructed in each region based on information provided by a local consensus group.

The participation of NSW and WA Agriculture regional economists and extension staff provided the ideal infrastructure for this approach. Regional staff had little difficulty in assembling local groups consisting of farmers and farm advisers, such as accountants, to provide information and comment. In addition, due to their local knowledge and understanding of the farming systems in their area regional staff were able to advise the research team on issues related to drought management prior to meeting with farmer groups. This enabled the researchers to enter into more informed discussions with the consensus groups and to extract pertinent information more readily. Frequently, difficult modelling issues had already been identified and could be discussed specifically with the group.

Each consensus group provided production and financial information to model a 'demonstration' farm. The demonstration farm was intended to be as simple as possible while still reflecting the key features of farming operations and conditions in that region. Thus, while the members of each consensus group were able to identify with the model farm for their region, and relate its performance to their own businesses, it could not be described on any objective basis as a 'representative' or 'average' farm. The demonstration farm was developed in a step by step process with the group. It inevitably contained elements of their own properties, yet also reflected other common regional features and characteristics which their individual properties lacked.

Each group also described the major drought management activities which such a farm might employ. The lists provided naturally comprised a mix of tactical and strategic activities, however, the subsequent analysis was limited to the key strategic activities in that region.

There is considerable debate amongst practitioners of probability theory as to what constitutes a 'good' probability distribution. Historical distributions based on observed data may not be a good representation of future risk profiles or of the subjective distributions the decision maker acts upon. Furthermore, if subjective distributions influence the decisions made, then it can be argued that they are the ones that should be used (Anderson *et al* 1977; Milham 1994;

Reutlinger 1970). One of the main advantages of the consensus group approach was that probability distributions for on–farm production parameters could be elicited directly from the decision makers. Another problem with using historical data to describe probability distributions is the lack of regional information. As this study proceeded, it became obvious that quite precise regional adaptations were required to accurately reflect the characteristics of the various farming systems. Regionally–based subjective data could, however, be easily elicited from the consensus group and incorporated into the RISKFARM model. More difficult to capture at the regional level was the existence of correlations between variables such as commodity yields and prices.

The Strategies Modelled

One of the first problems faced in the project was how to define drought. In fact just what constitutes a drought was not even clearly identified in the documentation on the National Drought Policy (Crean; Senate Standing Committee on Rural and Regional Affairs, 1992). Drought in a livestock enterprise is usually signified by a lack of feed and perhaps drinking water due to poor rainfall. However, it can also be caused by feed shortages due to feral animal competition. It can encompass normal or slightly below normal rainfall and feed and some have suggested that the term should be reserved for periods of severe nutritional deficit (Thompson 1994).

Drought in a cropping situation is signified by insufficient moisture to sow or finish crops but again, hot dry winds which cause high evapotranspiration rates may promote moisture stress in crops, despite adequate rainfall. For the purposes of this study, drought was defined differently in each region, according to the perception of the local consensus group. In this way, it was possible to model a drought event which was regarded as being significant, had a quantifiable effect on cropping or livestock production and necessitated some action by the farmer.

In general the strategies modelled were those identified to the research team by the consensus groups. As might have been expected, these were mainly on–farm strategies relating to such things as decisions on stocking rate and feed reserves. While the strategic use of off–farm investments also received some mention, the use of IEDs was not specifically raised. Given, however, that IEDs are a policy measure directed at promoting the holding of financial reserves, they were also included in the study.

The simulated outcomes of implementing the selected strategies in two regions of NSW are discussed in this paper, the Central West – Condobolin, and the Western Division – Cobar. In the Condobolin area the main strategies investigated were holding a fodder reserve and/or a financial reserve. The fodder reserve strategy involved purchasing a 100 tonne silo at the beginning of the modelling period, filling it with oats from the first years production and maintaining it full of feed grain unless a drought necessitated the feeding out of this reserve. The size of the reserve and the decision rules determining feed and livestock management during drought periods were defined by the consensus group. The financial reserve strategy involved the use of IEDs and was examined both on its own and in conjunction with the feed reserve strategy. Under this strategy it was assumed that once taxable income reached a predetermined percentage above the 5-year average income, investment was made in an IED. On the other hand, when taxable income fell a predetermined percentage below the 5-year average income, the IED was partially or completely withdrawn.

In the Western Division – Cobar Region, the same financial reserve strategy was examined along with a physical reserve strategy in the form of conservative stocking. In this strategy it was assumed that stocking rates were reduced to 20 per cent below the district average in order to reserve pasture.

Critique of the Modelling Approach

The use of RISKFARM as a drought simulation model had several strengths and weaknesses. Its strengths include its comprehensive financial analysis, the fact that it is a dynamic model with a medium-term horizon and its use of stochastic simulation using the @RISK program.

Its major weakness is that it does not directly capture the environmental impacts of drought. To a large degree however the lack of biological links in the model was overcome by the use of 'expert' knowledge provided by the local consensus group. Biological effects are determined by consideration within the consensus group of what effects would occur in their area as a result of drought conditions. Another weakness is that RISKFARM is not an optimising model and it is thus not possible to use it to predict behavioural responses to changing conditions. The focus in this study was not, however, on predicting responses but rather evaluating the outcomes of actions that the farmers in the various regions indicated they have or might take.

These strengths and weaknesses largely point to the difference between an optimising model and a simulation model. An optimising model would need to have a far greater consideration of biological factors as it would access all possible outcomes and select an optimal strategy. Stochastic simulation models such as RISKFARM rely on such strategies and intentions being pre-specified.

Preliminary Results

Results from RISKFARM can be expressed graphically and the financial information generated can include net cash position, net worth, assets, liabilities, equity and return on capital. Results for both net cash position and net worth were generated in the simulations and they presented similar results. These results are presented in the form of a CDF for each strategy illustrating the risk profile of cumulative net worth in the last year of the 5-year modelling horizon. CDFs for both net cash position and net worth are presented, for the purposes of brevity however, the discussion in this paper focuses on the net worth outcome.

Figures 1 and 2 reveal that in the Condobolin region the estimated CDFs of the various strategies were very close together, indicating that their effects are similar. Indeed, except in the extreme tails of the CDFs, the outcomes of the reserve strategies, both individually and jointly, are only marginally better than the outcome of doing nothing. From a visual appraisal it appears that the two feed reserve strategies are predominately to the right of the other strategies. The 'Reserve with IED' strategy always dominates the 'No Reserves with IED' strategy while the 'Reserve with No IED' strategy always dominates the 'No Reserve with No IED' strategy. This suggests that in general it is beneficial to invest in a feed reserve in that region.

In the upper range of the CDFs, the 'Reserve with No IED' and the 'No Reserve with IED' CDFs cross over. This suggests that the benefits of the feed reserve during the poor times are taken over by the benefits of IEDs during good times. It would appear that IEDs are more beneficial during higher income periods and for higher income earners.

More important, however, is the fact that it is exogenous factors that contribute the most to the risk profile of financial performance rather than the reserves strategies modelled. This is revealed by the fact that the margin between the 'worst' and 'best' strategies is at all times small relative to the total range of possible outcomes. The exogenous factors most likely to be of consequence are variability in commodity prices and the occurrence of a drought.

FIGURE 1

Comparison of Condobolin Strategies

Cumulative Net Worth in the last year of the model

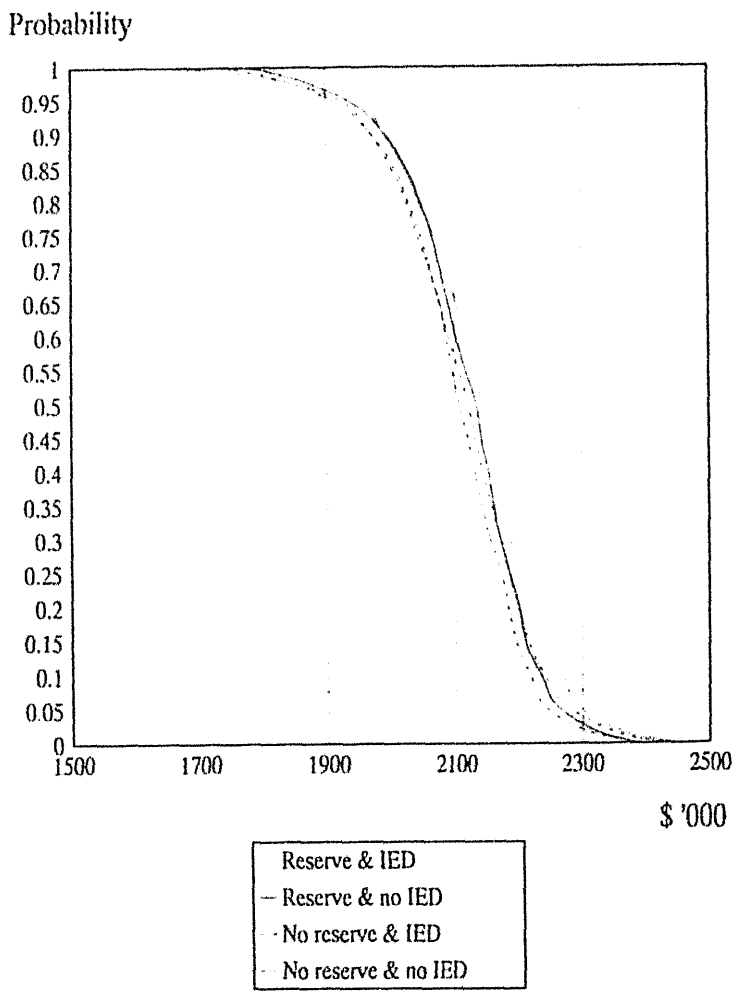
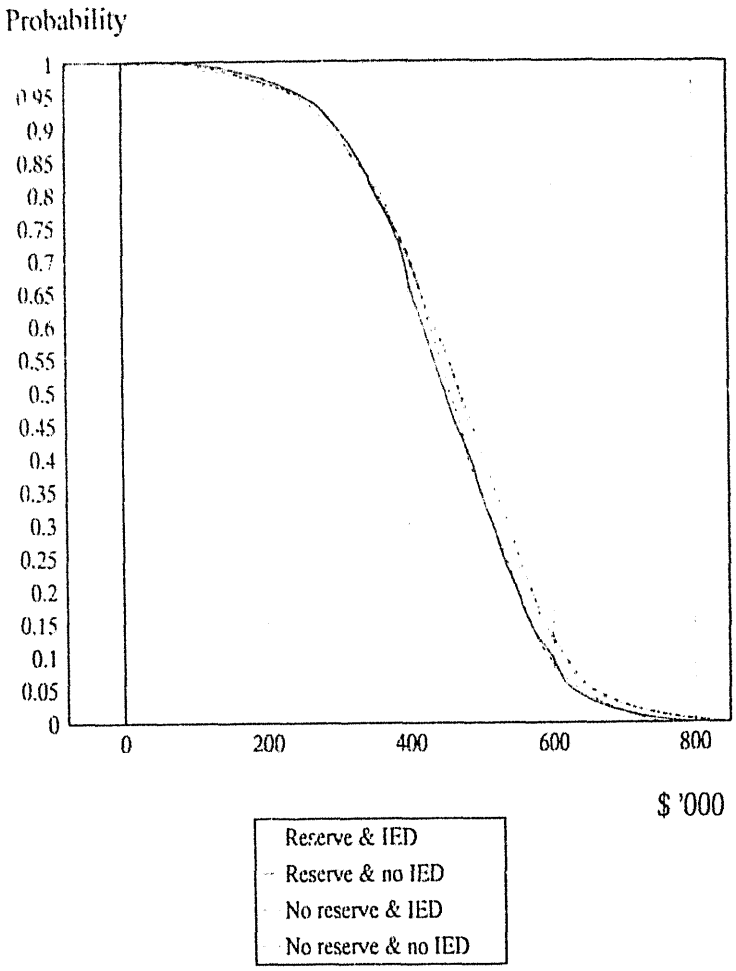


FIGURE 2

Comparison of Condobolin Strategies

Cumulative Net Cash Position in the last year of the model



By analysing the simulation results generated by the @RISK program the magnitude of the effect of such exogenous factors can be determined. For example, Table 1 shows the probability of drought occurring in the highest and lowest deciles of the simulation results for both the Condobolin and Cobar areas. The RISKFARM program allows for four stochastic years in which drought can occur: in the Condobolin region, 77 per cent of the time there were no drought events in the highest decile and 77 per cent of the time there were at least two drought events in the lowest decile. This implies that the incidence of drought is a significant exogenous factor in determining the net worth position of the 'demonstration' farm at the end of the 5-year modelling period.

The simulation results for the Cobar region are displayed in Figures 3 and 4. While, the CDFs shown are more spread than those for the Condobolin region, the effect of exogenous factors was still the overriding influence. In terms of the effects of a drought shock in this region, 70 per cent of the time there was no drought event in the highest decile. In the lower decile there are at least two droughts 55 per cent of the time.

TABLE 1

Frequency of Drought Occurring in the Highest and Lowest Deciles of Owner Net Worth in the Condobolin and Cobar Areas

Region	Net Worth Decile	Number of Droughts			
		0	1	2	3
Condobolin	highest decile	77%	23%		
	lowest decile		23%	55%	22%
Cobar	highest decile	70%	30%		
	lowest decile		45%	33%	22%

FIGURE 3

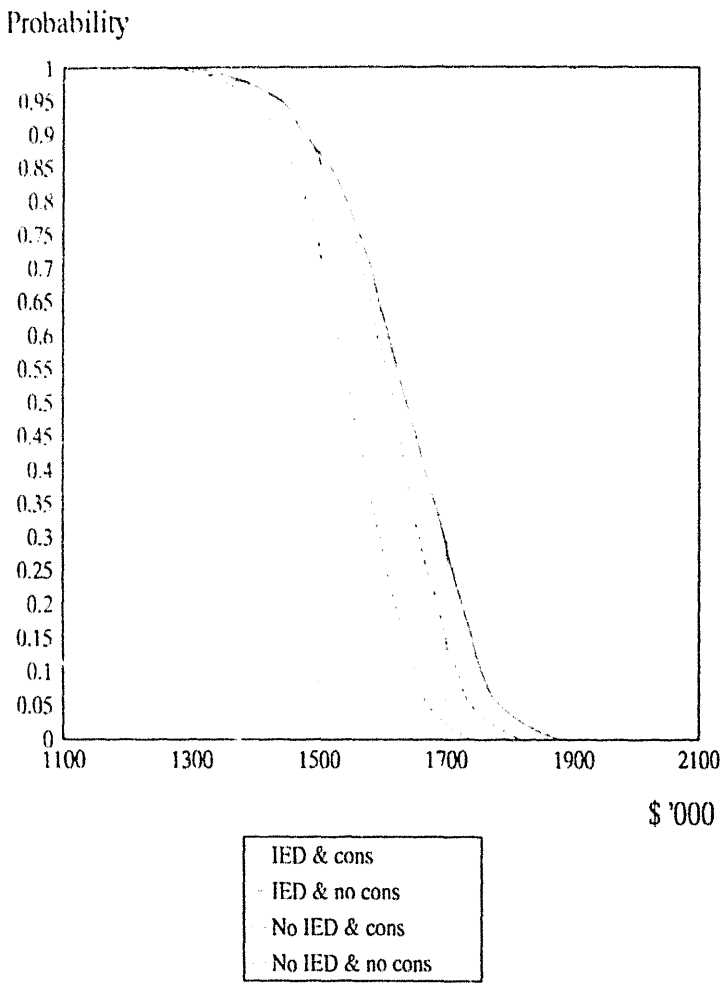
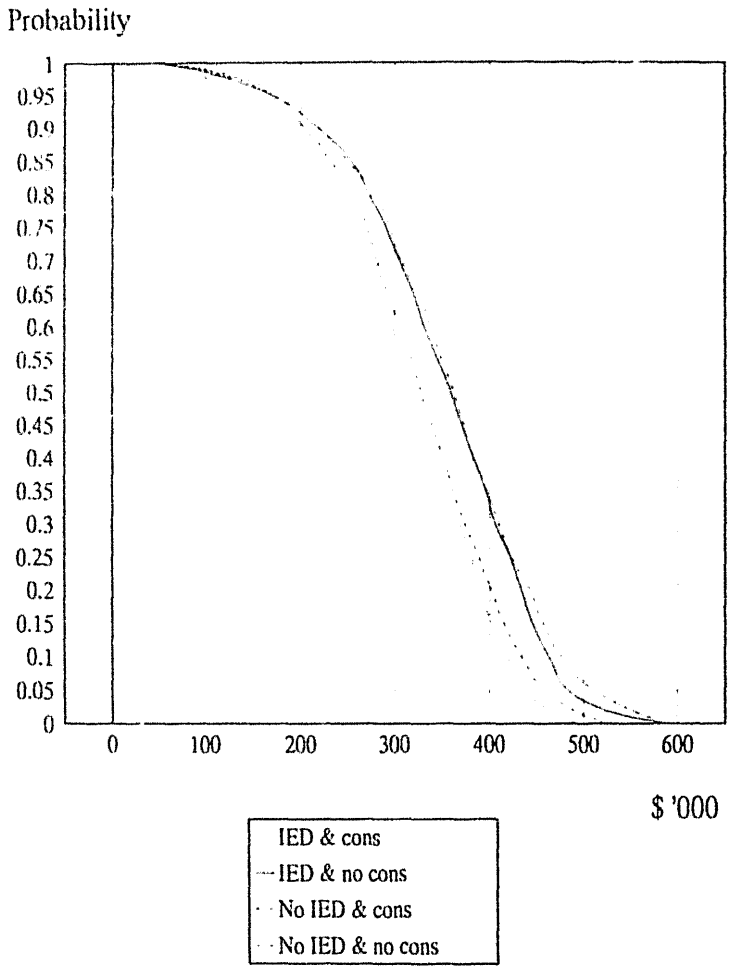

Comparison of Cobar Strategies
Cumulative Net Worth in the last year of the model
Probability
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1100
1300
1500
1700
1900
2100
$ '000
IED & cons
IED & no cons
No IED & cons
No IED & no cons

FIGURE 4

Comparison of Cobar Strategies

Cumulative Net Cash Position in the last year of the model



Visual appraisal of these figures suggests that investing in IEDs is generally more likely to improve the cumulative net worth position, but during low income periods (or for a low income earner) they are not so obviously attractive. It also appears that in general the strategies that do not practice conservative stocking dominate those that do. However in the lower range of the CDFs, where drought occurs more frequently, dominance is less obvious. (A strategy of varying stocking rate to pasture availability would be the ideal option, however, modelling such a strategy was beyond the scope of this project.)

It should be noted that the conservative strategy is not as dominant in the Cobar area as was indicated in earlier results from this project (Jackson *et al* 1994). This is due to a change in modelling technique. In the original work a drought was enforced in the second year of the model and a recovery was modelled in the three following years. That is, this method focused on the outcome of following various strategies when a drought was certain to occur. Naturally, this highlighted the benefits of conservative stocking, which are primarily evidenced during poorer years (e.g. Meppem and Johnston, 1990). However this method did not fully take into account the occurrence of good years where operating under a conservative stocking rate may not be preferable. The new more sophisticated method enables, a clearer specification of the likelihood and frequency of drought occurring based on random sampling from historical records, therefore yielding different results. Such differences highlight the importance of the modelling assumptions and the dangers inherent in being prescriptive.

It is also interesting to observe that in the Condobolin area the highest and lowest deciles of the CDFs were influenced more by drought than in the Cobar area. This was shown by the fact that in the Condobolin area, there was a 77 per cent probability of no drought occurring in the highest decile compared to 70 per cent for the Cobar area. In terms of the lower decile there was a 77 per cent chance of at least two droughts occurring in the five year period in the Condobolin area as compared to only a 55 per cent chance in the Cobar area. It appears that there is a greater correlation between farm financial performance and the incidence of drought in the Condobolin area compared to the Cobar area. That is, the occurrence of drought in the Condobolin area has a greater effect on the variability of farm financial performance than drought in the Cobar region.

The results presented in this paper are preliminary and are only indicative of the likely outcomes of following different strategies. However, results from similar analyses in the Scone and Northern Tablelands areas of New South Wales are consistent with these results (D. Thompson and D. Jackson, pers. comm. CARE, January 1995).

Conclusions

There are both management and policy conclusions to be drawn from these results. In terms of the management conclusions there are three main areas where opportunities exist for farmers to increase the amount of information to base their decisions on.

First, climatic conditions in many parts of Australia are extremely variable and unpredictable and the process of deregulation and microeconomic reform is exposing farmers to more and more price and financial risk (e.g. Powell and Milham, 1990; Powell and Wright, 1987.). Hence, deterministic evaluation of major investment and restructuring decisions is becoming increasingly inadequate and stochastic budgeting is becoming an essential part of the planning process (Milham and Hardaker, 1990). This does not have to involve the use of complicated computer models. A simple sensitivity analysis based on minimum, maximum and most likely values may be a very effective form of stochastic budgeting for investment decisions. Progression to the use of stochastic simulation programs such as @RISK would occur with increased understanding of the benefits of such information or if the size or nature of the decision requires more detailed information.

Second, the use of climatic data such as that provided by the AUSTRALIAN RAINMAN program has the potential to greatly benefit farmers in their decision making process. Programs such as this can be used to provide an objective indicator of the likelihood of drought. Farmers perceptions of the likelihood of drought in their region may prove to be different to the information gained from analysing 100 years of climatic history in their local region. Combining their perceptions with the added information from AUSTRALIAN RAINMAN would enable farmers to make better informed decisions regarding the probability of drought and the need to prepare for it.

Thirdly, it would also be of great benefit to farmers if they could develop risk profiles for decisions to be made. This would enable them to determine which are the most important of the manageable risks and hence define the risks which are most worth doing something about. There is scope for further research developing risk profiles to determine the magnitude of the contribution of the various uncertain variables, e.g. climate, commodity prices and interest rates etc., to total risk in financial performance. As drought is just one of the exogenous factors affecting farm financial performance, research should be directed towards total risk management rather than just drought risk management.

With increased micro–economic reform and deregulation farmers will be exposed to greater risk and there will likely be an increase in the incidence of temporary financial stress and failure. Government has expressed the view that once farmers become self–reliant dependence on government support would significantly decrease. Information, extension and training related to the promotion of self reliance will likely reduce the incidence of financial stress but the National Drought Policy appears to be based on a somewhat false expectation about the effectiveness of a self reliance policy. The results of this study indicate that following investment strategies to improve self reliance will only result in a marginal increase in the probability of improving farm financial performance. That is, the relative difference between investing in reserves and not doing so is small. The results obtained suggest that self reliance is in fact little help when a severe exogenous shock such as a protracted drought is encountered. In this context, it appears that high expectations about the effectiveness in improving long–term sustainability of policy measures to encourage self reliance are likely to be disappointed.

As farmers face increased exposure to risk it is also important to insure that the social welfare safety net is appropriately structured and has the resources to service farmers who become poverty stricken (Milham and Davenport 1995).

Policy implications also arise with respect to exceptional circumstances criteria. In the Condobolin area the results show that the incidence of two drought years over the five year period would have a substantial detrimental effect on farm financial performance. This can be expressed as 24 dry months out of 60, which is much lower than the exceptional circumstances criteria of 24 dry months out of 36. Some would argue that this shows the exceptional circumstances for drought criteria are inappropriate for this region and probably for other regions also. Another conclusion that can be made relates to the fact that in the Cobar area the effect on farm financial performance of two years drought out of five is not as significant as in the Condobolin area. This would suggest that exceptional circumstances criteria should be regionally orientated. Regional climatic data provided by programs such as AUSTRALIAN RAINMAN could be used to incorporate such an orientation.

Given that the overall aim is to in some way improve financial performance, it is interesting to speculate on what the precise objectives of public policy are in term of modifying the distribution of this outcome. Looked at in this context, there are a range of possibilities including:

- reducing downside risk, such as by providing assistance to farmers under financial stress, which would have the effect of truncating or tightening the left hand tail of the CDF of financial performance;
- reducing the variability of financial performance, for example through income smoothing, which would involve reducing the overall spread of the CDF; and
- seeking a general enhancement of financial performance, say through microeconomic reform and trade liberalisation, which could be represented as shifting the entire CDF to the right.

The political economy of the introduction and subsequent multiple revisions of the drought bonds/IEDs/farm management bonds schemes would suggest that these instruments are primarily intended to alleviate financial stress during downturns. However, the results of this study indicate that, at least in the case of IEDs, most benefit is derived when the farm business is performing well. This would suggest that this is a poorly targeted policy instrument, an empirical result which confirms the conclusions of earlier, more theoretical analyses (e.g., Douglas and Davenport 1993). While not addressed in this study, other research has provided similar results with respect to the interest subsidies provided through the RAS and the exceptional circumstances provisions (see Hoadley *et al* 1994).

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