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Rural Industries Research and
Development Corporation

Managing the Risks of Climate Variability in Australian Agriculture

– Decision-making in agriculture under conditions of uncertainty –

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by Mark Barber

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Foreword

Agriculture operates in an uncertain environment. Markets, seasonal conditions and a host of other variables influence the financial prospects of farming enterprises daily. Each day farm managers make a host of decisions based on assumptions about these variables. Integral to each farmer's decision-making is the ability to adopt strategies to changing circumstances.

Current climate change forecasts indicate that not only will farmers be facing the possibility of a drier climate, but the frequency of extreme weather will increase. Farmers must therefore have at their disposal a wide range of risk management tools and options.

This report highlights the fact that climate forecasts can deliver significant value for farmers; but the current standard of climate forecasting needs to be significantly improved. However, the prospects of achieving this are low at present.

This report suggests that, in the absence of any major improvements in climate forecasting, farmers need to develop new approaches to managing their enterprises and utilise the wide range of emerging market-based risk management options.

After introducing a range of market-based options for adjusting to seasonal uncertainty, the report analyses the adequacy of current financial analytical tools. It concludes that the analytical tools farmers currently use to make these decisions must reflect the way they approach investments and, most importantly, must structure decision-making to retain flexibility. Traditional approaches, when used, are limited in the way they manage uncertainty.

The real options methodology introduced in this report, appears to reflect the way farmers make decisions. This technique, gaining in popularity in other sectors, should be examined by farmers and their advisors.

This report does not make any policy recommendations but rather lays out a range of interesting techniques and instruments agriculture can employ to better manage the increasing climate uncertainty it appears to be facing.

This report, an addition to RIRDC's diverse range of over 1800 research publications, forms part of our Global Competitiveness R&D program, which aims to identify the impediments to the development of a globally competitive Australian agricultural sector and supports research investment on options and strategies for removing these impediments.

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Peter O'Brien
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Executive Summary

What the report is about

Agriculture in Australia has always had to deal with an uncertain and volatile climate. Droughts and flooding rains have entered into folklore.

This report summarises some contemporary management and market based approaches to the management of climate variability in Australian agriculture. The report also describes how the role of an adaptive management methodology, known as real options, can play in agriculture when faced with considerable uncertainty.

Who is the report targeted at?

There are a number of approaches that farm business managers have, or will have, to better manage the uncertainties of climate change, particularly if climate variability increases as a result of climate change. Enterprises and businesses able to adapt to increased climate variability will be at an advantage to those that do not.

An implicit benefit of improving the market's capacity to manage climatic risk is reduced reliance on improving climate forecasting. Ensuring that investment decisions are flexible and can respond in a least cost way to changing circumstances, will be critical to the profitability and sustainability of Australian farming in the event of an increase in climate variability.

Background

Efficiency of resource use in agriculture would be improved by a reduction in the level of climatic risk. However, resolving the uncertainty by improving climate forecasts is a long way off. If uncertainty is unavoidable, then the issue facing agriculture relates to extracting more value from its production and marketing within the unavoidable climatic constraint, Government policies designed to shield business from uncertainty could be counter productive, as they would diminish the incentive for sound risk management.

Aims/objectives

This project aims to better prepare the agricultural sector for increased climatic variability by decreasing agriculture's reliance on improving climate forecasting through improved capacity to manage climate-based risk. This allows some of the research resources to be diverted to areas of greater potential pay-off, such as plant breeding and agronomy, or postponed to a later date when technical capacity in forecasting has improved and costs have reduced.

Ensuring that investment decisions are flexible and can respond in a least-cost way to changing circumstances, will be critical to the profitability of Australian farming in the event of an increase in climate variability.

Methods used

This report reviewed and reported a number of risk management tools that farmers have, or are likely to have, available to them to better manage the uncertainties of climate variability. A range of market based approaches such as diversification of farm equity, insurance and hedging are reviewed and discussed in this paper. The paper also looks at the need for adaptive decision making at the farm level to reduce the impact of high levels of climate variability. A particularly useful methodology, real options, is described in some detail.

Results/key findings

There are a number of approaches that farm business managers have, or will have, to better manage the uncertainties of climate change, particularly if climate variability increases as a result of climate change. Enterprises and businesses able to adapt to increased climate variability will be better placed than those that do not.

Sound strategy in response to greater climatic variability will not involve a once and for all resolution and it will not deliver certainty to stakeholders. Indeed, given the inherent uncertainties, striving for certainty would represent poor industry and government policy and would encourage inefficient resource use. In many cases, those dependent on rainfall and irrigation (i.e. water in general) would be best placed to manage uncertainties cost-effectively – by developing robust usage and insurance strategies.

Robust usage and insurance strategies are predicated on reducing exposure to downside risks at an acceptable cost, while optimising exposure to upside potential. Reducing seed and fertiliser rates, when planting crops in anticipation of low rainfall, may reduce the downside risk of drought but limit the potential yield if the season were favourable. Thus it can be expected that enterprise strategies in agriculture that are able to adapt to increased uncertainty (should it eventuate), will be favoured at the expense of those unable to do so. Likewise, farm businesses better able to manage risk will expand at the expense of those less able to adapt to increased volatility.

Allowing risks to be borne by those best placed to manage them is another strategy to improve agricultural efficiency in the face of increasing climate variability. While structural adjustment is likely to be the most important market mechanism to allow this to happen, there are a number of other market mechanisms to facilitate the transfer of risk. One group involves the diversification of agricultural equity. Diversification of the ownership of agricultural equity distributes the risks of investment in agricultural enterprises across a much wider group of investors than the traditional family farm.

Traditionally, farmers rely on debt and surplus cash flow to fund productivity improvements and to grow the business. However, debt has prudential limits and surplus cash flow can be volatile and slow to accumulate. Attracting new capital to agriculture, particularly in forms that allow existing businesses to grow faster than using debt and surplus cash flow alone, should be an important part of farming's response to the prospect of increased climate variability.

New funds such as PrimeAg, and the Macquarie Pastoral Fund, which buy and run agricultural enterprises, are important sources of new capital for agriculture. These funds are aiming to raise between $650 million and $1.0 billion from a wide range of investors. While they are important new sources of capital, they are based largely on a traditional corporate agriculture financial model.

Other more innovative funds are developing and expanding alternative investment products based on investing in, or with, existing farm businesses. For example, Australian Agricultural Contracts Limited (AACL), launched in its current form in 2004, now has over 200 share-farming agreements in Western Australia. It is expecting to pool over 400,000 tonnes of wheat and barley this year (including 20,000 to 30,000 tonnes from the eastern states for the first time). This will make it the largest grain producer in the country.

Australian Primary Producers (APP) is another example of an agricultural fund investing in existing farm enterprises. APP is aiming to raise up to $150 million to purchase a 50 per cent share in a range of farm businesses with sound financial track records and management teams.

Diversification of risk may be achieved in ways other than by diversification of equity. Insurance companies arrange the diversification of risk for a fee. There have been a number of studies into climate and multi-peril insurance. In the past climate (mostly rainfall) based insurance products have failed due to:

- poor correlation of the risk (i.e. low rainfall) that is easily and transparently measured, and the financial damage being insured against (low enterprise returns as a result of poor seasonal conditions)

- premiums that are higher than the perceived cost of self insurance by farm managers. Few, if any, multi-peril crop insurance products have been offered around the world on a purely commercial basis.

However, if climate variability increases, the demand, and hence willingness to pay, for climate insurance may mean that this form of insurance could become commercially viable. If demand increases, new forms of actuarial techniques are likely to be developed that improve the alignment of premiums with risk and potential payouts. These new techniques will take advantage of a number of new technologies, including remote sensing.

Climate hedging and climate derivatives markets are another way of 'laying-off' risk. Climate variability hedging requires counterparties to the risk. An increased impact of climate change across the economy may increase the prevalence of counterparties to the climate risks faced by farmers, albeit at a greater cost.

Improved agricultural market efficiency can also be achieved by introducing new ways to improve understanding and management of uncertainty, through adaptive management techniques and using real options applications. Applying new analytical tools such as real options that value flexibility will be important in determining the optimisation of farm resources in the face of greater levels of uncertainty.

Implications for relevant stakeholders

Improving agricultural market efficiency, in relation to managing climate variability (both long and short term), relies on several factors:

- Improving climate forecasting to the point where marginal costs of improving accuracy equal marginal returns of its application (accepting that it is inefficient to seek to reduce uncertainty beyond a certain point).

- Improving the market's capacity to manage the unavoidable uncertainties. This can be achieved in several ways:

  - introducing new techniques to better understand and manage uncertainty
  - adaptive management using real options applications
  - allowing risks to be borne by those best placed to manage them
  - introducing new forms of equity to spread the risk over a wider group of investors
  - climate and multi-peril insurance
  - climate hedging and climate derivatives markets.

Recommendations

The prospects are for Australia's climate to become hotter, dryer and more volatile. Even if the climate change projections turn out to be incorrect, there is benefit to Australian agriculture in adapting to greater climatic variability. The measures adopted will improve productivity and reduce risk in any case. Those measures include:

- improving weather forecasting, especially forecasting within seasons
- developing insurance products and climate hedging markets
- spreading risk by diversifying enterprises, location across areas of different climate, ownership across several investors or a greater number of stakeholders
- improving agronomic practices to increase ground cover, carbon and water retention in the soil
- changing enterprises
- increasing targeted investment in plant breeding, to produce drought tolerant crop and pasture species
- adopting farm management decision-making techniques to analyse real options in response to changing conditions throughout the season.

Introduction

Market theory argues that uncertainty prevents efficient outcomes. This leads to the conclusion that agricultural markets are inefficient because of rainfall uncertainty. It is therefore argued that to increase agricultural market efficiency, climate forecasting needs to be improved. This is hardly a revelation! This is one of the arguments used to justify the commitment of public funding to support climate forecasting research for many years.

Shielding business from risk reduces the capacity to transfer risk to those best placed to manage it and reduces the efficient use of resources, particularly in periods of increased uncertainty. The effect of intervention policies, aimed at shielding farmers from risk, is that more efficient responses are likely to be crowded out.

Government intervention in the management of climate risk for farmers may also promote a culture of over-reliance on resolution of the risk, such as improved climate forecasting, particularly when funded with public money.

The results of public and private funding for improved climate forecasting to date could be described as mixed. A recent paper showed that the Australian Bureau of Meteorology (BOM) seasonal rainfall forecasting system, based on the five phases of the Southern Oscillation Index, is relatively poor. Consequently the value of BOM seasonal forecasting for farmers is limited (Vizard et al., 2005)

However, many studies have concluded that the value of reasonably accurate seasonal forecasting for a range of dry land cropping enterprises is high (see: Marshall et al., 1996, Mjelde & Cochran, 1988 and Petersen & Fraser, 2001). Growers, agronomists and farm advisors have also indicated reasonably accurate seasonal forecasting would be useful for their businesses (George et al., 2007).

The key question is whether it is possible for more accurate forecasting to resolve uncertainty due to climatic variability and, if so, at what cost. If the uncertainty is unavoidable or the cost too high, then the question becomes: "Can agriculture extract more value from its production and marketing within that unavoidable climatic constraint?"

Some market participants thrive on exploiting uncertainty. These participants offer to manage risk at a lower price than that at which those exposed to the risk can manage themselves. At this stage water markets are emerging as one market where climate uncertainty could be managed, by acquiring options to extract surface or ground water resources, but the extent is limited and there are dangers in overreliance on one market. Also water markets are incomplete as they do not cover the whole hydrological pool. Intercepting water with farm dams for stock and domestic use, or with vegetation such as improved pastures or forest plantations, before it enters the pool available to extractive users, is currently not part of water markets. These forms of water use are not confronted with clear opportunity costs of the water they intercept, which may not lead to the most efficient use of the water.

Measures of productivity may not be accurate in a future where water is scarce if the opportunity cost of the water, a significant factor of production, is not included. Calculations of water use efficiency will increasingly have to include the opportunity cost of the water to other users off the farm.

Improving agricultural market efficiency, in relation to managing climate variability (both long and short term), relies on several factors:

- improving climate forecasting to the point where marginal costs of improving accuracy equal marginal returns of its application (accepting that it is inefficient to seek to reduce uncertainty beyond a certain point)
- improving the market's capacity to manage the unavoidable uncertainties. This can be achieved in two ways:
    - introducing new techniques to better understand and manage uncertainty
        - adaptive management
        - real options applications
    - allowing risks to be borne by those best placed to manage them
        - Introducing new forms of equity to spread the risk over a wider group of investors
        - Climate and multi-peril insurance
        - Climate hedging and climate derivatives markets.

An implicit benefit of improving the market's capacity to manage risk is that it reduces reliance on improving climate forecasting. This would allow some of the research resources to be diverted to areas of greater pay-off, such as plant breeding and agronomy, or postponed to a later date when technical capacity in forecasting has improved and costs have reduced.

Emphasis should be on climate forecasts that align better to the adaptive management capacity of farmers and to the production systems they are operating (more accurate medium-term forecasts are likely to be less costly to produce and more effective for farmers to use). This means that better decision-making by farmers, based on real options, can also provide forecasters with better advice on what is required by farmers and agricultural markets and when it is required.

The structure of this paper

This paper begins by exploring recent thinking on the value of climate forecasts, the technical capacity to improve what is currently available and discussion of the costs. The first section also reviews what climate information farmers currently use and the basis for climate-sensitive production decisions.

The second section considers projections of climate change, greater climate variability and the significance of a proposed carbon trading scheme for agriculture.

The third section examines the capacity to improve climate forecasting, the inherent limitations on the accuracy of seasonal forecasts and what is being done to improve their predictive capacity.

Products for managing and coping with risk – insurance, derivatives, spreading equity and leasing –are outlined in section four. Their essential feature is to reduce individual risk by diversifying enterprises, location, ownership and stakeholder participation.

Section five looks at four business organisations that are putting into practice the diversification of enterprises, location, ownership and stakeholder participation, to minimise risk. These organisations also benefit from scale economies in purchasing inputs, equipment utilisation and management.

The sixth section reviews how Australian agriculture is adapting to greater climate variability. It examines government measures to mitigate climate changes by improving agronomic practices, changing enterprises and adopting new management practices. Plant breeders are responding by developing drought tolerant crops and pastures.

Section seven discusses the limitations of traditional decision-making tools such as net present value (NPV), especially under conditions of uncertainty with rapidly changing climatic and market conditions.

This leads to an analysis in section eight of decision-making tools, for coping with risk and uncertainty, culminating in real options methodologies for farm management decisions.

Section nine illustrates how to apply real options analysis using a decision tree process.

Section ten outlines the decision possibilities to which real options analysis can apply.

Several illustrative applications of real options analysis are set out in section eleven. Case studies demonstrate the value of the analytical approach, especially the importance of flexibility to the enterprises involved.

The last section makes some recommendations on the next steps to take in managing climate risk and what the private sector and government could do to reduce the climatic uncertainties facing farmers in Australia.

Climate forecasting

To begin to understand how Australian farmers can improve their management of the uncertainty of the climate in which they operate, it is useful to understand the accuracy and value of the climate forecasting tools they have at their disposal. Of particular interest is how farmers perceive the value of the forecasts they currently use and how they mitigate the risk of errors in forecasting.

In Table 1 the effects of climate uncertainty on key business decisions are listed. They have been developed from a survey of growers, consultants and others involved in agribusiness. The results are largely those affecting enterprise management decisions during one production cycle (intra-year). The decisions nominated by the respondents clearly show how important climate information is and how farming systems are affected by seasonal forecasts.

Table 1 **Effects of climate on key business decisions listed by farming, agribusiness and consultants group**

Key decision in agriculture	Effects of climate variability on that decision
Cropping	Uncertainty in cropping, whether to grow more summer or winter crops. Herbicide use: residual herbicides affect crop options so climate outlook affects types of herbicides used. Residual herbicides are useful but can seriously limit options to take advantage of an event. Fertiliser inputs: in combination with subsoil moisture, take into account forecasts for in-crop rainfall when deciding how much pre-plant fertiliser to apply. If negative (dry) outlook then fertiliser will only be a budget application (maintenance-nil). If positive (wet) outlook the extra will be applied to capitalise on expected in-crop rainfall. Timing and variety: take note of forecasts regarding date of last occurring frost then decide how early to plant and with what varieties.
Irrigated planting area	Crop selection: summer or winter crops depending on the probability of rainfall and irrigation allocations
Stocking rate	Estimation of the number of stock days of feed available by using climate information to assess the odds of receiving effective rain by nominal green date (i.e. the date that crops receive 50mm in 2 weeks in 80% of years), stock numbers can be reduced or increased accordingly
Infrastructure	Being prepared to make a financial commitment to maintain bores, dams, hay storage etc. to ease through dry spells
Staffing	Staffing level needs would vary during different times of the year. Knowing when the season will break would be useful.

Source: Ash et al., 2007

However, despite the importance of climate information for these decisions the respondents also nominated a number of constraints on the use the use of current intra-year climate information.

In Table 2 a number of constraints are listed by those surveyed; the most important of which are uncertainty over accuracy and perceived accuracy.

Table 2 **Barriers to using variable and seasonal climate forecast information ranked in order of perceived 'greatest barrier' to 'least important' barrier**

Barriers	Producers (n=39)	Educators (n=12)	Consultants extension (n=27)	Total (n=78)
Uncertainty over accuracy[A]	1	1	1	1
Perceived inaccuracy	3	3	2	2
Competing information	2	2	4	3
Forecast difficult to interpret	7	3	3	4
Not enough flexibility	6	5	3	6
Additional information necessary	4	4	5	5
Lack access to expertise	5	4	6	7
Difficult to access information	8	5	9	8
Value not demonstrated	9	6	7	9
Proof of value necessary	10	4	8	10
External constraints	11	7	10	11

A Suggested ways to better understand and manage the 'uncertainty over accuracy' limitations in using climate information are: need for more localised forecasts, not general; need to increase knowledge of limitations to accuracy; develop more accurate forecasts with higher degrees of certainty; demonstrate past accuracy; education; more research and development, and always provide skill scores (n=57).

Source: Ash et al., 2007

The practitioners (the farmers and their advisors) recognise the need for improved climate information and there have been a number of studies conducted to measure the value of improvements.

One such study, *An assessment of the value of seasonal forecasting technology for Western Australian farmers*, conducted by Petersen and Fraser (2001), found that improvements in seasonal forecasts could significantly lift the profitability of Western Australian farmers. They found that a 30 per cent decrease in seasonal forecast uncertainty increases annual profits by approximately 5 per cent. In this study, based on expected yields and grain prices at the time, the accumulated annual benefit in the Merredin region (an area with 754 farm holdings over 35,500 km^2 of land) is $2.0 million.

Petersen and Fraser (2001) found that seasonal forecasting tools available to farmers in central and south Western Australia were limited. The Southern Oscillation Index (SOI) is a key indicator of the El Nino Southern Oscillation (ENSO) phenomenon and is one of the more widely used forecasting tools in Australia.

The SOI is a measure of the standardised difference in atmospheric pressure between Tahiti and Darwin. It significantly correlates with Australian rainfall events in subsequent months, a lag that makes it valuable as a forecaster of season rainfall in some regions (Bureau of Meteorology, 1993). Correlations between rainfall events and the SOI are strongest in northern and eastern regions of Australia (up to 0.6 in parts of northern Queensland, New South Wales and Tasmania). Correlations of the SOI and rainfall events are much lower in central and western regions. At this stage no other seasonal forecasting tools have been developed for regions where the SOI has weak correlations.

Petersen and Fraser (2001) claim that there are few economic studies of the value of seasonal forecasts and those that are available suffer from two weaknesses. The first is that most studies fail to consider the interdependencies of enterprises in the whole farm context. The second weakness is the small range of years for which data are compared.

Petersen and Fraser (2001) use a whole farm mathematical model called Model of an Uncertain Dryland Agricultural System (MUDAS). The model uses 11 discrete weather-year states, each with an associated probability of occurrence.

The MUDAS model is used to determine the optimal level of farm activities that maximise wealth (as measured by the level of profit added to the value of land, plant and stock) under each weather state.

The farm activities modelled are the predominant ones in the Merredin district: sheep, wheat and lupin production. Each activity is modified to account for soil types and typical enterprise interactions, such as pasture phases, supply crop rotations with soil nitrogen and higher weed burdens, etc. The model allows tactical management decisions to be made as the year unfolds to either minimise losses or capitalise on extra profits.

The tactical adjustment options presented in MUDAS can be made at four stages (see Table 3 below) and relate to enterprise areas, machinery and labour usage, seasonal sheep live weight patterns, sheep agistment, some aspects of pasture and stubble management, lupin feeding and application rates of nitrogenous fertiliser.

Table 3 **Four stages at which tactical decisions are made**

State	Accumulated knowledge	Management decisions	Actual time of year
1		Determination of initial farm plan to be applied across all weather-years (this plan is adjusted in stages 2-4)	Beginning of the year
2	Quantity of summer rain	Feed decisions	March/April
3	Timing and nature of the sowing opportunity	Tactical adjustments concerning crop and pasture areas, deferment of pasture feed, the livestock enterprise, hiring of additional casual labour and rates of application of crop and pasture nitrogenous fertilisers	April-June
4	Growing conditions	Agistment, livestock feeding and harvest labour	July-November

Source: Petersen & Fraser, 2001

The majority of tactical adjustments that are incorporated into the MUDAS model suggest that the livestock enterprise allows the greatest level of intra-year tactical adjustments, as well as providing seasonal adjustments at the start of the year through adjusting the enterprise mix. This clearly demonstrates that a whole farm approach to valuing seasonal forecasts is critical, as the majority of tactical adjustments appear to involve the interaction of the livestock enterprises and the crop rotation. Without this level of tactical adjustment the value of seasonal forecasts would be significantly underestimated.

The MUDAS model is run using an increase in accuracy of seasonal forecasts of 30 per cent. This specification is viewed by Petersen and Fraser as the minimum standard for the information advantages of a forecasting technology, and therefore will produce conservative estimates of improved forecasting value. The response of farmers to improved seasonal forecasts is to reduce the losses in poor years and enhance the gains in good years. This clearly reflects the attitudes of survey respondents in Ash et al (2007) cited above.

The results of the MUDAS modelling are shown in Table 4 below. The long term impact of improvements in seasonal forecasting can be summarised as:

- a relatively small increase in wheat area at the expense of lupins and pasture
- a small increase in wheat yield due to an increase in the application of nitrogenous fertiliser
- A reduction in the amount of agistment and supplementary feeding for sheep due to a small decrease in average sheep numbers.

Table 4 **The impact of seasonal forecasting on average land use**

Land use	No seasonal forecasting technology		With seasonal forecasting technology	
	Ha	%	Ha	%
Total crop	1211	48.4	1214	48.6
Wheat	822	32.9	829	33.2
Lupins	389	15.6	385	15.4
Pasture	1289	51.6	1286	51.4

Source: Petersen & Fraser, 2001

The financial results of this modelling suggest that by improving forecasting accuracy by 30 per cent, farmers would be able to improve profitability by 5 per cent or $1.23 per ha. Also there was a reduced variation in annual profitability of approximately 26 per cent. While not specified in the paper by Petersen and Fraser (2001), a reduction in variation of financial performance may also lead to a reduction in lending costs as the business represents a lower level of risk.

When applied to the whole Merriden region this resulted in a total increase in average wealth of $2.0 million per year.

This result provides some indication of the value of improvements in climate forecasts and how much growers and others would be willing to pay for such improvements. The results from Petersen and Fraser (2001) are lower than others have reported. For example, two studies by Hammer (1996) and Marshall et al. (1996), found that tactical adjustments due to improved information derived from seasonal forecasting for wheat crop management in the Queensland grain belt, increased profit by approximately $10 per ha and $3.60 per ha respectively. However, most of the differences in value can be explained by the seasonal variations experienced by the regions studied.

These studies suggest that the value of climate forecasts is dependent on the decision set, the structure of the payoff function, degree of uncertainty in decision-makers' prior knowledge of climatic conditions, and the nature of the information system.

The key message from all these studies is that improved forecasting could be of significant value to farmers where they are likely to be able to:

- understand them and know how to apply them (Ash et al., 2007)
- adapt to take advantage of improved climate information (Marshall et al., 1996)
- resolve more uncertainty than with alternative forms of risk management
- use the seasonal forecast to provide more certainty than the historical probability of a seasonal outcome occurring.

In summary, the value of a seasonal outlook to the manager of a particular production system depends on the skill or accuracy of the forecast, and its marginal value relative to other available sources of information (The Regional Institute, undated).

However, while there is considerable value in improving seasonal forecasts, an analysis of their historical performance suggests that they are little better than the historical probabilities of a climatic event occurring at present.

In Australia, Vizard et al. (2005) estimated the value of climate forecasts and found no value above of that of historical probabilities. They found that the seasonal rainfall forecasting system currently used could not have reliably added significant value to any decisions made by growers. They estimated that growers who routinely acted upon the forecasts would have experienced results ranging from small losses to, at best, small gains.

Vizard et al. (2005) compared seasonal forecasts, issued by the BOM between 1997 and 2005, to seasonal outcomes for over 260 towns in Australia. That is, they compare the forecast with what actually occurred. Overall, they found that the seasonal forecasts almost entirely replicated historical probabilities (underlying risk). This means that the seasonal forecasts analysed correlated strongly with the rainfall probabilities and did not reduce uncertainty in any significant way (Vizard et al., 2005).

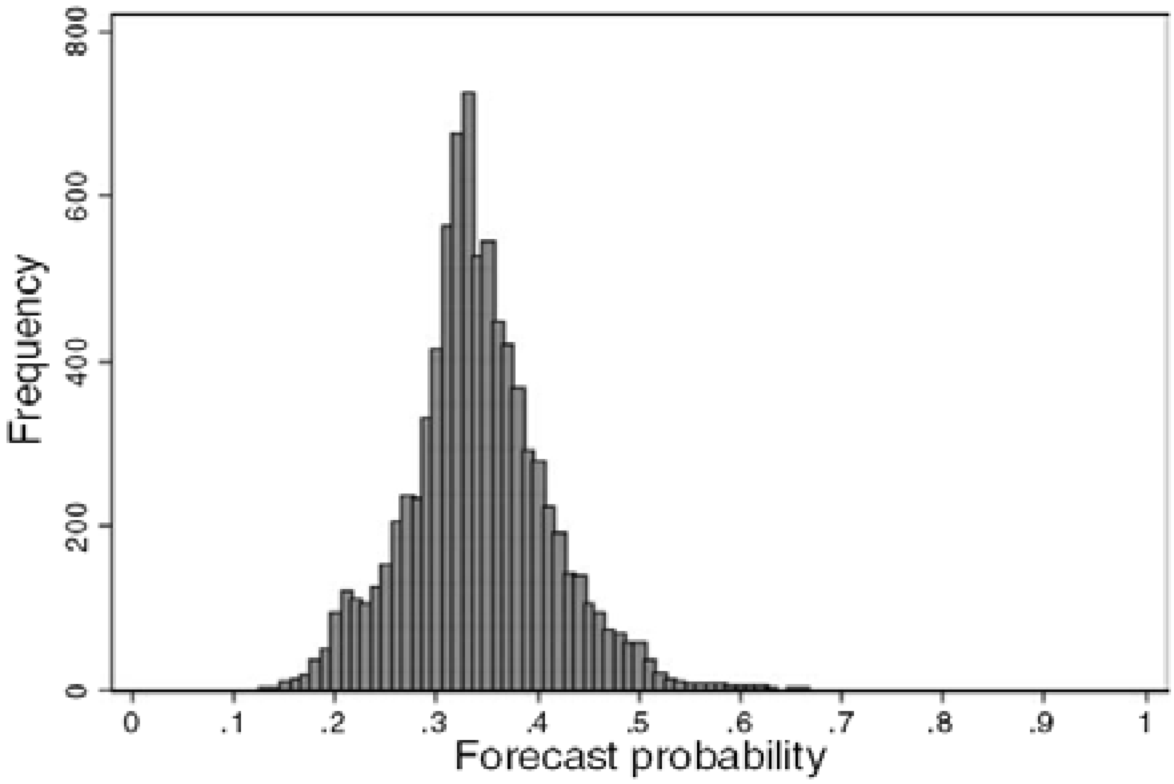
The results of the analysis are shown in Table 5. They show that the forecast skill for dry and wet years (wet being above the 67 percentile – the upper tercile – and dry being below the lower tercile), is almost negligible, not only for wet and dry years but also across regions for which the forecast is made.

Table 5 **Means and variance of outcomes (x) and forecasts (f). The gradient ± robust error and intercept of the ordinary least squares regression of outcome versus forecast**

	Mean					**Variance**		**Var Ratio**		
	μ_x	μ_f	$\mu_{x\|f=0}$	$\mu_{f\|x=1}$	Diff	σ_f^2	σ_x^2	$\frac{\sigma_f^2}{\sigma_x^2}$	Gradient	Intercept
Overall										
'Dry'	0.34	0.34	0.336	0.345	0.0091	0.0049	0.2252	0.0216	0.42 ± 0.36	0.20
'Wet'	0.31	0.33	0.328	0.342	0.0148	0.0053	0.2122	0.0252	0.59 ± 0.26	0.11
Region ('Dry' forecasts)										
1	0.35	0.33	0.325	0.327	0.0016	0.0044	0.2282	0.0193	0.08 ± 0.57	0.33
2	0.34	0.35	0.344	0.350	0.0062	0.0046	0.223	0.0205	0.30 ± 0.76	0.23
3	0.29	0.33	0.322	0.334	0.0115	0.003	0.2062	0.0144	0.80 ± 0.55	0.03
4	0.24	0.34	0.341	0.343	0.0016	0.0028	0.1805	0.0156	0.10 ± 0.62	0.20
5	0.41	0.37	0.363	0.368	0.0045	0.005	0.2425	0.0204	0.22 ± 0.67	0.33
6	0.36	0.33	0.323	0.347	0.0237	0.0094	0.2318	0.0407	0.58 ± 0.49	0.17
7	0.34	0.33	0.325	0.352	0.0274	0.0054	0.2238	0.0243	1.13 ± 0.56	-0.04
8	0.31	0.34	0.332	0.353	0.0205	0.0023	0.2156	0.0109	1.88 ± 0.78	-0.32
Season ('Dry' forecasts)										
Autumn	0.43	0.33	0.326	0.328	0.0018	0.0029	0.2452	0.0117	0.16 ± 0.58	0.38
Winter	0.38	0.36	0.357	0.368	0.0115	0.0058	0.2365	0.0243	0.47 ± 0.65	0.21
Spring	0.26	0.35	0.341	0.367	0.0260	0.0062	0.1919	0.0323	0.81 ± 0.45	-0.02
Summer	0.30	0.32	0.321	0.322	0.0005	0.0036	0.2094	0.0171	0.03 ± 0.52	0.29

Source: Vizard et al., 2005

Chart 1 **Distribution of the ‘dry’ forecast probabilities from June 1997 to May 2005 (n=8384). The interval range of the categories is 0.01**



Source: Vizard et al., 2005

Climate change and increases in climate variability

While there is a considerable amount of uncertainty as to how climate change will affect climate variability, a recent report released by the CSIRO and the Bureau of Meteorology (Hennessy, et al., 2008) suggests that the frequency of extreme climate events is likely to increase dramatically in some regions. Other recent reports support the CSIRO predictions of general decreases in average rainfall but, more importantly, increases in variability of climate, rainfall and water yield from farm lands.

On the 30 of September 2008, Professor Ross Garnaut released Report of the Garnaut Climate Change Review (2008). The report found that since 1997, south-east Australia has seen a number of changes in rainfall patterns, and commented that:

> *Only one autumn since 1990 has had rainfall above the 1961-90 autumn average.*

Changes in autumn rainfall in the southern agricultural areas of Australia are important for several reasons. Autumn rain events allow the winter crop to be sown. This dependency is negatively correlated to the amount of stored soil moisture. That is, reliance on the level of autumn rainfall declines as the level of stored soil moisture (moisture accumulated over summer) increases. Second, autumn rainfall fills the soil profile up, affecting surface run off over the winter and spring. The amount of surface water yielded by the land is reduced if autumn rains fail.

Surface flows are also affected by the temperature. Higher temperatures reduce soil moisture levels, which affects surface water yield. Ground water recharge is also reduced as more water evaporates than finds its way into ground water reserves. A decline in ground water reserves also reduces stream flows where the ground water enters surface drainage systems. Research suggests that a 1^{o}C increase in maximum temperature results in a 15 per cent decrease in stream flow in the Murray-Darling Basin (MDB).

Table 6 shows the results of the CSIRO's modelling of the impacts of climate change on Victorian rainfall in the no mitigation case. The CSIRO report predicts that Victoria is likely to experience some of the highest levels of increased variability of temperature and rainfall.

Table 6 **Projected changes to Victoria's average rainfall in a no-mitigation case (percentage change relative to 1990)**

	10th Percentile (dry outcome)	**50th percentile (best estimate)**	**90th Percentile (wet outcome)**
2030	-8.3	-3.5	0.9
2070	-30.3	-12.9	3.4
2100	-44.7	-19.0	5.1

Source: Hennessy, *et al*., 2008

Quite modest changes in precipitation and evaporation could reduce soil moisture levels and stream flows substantially. That, in turn, could significantly reduce agricultural production. Table 7 shows the decline in the value of irrigated production from the MDB, compared with a world without climate change.

Table 7 **Percentage decline in value of irrigated agricultural production in the Murray-Darling Basin from a world with no human-induced climate change**

	No-mitigation case	**Strong global mitigation with CO2-e stabilisation at 550 ppm by 2100**	**Ambitious global mitigation with CO2-e stabilisation at 450 ppm by 2100**	**Hot, dry extreme case (the 'bad-end story')**
Year				
2030	12	3	3	44
2050	49	6	6	72
2100	92	20	6	97

Source: Garnaut Climate Change Review, 2008

Note: ppm: parts per million

While climate change is likely to increase climate variability, policies designed to reduce emissions to head off the worst case scenarios of climate change will themselves create a great deal of uncertainty for agriculture. They could potentially affect agriculture's options in responding to climate variability.

Technical capacity to improve climate forecasting

The following section draws on the results of the background and summary report of the Workshop on the Science of Seasonal Climate Prediction held at The Shine Dome on 2-3 August 2006.

Considerable emphasis has been given to improving seasonal forecasting in Australia and indicators such as the SOI and BOM seasonal predictions have attracted a great deal of interest from farmers. As a result much research has been carried out on the development of seasonal climate prediction methodologies.

This research has been based on evidence that there is at least some potential predictability of seasonal anomalies in the Australian region. However, these anomalies are likely to be more valuable in some regions than others, due to the size of the continent and the large variation in the oceans that influence the climate. The nature of the predictability is mainly linked to the global-scale influence of ENSO, but there is some evidence of potential predictability from other large-scale drivers such as sea surface temperature (SST) anomalies in the Indian Ocean.

It appears that, while there has been a lot of research on the development and application of prediction systems and new indicators with predictive value, there has been relatively little research on exploring the actual limits of potential predictability. Studies on predictability aim to determine its theoretical limits. These studies are important because no amount of ingenuity in a prediction system can overcome the inherent limits to the predictability of seasonal climate anomalies.

What is not clear at this stage is whether the level of accuracy of current predictions stems from errors in the estimation techniques (e.g. systematic errors in the dynamic models) or that the inherent predictability of the climate system is low.

Box 1 **What is the potential for improvement in skill and lead time in the near term**

There is potential for improvements in forecasting skill and lead times of seasonal predictions. It can be argued that, following the initial success of intermediate coupled models in predicting ENSO events two decades ago, there was a tendency to over-state the progress in the science of seasonal prediction based on dynamic models. On the other hand, we now have a better understanding of the climate processes associated with seasonal scales of variability and of the problems limiting the forecasting skill of dynamic models.

A focused program of research on the development and application of dynamic models for seasonal prediction is expected to lead to improvements in seasonal forecasting, in comparison with the baseline level that has been established by statistical forecasting systems. The relative simplicity of statistical systems means that novel statistical methods will also continue to be developed and applied to practical problems.

In Australia, the collaborative Australian Community Climate and Earth System Simulator (ACCESS) program will provide the framework for dynamic prediction across all time scales. However, in addition to the development of the broad framework of ACCESS, there is a need for a specific program of research and development focused on priority issues for seasonal prediction. These issues include better understanding and prediction of the MJO, which is the dominant mode of intra-seasonal variability in the tropics, and better techniques for assimilating ocean and atmospheric data into coupled dynamic models, so that the initial state of the climate system is specified accurately.

As with all model development programs, the modelling activity needs to be supported by more strategic research on climate processes and on basic questions of predictability. Indeed improvements in our understanding of climate predictability are required for us to determine the inherent limits on any seasonal prediction system.

The research and development required to improve the forecasting skill and lead time of seasonal predictions needs to be complemented by continuing enhancements to the products available to the user community. The detailed nature and scope of forecasting products are determined by a balance of scientific feasibility with user requirements. Continuing communication between the climate and user communities is needed to ensure that balance is achieved.

Source: Australian Academy of Science, 2006

The current value of seasonal forecasting can be summarised as:

- It appears that current forecasting does not reduce risk for farmers as climate forecasts are not accurate enough satisfy farmers' decision thresholds.
- The increase in accuracy that would be required is significant - up to 17 fold (Vizard et al, 2005).
- There is considerable value in improving seasonal forecasts, but the technical capacity to improve them appears limited.
- The level of seasonal variability is forecast to increase, just as the frequency of extreme climatic events is also forecast to increase (Hennessy et al., 2008). This is likely to mean that, to reduce risk, seasonal forecasting will need to improve to well beyond the standard that is currently required in the absence of significant climate change.

Therefore, in the absence of any foreseeable improvement in seasonal forecasting accuracy to a level where it is of value to growers, alternative methods of managing climate variability need to be considered. This does not mean that research into seasonal forecasting should be abandoned or sidelined. Rather, investment to improve seasonal forecasting must be undertaken as part of a broad suite of risk management tools for farmers to manage climate variability.

Agriculture and adaptation to increased risk

The previous sections have explored the current level of predictability of climate variation and hence the capacity of forecasting to reduce risk. These sections have also considered the impact climate change will have on climate variability and the uncertainties created by the Australian Government's response to anthropomorphic climate change. The conclusion is that climate variability is expected by many to, but the capacity for forecasting inter-seasonal variations is unlikely to show any significant improvement in the near future.

Therefore agriculture in Australia, particularly those areas likely to experience significant increases in risk, will have to adapt to greater climate variability and, most likely, trading risk, due to Government mitigation policies. Added to this will be increases in the cost of water as it becomes scarcer as rainfall and stream flows decline.

Agriculture has two broad adaptation options available:

- operationally manage risk through improved adaptation tactics
- allow the risks to be borne by those best able to manage them.

The management of risk, by adapting enterprises to better manage it, deals with changes such as new crop varieties or developing the ability to adjust to seasonal conditions as they arise.

As a general rule, the intention is to modify production systems to manage the downside risks but retain exposure to upside potential.

Allowing risks to be borne by those best able to manage them, deals with:

- structural adjustment as enterprises able to adjust are expanded at the expense of those that have limited capacity to adjust (within the farm and between farms)
- introducing new ownership models with equity investments that allow a portfolio to be constructed, with exposure to investments outside agriculture that can be adjusted in response to relative changes in risk across the portfolio
- insurance products that allow the marginal difference of risk management to be traded.

The following sections deal with each of these adjustment options in more detail.

New risk management products

Insurance products

The history of drought insurance gives few grounds for confidence. Overseas, various crop insurance schemes have not been commercially viable, with the amounts paid out plus administration costs being about three times greater than the premiums paid in by farmers. The insurance schemes have only survived because governments have subsidised them.

In Australia, it is possible to insure against hail and fire but not the impact of drought. Three studies – Industries Assistance Commission (1996), Ernst and Young (2000) and the Multi Crop Insurance Task Force (2003) – have investigated the viability of multi-peril crop insurance and concluded that it was not feasible without government subsidy or underwriting of risk (Hertzler, 2006).

Hertzler (2006) observes that one reason that multi-peril crop insurance is not expected to be viable, is that many Australian farmers already have Farm Management Deposits as a tax-effective way to put funds aside for withdrawal when farm income is historically low. Several farmers also have off-farm investments in non-farm property and shares. Farmers diversify geographically by operating farms in different rainfall zones and have the capacity to switch enterprises on their farms in response to changes in climatic conditions. That is, there are many management strategies to cope with the impact of drought and other causes of fluctuating farm incomes. The value of multi-peril crop insurance has to be assessed against alternative means for coping with the effects of climatic variability.

Drought insurance schemes based on expected yield are not likely to be viable because of:

- uncertainty about the causes of the low yield, which could be due to the crop being planted at the wrong time, incorrect type and amount of spray, failure to fertilise, incorrect harvester adjustment, fraud and so on (the moral hazard problem)
- uncertainty about expected yield for the region or state – on which to base premiums – versus an individual yield on farm (the adverse selection problem)
- uncertainty about the probability of a drastic yield reduction over the insured area due to events such as the widespread droughts of 2002 and 2006, which could bankrupt the scheme (the systemic risk problem).

Put together, these factors make insurance for yield a very risky business for a potential insurer without support such as underwriting by government.

Derivatives markets for climate risk

A more promising approach is drought insurance based on rainfall events and products derived from the amount and incidence of rainfall. Rainfall insurance is regularly purchased by municipalities, energy companies, tourist industries and event organisers to protect themselves against loss of revenue due to inclement weather. Insurance companies provide it because of the relatively greater certainty – there is no moral hazard, rainfall data are very comprehensive and are collected by an independent third party, so the adverse selection problem is minimised, and the maximum payout for a one-off event can be negotiated in advance, thus limiting the systemic risk (Hertzler, 2006).

The disadvantage of rainfall insurance from the farmer's perspective is the basis risk – the relatively poor correlation between rainfall and income. It is up to the farmer to draw the relationship between rainfall and income that best reflects his/her personal experience.

The basis risk borne by the farmer can be reduced in the case of a cropping enterprise by taking out insurance on monthly – as distinct from annual – rainfall at the critical times (say at planting time and during spring) and also taking out insurance on monthly temperatures, including cover for severe frosts.

The critical questions, of course, are:

- the extent to which a farmer believes that the amount of rainfall and its incidence, combined with temperatures and their incidence, throughout the cropping season predict yield
- the relationship between crop yield and revenue
- the level of premium that an insurer would have to charge to justify offering a tailored insurance policy required by the farmer.

As noted by Hertzler (2006), insurance products based on derivatives – linking relevant weather information, crop yields and income – are yet to be developed, so it is timely to conduct a survey of farmers to gauge the potential interest in using such products.

Raising equity and diversifying to reduce risk

Agriculture in Australia is regarded as a capital intensive industry. Large amounts of capital are required to purchase the land, stock and plant and to fund the cash cycle. But many other businesses are confronted with similar capital requirements; factories have to be sited and built, machinery purchased and raw materials and wages funded.

In agriculture the operator of the business contributes all of the equity, while in most other small to medium businesses the capital contributions can come from a variety of sources. The land the factory is on is often owned by someone else, the factory itself may be leased and there may be a number of contributors of equity to the entity that buys the raw material, employs the staff and produces the products.

The dependence of agricultural businesses on the equity contribution of the operator means that, for those in the industry or those who want to enter, the capital requirements are large. This creates significant capital barriers to entry and exit, which, in turn, makes structural adjustment in farming slow, difficult and often traumatic.

When all of the equity is contributed to the business by the operator, the operator bears all of the risk. The introduction of non-farm equity can spread the risk over a larger number of investors, which reduces the impact of variations in profitability.

While the benefits of increasing non-farm equity in agriculture are known, the amount that flows in remains a trickle. Every business competes for capital and the assessment of risk and returns is highly subjective. This report does not seek to make the case that agriculture is profitable and attractive to investors by analysing risk and return, rather, it analyses the constraints on the movement of capital so that agriculture may compete more effectively
.
Constraints on the flow of equity can be categorized broadly into two groups; one is the way agriculture presents itself to potential investors, and the other is the lack of suitable structures to match the needs of the agricultural businesses with those of investors.

This report analyses the constraints and proposes strategies to overcome them and presents new structures that should facilitate a greater flow of capital into farming.

We do not make the assumption that there is insufficient capital for agriculture, indeed given the recent improvements in farm returns and the growth of Farm Management Deposits (FMDs) the opposite could be argued. Nor do we see the raising of equity displacing debt, since debt is cheaper to establish and fund. We see that the raising of non-farm equity for agriculture will displace some existing farm equity, freeing it to diversify, increase productivity, and contribute to solutions for succession planning.

What is equity?

Equity is essentially ownership of an asset after claims made by debt and other creditors have been met. If there are no claims on the assets, equity is deemed to be 100%. Equity is similar to a traded option contract, as it allows the holder to share in the cash flows but they are not guaranteed. The price paid for the right to participate in the cash flows, the equity investment, is similar to an option premium and is made up of the present value of the expected future cash flows plus compensation for the risk that the cash flows may be erratic or may not eventuate at all.

As equity shares the risk of cash flow variability and ranks below debt and other creditors, it tends to be more expensive. Debt has risk but it is the risk of default, which can be managed through a contract and a first claim over assets. While equity sits at the bottom of the hierarchy of claims on assets and cash flows, it has access to all of the cash flows once higher claims have been satisfied, giving it unlimited upside potential.

While the holder of equity seeks to be rewarded for the additional risk from exposure to variations in cash flows, equity usually has higher transaction costs as well. The higher transaction costs are due to a higher level of initial assessment of the risks of the investment by the investor. There are also regulatory controls on the ways equity can be raised, which seek to protect the interests of investors and maintain confidence in capital markets.

Equity also attracts higher costs from increased monitoring of performance. These monitoring costs are sometimes referred to as agency costs as they result from the principals of the business ensuring that their agents, the managers of the assets, are acting in the principals' best interests.

Ensuring that the agent has sufficient incentive to act in the best interests of the principals is called the principal-agent problem. The costs associated with ensuring that the agent does act in the best interest of the principal are called agency costs. The principal-agent problem is a recurring issue in all capital markets.

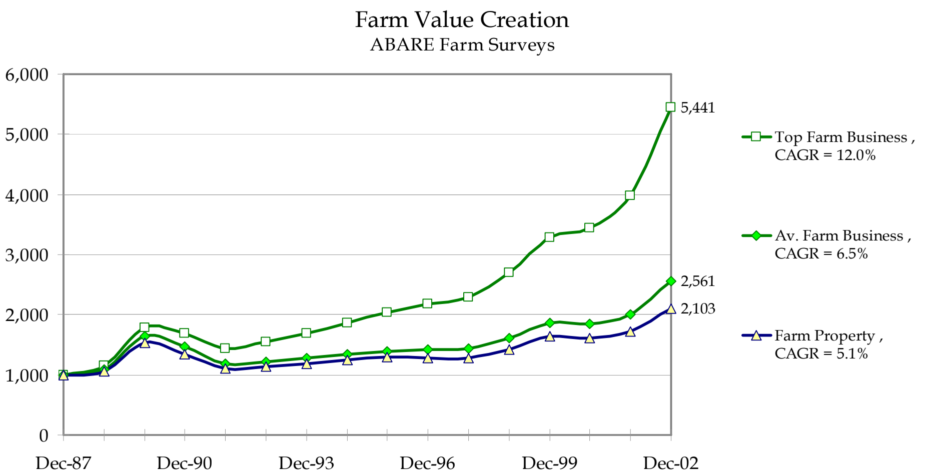
Equity also allows for multiple owners, which spreads the risk of investment in the business. Each of the owners can manage the risk to which they are exposed in any one business by diversifying their portfolio of investments. A single owner of a farm can also diversify by using profits generated by the agricultural business to build up investments off-farm. For the vast majority, farm ownership is the largest single investment they will have.

Hybrid equity products have some of the features of debt and some of equity. Possibly the most important aspect of equity is the ability to vary servicing it to match cash flow variations. Therefore, many hybrid equity products that are developed in other sectors of the economy use this aspect of equity and couple it with the security of debt.

New products need to be developed

Farm benchmarking studies routinely show that farming is a profitable business. Rates of return on equity for the top 20% of farm businesses can regularly exceed 10%. Average rates of return on equity, excluding capital appreciation, average from 5% to 10%. This is demonstrated by the information from Mike Carrol (former head of Agribusiness Banking at the National Australia Bank) in Chart 2.

Chart 2 **Farm business and land accumulation index**



Source: Carrol, 2003

It is clear that rural land alone is an asset that returns competitive rates when compared to other asset classes. The risk/reward profile of agriculture demonstrates that farming is not as risky as many potential investors perceive it to be. Thus, it appears that one of the more significant barriers to raising equity by rural businesses may well be the lack of products and structures that match investors with those businesses.

The main obstacles to raising equity in agriculture have been:

- high transaction costs, principally due to the dominance in the industry of small enterprises;
- principal-agent problems
- non-standardised products or approaches
- asymmetric information between those running the farming business, and thus knowing how it is performing, and those looking to invest.

Raup (1986) has identified four elements that are crucial to the development of non-farm equity:

- the principal-agent problem must be addressed to preserve the management incentive in agriculture and reduce accusations of simply tenant farming
- any instruments or arrangements developed must provide flexibility to the farmer and liquidity (exit ability) to the investor
- the investor requires a secured equity position equal to the farmer's equity position so that the investor's claim is not secondary to the farmer's in case the business fails
- the double taxation feature of a corporate structure should be avoided.

In addition, there is the need to:

- standardise instruments or arrangements to reduce transaction costs and create a history of performance;
- develop an intermediary to manage the asymmetry of information; and
- spread the risks across multiple businesses to reduce default risk.

Leasing

Calculation of non-fixed lease payments

A lease payment based on the gross value of production generated by the lessee shares the risk between the lessee and lessor. This type of lease payment relies on both the productivity of the business and the prices received for the commodity being produced. The gross income could be received as a percentage of the product or its value after sale. If a percentage of gross product is received it places the responsibility of marketing on the lessor; if the value method is used the lessee markets the commodity. Either way is possible, depending on how the lessor would prefer to operate.

A share of the commodity may attract investment from millers, wool processors and other commodity users, to secure raw materials. The originating company could market the produce on behalf of the SPV investors also.

This method is similar to the securitisation model proposed by Dwyer et al (2004), where land is exchanged for a share of gross proceeds instead of cash. In this case, however, the capital appreciation of the land goes to the investors, not the operator of the business, which would be reflected in the percentage of the gross return negotiated between the parties.

Determination of lease payments based on commodity prices

Lease payments could, in part or in full, be negotiated on the market value of the primary commodity being produced. Alternatively, a floating lease negotiated with the lessee and the originating company could use commodity derivative markets to reduce the risk of lease payment fluctuations.

For example, the lease payment for a large cropping operation may be linked to variations of the wheat and canola prices. If the wheat price goes up by 5%, the price of the lease may do the same.

Alternatively, the price of canola may drop by 5%, which would offset the rise in wheat. Any number of variations can be developed to link the commodity prices to the lease payment.

Linking the prices and leases creates a hedge for the lessee, as lease payments will fall if prices go down. On the other hand, the landholder has more exposure to commodity markets and can use futures and options markets to manage this risk.

Case studies of new finance products

The first two case studies demonstrate two traditionally structured corporate investments in Australian agriculture. These investments demonstrate how, through public and private capital investment vehicles, the risks of farm production can be distributed across a wide range of share holders. Each of these shareholders has diversification options within their own portfolios. The effect of this investment structure is that the risks of the individual investment can be reduced by diversification.

In addition to the diversification opportunities, these investments also diversify production risk across a portfolio of properties in different geographical zones and producing different agriculture products.

The first two investment case studies represent how agriculture as a whole can better manage risk. The last two case studies are based on innovative financial structures that allow small to medium size farm businesses to achieve similar diversification benefits to the more traditional investment structures.

PrimeAg

PrimeAG's strategy to minimise the adverse consequences of risks, such as erratic rainfall, drought and short term commodity price fluctuations, is to:

- capture the advantages of significant economies of scale by investing in select, quality, Australian rural properties within 'hubs' (a number of farms located in close proximity to increase purchasing power and to achieve lower production costs from more efficient labour and equipment utilisation)
- diversify location of the 'hubs' across different climatic zones to spread the risk of drought across several areas
- diversify production across several commodities, with the ability to switch between commodities in response to price movements or climatic changes
- select properties in safe rainfall areas and, where appropriate, with irrigation water entitlements.

(PrimeAG Australia Limited, 2008).

Macquarie Pastoral Fund

The Fund was set up in 2007 to create a portfolio of land and livestock enterprises on a large scale and spread, to capitalise on the potential future growth in world demand for beef and sheep meat production, while leveraging some of Australia's natural competitive advantages.

Macquarie notes that the returns on large scale farms since 1979 have been comparable to equities but with lower.

The Fund provides equity-like exposure to the operating business, but because the underlying assets of the fund are land and livestock, investors have the security and capital growth potential normally associated with an investment in tangible assets.

Properties cover a wide geographic spread, taking in Western Australia, Northern Territory and the NSW Riverina. Since this spread of properties takes in three climatic zones, Macquarie expects it to reduce the risks of adverse weather effects (Macquarie Bank website, www.macquarie.com.au accessed on the 21/07/2008).

Australian Agricultural Contracts Limited (AACL)

AACL developed a product called Grain Co-Production in Western Australia to assist grain farmers to better manage their production risks and to provide farmers with access to investor funds in line with other major Australian industries. It was launched nationally in 2008. Total investment by AACL is currently $65 million, contracting some 170 farmer clients to grow about 380,000 tonnes of wheat and barley (AACL, 2008).

Grain Co-Production is effectively a cash-flow and income protection product, based on the principles of share farming. Investors provide the funds to grow wheat and/or barley crops and farmers provide the land, equipment, inputs and expertise. The risks and rewards of growing the crop are shared by the farmer and investor, with farmers rewarded for over-performance.

Farmers benefit from the reduced risk by being provided with a guaranteed amount of income on a contracted area of their farm each season. The majority of the payment to farmers is made at seeding time, underwriting their cash-flow regardless of the season.

Should the contracted crops under-perform or fail, then the investors incur that loss, not the farmers. As such, the investors' funds provide a form of income protection to the farmer by sharing the risk of the crop with the investor. AACL contracts crops in many different locations and pools the result to manage the investors' risk of growing grain in one location.

By stabilising cash-flow, regardless of the season, Grain Co-Production enables the farmer to make more pro-active decisions knowing that downside risk is effectively covered. However, the cost to the farmer in ameliorating that risk is giving up an amount of income to the investors in better seasons. The decision on whether to use grain Co-Production comes down to the farmer's attitude to risk – whether they prefer a higher average, but fluctuating, income or a more consistent year by year cash-flow over the long term but at a lower average. An example of this is shown in Chart 3.

Chart 3 **Net income from grain production with and without risk sharing with Grain Co-Production**

Source: AACL website, www.aacl.com.au accessed on 17/07/08

Australian Primary Producers (APP)

The key elements of APP's investments are scale and diversification.

APP pools funds from investors to invest in a range of farming businesses to benefit from scale economies from land, water and livestock assets. To reduce AAP's exposure to prices and climatic variations, investments are spread across a range of agricultural industries and commodities, including dairy, grains, meat, herbs, vegetables and seafood.

APP's operational aim is to own 50 per cent of up to 15 large-scale established farming businesses. This strategy frees up capital for the existing owner, allows APP to reduce risk by buying into a business with a measurable track record and allows the current operator to be retained if that arrangement is suitable to both parties.

Managing to reduce climatic risk and profit from new opportunities

Success in managing risk depends on the adaptive capacity of the individual or enterprise to respond in ways that minimise loss and – preferably – take advantage of the new set of circumstances.

Management responses take into account a wide range of factors, such as experience with past climatic variability, confidence in weather forecasts, financial security, projected enterprise profitability, enterprise mix, location, access to capital, access to – and acceptance of – new technology, attitude to risk, expectation of government intervention to reduce or share the risk, off-farm opportunities (commercial and social), and level of education and training (Gunaskera et al., 2008).

Provided that managers are flexible and not inhibited by perceptions that government policy will protect them from climatic or market volatility, there are several current and emerging opportunities to adapt to changing climatic conditions as they arise and therefore to lower the risk from unexpected variability.

For example, the impact of a drought on grain yields can be reduced significantly by adopting a suite of agronomic and management strategies prior to the event. Conversely, susceptibility to adverse climatic events may be exacerbated by factors other than climate. Even in a 'good' year, some crops do not access the moisture that is available in the soil because of soil problems, such as poor (including damaged) soil structure, low organic matter, salinity, boron toxicity and root diseases that may have damaged the root mass and reduced water harvesting capacity and efficiency. These problems can be corrected with improved agricultural practices and the use of improved plant varieties, which deliver greater productivity, both when water is abundant and when it is limited (Kuchel, 2008).

Many of the management level adaptation options are largely extensions or intensifications of existing climate risk management or production enhancement activities, in response to a potential change in the climate risk profile. For cropping systems, for example, there are many potential ways to alter management to deal with projected climatic and atmospheric changes. If widely adopted, these adaptations, singly or in combination, have substantial potential to offset negative climate change impacts and take advantage of positive ones (Stokes and Howden, 2008). Some of these are discussed later in this section

Grazing management

In broad scale grazing enterprises successful strategies for coping with climate variability include the capacity to vary stocking rate (such as trading cattle rather than breeding), diversifying sources of income (investing off-farm rather than in the farm next door), and diversifying climate risk geographically by operating multiple pastoral properties in regions with different patterns of climatic variability (see sections on PrimeAG and Macquarie Pastoral Fund, pp 16-17).

Based on the expectation of dryer and warmer weather over large parts of Australia's grazing country, consideration will have to be given to sowing new pastures better adapted to higher temperatures, higher CO_2 concentration, water constraints and changes in soil fertility, as well as providing additional nitrogen through use of sown legumes. However, if new pasture species are to be introduced, it will also be necessary to adjust grazing management to assist their establishment, take account of risks of introduced species becoming weeds, impacts on biodiversity, and effects on soil acidity – particularly for introduced legumes. Basically, the concept of 'safe carrying capacity' will need to be redefined (Stokes and Howden, 2008).

Changing enterprises is also an option for adapting to a warmer and dryer climate. For example, on suitable rangelands there is the opportunity to reduce current sheep and cattle numbers and replace them with kangaroos. According to Wilson (2008), increasing kangaroo numbers to produce the same amount of meat as cattle by 2020 would provide substantial conservation benefits, including: a lower grazing impact through less damage from hard-hoofed livestock; maintenance of kangaroo and other wildlife habitat; and a reduction of some three per cent in methane emissions because kangaroos are not ruminants. In the event that an emissions trading scheme includes agriculture, there could be clear financial incentives to switch to non-greenhouse gas emitting forms of meat production (Wilson, 2008)

The incentive for individual owners and managers to adopt successful risk management strategies to cope with climate change depends on:

- confidence that climate change can be separated from the naturally high year-to-year climate variability inherent in broad scale grazing systems
- the motivation to change based on the perceived risk and opportunities of climate change
- establishment and implementation of applicable new technologies and demonstration of their benefits
- buffering against establishment failure of new practices during less favourable climate periods;
- alteration of transport and market infrastructure to support altered production
- development and modification of government policies and institutions to support implementation of the required changes for the long term, rather than supporting on a continuing basis those who decided against making the necessary adjustments.

Cropping management

With cropping there is capacity to reduce risk through further refinement of existing approaches, such as zero tillage and other minimum disturbance techniques, retaining residue, extending fallows, row spacing, planting density, staggering planting times, and controlled traffic or 'tram line' paddock systems.

Valuable research is being conducted to improve the yield, quality, management and disease resistance of wheat, as well as new farming methods to improve the sustainability of cropping in conditions of greater climatic variability. However, investment in research and the rate of adoption at the farm level needs to be stepped up if grain production in Australia is not to suffer from the adverse climatic conditions that are predicted.

Plant breeding

To deal with the expectation of hotter weather and more frequent droughts, wheat breeders are concentrating on: water use efficiency, high vigour**,** salt tolerance**,** wheat strains for the high rainfall zone**,** drought resistance and dual purpose wheat strains (grazing and grain).

There is likely to be greater capacity to deal with climatic stress as a result of research being conducted to define mechanisms used by grass species, other than cereals, to tolerate extreme environmental conditions and to transfer genes responsible for this tolerance into wheat and barley varieties (Australia Centre for Plant Functional Genomics, www.acpfg.com accessed on the 20/07/2008).

There are over 1,000 genes activated in response to drought. The response varies according to the many different types of drought that a plant must face, and the numerous strategies that plants use to minimise the effects of drought (which often involve lack of water, high temperatures and greater light intensity). A plant's drought strategy includes:

- having fewer stomata (holes in the plant tissue where water escapes) on the leaf surface, therefore allowing less water to escape from the plant

- changing the leaf angle so leaves are not facing direct sunlight
- increasing the waxiness of the leaf surface to retain moisture
- improving root structures so more water can be accessed
- producing antioxidants that help buffer the plant against the stress.

The plant breeding goal is to find new sources of drought tolerant plant material and create a genetic map or gene library of all the genes involved. This gene library then becomes a reference point for understanding drought tolerance. Introducing these genes that give drought tolerance can be done through conventional breeding programs or with more precision and faster using transgenic technologies

CSIRO's Wheat Functional Genomics Project, is also committed to identifying wheat genes that assist in breeding improved varieties, particularly the genes that influence

- water-use efficiency
- salt tolerance
- soil acidity
- frost tolerance
- water logging tolerance;
- water stress tolerance
- flowering processes in cereals
- disease resistance.

(CSIRO, *Wheat genome, hunt for drought adaption*, CSIRO fact sheet on www.csiro.com.au, accessed on the 25/07/2008)

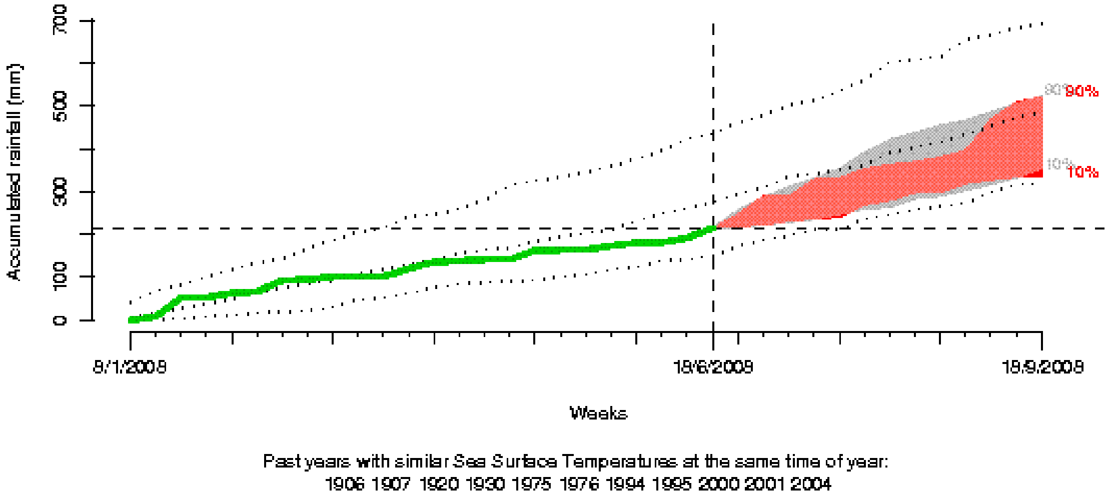
The more rapidly this research can be conducted and effective results achieved, the more likely Australian agriculture is to benefit from the opportunities it will produce for adapting to climate variability, and the contributions it will make to productivity. It is therefore in the interests of Australian agriculture that artificial constraints on plant breeding, such as bans on the commercialisation of crops derived from transgenic technologies, should be removed.

New grazing management products

In response to the needs of graziers to make better decisions on future stocking rates based on potential pasture productivity, several sophisticated models have been developed that combine the historical are freely available on the internet.

The pasture growth curves that are produced by these models provide an indication of the upper and lower bound expectations of pasture availability and the most likely scenario. These models are important contributions to options analysis as they provide a range of potential outcomes and the probabilities of each one occurring.

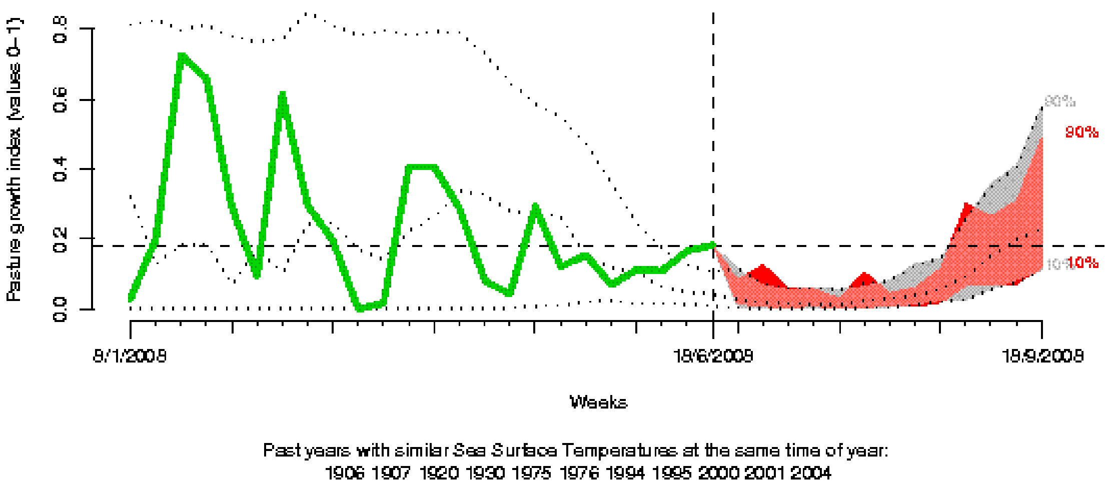
Chart 4 **Accumulated rainfall from 1 Jan 2008 to 18 June 2008 for Yass (Derringullen)**



Source: MLA Rainfall to Pasture Growth Outlook Tool accessed on 30 June 2008

Chart 5 takes the outputs of Chart 4 and produces a pasture production estimate with upper and lower bounds. These charts are for the Yass area and show the pasture productivity curve for the 10 and 90 percentile rainfall outcomes for the region. The pasture curves take account of temperature, existing pasture growth and historic probability of rainfall for the forecast period.

Chart 5 **MLA pasture growth predictor**



Source: MLA Rainfall to Pasture Growth Outlook Tool accessed on 30 June 2008

The limited application of traditional analytical tools

This section begins with reviews of a key analytical tool and then introduces the concept of real options analysis, examining the strengths and limitations of each method. The section then provides a description of decision tree analysis, which has been widely used by a number of other industry sectors. Decision trees are powerful because they allow for an adaptive process, and they are able to encapsulate complex choices and consequences in a readily understandable form. At the same time, decision trees build on the traditional net present value (NPV) approach, which eases their implementation.

The section then discusses how decision tree analysis can be extended to a real options analysis where the value of uncertainty is understood. It examines what decisions can be taken to reduce potential downside risk and maximise exposure to upside risks. It concludes by demonstrating the application of real options analysis using a range of typical farming applications.

Buying a wether

Using an NPV analysis allows the farm manager to understand, for example, how much a wether is worth. The value of the wether is established by this process for a farmer who owns the animal or someone who is considering buying it. As with any asset, the wether's value is determined by the future revenue it can generate, less the costs associated with producing that revenue. In the case of a wether the cash flows are reasonably simple and are made up of:

- wool sales; plus
- the eventual sale price of the animal at the end of its productive life; less
- animal health costs, fodder, pasture costs, labour and shearing.

The other important variables are the time over which the asset will be held and the discount rate. The discount rate used reflects the cost of capital for the business, and may contain a risk premium. The risk premium simply increases the value that the asset's cash flows must reach to make the investment viable.

A positive NPV means that the cash flows, after adjusting for the cost of capital and risk, are positive and that the investment should be considered. If the NPV result is negative, the investment should not be undertaken. This presents the investor with a stark choice, to invest or not to invest.

NPV calculations can have sensitivity analysis attached to them as well. This means that changes to key variables can be tested against the effect they have on the final result.

Table 8 shows a simple NPV calculation of a fine wool merino wether purchase. The cost of purchasing the wether is the up-front cost that would be incurred (or revenue forgone if the analysis deals with selling wethers). The rest of the spreadsheet contains estimates of the annual cost of maintaining the animal and the revenues earned from the sale of the fleece and eventual sale at maturity.

Table 8 **Merino wether NPV analysis**

		Year		0	1	2	3	4	5
Purchase Price		Landed GST Exclusive		$35.00					
Stocking Rate				13.50	DSE/ha				
DSE Value					1.1	1.1	1.1	1.1	1.1
Expenses									
Vaccination					$0.30	$0.30	$0.30	$0.30	$0.30
Drench	1	$0.40			$0.40	$0.40	$0.40	$0.40	$0.40
	2	$0.40			$0.40	$0.40	$0.40	$0.40	$0.40
Jetting					-	-	-	-	-
Shearing		$3.85			$3.85	$3.85	$3.85	$3.85	$3.85
Crutching		$0.90			$0.82	$0.82	$0.82	$0.82	$0.82
Weed Control	$2.00	ha			$0.18	$0.18	$0.18	$0.18	$0.18
Phosphorus	0.6	kg/hd/year			$1.27	$1.27	$1.27	$1.27	$1.27
	$236.00	tonne/spread							
Total					$7.23	$7.23	$7.23	$7.23	$7.23
Deaths		2%			$7.37	$7.37	$7.37	$7.37	$7.37
Labour									
Labour efficiency		9000 /labour unit							
Wages		$25,000.00							
On costs	22%	$5,500.00							
Vehicle		$5,000.00							
Total		$35,500.00							
Cost DSE		$3.94			$4.34	$4.34	$4.34	$4.34	$4.34
Overhead Expenses		$63.00			$5.13	$5.13	$5.13	$5.13	$5.13
Total Expenses				$35.00	$16.85	$16.85	$16.85	$16.85	$16.85
Income									
Wool	kg	Greasy			3.50	4.70	5.20	5.20	5.20
	Micron				18.00	18.50	19.20	19.20	19.50
	Yield				0.69	0.69	0.69	0.69	0.69
	kg	Clean			2.42	3.24	3.59	3.59	3.59
	cents/kg	Clean			1233.00	1116.00	964.00	964.00	911.00
	Wool income				$29.78	$36.19	$34.59	$34.59	$32.69
	Carcase Value								$15.00
	Total Income				$29.78	$36.19	$34.59	$34.59	$47.69
	Cashflow		-	$35.00	$12.93	$19.35	$17.74	$17.74	$30.84
		WACC							
Per head	NPV	10.00%	$37.34	$35.00	$11.76	$15.99	$13.33	$12.12	$19.15
	IRR	41.39%							

Source: ACIL Tasman

The result of the NPV calculation provides an assessment of the value of the wether given the revenue and cost assumptions. Based on this assessment, the wether would produce an NPV of $37.34, which is a sizeable return on an investment of $35.00, the cost of the wether in year 0. This NPV exceeds the farmer's weighted average cost of capital (WACC) considerably and the wether should be purchased along with as many of his mates that the farmer can obtain.

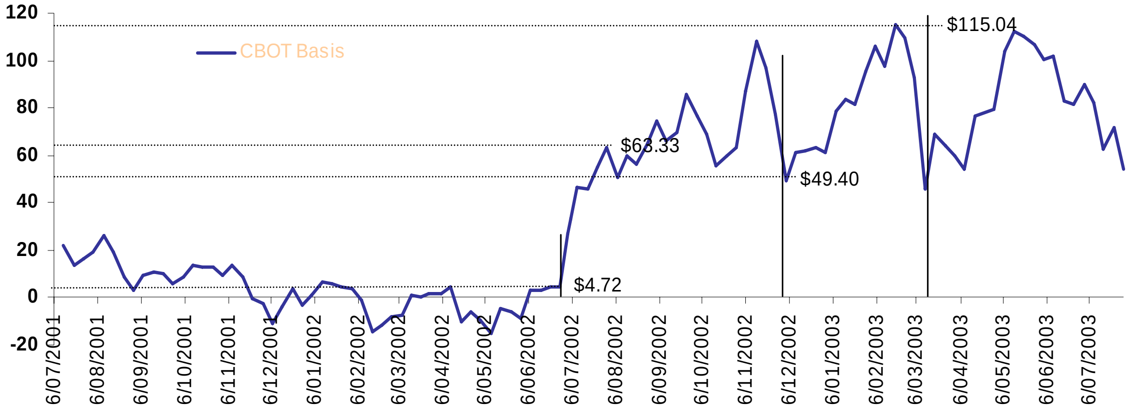
For the farmer who owns the wether, if an offer of $35.00 were made this would dramatically under-value the future earning capacity of the animal and would be likely to be rejected.

However, if offered $72.34, at which point the NPV is zero, the farmer should be indifferent to selling or keeping the wether as the cash flow would equal the sale price.

In this discussion, the main assumption of the NPV calculation used is that the wether is kept for the entire period, i.e. all of the decisions are made up front. The period can be adjusted but would require a recalculation and would not be comparable to NPVs for different periods. Thus the NPV analysis assumes that the farmer does not have the option of selling the wether part way through the analysis. This decision to sell the wether part way through the analysis period may be considered if the price of wethers goes up or costs rise. Cost increases may occur if the seasonal conditions change and the farmer is faced with higher feed and labour costs.

Feed costs

Chart 6 **Australian Prime Wheat 2-Chicago Board of Trade Soft Red Winter Wheat contract (rolling month) basis AUD per tonne**

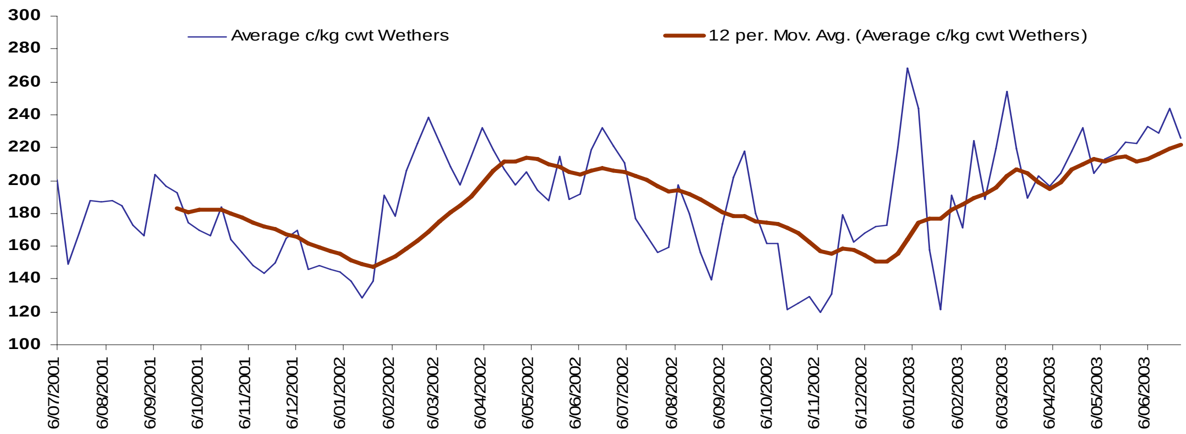


Source: Elders Risk Management and Graincorp

Chart 6 and Chart 7 show the volatility of farm feed costs (as represented by the wheat price) and livestock prices during periods of extreme seasonal variation. Both these charts cover the period between June 2001 and July 2003, a time of below average rainfall across most of southern Australia.

In November 2002, wheat prices in Australia were $100 per tonne more than the world price and wethers had fallen to well below half their value at the beginning of the year. The effect of increased costs and depressed livestock prices has a dramatic affect on the profitability of owning an animal.

Chart 7 **Average cents/kg Dubbo wethers**



Source: ACIL Tasman

Data source: National Livestock Reporting Service

What decisions?

A standard NPV calculation does not include the capacity of the farmer to change his strategy in response to changes in prices or costs. Omitting this variability from its calculation in effect assumes that the farmer does not have the flexibility to adapt to changing circumstances.

Sensitivity analysis can be included to mirror changes in costs, the price of wool and other cash items. This provides useful information and can, when each variable is weighted for the probability of an event occurring, show the most likely outcome. But even the inclusion of this component in an NPV calculation does not reflect the flexibility a manager has during the course of the investment and does not value this flexibility.

By not replicating the flexibility of farm decision making, NPV calculations create distortions when making decisions; then undervalue projects that can be adapted to changing conditions, which is critical as seasonal conditions deteriorate during a drought.

Some of the options a manager may have when considering purchasing or selling the wether are:

- delay purchase until seasonal conditions are more certain (or forecasts are more reliable i.e. over a shorter period)
- sell the wether part-way through the anticipated investment horizon
- buy some of the wethers now (if multiple purchases are being considered) and the rest at a later date (or sell some now and the rest later).

These are all intuitive strategies the farmer considers when deciding whether to buy or sell livestock, but are not a feature of NPV calculations.

Analysing decisions under uncertainty

Risk and uncertainty

As can be seen from the example in the preceding section, the traditional analytical tools used to evaluate investments and management decisions are limited. They do not reflect the intuitive decision-making processes farmers undertake each day. Complex decisions made where there is considerable uncertainty, are likely to be better analysed using a method that replicates the flexibility farm managers have in deciding on an investment.

Real options

The term "real options" refers to the application of option theory (initially developed for financial markets) to "real investments", which involve uncertainty and flexibility. Options analysis (for both financial and real options) emerged out of the desire for better ways of managing downside risk, while retaining access to upside opportunities, and of providing a sound basis for the valuation of opportunities.

As the name suggests, a real option entails the right to undertake an action – such as to invest in or abandon an investment – but without any obligation to do so. Importantly, real options analysis recognises the reality that managers can, and do, adapt to technological or market changes and that the scope for doing this is important to the value of a project.

Real options existed – and were being valued – long before the term was coined. However, over the past 10-15 years there has been a strong trend towards recasting the basis for assessment of projects, especially projects with substantial up-front risks and uncertainties –common features of almost every significant farm management decision. This has seen the development of a new range of methodologies that have been combined with more traditional tools for risk-based decision support.

Probably more importantly, we are seeing a fundamental shift in the approach taken to planning for investments with high levels of uncertainty – with modelling and management of risk being made central to the investment model, rather than peripherally included in sensitivity analyses. This is particularly so if climate variability increases with the rate of climate change.

Real options methods will often lead to higher project valuations than traditional deterministic approaches such as NPV, because they recognise that risks can be managed to avoid bad outcomes or to take advantage of good outcomes, for example by expanding, abandoning or delaying a project. In other words, the option analysis values the strategic options – the flexibility – available to a firm that will influence its value to shareholders.

Also important is the ability of real options analysis to enable the overall value of the project to be increased. Identifying irreversible costs can enable management to design the project in ways that maximise the benefits of flexibility, and that improve the information available, before needing to decide on a commitment to those large irreversible costs.

The distortions that result from traditional deterministic NPV valuation methods tend to be most acute when uncertainties are greatest and when there is greatest scope for adaptive decision-making – common characteristics of decisions made during the onset of drought.

While there are a number of sophistications that can be applied to real options methodology, such as Black-Scholes valuations (see for example Amram and Kulatilaka, 2000) and Monte Carlo simulations, many of the benefits of real options analysis can often be derived, relatively simply, through the intelligent application of decision tree tools. In other cases, especially where key contributors to risks involve almost continuous change in key variables – such as market values of wethers, the price of wool or seasonal conditions – real options analysis offers an expanded set of tools well suited to the planning and valuation task.

Modern real options theory, as applied to most investments, should be viewed as a powerful combination of both a set of valuation tools and a way of looking at investments. It is a way to maximise value derived over time, and to manage risk sensibly and in a way that builds value, despite high levels of uncertainty.

Simple example of real options approach

Table 9 provides a simple numerical example that illustrates some key aspects of real options analysis. It considers the simple investment of purchasing, or continuing to own, a fine wool wether, which costs $35 to undertake. That is the cost of the wether, either to purchase or the sale price forgone if retained.

Uncertainty is introduced into this example by assuming that in period 1 the wool revenue per head might rise to provide revenues of $35 per annum, or equally it might fall to $25 per annum.

Under a traditional NPV calculation, the expected value would be calculated, and discounted along with the costs to determine the expected NPV. At a discount rate of 10%, the NPV is $23.59. This is shown in Part B of the table.

Part C shows the value attached to the option of waiting for one period before investing in the wether, to determine if wool prices rise or fall. If the price rises, the investment will be undertaken in period 1, in which case revenues will be $35 pa and the costs are as before. If prices do not rise the investment will not be undertaken and there is no cost associated with this decision.

If prices do rise the wether would be purchased. This gives an expected NPV of $29.37, so that the option of waiting one period and then undertaking the investment, is worth the difference between the NPV of investing in year one and waiting a year for the prices to rise. In this instance the value of the option is $5.77, which is only of marginal value.

Table 9 **Wether decision with small wool price variation**

	Period		0	1	2	3	4	5	Prob
A	Assumptions								
	Possible revenues								
	High			35	35	35	35	35	0.5
	Low			25	25	25	25	25	0.5
	Costs			17	17	17	17	17	
	Purchase of wether		35						
	Carcase value							15	
	Discount rate		10%						
B	Expected cash flow based on probabilities of revenues								
	Expected revenue			30	30	30	30	45	
	Expected costs		35	17	17	17	17	17	
	Net cash flows		-35	13	13	13	13	28	
	NPV	$ 23.59	-35	11.82	10.74	9.77	8.88	17.39	
C	Cash flow: wait for revenues to go up								
	Expected revenue				35	35	35	50	
	Expected costs				17	17	17	17	
	Net cash flows			-35	18	18	18	33	
	NPV	$ 29.37	0	-31.82	14.88	13.52	12.29	20.49	

Source: ACIL Tasman

In the example cited above, the value of waiting a year until there is more certainty about the wool price is of limited value, as the volatility is relatively small. However, when the volatility of wool prices increases, the value of creating the option of not investing and waiting for a year until wool prices become more certain, rises.

The value of the option to wait a year before buying the wether when the price prospects for wool become more uncertain is shown in Table 10. In this scenario, the value of wool when the investment is being considered is low enough to make the investment produce a negative NPV of $4.84. If the decision to buy the wethers is delayed by a year and wool prices rise, the NPV rises to $14.96. Thus the value of the option to delay a year is the difference between -$4.84 and $14.96, which equals $19.90.

If wool prices do not rise, the farmer does not have to exercise the option and does not buy the wethers.

Indeed, if these were the only uncertainties, then the analysis suggests a value for this option – the maximum ‘option fee’ that it would be worth paying to secure the rights – of about $19.90. The simple calculation provides a basis for valuing this option.

Table 10 **Wether decision with large wool price variation**

	Period		**0**	**1**	**2**	**3**	**4**	**5**	**Prob**
A	Assumptions								
	Possible revenues								
	High			30	30	30	30	30	0.5
	Low			15	15	15	15	15	0.5
	Costs			17	17	17	17	17	
	Purchase of wether		35						
	Carcase value							15	
	Discount rate		10%						
B	Cash flow								
	Expected revenue			22.5	22.5	22.5	22.5	37.5	
	Expected costs		35	17	17	17	17	17	
	Net cash flows		-35	5.5	5.5	5.5	5.5	20.5	
	NPV	-$ 4.84	-35	5.00	4.55	4.13	3.76	12.73	
C	Cashflow: wait for revenues to go up								
	Expected revenue				30	30	30	45	
	Expected costs				17	17	17	17	
	Net cash flows			-35	13	13	13	28	
	NPV	$14.96	0	-31.82	10.74	9.77	8.88	17.39	

Source: ACIL Tasman

This analysis also applies to the farmer who is considering selling the wether. If wool prices do rise the wether may become more valuable.

Note, however, that the decision to wait entails sacrificing the option of accessing the certain year 0 revenues of $11.82 in their own right, with the potential to help defray the capital costs of buying the wether. Recognising this, and the fact that there is a 50 per cent chance that the wether would be purchased, suggests that yet another option might reasonably be considered – that of proceeding to buy the wether in year 0, but retaining the option to then sell the wether in year 1 if the wool price does not increase at the end of this period. If these calculations are worked through, we derive an expected NPV of -$2.52[1].

[1] Assuming the wether is worth $25.00 at the end of year one.

Often the option of discovering additional information is not costless. In the above example, the cost of learning the Year 1 price before committing to the wether was a loss of net production revenues of $11.82. More generally, options theory has been used extensively in the analysis of oil and gas exploration, where there is uncertainty as to the quantity of oil in the field, in addition to the future price. In this case, additional information can be obtained by delaying full development of the field and undertaking exploratory drilling to discover its likely size. The cost of exploratory drilling can be compared to the option value of the additional information in deciding whether to undertake the full investment.

This highlights an important aspect of real options analysis, namely the ability of management to use the insights gained to improve the value of the project. In this very simple example, the source of uncertainty was clear, and the action needed to gain additional information (i.e. wait one period) was also very clear. However, in real-world examples, the source of inflexibility and the means of reducing the impact of irreversible costs are often far from obvious. Therefore options analysis can be used to add value to a project through a clear understanding of the uncertainties involved and the strategic options open to management. It can offer a powerful tool for assessing whether the incremental costs of deeper probing are likely to be cost-justifiable.

Approaches to option analysis

Decision analysis (which includes decision tree analysis) has long been used by engineers in systems design, to examine contingent decisions and the implications of uncertainty for the design and valuation of project options. Far less commonly it has been used by banks and institutional investors weighing-up whether to invest.

A decision tree maps the sequence of decision and chance nodes, which define the project under consideration. The decisions emanating from a decision node represent the options available to the decision maker. The chance nodes identify where an external event will influence the project, and assign probabilities to each outcome. These outcomes need to be specified as discrete possibilities – unlike other real options tools – even if this means approximating a continuous outcome. For example, a price outcome might be approximated by two or more 'representative' prices, each with a specified probability.

Decision analysis corrects some of the inadequacies of NPV calculations because it recognises that only with the resolution of uncertainty will the most appropriate decision be revealed. It does not pre-commit to a decision in the first time period, and instead identifies an array of options.

One of the disadvantages of the decision tree approach is that it can become cumbersome, with "bushy trees", because it is necessary to set out all of the possible scenarios. However, modern software packages, such as Data 3.5 from Treeage Software, facilitate the construction of decision trees through their replication facility (called 'cloning'). Such packages also allow the incorporation of Monte-Carlo simulation to calculate expected payoffs. Simulation addresses the problem of the "flaw-of-averages"[2]. It also enables the likely bounds of outcomes to be tested – for example to test the sensitivity of the conclusions to changes in the discount rate or changes in the probability of factors beyond control of the firm.

Decision tree analysis:

- structures the problem in a way that is intuitively understandable
- is able to deal with multiple sources of uncertainty
- defines optimal choices based on the consideration of the probabilities and outcomes of each choice
- identifies an 'optimal' strategy over many periods of time.

The discipline of identifying the different states of the world and the decision points, is itself valuable in developing management's understanding of the project. In attempting to identify flexibilities and constraints, managers often identify new options and strategies. Indeed, the identification of operational strategies is a particular advantage of decision tree analysis. This can be a strength in dealing with volatility where causes are not well understood, and a weaknesses in slurring over sources of uncertainty that might prompt better design of options and other risk management strategies.

Figures 1, 2 and 3 show the structure of a decision tree for the simple wether investment example discussed earlier. In the diagram, squares denote decision points and the circle denotes a chance point. The project involves an initial decision about whether to purchase a fine wool merino wether, which costs $35.00, and a series of subsequent decisions to keep the animal or sell it. Before making the second and subsequent decisions, managers are able to observe the initial outcomes, and determine whether these are favourable.

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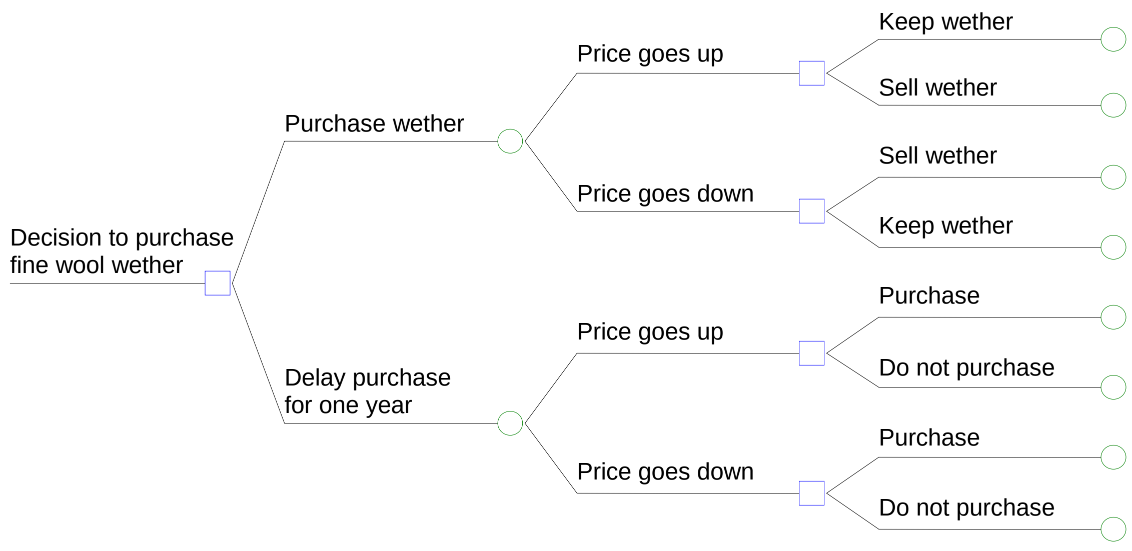
[2] The so-called "flaw of averages" dictates that a function of expected inputs will only equal expected output if there is a linear relationship between all variable inputs and output. Thus in general $\varepsilon[f(x)] \neq f(\varepsilon[x])$. This means that where there are variable inputs, a proper assessment of a project's NPV will often require a Monte-Carlo or similar simulation to derive the expected NPV (instead of using the expected values of each input). This expected NPV can then be compared with the value of the project after allowing for flexibility, to derive the value of the option. See Dixit and Pindyk (1994).

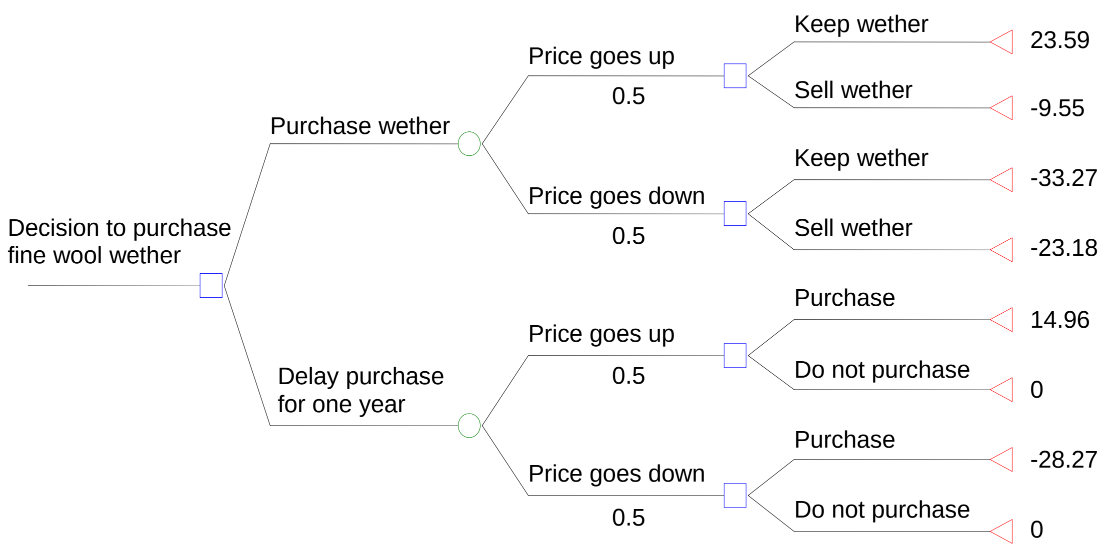
Figure 1 **Decision tree structure**



Source: ACIL Tasman

Once the tree has been laid out, decision analysis solves the decision tree from right to left, in principle working down each branch, to find the best possible decision at each point. One decision rule commonly used is to select the decision that offers the best average value, where average is a weighted average of the present values by their probabilities[3].

Figure 2 **Decision tree structure with values**

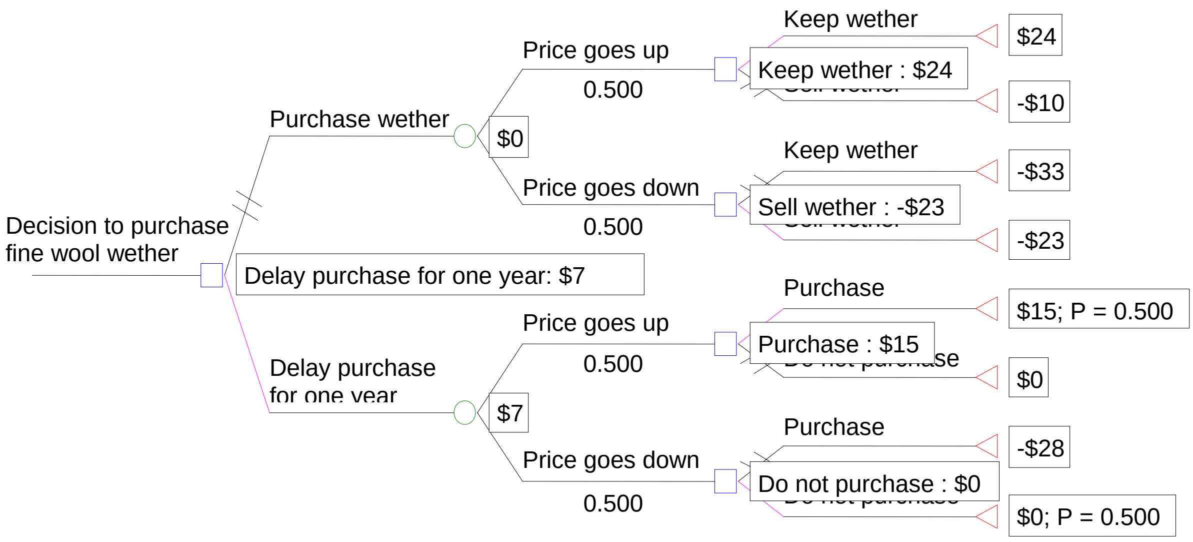


Source: ACIL Tasman

[3] Another rule used is to take account of the risk attitudes of the user/farmer, and build a risk-adjusted objective function.

Once the decision tree has been constructed the value for each of the options can be defined. Simple NPV spread sheet analysis can be used here to determine each of the expected values.

Figure 3 **Decision tree structure with roll back**



Source: ACIL Tasman

Once the decision tree has been constructed and the values inserted, the weighted options can be calculated automatically by the software. The result provides an optimum decision, based on the probabilities inserted at the initial decision point. Although it is designed to provide information in year one, critical decision points can be identified by this method and monitored as the project evolves.

Several authors have argued that although the decision-tree approach is a first step in managing strategic investments, care is needed because it does not provide valuations that are consistent with valuation in financial markets. In particular, standard decision analysis does not recognise that risk, and hence the appropriate discount rate will vary throughout the life of the project.

One possible approach is to incorporate a changing discount rate into the decision tree. This is likely to be most appropriate where there are distinct phases in the project, with very different risk profiles. One such example is a project involving exploration for oil, followed by production if the field is successfully developed. The exploration task is subject to very high specific risks, suggesting that a high discount rate is appropriate for the initial stages of the decision tree. However, once exploration has been undertaken and development of the field begun, the risks are much lower. Accordingly, the discount rate used within the decision tree should be lower for this stage of the project.

More recently, other approaches for dealing with varying risks have been proposed. However, as these rely on the insight provided by Black and Scholes, these further developments of decision tree analysis are considered after an examination of the Black-Scholes approach below.

Insights from real options analysis

Real options analysis is valuable when**:**

- there is a contingent valuation decision
- there is sufficient uncertainty that it may be sensible to wait for more information – or to invest in gathering information before making a commitment.
- value flows from the possibility of future growth options rather than just current cash flow
- uncertainty is great enough to make flexibility worthwhile
- there will be project updates and mid-course corrections.

Many different types of application have been examined by option theory. Some of these are outlined below.

The option to delay

The option to delay a project may confer a positive value on a project with a negative NPV based on current expected cash flows – as was illustrated earlier. Similarly, a project with a positive NPV may not be undertaken immediately, because the option of delaying the project may further increase its value. In particular, the possibility of a downturn, and the ability to avoid an action that could prove to be a mistake, is what makes waiting valuable. The option to delay is most likely to be valuable when the firm has the rights to a project for a long time (for example, control over a natural resource), and the variance of project cash flows is high.

It may also be appropriate to shut-down temporarily – to delay the project even after it has entered production – if revenues fail to cover variable costs. If there is a fixed cost associated with shutting down and/or re-starting (as is the case in many production lines), the firm will consider the value of temporarily stopping, with the option of subsequently re-starting, as against the option of continuing to operate at a loss, given the possibility of revenue subsequently improving.

Growth options

Traditional valuation tools undervalue investments that contain options to expand into new markets or products at later stages, based upon favourable outcomes in the initial stages. If the initial project is a pre-requisite for subsequent expansion, its valuation should take account of the option to expand. Where future projects have the possibility of high NPVs, a firm may accept a negative NPV for the initial investment because of its option value. An extreme, but common, example of this is a feasibility study – which almost always has a negative NPV if assessed out of context.

Similarly a firm may build initial production capacity in excess of the currently expected level of output, to provide the option of increasing production later if conditions are favourable.

Investment platforms

Platform investments create valuable follow-on contingent investment opportunities. For example, an R&D project may lead to further marketable products. Similarly a product patent provides a firm with the right to develop a product and market it – while investment in a marketing chain for the product may have option value as a platform for marketing a wider product range in the future. Traditional tools can greatly under-value these options.

Flexibility investments or switching options

Flexibility investments build options into the design of the project. For example, manufacturing equipment could be switched across products, or plant switched between input fuels. The value of the additional flexibility is traded off against the higher initial cost of the project, and sometimes higher operating costs.

Modular investments

Modular investments create value through product design. A modular design allows modules to be changed and up-graded independently so they preserve flexibility, by allowing the design of a component to be changed later or by lowering the costs of exercising flexibility. The value of this flexibility is traded-off against the up-front cost of developing and delivering a modular design.

Learning investments

Learning investments are made to obtain information that is otherwise unavailable. The learning effort is designed to create the highest-valued information in the shortest amount of time (or to maximise the net value of the investment, taking into account the opportunity cost of time). As indicated above, oil exploration is an example of a learning investment as it provides geological information on the likely size of the reserves. The value of this information is then determined by the outcome on all sources of uncertainty – thus the option value of the reserves will depend on the expected oil price and its volatility.

The option to abandon

As the simple example above showed, the option to abandon enables a firm to contain its downside risk. The option to abandon has value because firms can scale back or terminate projects if they do not measure up to expectations.

Shadow costs

Standard valuation techniques may overvalue some projects because they fail to recognise the loss in flexibility that results if acceptance of one project eliminates options attaching to other projects. For example, building a plant in one city may eliminate the option to expand the capacity of plants in nearby cities.

Real options applications

In this section several illustrative applications of real options analysis are set out. The case studies chosen are put forward as demonstrating the application of the technique. In each case, the value of the analytical approach becomes clear, as well as the value of flexibility to the enterprises and situations being analysed.

In Table 11 a number of key decisions for a range of agricultural enterprises are cited. The forecast lead times are then nominated for each of the key decisions by these enterprises.

Table 11 **Summary of forecast requirements for several agricultural regions and industries, based on a survey and workshop involving farmers, agribusiness, agricultural researchers and agricultural extension officers**

Agricultural enterprise	Key decision	Forecast lead time	Forecast period
Northern Australian rangelands (beef, summer-dominant rain)	Stocking rate decisions in May (1st round muster) and September (2nd round muster) on pasture growth in the following wet season Nov.-Mar.	May: 6 months Sept.: 2 months	5 months
Southern Australian rangelands (sheep/wool, winter-dominant rain)	Stocking rate decisions in April/May about pasture growth in following winter June-Aug and following summer Dec.-Mar.	For winter: 1 month For summer: 8 months	3 months 4 months
Winter-dominant rainfall (wheat/pulses/canola)	Decisions on varieties to plant, fertiliser inputs and planting density in April for the length of the crop season. Decisions on inputs in the middle of the crop-growing period (June/July)	1 month	4-6 months 3 months
Summer-dominant rainfall (wheat, sorghum, cotton)	Decision to plant in imminent season (April for winter crop and Oct for summer crop) or deferral of planting to subsequent season, plus choice of crop and variety and adjustment of inputs on rainfall and temperatures	April: 1 month Oct.: 1 month	4-6 months 4-6 months
Sugar production in irrigation areas in NE Australia	Decisions about whether to use irrigation water supplies in Sept.-Dec. based on expected rainfall occurrence in following summer Jan.-Mar.	Oct.: 3 months	3 months
Sugar mill planning in rain-fed tropical sugar systems	Mill planning decisions in Nov.-Dec. about harvest period conditions (mainly wetness) in the following Jun-Dec., especially late in the harvest in Nov.-Dec.	Nov.: 7 months	6 months
Agribusiness in cereal-growing regions	Grain storage, transport and fertiliser supply decisions in Nov for next year's winter grain production	Nov.: 6 months	4-6 months

Note: In the context of this table, forecast lead time refers to the period between the date on which the forecast is made (or desired decision date on which a forecast would be useful) and the start of the period being forecast. The forecast period is the actual period over which the forecast runs.

Source: Ash et al,, 2007

Applications of real options

The following section is a case study on how real options can be applied. It shows how real options can be applied to every day tactical decisions made by farm managers and their advisors. The example is based on an interview conducted with a northern NSW crop manager. All of the figures are illustrative only but care has been taken to ensure they represent likely gross margins and outcomes.

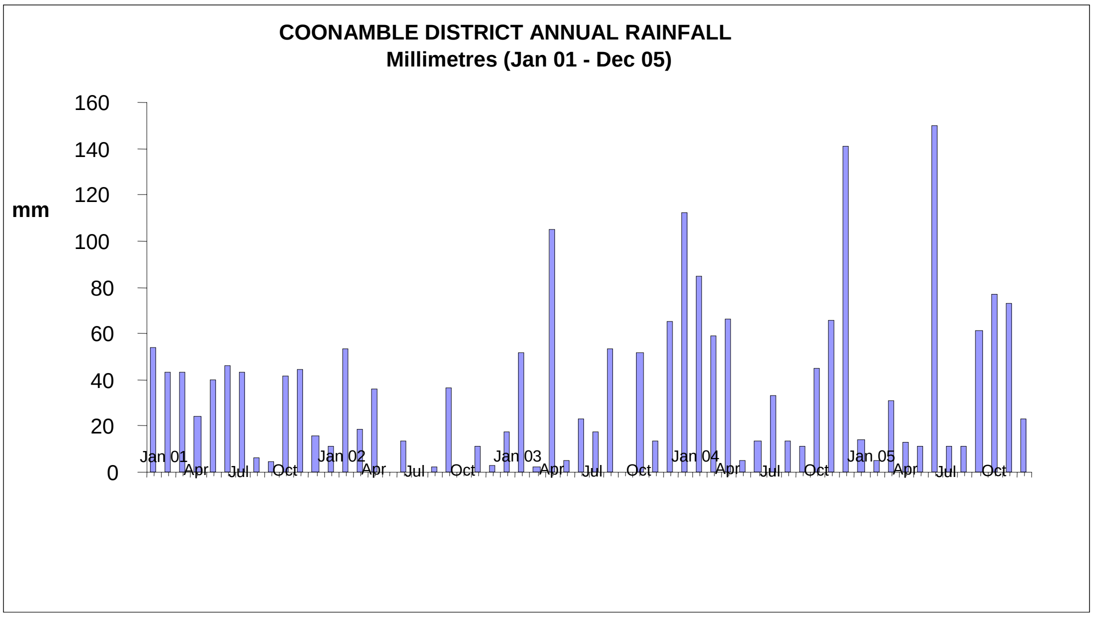
Case study

The business that this case study is broadly based on is predominately a winter dry-land cropping enterprise of over 10,884 hectares west of Coonamble. The property produces wheat (predominantly prime hard), and chickpeas/canola/barley when the season permits. There are no livestock run on the property and no irrigation licences.

Rainfall is expected in storms during the summer months. There is usually little run-off due to the flat nature of the country and the furrows created by machinery in cropping, hence the rain that falls is stored in the fallow country in the soil. There is short fallow (ST) and long fallow (LF) country. SF paddocks have had a crop during the previous winter, whereas LF paddocks would have been bare of vegetation from the previous winter. LF paddocks have the potential to produce greater crop yields, due to the reduced disease status and the greater amount of water stored in the soil.

Summary statistics for the property

Chart 8 **Coonamble district annual rainfall Jan 01 – Dec 05**



Source: ACIL Tasman

Table 12 **Summary crop statistics for case study property 2001-05**

Year		Wheat	Canola	Chickpeas	Barley	Fallow	Total Area
2001	Area (Ha)	6,085	267	1,963	1,138	1,431	10,884
	Tonnes	15,897	369	2,671	2,470		
	Yield/Ha	2.61	1.38	1.36	2.17		
2002	Area (Ha)	324		202		10,358	10,884
	Tonnes	144		77			
	Yield/Ha	0.44		0.38			
2003	Area (Ha)	1,255	238		162	9,229	10,884
	Tonnes	2,053	325		313		
	Yield/Ha	1.64	1.37		1.93		
2004	Area (Ha)	6,299	1,769	1,255	1,287	273	10,884
	Tonnes	19,239	2,180	1,652	4,830		
	Yield/Ha	3.05	1.23	1.32	3.75		
2005	Area (Ha)	1,780			560	8,544	10,884
	Tonnes	4,676			1,657		
	Yield/Ha	2.63			2.96		
AVE.	Area (Ha)	3,149	569	1,140	787	5,239	10,884
01-05	Tonnes	9,136	1,066	1,278	2,318		
	Yield/Ha	2.34	1.26	1.12	2.95		

Source: Personal communications with property owner

2002 Cropping Year

At the beginning of summer in 2001-02 the expected rains failed to eventuate.

During the 2001 cropping year the property had produced above average wheat, canola, chickpeas and barley crops from a large proportion of the arable area (86%), dictating a small area of LF country coming into 2002. Despite applying herbicide to weeds that germinated from showers over the summer, little water was retained in the soil, partially due to the incidence of rain and summer heat.

Cut-off dates for the optimum sowing window in the Coonamble district are mid-May for canola, end of June for wheat and chickpeas, and the middle of July for barley.

Buoyed by a successful cropping result in 2001, the farmer decided to use moisture seeking equipment to sow canola into the small area of LF country after 40 ml of rain in April. In May, on the expectation of the usual autumn break and the sheer size of the area to be sown with the available machinery, the farmer started sowing wheat and some chickpeas 'dry'. The farmer sowed almost 2,428 ha, incurring all the associated costs of establishing a crop and then waited for further falls of rain. None came and no further crops were sown. Some of the crop that germinated and produced some leaf was baled and sold as fodder to neighbouring properties – the remainder was retained and protected from kangaroos to harvest some seed for the next year.

The 2002 result was a disaster as the crop incurred the expenses, but nothing came of the effort – as the farmer said "*…it would have been better not to have sown the crop at all*".

This case study shows the range of decisions, based on seasonal conditions, soil moisture levels and markets that were made for each crop type and each paddock in 2002. The drought meant that yields were well below expectations and significant costs of sowing were incurred.

Real options could be applied in a number of ways to the cropping management of this property. They could be used to assist in making longer term crop rotation decisions based on: price forecasts; relative risks of growing particular crops taking account of their susceptibility to drought and other environmental stresses and the frequency of their occurrence; and machinery and labour requirements. However, for the purposes of this paper the last statement in the case study is the significant one - where the farmer states that if more information was available on the fortunes of the crop, then he may have reconsidered planting it in the first place. This postulation has all the elements of a real options analysis.

The decision to sow the crop is ultimately based on what the farmer predicts the financial outcome of that decision will be. This is largely based on a forecast by the farmer that the yield of the crop multiplied by the expected price will exceed the costs of growing it. The costs of growing the crop are reasonably well known and are largely incurred up front. The yield and price of the grain grown are not known for 6 to 8 months, depending on the crop.

The use of real options in this situation lies in the capacity of the manager to make changes to the investment once it has commenced, in response to changing circumstances – the greater the flexibility, the greater the value of the option.

An options decision analysis of a cropping program such as this provides not only an analysis of the optimum strategy for the cropping manager, but also:

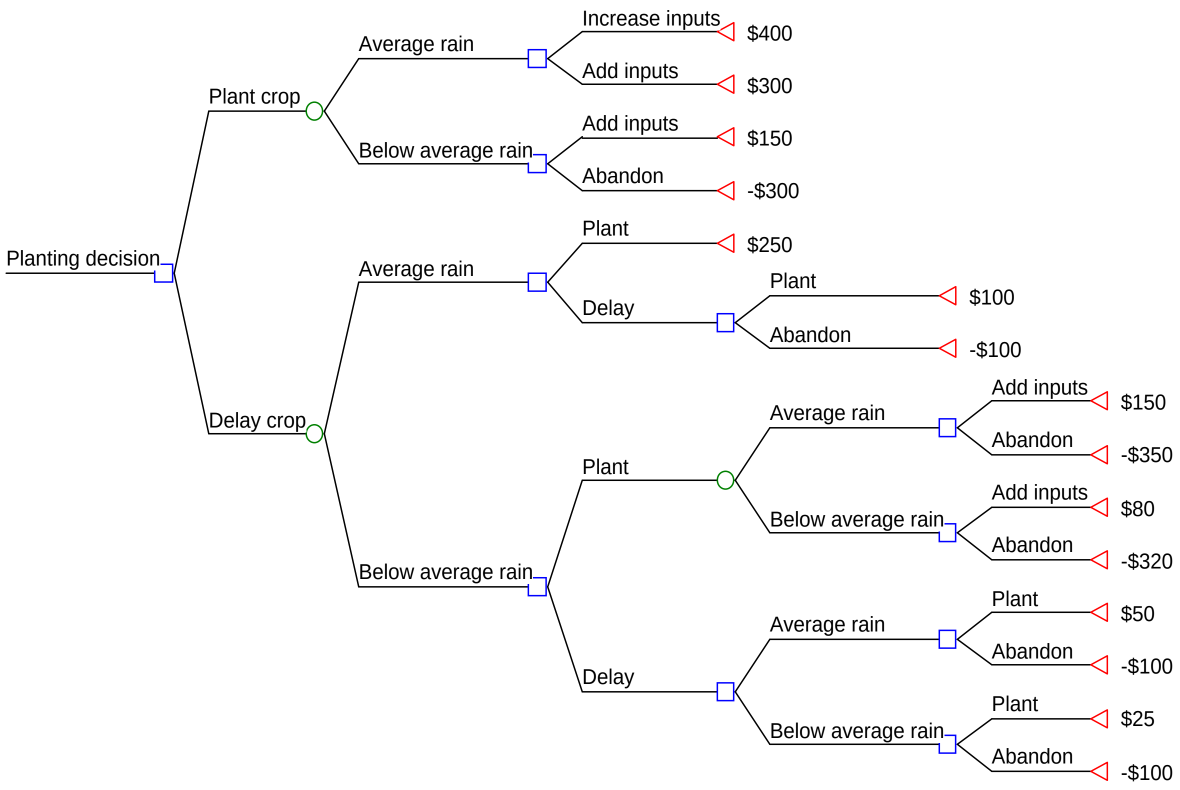
- an indication of where the most critical decision points are
- what flexibility a cropping manager has at the start and during the crop production cycle
- the variables for which the decision is most sensitive
- the value of additional information (e.g. does delaying planting the crop until seasonal conditions become clearer cost more than the potential yield loss from waiting?).

One result of undertaking an options analysis of the farming system would be to identify the volatility of returns for some crops. That would assist in designing a cropping system able to defer planting, push back cost or switch to a different crop type.

In this example rainfall refers to the total seasonal rainfall being average or below average. As the season progresses, the probability of achieving average rainfall, if the earlier months are below average, diminishes.

The crop values are based on the gross margin that the crop would produce given the seasonal conditions for each branch of the tree and the delays before the crop is planted.

Figure 4 **Decision tree structure and values**



Source: ACIL Tasman

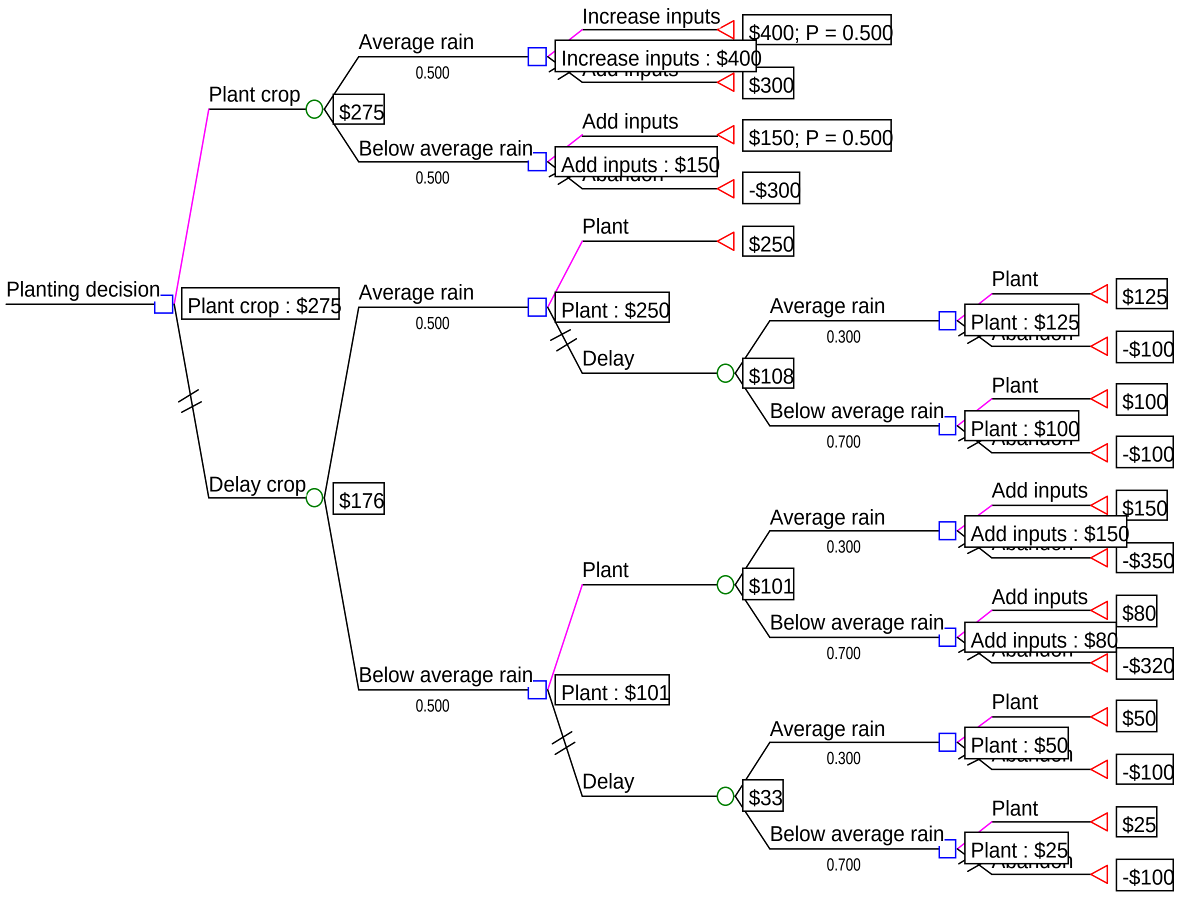
The decision tree in Figure 4 demonstrates how a manager may view the cropping program and set up a decision tree to examine the options for varying the cropping program. The critical decisions are whether to delay planting the crop and at what stage the crop should be abandoned. However, the analysis also provides some insights into the sensitivity of knowledge about the probability of the season being below average.

The result in Figure 5 shows that, if there is an even chance of above, or below, average rainfall, planting the crop on time produces a higher expected return than delaying planting. This is because the expected pay-off from the crop is higher than the yield loss associated with delaying planting if the season turns out to be average or better.

When the seasonal condition probabilities are changed from even to a 65 per cent chance the season will be below average, the weighted payoff from sowing the crop on time decreases from $275 to $238 per ha (see Figure 6). It appears that the crop payoff from being late outweighs the chances of the season being below average and the impact this may have on the crop.

The key sensitivity in this analysis is the yield of a crop that is sown on time, when that crop receives below average rainfall for the season.

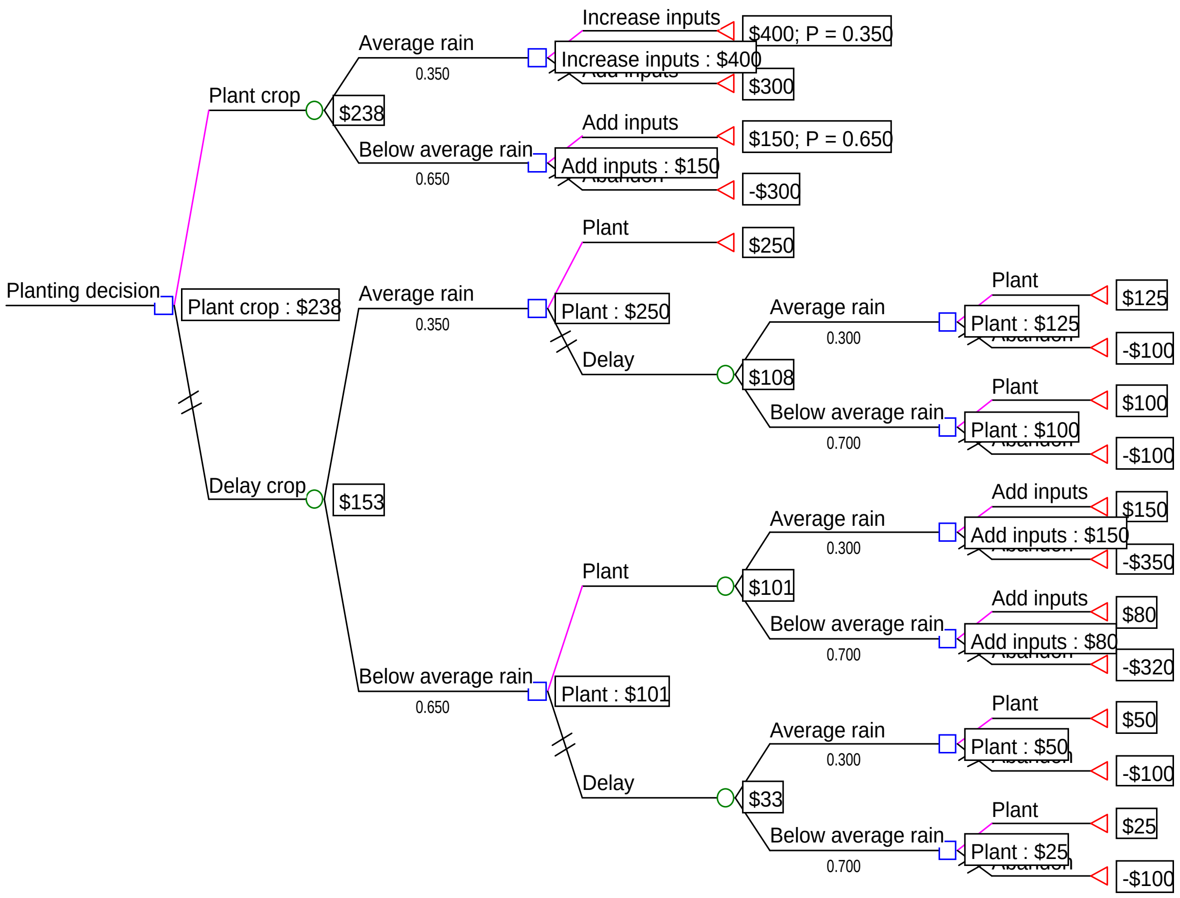
Figure 5 **Decision tree structure with roll back**



Source: ACIL Tasman

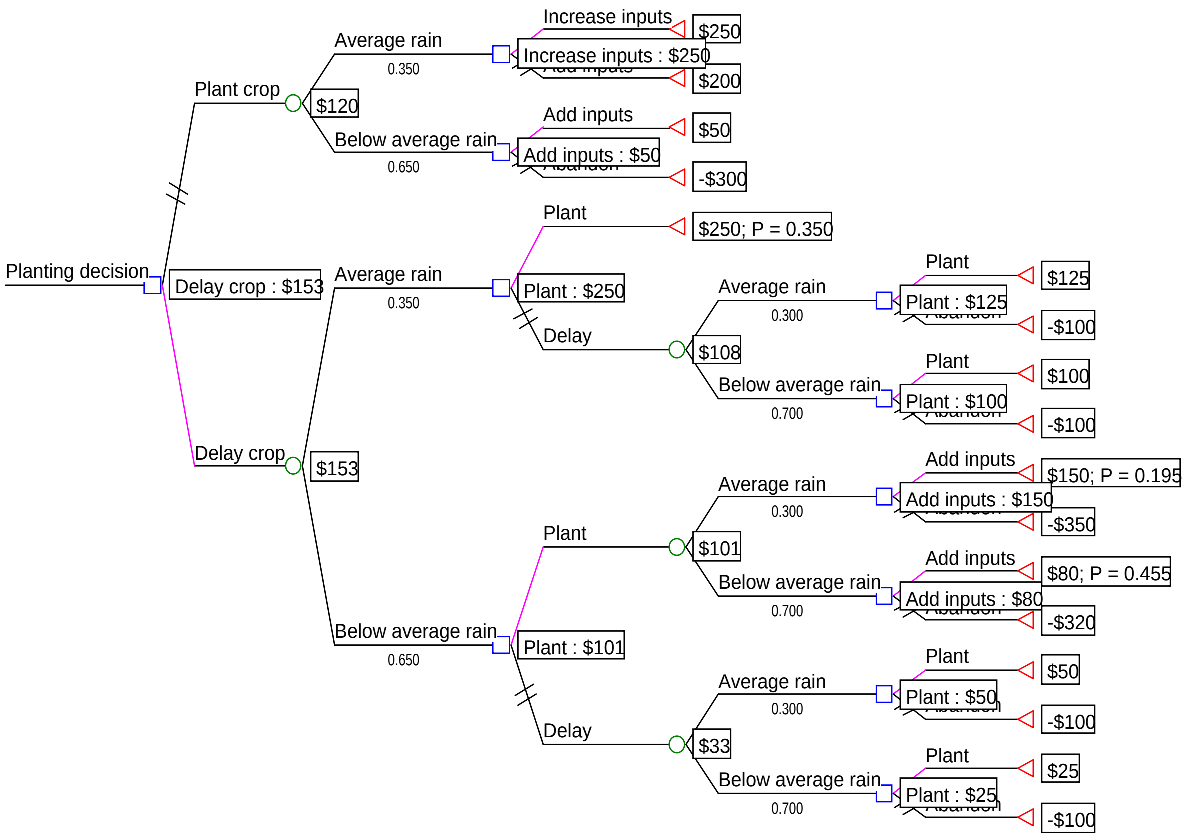
The sensitivity to variations in the crop gross margins can be seen in Figure 7. There, when the payoff from high inputs and average rainfall is reduced from $400 per ha to $250, and where there is a 65 per cent probability of the seasonal rainfall being below average, it is better to wait for seasonal conditions to be more certain before planting the crop.

Figure 6 **Decision tree structure with roll back and low probability of average rainfall**



Source: ACIL Tasman

Figure 7 **Decision tree structure with roll back and low gross margins for early sowing and average rainfall**



Source: ACIL Tasman

The following years are summarised by the farmer. Each time it can be seen how real options analysis would have been able to inform the manager of key sensitivities for the decisions faced, and how investments could be structured to limit the downside and increase the potential for higher returns.

In each instance, the intuitive thinking of the farmer demonstrates how options are incorporated into virtually all of the decisions made, without being formalised. One example is waiting for rain in 2003 after the long fallow paddocks had been sown, before planting the rest of the crop. Another example was the diversification of enterprises, including letting some of the country out for agistment, on a newly acquired parcel of land. Finally, in 2005, the late sowing of wheat incorporated assumptions on wheat market prospects, seasonal forecasts, late sowing yield penalties and other crop prospects. NPV calculations alone, had they been used, would not have been able to assist the farmer to make these decisions.

Simplifying decision trees

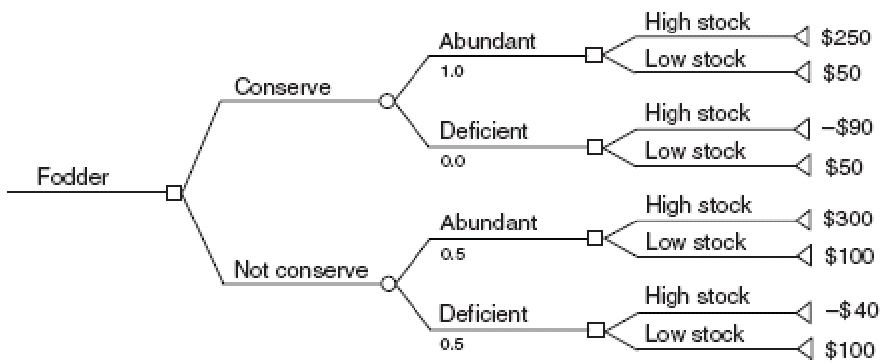
In a similar way to the key decision in the second row of Table 11, Hertzler (2007) demonstrates how a grazier may adapt to climate change by conserving fodder and altering stocking rates (see Figure 3, p.31).

Hertzler's example connects a grazier's decision to the probability of a climate event occurring. The first decision (on the left of the tree denoted by a square) is whether or not to conserve fodder. The decision is then subject to two possible climate events creating an abundance of pasture growth (a change event denoted by a circle). This means that there are now four possible outcomes (two outcomes of the decision x two climate outcomes).

If fodder is conserved, the probability of abundant fodder is 1.0 and the probability of deficient fodder is 0.0. If fodder is not conserved, the probabilities are both 0.5. Each of the four outcomes (fodder decisions x climate events) has a high and low stocking rate decision option for the farmer. There are now eight possible outcomes.

Each of the eight possible outcomes has a financial outcome for the farmer (called a terminal value and denoted by a triangle). When each of the outcomes is weighted for the probability of it occurring, the expected value of each decision can be calculated. For example, the expected net returns of conserving fodder are 250×1.0+50×0.0=$250. The expected net returns of not conserving fodder are 300×0.5+100×0.5=$200. In this example, it is optimal to conserve fodder.

Chart 9 **Decision tree for fodder and stocking rate decisions**



Source: Hertzler, 2007

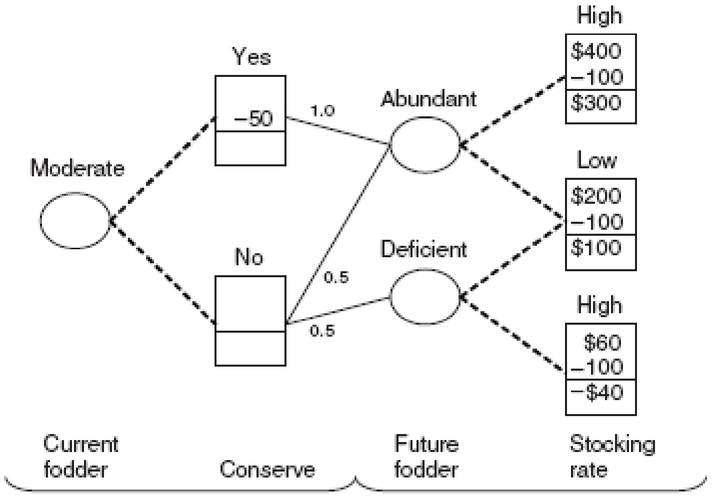
As events are mutually exclusive, decision trees tend to get big and bushy as can be seen in the previous cropping example. To calculate the result the whole tree must be evaluated.

To simplify decision tree diagrams Hertzler (2006) suggests a modular reconfiguration of the decision tree.

States of nature, however, are not mutually exclusive. Decisions usually just shift the odds of ending up in a desirable or an undesirable state. Once in a particular state, decisions may depend only upon that state and not on the history of the system. This is Bellman’s Principle of Optimality (Smith, 1991), which allows decision diagrams to be created in modules and linked together for complex systems. To simplify the decision tree analysis Hertzler proposes the decision diagram in Figure 4 (p.37), which connects a grazier’s decisions to states of nature.

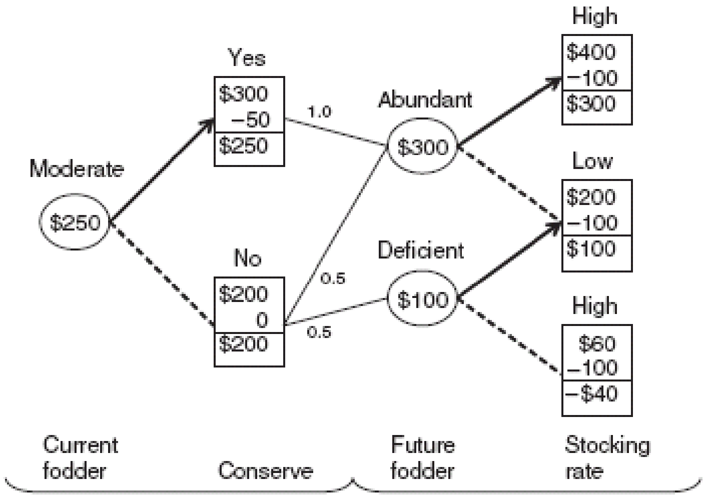
In these diagrams the states of nature (in this case abundance or deficit of future fodder) common to particular decisions are collapsed to reduce the complexity of the decision tree.

Chart 10 **Initial decision tree diagram for grazing decisions**



Source: Hertzler, 2007

Chart 11 **Final decision tree diagram for grazing decisions**



Source: Hertzler, 2007

Conclusion

The prospects are for Australia's climate to become hotter, dryer and more volatile. Even if the climate change projections turn out to be incorrect, there is benefit to Australian agriculture in adapting to greater climatic variability. The measures adopted will improve productivity and reduce risk in any case. Those measures include:

- improving weather forecasting, especially forecasting within seasons
- developing insurance products and climate hedging markets
- spreading risk by diversifying enterprises, location across areas of different climate, ownership across several investors or a greater number of stakeholders
- improving agronomic practices to increase ground cover, carbon and water retention in the soil
- changing enterprises
- increasing targeted investment in plant breeding, to produce drought tolerant crop and pasture species
- adopting farm management decision-making techniques to analyse real options in response to changing conditions throughout the season.

The incentive to adopt these measures depends on an array of factors, such as experience with past climatic variability, confidence in weather forecasts, financial security, projected enterprise profitability, enterprise mix, location, access to capital, access to – and acceptance of – new technology, attitude to risk, expectation of government intervention to reduce or share the risk, off-farm opportunities (commercial and social), and level of education and training.

Managers must be encouraged to be flexible and must not be inhibited by perceptions that government policy will protect them from climatic or market volatility. Then they can take advantage of the current and emerging opportunities to adapt to changing climatic conditions as those conditions arise. Since each manager will have a different perception of risk, it is up to the individual to decide how to adapt in order to lower the risk of unexpected changes in the climate.

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Managing the Risks of Climate Variability in Australian Agriculture

– Decision-making in agriculture under conditions of uncertainty –

RIRDC Publication No. 09/014

Agriculture in Australia has always had to deal with an uncertain and volatile climate. Droughts and flooding rains have entered into folklore.

This report summarises some contemporary management and market based approaches to the management of climate variability in Australian agriculture. The report also describes how the role of an adaptive management methodology, known as real options, can play in agriculture when faced with considerable uncertainty.

There are a number of approaches that farm business managers have, or will have, to better manage the uncertainties of climate change, particularly if climate variability increases as a result of climate change. Enterprises and businesses able to adapt to increased climate variability will be at an advantage to those that do not.

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