Investment Analyses for
the Managing Climate Variability Program

**Final Report to
Land and Water Australia**

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by

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Executive Summary

The Managing Climate Variability Program (MCVP) managed by Land and Water Australia (LWA) is scheduled to be completed by June 2007. In accord with LWA policy, the impact of the program required assessment and the impacts subjected to a cost benefit analysis (CBA). At the same time, prospective analyses were required to demonstrate potential benefits from new investment in a second phase of MCVP that would commence later in 2007.

Four impact analyses were carried out, all including a cost benefit analysis. The first two were analyses of historical investments. The second two were prospective investments that could be considered for future investment by MCVP. The four analyses were:
1. Investment Performance of the Managing Climate Variability Program
2. Example of Analysis of a Natural Resource Management Impact
3. Prospective Analysis of Increased Forecast Skill
4. Prospective Analysis of Further Investment in Yield Prophet

Assumptions for valuing benefits were made in a consistently conservative manner in all four analyses. Sensitivity analyses were conducted for those variables that were thought to be uncertain or key drivers of the investment criteria. Ratings were given to the confidence in each analysis. The ratings included one for the coverage of benefits and a second for the degree of certainty in the assumptions.

The investment criteria estimated from each analysis are shown in Table 1.

Table 1: Summary of Investment Criteria from the Four Analyses
(Discount rate 6%; results refer to the investment by MCVP only)

Analysis	**Net Present Value of MCVP investment ($ million)**	**Benefit-Cost Ratio**	**Internal Rate of Return (%)**
MCVP – historical	5.59	1.7 to 1	10.6
Example of MCVP NRM project -historical	4.76	25.0 to 1	9.3
Prospective investment in skill improvement	42.70	25.6 to 1	31.9
Prospective investment in Yield Prophet	18.42	39.8 to 1	No solution

The two analyses of past investment in MCVP have produced positive investment criteria. However, the investment criteria for MCVP were not as high as those for CVAP (the previous climate variability program) or for CVAP and MCVP combined. This is possibly because of declining marginal returns where there is a fixed constraint to improvement (skill level of the forecasts). While adoption has increased with MCVP, the increase was less than that previously assumed for CVAP.

The investment in the program was appropriate, given the former success of investments in climate variability research by LWA and its partners. The past investment is also considered to have been effective as more farmers are now taking seasonal climate forecasting into account in their farm decision making.

The NRM example explores some public benefits from the investment in one project in the Western Division of NSW. However, the potential environmental benefit from this investment has not been included in the overall program analysis for MCVP due to the difficulty of making credible assumptions concerning the impact on the environment from the decision support system produced by the program.

The two prospective analyses have strengthened the case for investment in both enhancing forecast skill and in a major management application currently being supported by the MCVP for cropping farmers.

Several other areas for prospective investment are also identified including:
1. Catchment and regional studies of the use of seasonal climate forecasting
2. Management of water storages and environmental flow management
3. Accelerating the development of models to reduce perceived and actual impacts of climate change on current seasonal climate forecasts
4. National leadership on understanding climate risk management
5. Positioning multiple production locations in the face of climate change and increasing variability

Glossary of Economic Terms

Benefit-cost ratio (B/C Ratio) - The ratio of the present value of investment benefits to the present value of investment costs.

Discounting - The process of relating the costs and benefits of an investment to a base year using a stated discount rate.

Internal Rate of Return (IRR) - The discount rate at which an investment has a net present value of zero, i.e. where present value of benefits = present value of costs.

Investment criteria - Measures of the economic worth of an investment such as Net Present Value, Benefit-Cost Ratio, and Internal Rate of Return.

Net Present Value (NPV) - The discounted value of the benefits of an investment less the discounted value of the costs, i.e. present value of benefits - present value of costs.

Present Value of Benefits (PVB) - The discounted value of benefits.

Present Value of Costs (PVC) - The discounted value of costs.

1. Introduction

1.1 Background

Rural Research & Development Corporations (RDCs) are increasingly required to provide evidence of the impact of the research that is funded using both industry and government contributions. As part of its portfolio of investment, Land and Water Australia (LWA) supports programs in an industry arena where, in conjunction with industry RDCs, it addresses generic issues of interest to one or more industry sectors.

The Managing Climate Variability Program (MCVP) managed by Land and Water Australia (LWA) is scheduled to be completed by June 2007. In accord with LWA policy, the impact of the program required assessment and the impacts subjected to a cost benefit analysis (CBA). As the program is about to enter a new phase, the evaluation also identifies some issues for the future and includes several prospective analyses on potential areas for future investment that may commence later in 2007.

1.2 Objectives

Terms of reference for the evaluation were:

1. Provide a case study analysis based on an economic evaluation of the Managing Climate Variability Program (MCVP). This can be achieved either in combination with the CVAP evaluation or separately to it.
2. Provide some additional commentary and conclusions regarding the appropriateness and effectiveness of the investment in MCVP as well as identify constraints and gaps that have emerged from the evaluation.
3. From the evaluation process, identify areas where potential future investments could be effectively made in future.
4. Where possible conduct prospective benefit-cost analyses on potential areas for investment along the lines of "if this were achieved from future investment in MCVP, of what order would be the return on such future investment?"

1.3 Structure of Report

Section 2 of the report provides a brief description of the methods used in undertaking the cost-benefit analyses (CBAs) that are both historical and prospective in nature. Section 3 summarises the findings from the evaluation and Section 4 provides a brief commentary on the results. Section 5 presents the conclusions. Detailed descriptions of the individual CBAs for the set of investments analysed are presented in Appendices 1 to 4.

2. Methods

Four analyses were carried out, all including a cost benefit analysis. These were:

1. Investment Performance of the Managing Climate Variability Program
2. Example of a Natural Resource Management Impact
3. Prospective Analysis of Increased Forecast Skill
4. Prospective Analysis of Further Investment in Yield Prophet

The CBA for the investment in MCVP (Number 1) involved a description of the investment, including the titles of each of the projects funded, together with the financial investment in each of the projects by MCVP and others (including values of in-kind contributions from researchers). The outputs and outcomes from the projects are described, and the impacts and benefits identified. The principal benefits are valued and investment criteria estimated. A similar approach was applied in the example of a natural resource management impact (Number 2).

The methods used are consistent with those used by Agtrans Research for recent evaluations of investments made by other Research and Development Corporations including Land & Water Australia, Meat & Livestock Australia and the Sugar Research & Development Corporation.

The two prospective analyses (Numbers 3 and 4) required assumptions concerning the extent of resources that would be invested and the hypothetical impacts that such investments would produce.

The following steps were followed to evaluate each historical or prospective investment:

1. Relevant published papers, reports, and other material were assembled, sometimes with assistance from LWA personnel.
2. An initial description of the background to the investment, description of projects and their costs, outputs, outcomes and benefits was drafted. Additional information needs were identified.
3. Further information was assembled where required from researchers and from industry sources to assist with assumptions when quantifying benefits.
4. Analyses proceeded through several drafts, both internally within the project team, as well as externally.

All investments were analysed as to whether they had produced, or were likely to produce, economic, social or environmental benefits. All benefits identified were described. At least some benefits were then valued quantitatively to enable a CBA to be carried out.

While effort was made to identify environmental and social benefits, few identified benefits were able to be quantified (the exception being the valuation of land degradation avoided in the example in Number 2).

A discount rate of 6% was used in each CBA. For the two historical analyses, all annual dollar costs and benefits were expressed in 2006/07 terms and discounted to the year 2006/07. For the two prospective analyses, dollars were expressed in 2007/08 terms and discounted to the year 2007/08. A forty year time frame was used in all analyses, with the first year being the initial year of R&D investment. R&D financial investments included those for MCVP as well as contributions (dollars and in-kind) from other funding organisations as well as from any participating R&D or industry group.

Attribution of benefits to the MCVP investment was achieved by multiplying the total expected benefit stream by an attribution factor equal to the proportion of resources that MCVP contributed to the total investment that produced the benefits. This attribution factor was based on the total undiscounted costs measured in real terms.

Assumptions for valuing benefits were made in a consistently conservative manner in all four analyses. The investment criteria produced are highly dependent on the assumptions made in each analysis. There are two areas of potential concern with regards to confidence in the analyses. The first is the coverage of benefits. Where there are multiple types of benefits it is often not possible to quantify all the benefits that may be linked to the investment. The second involves the assumptions relating to the difference that the investment has made. Some of these assumptions can be contentious and many made in the analyses are a matter of judgment. To help address the uncertain assumptions, sensitivity analyses were conducted in each CBA, where the investment criteria are recalculated with variations of some of the uncertain assumptions.

A rating has been given to the confidence in the results of each investment analysis. Two confidence ratings are provided. One is for the coverage of benefits and the other for the degree of certainty in the assumptions. The rating categories used are High, Medium and Low, where:

High: denotes a good coverage of benefits or reasonable confidence in the assumptions made

Medium: denotes only a reasonable coverage of benefits and/or some significant uncertainties in assumptions

Low: denotes a poor coverage of benefits or many uncertainties in assumptions

Using these ratings, Table 2.1 presents an estimate of the confidence in the investment criteria for each of the analyses.

Table 2.1: Confidence in Analysis of Each Investment

Investment Analysis	**Coverage of Benefits**	**Confidence in Assumptions**
MCVP – historical	Medium	High
Example of MCVP NRM project - historical	High	Low
Prospective investment in skill improvement	Medium	Medium
Prospective investment in Yield Prophet	High	Medium

3. Summary of Results

Table 3.1 provides a summary of the benefits identified in a triple bottom line format for each of the four analyses.

Table 3.1: Summary of the Economic, Environmental and Social Benefits from Each Investment

Economic	Environmental	Social
MCVP – historical		
Quantified benefits		
Increase in average level of profits for farm businesses		
Non-quantified benefits		
Decreased farm income variability Improved success rate of improved pasture establishment Improved planning for agribusiness (e.g. physical inputs) Improved management of water storages for irrigators More efficient and effective government policies for delivery of drought support Improved management processes for non rural sectors such as electricity generation and emergency services	Improved sustainability of land and pasture resources from cropping and grazing systems more attuned to expected rainfall variability Reduced wind and water erosion and soil export to waterways Improved understanding of the patterns of climate variability to inform natural resource management decisions Improved success rate for tree planting for natural resource management purposes Improved allocation of water to the environment Improved forecasting for bushfires	Reduced stress for land and water managers due to more objective processes in decision making and being able to plan ahead. Greater equity between landholders in drought support decisions Improved personal capacity of land managers to manage climatic variability Improved understanding of the potential impacts of climate change and of possible adaptations
Example of MCVP NRM Project –Historical		
Quantified benefits		
Increased gross margin from early destocking stimulated by Cover Alert	Reduced level of degradation of Western Division grazing lands resulting in less soil erosion, improved	

	biodiversity and improved landscape aesthetics	
Non-quantified benefits		
		Reduced stress and improved understanding and capacity to adapt and cope with impacts of drought, climate change and environmental degradation
Prospective Investment in Forecast Skill Improvement		
Quantified benefits		
Increased adoption of seasonal climate forecasting leading to improved profitability in agriculture and decreased farm income variability Higher proportion of those adopting seasonal climate forecasting (taking notice of forecasts) who can capture long-term profits from its use Offsetting the reduction in statistical model forecasting skill due to climate change		
Non-quantified benefits		
Improved management of water storages for irrigators Benefits to a wide range of climate-sensitive industries from improved seasonal forecasts Improved planning for agribusiness (e.g. physical inputs) More efficient and effective government policies for delivery of drought support	Improved sustainability of land and pasture resources from cropping and grazing systems more attuned to expected rainfall variability Improved understanding of the patterns of climate variability to inform natural resource management decisions Improved success rate for tree planting for natural resource management purposes	Reduced uncertainty and stress for land and water managers due to more objective processes in decision making and being able to plan ahead. Improved personal capacity of land managers to manage climatic variability and adapt to climate change

	Improved allocation of water to the environment Improved forecasting for bushfires	
Prospective Investment in Yield Prophet		
Quantified benefits		
Increased use of YieldProphet across Australia More accurate yield forecasts translating into improved planning and responses and higher profits		
Non-quantified benefits		
	Improved use of nitrogen resulting in reduced extent of leaching and deep drainage	Improved capacity of cropping farmers to manage initial inputs, crop management and grain storage and marketing

The investment criteria estimated from the four CBAs are shown in Table 3.2. These criteria have been estimated for a benefit period of 40 years after the first year of investment. The results are expressed in 2006/07 $ terms (historical analyses) or 2007/08 $ terms (prospective analyses) and all benefits and costs are discounted to the 2006/07 year (historical analyses) or the 2007/08 year (prospective analyses) using a 6% discount rate. A full account of each analysis is provided in Appendices 1 to 4.

Table 3.2: Summary of Investment Criteria Estimated from Individual Analyses

Criterion	**All Benefits and All Costs**	**Benefits to MCVP and MCVP Costs**
MCVP – Historical		
Present Value of Benefits ($m)	28.55	13.31
Present Value of Costs ($m)	16.58	7.72
Net present value ($m)	11.97	5.59
Benefit-cost ratio	1.7 to 1	1.7 to 1
Internal rate of return (%)	10.6	10.6
Example of MCVP NRM Project –Historical (tentative results only)		
Present Value of Benefits ($m)	17.54	4.96
Present Value of Costs ($m)	0.69	0.20
Net present value ($m)	16.85	4.76
Benefit-cost ratio	25.3 to 1	25.0 to 1
Internal rate of return (%)	9.3	9.3
Prospective Investment in Forecast Skill Improvement		
Present Value of Benefits ($m)	133.33	44.44

Present Value of Costs ($m)	5.21	1.74
Net present value ($m)	128.11	42.70
Benefit-cost ratio	25.6 to 1	25.6 to 1
Internal rate of return (%)	31.9	31.9
Prospective Investment in Yield Prophet		
Present Value of Benefits ($m)	30.20	18.90
Present Value of Costs ($m)	0.76	0.48
Net present value ($m)	29.44	18.42
Benefit-cost ratio	39.8 to 1	39.8 to 1
Internal rate of return (%)	No solution	No solution

4. Commentary on Analyses

4.1 MCVP – Historical Investment

The analysis of the past and current investment in MCVP has reported positive investment criteria. The investment in the program was appropriate, given the increasing importance of climate variability in Australia and the former success of investments in climate variability research by LWA and its partners. The MCVP investment is also considered to have been effective as more farmers are now taking seasonal climate forecasting into account in their farm decision making.

However, the MCVP investment provided a lower net present value and a lowered rate of return compared with the investment in CVAP, the former climate variability program managed by LWA. The explanation for this is as follows.

CVAP took advantage of the earlier innovators so that the adoption during the second half of the 1990s and early 2000s was quite strong as farmer awareness increased and as friendlier forecasts and applications became available. However, the skill level of forecasts has not increased in the past fifteen years. While MCVP broadened the scope of users through applications and improved geographical coverage, the static forecast skill level started to slow the rate of adoption.

Gaps and opportunities emerging that might be addressed in a further round of investment in MCVP include:

1. Catchment and regional studies regarding climate change and climate variability including the use of SCF
2. Management of water storages and environmental flow management incorporating SCF
3. Accelerating the development of POAMA to reduce perceived and actual impacts of climate change on current SCF
4. Change to National leadership on understanding climate risk management
5. Positioning multiple production locations in the face of climate change and increasing variability (e.g. bananas, beef production, feedlots)

Each of these opportunities is discussed below.

Catchment and regional studies regarding climate change and climate variability including the use of SCF

Understanding climate variability and climate change will be increasingly important for managing at catchment level to achieve catchment targets. Current levels of understanding are unlikely to be adequate given the degree of confusion evident in the community generally. There are many tools available but these may only be a partial answer. Alternatives include a greater MCVP role in preparing guidelines and in sponsoring training activities with key providers. One of the issues is that the current most common and recommended approach to climate change adaptation studies is simply to take regional projections for 2030 and redefine current risks. Uncertainty is thus ignored as inconvenient.

Management of water storages and environmental flow management incorporating SCF

Forecasts of streamflows can be invaluable in managing variability. ENSO indicators such as the SOI and SST (Sea Surface Temperatures in the Pacific and Indian Oceans) have been used in statistical forecast schemes a season or two ahead. The relationship is often amplified through spatial and temporal integration compared with an equivalent rainfall forecast. Persistence (serial correlation) has also been shown to be an important factor in some Australian regions and for some seasons.

There are indications that variations in climate and ocean systems over decadal time scales modulate ENSO impacts. For example the SOI correlation with Murray River flows is much higher when a measure of decadal variability in the Pacific is negative compared to when the index is positive.

Two case studies have shown that use of seasonal climate forecasts could increase the managed water yield from a water resources system by 10 to 20%. The increases shown are for irrigation systems where irrigation requirements and crop requirements from rainfall are negatively correlated. Environmental requirements are more likely to be positively correlated with rainfall. There are therefore opportunities to reduce trade-offs required to meet environmental requirements by using seasonal climate forecasts.

Chiew and McMahon (2001) showed for the Lachlan River catchment that a 14% expansion in area planted was possible with little extra risk if seasonal climate forecasts were used. A 23% expansion was possible with some extra risk. Abawi (2000) showed that for a northern Murray Darling system, an increase in area of up to 30% was possible comparing positive and negative SOI phases. The potential exists to better allocate additional water to irrigation and environmental uses at less risk

Environmental flow regimes which attempt to retain and mimic elements of the natural regime will clearly be inadequate if they fail to account for ENSO. Statistical approaches which simply capture the monthly characteristics and month-to-month persistence will completely miss the ENSO pattern at a longer seasonal and annual time scales. The key characteristics are:

- Interannual variability at continental scale (important for migratory species),
- El Niño and La Niña events, each averaging once every four to five years, but with protracted episodes,
- Possible increased frequency of El Niño events and increased streamflow variability with climate change,
- Droughts and wet periods associated with major ENSO events often extending for up to a year from autumn,
- A tendency for droughts and floods to alternate (a land of droughts and flooding rains).

Accelerating the development of POAMA to reduce perceived and actual impacts of climate change on current SCF

The BOM Annual Report (2005-06) has published for the first time a skill measure for its current SCF. The analysis shows an average hit rate or percent consistent of 59% across 36 recent forecasts of the 12 monthly forecasts for tmax, tmin and rainfall. Temperature forecasts are much more skilful than for rainfall so it is possible, even probable that the rainfall forecasts are approaching zero skill. If that is confirmed or likely, there is a compelling case for urgent increased funding by the Bureau to accelerate funding of POAMA. The development of POAMA has been very slow since CVAP funding finished in 2002. This reflects the lack of any strong advocacy for publicly funded research on climate variability and the overwhelming priority of climate change research largely directed at IPCC requirements. Given the generic nature of the benefits from improved SCF there is a case for MCVP leadership to foster a better informed input from relevant user organisations such as NFF in efforts to increase public funding.

A further example supporting urgent priority for POAMA concerns the Indian and Pacific Ocean sea surface temperature data made available for the Bureau's 9-phase approach to seasonal climate forecasts. The data were thought to be seriously corrupted years ago by temperature trends and they should sensibly have simply been withdrawn. The forecasts have been locked into two of the nine phases for most of the last five years. It is highly likely that users are being seriously misled by responsible national organisations. Further, the continued operational use by two nationally available decision support tools can only undermine the excellent work done by Australian agencies to promote the responsible use of seasonal climate forecasts.

Change to National leadership on understanding climate risk management

There is an urgent requirement for proactive national leadership to provide the community with more useful information on our emerging climate, including a shift from a conservative and defensive science perspective to a risk management perspective that adequately conveys uncertainty.

The last summer has seen an extraordinary and mostly unhelpful range of publicly aired views on our current climate from scientists and politicians. Managers of climate risk are making decisions on whether or not the recent trends in rainfall in some regions are part of natural variability or evidence of climate change. Given a strong bias for certainty and intolerance of ambiguity, many feel compelled to opt for one or the other. When the evidence is unclear, decision making needs to take <u>both</u> possibilities into account to ensure a robust solution. Some water authorities are reported as assuming arbitrary reductions to historic rainfall and runoff patterns for want of better advice.

Perth water supply is a classic example where a response to a downward rainfall trend was deferred for more than a decade whilst a research program was assembled. The statistical tools for identifying unusual trends may not be adequate. For example the upward trend in the north west and the downward trends in rainfall in southern and eastern Australia became established during the 1990s. There is not likely to be any known precedent for such coherent continental patterns to then persist into the next decade as they have. Statistical tests are preoccupied with showing that trends at specific locations are in some sense within the range of natural variability. In any case, even if a trend was within the scope of natural variability, the cumulative impacts may not be.

The Bureau has the general role '*to provide decision makers and the general public with accurate observations and information about our changing climate'*. This seems to result in the Bureau disbursing totally accurate comments on actual recent trends and whether they were in some sense unusual or even statistically significant, all entirely valid to a curious scientist but of little use informing risk managers looking ahead. The NCC (BOM National Climate Centre) Annual Report even makes a dubious counterpoint '*Unambiguous communication of climate information is the key to its effective* use'. But ambiguity may be the message.

The Bureau website appears to link and defer to AGO for any climate change issues other than observations and trends to date. But the AGO adds to the confusion with its emphasis on current trends as being work in progress and part of the research agenda, effectively ignoring the demand for information for current decision making. Those charged with educating the community have clearly failed. Scientists take refuge in the need for more research. Even the IPCC report is regarded by some as too conservative because it only lists areas where the evidence is strong and ignores many issues where the evidence is weaker, but collectively their combined risk may be considerable.

The fundamental issue in the communication problems raised above is the inability of scientists to convey uncertainty (What they <u>don't</u> know) in ways useful to a climate risk manager.

Positioning multiple production locations in the face of climate change and increasing variability (e.g. bananas, beef production, feedlots)
Previous MCVP and CVAP research has typically been narrowly focused to the extent that research was on climate risk management at a production level, either nationally in aggregate or at a farm level. One of the features of the ENSO impact on Australia is the extent of the impact spatially and the extent to which there are coherent patterns on a seasonal and geographic basis. A striking example is the grain industry experience. The eight major droughts from a grain production point of view have all been El Niño events. But that would not be true for an individual location in the grain industry.
A grazing property may have an increased risk of drought in an El Niño but a much higher risk of an impact on livestock markets or feed process. The dairy industry is another example where production in drought is often maintained by purchased feed or irrigation water. No research has been done on these issues in a way that would inform climate risk managers.

4.2 Example of MCVP NRM Project -Historical

The NRM example explores some private and public benefits from the investment in one project in the Western Division of NSW funded within the first phase of MCVP. The potential benefits from this investment have not been formally included in the overall

MCVP analysis due to the difficulty of making credible assumptions concerning the impact on the environment from the decision support system produced by the project.

However, it was felt that a case study of this type could demonstrate the difficulties in carrying out analyses where environmental and natural resource management benefit were involved.

One difficulty is that the decisions aided by SCFs in rangeland situations can result in both private short and long term benefits from productivity gains (e.g. private benefits in the main from earlier destocking than without SCF) as well as public benefits. The latter may include the maintenance or improvement of landscape aesthetics, improved biodiversity, reduced erosion, improved waterway quality, and the retention of the options for alternative uses of land in the future (e.g. native animal ranching, tourism, and traditional pastoral uses). The case study attempts to value these benefits independently of one another.

Compared with previous phases, MCVP1 was much broader in scope and included several new directions in NRM research. A number of benefits likely to be delivered from the investment are likely to accrue in the natural resource management arena as the MCVP increased emphasis on catchment management. Improved decisions on management of water and drainage, nutrient runoff and nitrogen leaching, and maintenance of ground cover are likely to occur in future. Preliminary guidelines for reducing climate-related risk in tree establishment are now being used to increase success. The crop simulator APSIM has increased capacity to simulate production and potential environmental impacts in a wide range of environments.

4.3 Prospective Investment in Forecast Skill Improvement

The prospective analysis of investing in improving the skill level of SCF demonstrates that such an investment should be given a high priority. Given the assumptions made the analysis showed high returns with a most likely benefit cost ratio of greater than 25 to 1. Further, this conclusion is not particularly sensitive to major changes in key assumptions. Even a skill increase of one quarter of that proposed remains profitable. The fundamental reason is because the investment is generic. The use of SCF will increase and be of benefit nationally at a time when there is an increasing demand for improved products to manage climate-related risks.

Current SCF have two decades of use with little change in their intrinsic skill. They are accepted as of only low to moderate skill although they do for many locations and times indicate significant changes in the chances of above or below rainfall during ENSO events. Climate change is likely to be increasingly perceived as eroding the existing skill levels. Confirmation of this would constitute an urgent case for higher priority to improve skill. SCF are one of the most effective ways for climate sensitive industries to adapt as the risks and uncertainties change.

This prospective analysis has shown the feasibility of a significant improvement in current skill levels and that this will increase the proportion of farmers using and benefiting from the opportunities the forecasts bring for improved risk management. The benefits are evenly spread between three sources, new users, greater benefits from existing users, and from arresting the impact of climate change on forecast quality. The first benefit (the increase in use of SCF) is estimated by a derived relationship between adoption and forecast skill derived by Barry White.

Investment in research on improved skill will be able to benefit considerably and be highly complementary to the national framework now in place to better coordinate and integrate research on climate change and weather using GCM.

4.4 Prospective Investment in Yield Prophet

Previous investments by MCVP in YieldProphet have demonstrated benefits of collaborative projects linking R&D and science to agribusiness and to farmers. This is a key strategy for future investment for MCVP in term of ensuring that climate science findings are applied in the field and deliver benefits to Australians.

The assumed net profits to farmers from use of the model appear significant. The analysis demonstrates the very high returns possible from a decision support tool that can provide risk management information directly relevant to the production risks faced by individual farmers. However, the benefits that will result from further MCVP investment in YieldProphet need to be estimated by the incremental gain the investment will make compared with the situation without the investment (the counterfactual). Counterfactual scenarios considered are:

a) an alternative investor to MCVP would become involved (resulting in possibly zero additional benefits from an MCVP investment) or,
b) YieldProphet support will cease and then farmers would use one of the next best approaches to climate risk management, for example WhopperCropper.

Based on the assumptions made and given these equally weighted counterfactual scenarios the investment still appears very profitable for MCVP. This is so, even though approximately 75% of the benefits from Yield Prophet are likely to be captured anyway if MCVP does not fund the investment. Also, the investment criteria show that only several hundred users need to be involved for further investment to make a positive return. However, the assumed profitability from use of the tool does raise the issue of defining the market failure and the role of a program such as MCVP in supporting clearly profitable investment by industry, albeit requiring a continuing level of external investment and scientific support for the private benefits to be realised.

5. Conclusions

1. The historical analyses provide investment criteria that are positive, demonstrating that, at least for the assumptions made, the MCVP investment has provided an advance in knowledge and use of that knowledge by Australian land and water managers. The investment in MCVP was both appropriate and effective as demonstrated by the assumptions made and the investment criteria produced.

2. The investment criteria for MCVP were lower than those estimated for CVAP. This is possibly because of declining marginal returns where there is a fixed constraint to improvement (skill level of the forecasts). While adoption has increased with MCVP, the increase was less than that previously assumed for the impact of CVAP.

3. There are difficulties in strongly linking natural resource management benefits to investment in climate variability and to determining values of private and public benefits.

4. The significant benefit from an increase in forecast skill is clearly demonstrated in the third analysis where a benefit-cost ratio of 25 to 1 was estimated for potential investment in this area.

5. The investment criteria for further investment by MCVP in Yield Prophet are positive and high. This is despite counterfactual scenarios significantly eroding benefits from the MCVP investment.

6. Other constraints and gaps that emerged from the MCVP evaluation included the potential for reduced benefit from the impacts, actual and perceived, of climate change on forecast skill. If this is shown to be substantial, there is an urgent case for increased priority to GCM development.

7. There is also a case for MCVP to take a higher profile role in ensuring a greater emphasis on climate risk management aspects in pronouncements on current climate trends. The scientist concern with the evidence for change is at odds with a risk managers need to understand the degree of uncertainty and to make robust decisions accordingly.

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Appendix 1: Investment Performance of the Managing Climate Variability Program (MCVP)

Introduction

This report evaluates the most recent phase of a research program with the major aim of improving Australians capacity to manage rainfall variability. The program had its origins in the 1992 National Drought Policy. The three previous phases had broadened the focus of the research beyond drought to more general climate risk management issues but with a focus on supporting decisions a season ahead. The most recent phase was the Climate Variability in Agriculture Program (CVAP) that concluded in 2002. All phases have been managed by Land and Water Australia (LWA) on behalf of the funders which have included Australian Government programs and the majority of the Rural Research and Development Corporations. As part of LWA's Return on Investment (ROI) initiative, CVAP was subjected to a cost–benefit analysis in 2006 and results reported in Appendix 1 of Agtrans (2006).

As CVAP was drawing to a close, a new program entitled the Managing Climate Variability Program (MCVP) was initiated and managed by LWA. MCVP commenced in 2002/03. MCVP has maintained about the same rate of investment of about one million dollars annually as had been achieved by previous phases. Funding from the core stakeholders has been matched by contributions as part of partnerships with research and other organisations around Australia.

Investment Description

The directions of the MCVP were developed through consultation with investors, stakeholders and technical experts. Two notable changes from previous phases were the increasing interest in adapting to climate change in the short term and the need to strengthen the program in developing products more relevant to water and natural resource management issues. A new category '*Responding to climate change and variability*' was added to the National Research Priorities during MCVP.

A prospectus (White 2002) for the new MCVP had been launched with assistance from the National Farmers Federation in April 2002. The Prospectus advanced a target of raising six million dollars for a new program of research over the period from 2002 to 2006. As shown in Table 2 this target was almost achieved.

This report describes the investments, and then reports their outputs and outcomes in relation to the program goals and their return on the investment cost.

The program's goal was:
to increase the capacity of Australia to capture opportunities and manage risks related to climate variability. The priority area for investment was improving seasonal forecasts.

The goal has three sub-goals:

1. Increased Adoption (Regions and Industries) - Development of products and approaches to improve communication to users, including some projects in regions/industries where there was potential for significant exposure to climate change.
2. Increased Adoption (Natural Resources Management) - Development of products and approaches to improve communication to users in natural resources management, including some projects in catchments and regions where there was potential for significant exposure to climate change.
3. Improved seasonal climate forecasts - To rapidly improve the skill and/or applicability of statistical and modelled forecasts, for example the ease with which they can be used to show value of forecasts and to significantly improve the skill and value of seasonal climate forecasts at longer lead times.

A list of MCVP projects, grouped into subprograms, is presented in Table 1.

Table 1: MCVP Project Information by Subprogram

Project Code	Project Title	Start and Finish Dates	Research Organisation	Total Value ($) (MCVP contribution)
Monitoring/Policy				
ABA11	ABARE system for predicting farm performance	Mar 2003-Feb 2004	ABARE	49,776
BRR23	National monitoring & forecast system	Feb 2003 – Apr 2004	BRS	50,023
Total				99,799
Increased Adoption Regional				
ABA12	Enhanced forecasting of farm financial performance	Jul 2004-Sep 2005	ABARE	120,000
BCG1	‘Prophetable’ cropping using seasonal forecasting tools	Jul 2004-Jun 2006	Birchip Cropping Group	260,000
CLW61	Seasonal climate forecasts for risk based irrigation area and environmental management	Mar 2003-Dec 2003	CSIRO Land & Water	50,652
CSE40	Integrating NRM implications into a production based SCRM system	Jun 2006-Nov 2007	CSIRO Sustainable Ecosystems	105,000
DAN19	Climate science for better NRM in western NSW	Jan 2005-May 2007	NSW Dept of Primary Industries	180,000

DAN20	Seasonal climate forecasts to improve dairy farmers' feedbase management	Jun 2004-May 2007	NSW Dept of Primary Industries	114,000
DAW49	Building effective climate risk management in the WA grainbelt	May 2006-Feb 2008	Dept of Agriculture & Food WA	300,000
DFN1	Stimulating the adoption of AussieGrass in the Northern Territory	Jul 2006-May 2007	Dept of Primary Industry, Fisheries & Mines, NT	40,000
KON5	Managing climate risk for livestock producers	Jul 2003-Jan 2004	Kondinin Group	20,000
MIG1	Horses for courses: using the best tools for managing climate risk	Jul 2004-Apr 2007	Mingenew-Irwin Group	190,000
QPI54	National whoppercropper - delivering risk management to agricultural advisors	Jul 2004-Jun 2007	Qld Dept of Primary Industries & Fisheries	275,000
SRD6	Communication and evaluation of MCVP grain projects	Apr 2006-Apr 2007	South Australia R&D Institute	50,000
SRD7	Enabling NRM decision makers to make better use of climate science	Apr 2006-Apr 2008	South Australia R&D Institute	200,000
VPI8	Growing capacity in seasonal climate risk management in south-east	Jan 2006-Feb2008	Dept of Primary Industries, Victoria	300,000
Total				2,204,652
Seasonal Forecasting				
ANU49	Agro-ecological implications of changes in the terrestrial water balance	Nov 2004-Jan 2006	Australian National University	49,437
BOM7	DroughtCom: improving drought management through better communications	Jul 2003-Jan 2004	Bureau of Meteorology	20,000
CMR7	Oceans to grains: a new approach to targeted seasonal forecasting	Jul 2004-Jun 2007	CSIRO Marine Research	330,000

JCU20	Advanced climate forecasting – helping industry make better decisions more often	Nov 2004-Feb 2006	James Cook University	69,907
QNR31	Managing agricultural systems in a variable, non-stationary climate – Part II: grazing systems	Mar 2003-Jun 2004	Qld Dept of Natural Resources, Mines & Water	40,000
QPI48	Managing agricultural systems in a variable non-stationary climate – Part I: cropping systems	Mar 2003-Jun 2004	Qld Dept of Primary Industries & Fisheries	40,000
QPI49	National Drought Forum - sponsorship	Mar 2003-May 2003	Qld Dept of Primary Industries & Fisheries	10,000
QPI51	Targeted seasonal forecasts using RAINMAN V4	Sep 2003-Feb 2004	Qld Dept of Primary Industries & Fisheries	27,380
QPI62	Improving prediction of the Northern Australian wet season	Feb 2006-May 2008	Qld Dept of Primary Industries & Fisheries	500,000
SEACI	South-Eastern Australian Climate Initiative	June 2005-June 2008	CSIRO, BOM, University of Melbourne	600,000
Total				1,686,724
Increased Adoption NRM				
ANU41	Improved water management incorporating risk & climate awareness	Apr 2003-Dec 2003	Australian National University	50,000
CLW62	Incorporating climate variability into the assessment of alternative vegetation patterns	Mar 2003-Jan 2004	CSIRO Land & Water	50,277
CLW71	Incorporating climate change in catchment management strategies	Sep 2003-Apr 2006	CSIRO Land & Water	300,000
CSE16	Enhancing NRM by incorporating climate variability into tree establishment decisions	May 2003-Mar 2004	CSIRO Sustainable Ecosystems	49,924
CSE20	Increasing success of	Oct 2004-	CSIRO	100,224

	tree establishment by using seasonal climate forecasts	Aug 2007	Sustainable Ecosystems	
CSE24	Managing natural resource issues in a variable and changing climate	Oct 2004-Dec 2006	CSIRO Sustainable Ecosystems	70,334
Total				620,759
Communication				
CIC7	Development of a communication strategy for the MCVP	Oct 2004-Nov 2005	Cox Inall Communications	10,000
CUR12	Climag - Issue 1	Apr 2004-Jun 2004	Currie Communications	15,000
ECO7	MCV communication support	Feb 2006-Jun 2007	Econnect	132,500
UNE51	Evaluation of RAINMAN promotion and climate communications	Dec 2004-Jan 2005	University of New England	14,950
Total				172,450
Cross Cutting				
BLA2	Masters of the climate - innovative farmers coming through drought	Jul 2004-Apr 2005	Blackadder Communication	70,000
QNR37	Calculation verification and distribution of potential evaporation (PET) data for Australia	Nov 2005-Nov 2006	Qld Dept of Natural Resources, Mines & Water	100,000
QPI57	Using climate indicators in weather risk management for Australian wheat	Jan 2006-Nov 2006	Qld Dept of Primary Industries & Fisheries	99,800
USY11	Applying seasonal climate forecasting for profitable sustainable resource use	July 2004-Jul 2007	University of Sydney	84,000
Total				353,800
Program Support				
AGE4	Program management for the Climate Variability R&D Program	July 2002-May 2003	AGEC Consulting	32,700
AGE6	Program Coordinator - MCVP	Sep 2003-Dec 2004	AGEC Consulting	210,411
CRE1	MCV Program	2006/07-	Colin Creighton	115,000

	Coordinator	2006/07		
CSE14	Establishment of activities under the AFFA-funded NRM climate program	Dec 2002-Feb 2003	CSIRO Sustainable Ecosystems	20,000
Total				378,111

Investment Costs

Table 2 presents a summary of the annual investment costs for MCVP as well as other contributors to the projects (predominantly in-kind support from the research organisations).

Table 2: Summary of Investment Costs for MCVP by Year (nominal $ terms)

Year	MCVP Costs	Other Contributions (a)	Total
2002/03	402,593	581,223	983,816
2003/04	598,684	585,450	1,184,134
2004/05	1,122,438	1,160,292	2,282,730
2005/06	1,806,182	2,419,044	4,225,226
2006/07	2,146,036	2,446,609	4,592,645
2007/08	968,296	869,751	1,838,047
Total	7,044,230	8,062,369	15,106,599

(a) SEACI costs for "Other Contributions" have been limited to $437,000 over three years for other funders and $1,037,000 over three years from research providers. These sums are estimated as that part of the non-MCVP SEACI funding related to seasonal forecasts.
(b) There is the potential for 'other contributions' in the latter years to increase as some planned projects have not yet been contracted and some funds may be leveraged through these contracts.

Table 3 presents a summary of the annual contributions to MCVP by its partner organisations.

Table 3: Summary of Contributions to MCVP by Year (nominal $ terms)

Organisation	2003/04	2004/05	2005/06	2006/07	Total (a)
LWA	75,000	340,000	278,000	176,000	869,000
GRDC	422,401	649,931	698,518	953,097	2,723,947
RIRDC	50,000	50,000	50,000	50,000	200,000
SRDC	35,000	40,000	40,000	40,000	155,000
MLA	0	100,000	100,000	100,000	300,000
DA	100,000	200,000	0	0	300,000
DAFF/NHT	500,000	500,000	500,000	500,000	2,000,000
DEH	500,000	0	0	0	500,000
Total	1,682,401	1,879,931	1,666,518	1,819,097	7,047,947

Note: This summary of contributions does not include the in-kind tied project funding of $800,000 from GRDC, $750,000 from MLA and $530,000 from LWA

Principal Outputs and Outcomes

The program goal was addressed by projects in seven subprograms including an internal support subprogram. The principal outputs are first listed by projects. Second, the outcomes for the beneficiaries of the program are summarised within each of the six subprograms (excluding program support). Excluding program support, there are 40 projects covering a range of research and communication activities across regions and industries. The diversity reflects the priorities of the partners in the program as expressed through the program's objectives.

The scope of the following summaries is limited to outputs and outcomes that can be linked directly to the projects over the time frame of the projects. Improved climate risk management by farmers and natural resource managers over the duration of the projects is included. There will be further improvements into the future arising from the increased capacity of individuals and agencies and as experience and the knowledge base expand. At this stage the evaluation is limited to documenting some of the many and varied activities that build capacity and thus lead to improvements. Examples are the tools developed and the knowledge, networks and critical mass built up in and between agencies. Often additional resources will be needed to capitalise on increased capacity.

The most significant outcomes from the program are in the form of increased profitability and the more difficult to quantify benefits from more sustainable natural resource management. The increase is typically a consequence of changes in management practice following increased awareness and use of new tools and techniques and how these add to existing traditional approaches to climate risk management.

Monitoring and Policy Subprogram

Key Outputs

- Techniques developed to interpret national broadacre farm survey data from a climate risk perspective (ABA11)
- Integrated framework developed for a national agricultural monitoring system developed (BRR23)

The capacity of governments to develop policies based on forecasts of farm financial performance was increased by ABARE research on risk associated with climate variability. Previously existing technology had only enabled governments to forecast in terms of rainfall and crop and pasture production and there was little capacity to isolate climate-related risk from other sources of income risk.

The initial objective of ABA11 was to investigate the feasibility of linking output from two biophysical models — Aussie Grass and the Queensland Department of Primary Industries' shire scale wheat yield model — with ABARE's broadacre farm survey data, to forecast the regional impact of climate variability on farm financial performance.

Using data provided each year by Australian farmers, ABARE provides analysis and forecasts of farm incomes to support the implementation of drought policy, including exceptional circumstances determinations. A follow-on project funded by GRDC measured the sensitivity of farm incomes to climate variability across regions of Australia's wheat–sheep zone. The sensitivity of farm incomes to climate variability is strongly related to the diversity of on-farm and off-farm income sources. This is an important learning in terms of policy development.

A further small project (BRR23) had as its major outcome the development of an integrated national framework for monitoring drought. The framework has since been implemented as the web-based National Agricultural Monitoring System (NAMS) and contains a range of climatic and production information, initially for dryland broadacre industries, for over 600 regions throughout Australia. NAMS will result in more timely assessments of Exceptional Circumstances for defining government assistance measures. The system is heavily dependent on tools and techniques developed by MCVP and its predecessors.

Increased Adoption-Regional

Key Outputs

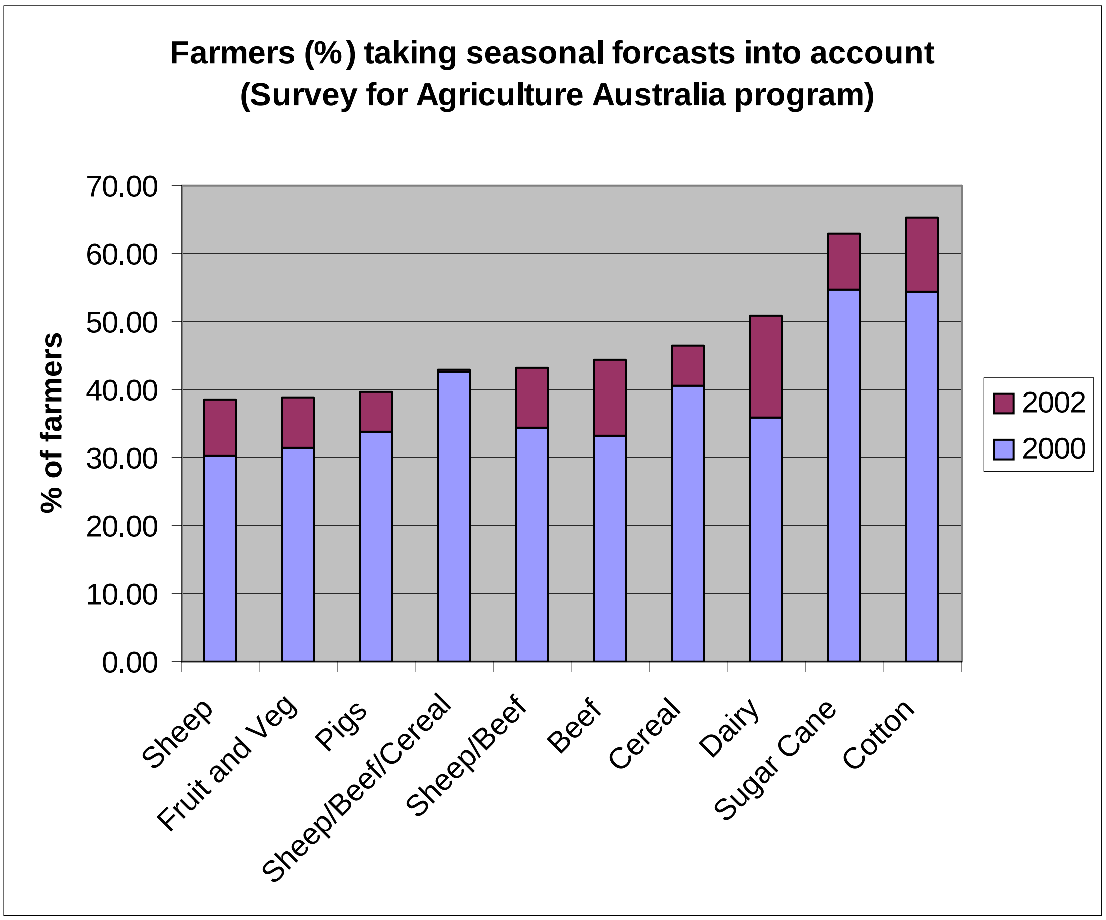
- Yield Prophet simulation approach to dryland cropping expanded by addition of modules for risks relating to Yield, Nitrogen and Climate, Nitrogen profit and Soil Water -there were 5,000 requests for Yield Prophet reports during 2005(BCG1).
- Procedures and parameters determined for adoption of Yield Prophet approach by farmer groups across the grain industry (BCG1).
- Development and delivery across southern and western grain regions of pre-run Whopper Cropper simulations for decision support by 172 commercial advisers - training is on target to finish mid-2007 (QPI54).
- A special climate section routinely featured in the GRDC publication *GroundCover* distributed to all grain farmers (SRD6).
- Water allocations including seasonal climate forecasts assessed for the Murrumbidgee Valley (CLW61).
- Key tools for managing climate risk identified with sub-tropical and tropical dairy farmers (DAN20).
- 'Climate Risk for Graziers' booklet distributed widely and showed how value of seasonal climate forecasts could be increased by knowledge of soil moisture and by pasture monitoring (KON5).
- Training and packages developed to meet climate risk needs identified for Western Australian farmers - project ends February 2008 (DAW49).
- "The Break" newsletter launched as part of south eastern Australian project working with farmer groups to support the adoption of climate risk management tools -project ends February 2008 (VPI8).
- AussieGRASS coverage expanded to include trial in the Northern Territory of potential value in grazing management (DFN1).

The fourteen projects in the subprogram have an extensive coverage compared with previous phases in terms of regions and industries. Projects in Victoria and Western

Australia are the first to comprehensively assess needs and the appropriate tools to contribute to improved climate risk management. A major outcome of the subprogram is the expansion in activities so that now the majority of Australian farmers have access to climate risk information through their State Government advisory services. This development comes at a time of rapidly increasing demand for reliable information on climate risks.

The increased adoption over the two year period from 2000 to 2002 is shown in Figure 1. The overall Australian average increased from 37.3% in 2000 to 44.7% in 2002.

Figure 1: Proportion of Farmers Taking Seasonal Forecasting into Account



Source: Climag (2005) based on surveys of 2,500 farmers commissioned by the Agriculture Advancing Australia Program.

Three projects in the subprogram were aimed at increased adoption of climate risk information in regional natural resource management. These projects (CSE40, DAN19, SRD7) are assessed in the NRM subprogram.

Several projects targeted grain industry groups using improved simulation approaches to more accurately simulate farm yields and identify alternative cropping strategies. The

Yield Prophet simulator based on APSIM has been demonstrated to be a valuable tool in all major grain regions. The project with the Birchip Cropping Group (BCG1) has been instrumental in taking Yield Prophet to a larger range of clients. During 2005, the service was accessed for 5,000 reports as farmers updated risk assessments over the cropping cycle. Trials have now clearly shown the feasibility of assessing climate risk online for individual farms. Key parameters need to be estimated at farm and paddock scale. Parameters to define available soil water are particularly important.

The experience with BCG has been invaluable in demonstrating that climate risk assessment based on models such as Yield Prophet can be of significant practical value across southern Australia. This outcome is a breakthrough given the widespread view that seasonal forecasts and cropping models would be of limited use in a winter rainfall environment with soils of generally lower water holding capacity than in northern grain regions.

The evaluation (CLW61) of commonly used seasonal water allocation methods used in the Murrumbidgee Catchment was the first in the rice industry to take into account seasonal forecasts which can potentially provide information of value from mid year on likely changes in allocation over the summer season.

Many of the outcomes from the projects will continue to generate benefits by strengthening capacity. The projects often work with groups of farmers to assess needs and select or develop locally relevant tools and techniques to efficiently meet needs. The degree of participation helps develop the understanding to implement robust approaches that can be more widely applied. Adoption by farmers is also responding to a more mainstream approach to expertise in climate risk management. The model of a small group of specialists working directly with farmers is being complemented by increased training of advisory staff in government agencies and in agribusiness (QPI54).

Seasonal Forecasting

Key outputs

- Major three year project, the South-Eastern Australian Climate Initiative (SEACI), launched in 2006 with MCVP as a partner and with longer lead seasonal climate forecasts as a priority.
- Project (QPI62) launched to improve prediction of the onset of the northern wet season and possible wet and dry spells.
- Contribution of cut-off low pressure systems to growing season rainfall identified for north western Victoria as part of the development of a regional approach to tailored forecasts (CMR7).
- National Drought Forum held to get feedback on communication activities during the 2002 drought (BOM7).
- Review of forecast systems for possible use in the sugar industry shows the current approaches were effective, but that further research on a physical basis for decadal variability was warranted (JCU20).
- Impacts of climate change and possible adaptations assessed using crop and pasture models for two regions (QNR31, QPI48).

- Pan evaporation trends analysed for the limited data available for Australia showing a small, seasonally even but spatially variable decline, partly attributed to a decline in windspeed (ANU49)

The accuracy (in the sense of performing better than chance) of seasonal climate forecasts has always been recognised as the key attribute limiting outcomes relating to improved climate risk management. This is not to dismiss the associated gains that have been made through increased understanding of climate issues generally and more recently from the prominence given to the potential role of climate change in influencing the current Australian climate.

The most widely used seasonal climate forecasts are still statistically based on rainfall three months ahead. Seasonal climate forecasts vary considerably in value by region and by season. A notable gap is limited skill in relation to the autumn break. There have been no significant improvements over the last decade and there are concerns that climate change may be limiting accuracy or alternatively perceptions of forecast value. It should be noted however that ongoing assessments do not reveal any major erosion in performance in terms of the forecasts performing better than chance. This issue will be further considered in a later section in terms of estimating any long-term decline in forecast skill.

The main contributors to outcomes have come from improved demonstrations of forecast value and applicability for example through using cropping models, and from regional activities to better champion and interpret forecasts in locally relevant applications.

The most promising avenue for research is through Global Circulation Models (GCMs) as exemplified by the successes of the Bureau's POAMA model part-funded by a previous CVAP investment. The POAMA model is being upgraded to forecast Australian rainfall and not only sea surface temperatures relevant to El Niño development. The level of resources and the scope of the science required to advance GCM development requires a collaborative approach between agencies and beneficiaries. MCVP has therefore invested in the South-Eastern Australian Climate Initiative (SEACI) to achieve it's objective. The Initiative is a major program with an investment by funding partners of $7.03m. There are 40 projects. The program will not be completed until 2008. Improved forecasts at longer lead times for streamflow and crop yields are the focus of one of the three themes of SEACI. The other two interrelated themes develop the capacity of GCMs for analysing climate change and variability across south-eastern Australia.

The project on the onset of the northern wet season (QPI62) will be of value to northern industries, particularly beef and sugar. The project incorporates the Madden-Julian Oscillation and the role it plays in wet and dry spells at the onset and during the wet season

In, the Oceans to Grains project (CMR7) in the Wimmera/Mallee, new approaches to climate patterns are identifying the key components that require research to better forecast seasonal climate. Not only are cut-off lows the key for good rainfall events in April-June, September-October, but also the Indian Ocean has a significant role in the weather patterns of north-west Victoria.

Understanding of climate change impacts is being developed by building on the tools and expertise built up through MCVP and its predecessor programs. The CLIMARC project which made long-term data available in electronic form has been invaluable in identifying climate-related trends. Much of the value comes from being able to perform assessments of impacts using simulation models of crops and pasture to characterise the climate of the last century and the impacts from climate change. The SILO system provides continuous data to run cropping models for any location and period.

Two projects (QNR31, QPI48) identified the production and natural resource management implications of climate change for scenarios in 2030 and 2070 for two case study regions. The projects were important as prototypes of how to conduct a regional impact study for major rural industries.

Increased Adoption NRM

Key Outputs

- Potential value of seasonal climate forecasts demonstrated in a case study of irrigation and environmental flow management but actual value limited by farmer perceptions of accuracy (ANU41).
- Potential value of seasonal climate forecasts demonstrated in landscape hydrology through reduced drainage and discharge from crops selected according to the season forecast (CLW62)
- Climatic factors determining seedling survival being identified for use in tree establishment -project ends August 2007 (CSE16, CSE20).
- Catchment scale trends in ground cover developed for use in AussieGRASS forecasts of degradation events -project ends May 2007 (DAN19).
- Planning tool for developing adaptations to likely climate change for stakeholders in catchment management (CLW71).
- Capacity developed to demonstrate climate change impacts on farm production and on environmental indicators such as drainage and nitrogen leaching for sites in three Australian catchments (CSE24).
- Drainage and nitrogen leaching forecasts being added to Yield Prophet Reports for farmers to enhance natural resource management projects ends November 2007 (CSE40).
- Real Options framework used in financial markets for analysing risks of over and under adapting to climate uncertainty being applied to role of climate information in natural resource management decisions project ends April 2008 (SRD7).

The outcomes from nine projects targeting increased adoption from a natural resource management perspective are summarised below (three projects - CSE40, DAN19 and SRD7 were classified in the Regional subprogram).

Compared with the previous phase, the subprogram marks a distinct broadening of the program to give greater priority to NRM issues particularly in relation to water resources and catchment management. Climate change also became an increasing priority. The funding from the Commonwealth Government via the Natural Heritage Trust was an important catalyst in the process.

The strategy used for including NRM built on the successes achieved with the production-focused approaches. Problem identification is more complex because a more diverse group of stakeholders is usually involved, often with well-established and traditional approaches to managing climate risk. In addition, there will usually be more diverse objectives. Often the main tools, for example the crop simulation models, have been designed with a focus on production issues and they have needed some modification and validation before they can be confidently used to look at NRM issues (CSE40). The models are usually point-based with little capacity to look at the spatial issues often dominant in NRM and in catchment management. The project CLW62 with capability for a landscape perspective was an exception.

The outcome from the nine projects that will have the greatest impact is the development of the capacity at farm and catchment scale to assess climate risks in terms of NRM impacts. The crop simulator APSIM has the capacity to simulate production in a wide range of environments. The capacity to simulate and thus potentially manage any adverse impacts shown by environmental indicators can now be added to the established production capacity. As an example the APSIM-based Yield Prophet package can simulate drainage and nitrogen leaching. An equivalent outcome for broader scale assessments in grazing situations is being developed for an indicator based on ground cover. The AussieGRASS package can routinely provide estimates of ground cover for the Australian continent.

The enhancements to APSIM have been demonstrated to be of value in broader scale studies of climate change impacts on NRM as indicated by the environmental indicators used in cropping situations. The catchment management planning tool for developing adaptations (CLW71) is a further addition to capacity for undertaking climate change studies.

Preliminary guidelines for reducing climate-related risk in tree establishment are now being used to increase success (CSE20). A concluding project will further increase the capacity of the forestry industry to manage the key risks relating to temperature and moisture extremes. The expanded effort to plant trees and shrubs across Australia has often been problematic due to climate risks (e.g. drought and frost) reducing establishment. Knowledge is now available on the potential to use seasonal climate forecasts to manage the risks. In addition, potential adaptations to climate change have been identified.

Communication

Key Outputs

- Success of *Climate Connect 2006* forum showcasing 24 MCVP projects before 120 key stakeholders and international program reviewers (ECO7).
- The program bi-annual newsletter *CliMag* reformatted with an expanded print run to update stakeholders on program developments and information sources (CUR12, ECO7).
- The program website (http://www.mangingclimate.gov.au) providing project Factsheets and detailed information to a wide range of users
- The Rainman STREAMFLOW package promoted by distributing on request 3,000 test copies Australia wide for trial use and feedback (QPI51).
- RAINMAN promotion demonstrates that the software once installed can be used gainfully with only basic skill levels (QPI62).

The subprogram produced a range of outputs to promote the program to current and potential stakeholders by increasing awareness of the range and relevance of the outputs from research. Although research projects are based on a participatory approach, the involvement is often limited to pilot groups in specific industries and regions. The communication strategy is broader in its reach.

Cross Cutting

Key Outputs

- Masters of Climate updated from 1999 and providing a resource of 14 widely used farmer stories on their insights and how they are adapting their climate risk management approach (BLA2).
- Overview economic analysis to increase adoption by developing more general approaches to valuing seasonal forecasts project ends July 2007 (USY11).
- SOI-based derivatives analysed to define potential role compared with insurance in climate risk management for wheat farmers (QPI57).
- Improved series of historical evaporation data developed for SILO for use in climate risk management analyses and in monitoring - project ended November 2006 (QNR37).

The four projects have diverse outputs not readily classified into one of the more targeted subprograms. The follow-up study (BLA2) on those surveyed in the 1999 Masters of Climate has given a much richer understanding of how farmers are evolving in the way they interpret climate information. The case studies were widely promoted through articles in national magazines and as a printed booklet that has met heavy demand. One of the key learnings for some participants was the need to move away from using a seasonal climate forecast to ‘pick winners’ and adopt a more basic climate risk management approach that could be readily updated and gave some degree of protection whatever the outcome.

The knowledge of the potential value of SOI-based derivatives will be an important contribution to better defining commercial approaches for farmers to self-manage some of the major fluctuations in income (QPI57). The wheat industry appears the most promising. The key outcome of decreased income volatility will be achieved if the SOI can be used as a proxy of farm yield variability and in turn farm income variability. The correlation may be stronger at more aggregated levels. For example the eight most severe droughts in terms of national wheat yields have all been El Niño events when winter SOI levels would be low. The advantage of the derivative approach is that a position would only need to be taken in low SOI years. If a poor crop follows, there would then be a payout. In the event of a good crop, the premium for the SOI product will be in the nature of cheap insurance.

Benefits Associated with the Investment

Economic
The principal economic benefit emanating from the investment is the increased profit and reduced income variability that those farmers will receive who use SCF due to the investment. A number of other economic benefits are likely to accrue to others in the agribusiness sector and government from improved planning and management from using SCF as a result of the MCVP investment.

Environmental
A number of benefits likely to be delivered from the investment are likely to accrue in the natural resource management arena as the MCVP increased emphasis on catchment management. Improved decisions on management of water and drainage, nutrient runoff and nitrogen leaching, and maintenance of ground cover are likely to occur in future.

Social
The program has raised awareness of SCF and climate change and increased the capacity of individual land and water managers to manage risk. Lowered stress levels of farmers and improved equity from drought support decisions are also likely.

A summary of the different types of benefits derived from the investment in MCVP is provided in Table 4.

Table 4: Summary of Triple Bottom Line Benefits for Investment in MCVP

Economic	Environmental	Social
Increase in average level of profits for farm businesses	Improved sustainability of land and pasture resources	Reduced stress for land and water managers due to more

	from cropping and grazing systems more attuned to expected rainfall variability	objective processes in decision making and being able to plan ahead.
Decreased farm income variability	Reduced wind and water erosion and soil export to waterways	Greater equity between landholders in drought support decisions
Improved success rate of improved pasture establishment	Improved understanding of the patterns of climate variability to inform natural resource management decisions	Improved personal capacity of land managers to manage climatic variability
Improved planning for agribusiness (e.g. physical inputs)	Improved success rate for tree planting for natural resource management purposes	Improved understanding of the potential impacts of climate change and of possible adaptations
Improved management of water storages for irrigators	Improved allocation of water to the environment	
More efficient and effective government policies for delivery of drought support	Improved forecasting for bushfires	
Improved management processes for non rural sectors such as electricity generation and emergency services		

Quantification of Benefits

Past Analyses
A number of former analyses of climate research investment by LWA are available as part of the LWA Portfolio Analysis Program. These include those concerning Indian Ocean Forecasting (2003), AussieGrass (2005) and CVAP as a whole (2006). Also the Climate subprogram of Land Water and Wool (LWW) has recently been analysed as part of the overall LWW evaluation. A number of other economic analyses are reported and some results summarised in the CVAP analysis of 2006.

All of these analyses support a positive return on investment. One of the reasons for the positive rates of return to such investment is the increasing role and recognition of climate and its variability as key drivers within the Australian agricultural economy. Therefore useful generic information or information relevant to specific situations is more likely to be taken up rapidly and provide significant benefits.

Table 5 repeats the table in the CVAP analysis for supporting evidence regarding potential benefits and profits from using climate applications.

Table 5: Supporting Evidence for the Existence of Potential Benefits from Use of Climate Applications

Author(s)	Description of analysis	Findings
1. Hammer and McCown (1995)	Reduced risk of exposure and improved profits from variety selection and management of nitrogen fertilizer for sorghum, sunflower and cotton	Depending on the risk level assumed, the mean value of increased profits from using SOI based seasonal forecasts varied from 0-20% for sorghum and sunflower and from 1 to 9% for cotton.
2. Stafford Smith et al (1996a, 1996b)	Utility of seasonal forecasting based on SOI values to pasture sheep and beef management in three Queensland locations	Long-term economic benefits and some long-term resource protection benefits identified in first study. Second study identified little benefit, due to the then current level of forecasting skill. Improved skill in forecasting appeared to have significant potential to increase economic returns and protect natural resources.
3. Marshall et al (1996)	Benefits to a Goondiwindi wheat grower from using seasonal forecasts	Mean value of the forecasting system was estimated at $3.52 per hectare.
4. Hammer et al (1996)	The value of skill in seasonal climate forecasting to wheat crop management in the northern grain belt	Nitrogen fertiliser rates and variety choice in relation to time of last frost were evaluated using tactics based on seasonal forecasting. Average long-term profits increased by about $10 per ha for nitrogen management and $5-10 per ha for choice of cultivar maturity.
5. Abawi et al (2000)	Forecasting of streamflow in the Border Rivers catchment in the northern Murray Darling Basin.	The value of the forecast to irrigated cotton producers could be up to $192 per ha but was linked to risk preferences. Irrigators with neutral or moderate risk averse attitudes would gain more.
6. Cobon and McKeon (2000)	Potential value of seasonal forecasts in managing grazing systems in western Queensland	Use of seasonal forecasting was valued at $1.07 per ha more than a constant grazing strategy measured at the district average stocking rate. Potential mean increase of almost $10,000 per annum for the property examined was produced with 19% less sheep with implications for reduced deterioration of the native pasture resource.
7. Chiew and MacMahon (2001)	Seasonal streamflow forecasting	Together with the Abawi et al (2001) study, these studies have shown the use of seasonal forecasts could increase the managed water yield from a water resource system by 10 to 20%.

8.Ash et al (2002)	Evaluation of seasonal climate forecasts for the extensive grazing industry in North-East Queensland	The study showed that significant economic benefits can be obtained by using seasonal climate forecasts in the extensive grazing industries. Modelling showed that average pre-tax profits could be increased by 14-19% by the use of seasonal forecasting (SOI based or surface sea temperature forecasts)
9. Jakeman, A.J. and Cuddy, S.M. (2003)	Improved Water Management Incorporating Risk and Climate Awareness	Further analysis using a range of alternative strategies showing increased gross margins of the order of 10-15% and with reduced risk.
10. Lythgoe *et al* (2004)	Seasonal climate forecasting has economic value for farmers in south eastern Australia	Farmers in south eastern Australia can increase profit without increasing the risk of making a loss by adopting a seasonal climate forecast to tune crop nitrogen nutrition
11. White (2004)	How valuable are seasonal climate forecasts	In general, returns on cost of up to twice the per cent shift in the forecast profitability can be achieved.

Current Analysis of MCVP
The past analyses of seasonal climate forecasting applications support the premise that increased profits result from use of SCF and there is potential also for capturing natural resource management benefits.

Economic benefits
The principal assumption associated with analysing the benefits from the MCVP investment are an increased adoption level of the use of SCF.

The two farmer surveys in 2000 and 2002 (Climag, 2005) showed the rate of adoption as indicated by the proportion of farmers taking seasonal climate forecasts into account in decision making increased from 37.3% in 2000 to 44.7% in 2002, an increase of 3.7% annually. The 2002 drought may have been a factor resulting in a short-term jump. The conservative assumption is that MCVP has resulted in a 5% increase over the CVAP base and would be phased in over ten years. Hence, it is assumed that MCVP has made a difference by increasing the numbers who take seasonal forecasts into account from 50% to 55%. This is consistent with the CVAP rate and takes into account that each had a similar level of investment of about one million dollars annually.

It is assumed that the proportion of farmers adopting the use of SCF that obtain dollar benefits from its use is the same as for CVAP (10%). Also, it is assumed that the level of profit for those obtaining financial benefits for those driven to adopt by MCVP would be the same as for CVAP (10%). The 10% profit increase is based on a range of analyses which show optimal returns for some specific decisions when there are significant shifts in probabilities. The 10% was not varied from the CVAP analysis on the basis that the forecast skill level had not increased and user experience would not have changed greatly over a short period.

The average net value of farm production over the past 5 years to 30th June 2005 was $8.48 billion per annum (expressed in 2006/07 financial terms). The potential gain is therefore 10% of $8.48 billion, a sum of $848 million per annum

Previous analyses have used an allowance to take account of forecast deterioration because of climate change. The allowance covers an actual erosion of skill as well as some loss in marketability from a perception of deterioration. There is little published information on decline in skill to date as would be expected given the relatively short period since forecasts were first developed. The Bureau of Meteorology (2006) has published a verification for the 2005-06 forecasts for their seasonal climate outlooks. Only a combined figure is presented for rainfall and maximum and minimum temperatures. The skill level of 59% compares with a no skill value of 50% for climatology. Given that temperature forecasts are known to be higher skill than rainfall, the actual rainfall forecast performance for that year appears to be little better than chance. Whilst it is difficult to generalise from one year for forecasts known to have low to moderate skill with high spatial and temporal variability in skill, it seems prudent to introduce a risk factor regarding future benefits. A 50% risk factor from the year 2012/13 has been assumed and is consistent with the approach already adopted for the CVAP evaluation which sets the baseline for MCVP benefits.

Environmental benefits

The analysis has not included any environmental benefit from either the CVAP or MCVP investment. This is due to the indirect linkages between the outputs and the possible outcomes regarding water quality, biodiversity and soil erosion. Avoiding a proportion of land degradation (e.g. through improved management of ground cover) could be one possible benefit being delivered. However, this benefit is correlated with good profit orientated decision making from SCF, already valued.

The remediation or avoidance of degraded land would be of benefit to society as a whole. This benefit could be categorised as a public benefit and could be considered separate to any enhanced land productivity benefit. This public benefit could first arise from the amenity value to the public (e.g. reducing the extent of soil erosion, clay pans etc) and from society knowing that the land resource is in an improved condition regarding soil, water and vegetation. This benefit could be valued in the current analysis through a benefit transfer of the public's willingness to pay (WTP) for landscape aesthetics (making degraded land more attractive and protecting native bush) (Van Bueren and Bennett, 2004). This method would rely on the benefit transfer applying equally to 'avoidance of degraded land' as well as to 'countryside restoration of degraded land'. This last phrase was that used in the questionnaire to develop the WTP estimate.

However, this approach has not been used in the current analysis due to the uncertainty of the strength of the relationships between use of SCF and avoidance of environmental degradation. The magnitude of the impacts, however, have been demonstrated in a example provided in the CBA of DAN19.

Three analyses
While the prime focus of this analysis is the MCVP program, three CBAs are carried out. First is a re-estimate of the investment performance of CVAP. This is undertaken as the MCVP program builds on the earlier CVAP investment. The second CBA is the central analysis, that for the investment in MCVP. The third CBA is for the combined investment in CVAP and MCVP.

There are different timing issues across the three analyses. Investment in CVAP commenced in 1992/93 so that the benefit period is 40 years from that year (the year of first investment). MCVP commenced in 2002/03 so that the benefit period extends to 40 years from that year. Investment in CVAP and MCVP combined commenced in 1992/93. The period of benefits is 40 years from that year for the combined investment.

A summary of the assumptions made and which are used in the three analyses is provided in Table 6.

Table 6: Summary of Assumptions for Investment Analysis of MCVP

Variable	Value	Source
Income		
Five year average net value of Australian farm production	$8.48 billion	ABARE Commodity Statistics (Table 17) for five years ending June 2006, expressed in 2006/07 dollar terms
Without CVAP or MCVP		
Proportion of Australian farmers that would take seasonal climate forecasting into account	40%	Agtrans Research and Barry White
Potential increase in profits without CVAP or MCVP	10%	Agtrans Research and Barry White
Proportion of farmers taking seasonal forecasting into account that actually benefit without CVAP or MCVP	5%	Agtrans Research and Barry White
First year of increased net profit without CVAP or MCVP	1996/97	Agtrans Research
Phase in of gains	Over 10 years to 2005/06	Agtrans Research
Risk factor for benefits due to forecasting deterioration	0.5 from 2012/13	Agtrans Research
With CVAP but without MCVP		
Proportion of Australian farmers that take seasonal climate forecasting into account with CVAP alone	50%	Various surveys including those of AAA
Potential increase in profits with CVAP alone	10%	Agtrans Research and Barry White

Proportion of farmers taking seasonal forecasting into account that actually benefit from CVAP alone	10%	Agtrans Research and Barry White
First year of increased net income with CVAP alone	1996/97	Agtrans Research
Phase in of gains with CVAP alone	Over 10 years to 2005/06	Agtrans Research
Risk factor for benefits due to forecasting deterioration	0.5 from 2012/13	Agtrans Research
With MCVP		
Proportion of Australian farmers that take seasonal climate forecasting into account with MCVP	55% (same as for CVAP but with added 5% due to MCVP)	Reduced trend compared to AAA trend from 2000 to 2002 (Climag, 2005)
Potential increase in profits with CVAP and MCVP	10% (same as for CVAP alone)	Agtrans Research and Barry White
Proportion of farmers taking seasonal forecasting into account that actually benefit from SCF	10% of all farmers taking seasonal forecasting into account (same as for CVAP alone)	Agtrans Research and Barry White
First year of increased net income	2006/07 for MCVP impact	Agtrans Research
Phase in of gains from MCVP	Over ten years from 2006/07	Agtrans Research
Risk factor for benefits due to forecasting deterioration	0.5 from 2012/13	Agtrans Research

Results

The resulting investment criteria for each of the three analyses are presented in Tables 7, 8 and 9. The period of analysis was for 40 years after the first year of investment. The results are expressed in 2006/07 $ terms and all benefits and costs are discounted to the 2006/07 year. A discount rate of 6% is used for all analyses

Table 7: Investment Criteria for CVAP by Type of Benefit and Costs Included (Discount rate is 6%)

Criterion	**All Benefits and All Costs**	**CVAP Benefits and CVAP costs (includes LWA)**	**LWA Benefits and LWA Costs**
Present value of benefits ($m)	419.99	143.63	6.21
Present value of costs ($m)	77.28	26.09	1.03
Net present value ($m)	342.71	117.54	5.17
Benefit-cost ratio	5.43 to 1	5.51 to 1	6.00 to 1
Internal rate of return (%)	28.7	29.8	51.9

Table 8: Investment Criteria for MCVP by Type of Benefit and Costs Included
(Discount rate is 6%)

Criterion	**All Benefits And All Costs**	**MCVP Benefits and MCVP costs (includes LWA)**	**LWA Benefits and LWA Costs**
Present value of benefits ($m)	28.55	13.31	1.64
Present value of costs ($m)	16.58	7.72	0.95
Net present value ($m)	11.97	5.59	0.69
Benefit-cost ratio	1.72 to 1	1.73 to 1	1.73 to 1
Internal rate of return (%)	10.6	10.6	10.6

Table 9: Investment Criteria for CVAP and MCVP by Type of Benefit and Costs Included
(Discount rate is 6%)

Criterion	**All Benefits and All Costs**	**CVAP/MCVP Benefits and CVAP/MCVP costs (includes LWA)**	**LWA Benefits and LWA Costs**
Present value of benefits ($m)	444.65	155.12	7.63
Present value of costs ($m)	93.87	33.80	1.99
Net present value ($m)	350.78	121.32	5.64
Benefit-cost ratio	4.74 to 1	4.59to 1	3.84 to 1
Internal rate of return (%)	28.2	29.0	47.1

Sensitivity Analysis

For the MCVP investment the sensitivity of the investment criteria to the percentage increase in profit is shown in Table 10.

Table 10: Sensitivity of Investment Criteria to Assumption of Increase in Average Profits from Use of Seasonal Forecasting
(Benefits and Costs for MCVP investment)

	Discount rate 6%		
	Low Value 5%	**Base value 10%**	**High value 15%**
Present value of benefits ($ m)	6.65	13.31	19.96
Present value of costs ($ m)	7.72	7.72	7.72
Net present value ($ m)	-1.06	5.59	12.25
Benefit-cost ratio	0.86 to 1	1.73 to 1	2.59 to 1
Internal rate of return (%)	5.0	10.6	15.0

Summary of Adoption Information

There is strong evidence that a significant number of Australian primary producers take seasonal climate forecasts into account in their decision making. CVAP played an important role in fostering this increased recognition and use. From 2000 to 2002, the proportion of farmers taking seasonal climate forecasts into account increased from 37.3% to 44.7% with the biggest increases in the southern and western states. MCVP was a similar program in relation to the size of the investment but had a wider focus in terms of industries and applications. MCVP for example supported major new extension projects in Victoria and in Western Australia where previously there had only been limited project-based activity. These projects will provide the base for increased adoption into the future. Similarly in the grains industry, projects created a higher profile for the program across the industry. An example is the special climate section routinely featured in the GRDC publication *GroundCover* distributed to all grain farmers.

MCVP products have also been ideally positioned to respond to the increased demand for climate risk management information stimulated by current concerns on climate change. MCVP projects on assessing the agricultural and natural resource management impacts of climate change have been important case studies for more widespread impacts and adaptation studies.

Conclusions

Over the six years from 2002/03 to 2007/08, the total investment in MCVP (excluding leverage outside the MCVP partners) has been $7.0 m in total nominal dollars. This investment has been more than matched by recipient organisations and third parties.

While there has been ongoing investment in seasonal climate forecasting outside of MCVP, the investment has undoubtedly contributed to an increased awareness of opportunities for Australian farmers, and natural resource and water managers to better manage climate risk. Based on a conservative extrapolation of the survey trends from five years ago, it is expected that seasonal climate forecasts are now taken account of by more than half of Australian primary producers.

Most of the improved decision making that has resulted has increased profits in agriculture. Other benefits, current and potential, also exist in the form of a reduced variability of income and in improved natural resource management, particularly in relation to the maintenance of groundcover. The resulting benefits will include improved water quality and biodiversity.

Making better informed use of seasonal climate forecasts continues to be a key strategy of the program. Projects such as 'Masters of the Climate' are demonstrating that farmers managing in a highly variable climate often need many years of exposure to learn to make better use of seasonal climate forecasts. One of the key learnings for some participants was the need to move away from using a seasonal climate forecast to 'pick winners' and adopt a more basic climate risk management approach that could be readily updated as the season progressed. A key aspect was the need recognised to ensure some degree of protection whatever the outcome.

An attempt has been in this economic evaluation to estimate the economic benefits and hence investment criteria for the MCVP investment. Results show that the returns to the investment are positive but less than that achieved by CVAP. The Net Present Value of the MCVP investment (without leverage) is about $5.6 m providing a benefit-cost ratio of 1.7 to 1 and an internal rate of return of 10.6%.

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Appendix 2: Example of Analysis of Natural Resource Management Benefits from Seasonal Climate Forecasts

Introduction

Past analyses of R&D investment in climate variability have recognised a range of implications for natural resource management and environmental sustainability from use of seasonal forecasts. These have been described in a qualitative manner and have related mainly to reduced land degradation due to earlier destocking on pastoral properties due to forecast information and improved water storage management. This analysis is of a regional approach involving a Catchment Management Authority and the use of a Cover Alert to trigger destocking decisions by pastoralists when the Cover Alert reaches critical levels.

The benefits valued in previous grazing analyses, for example Ash et al (2000), have been estimated from improved net income of pastoralists due to stocking rate management and destocking and restocking decision making. While this is regarded usually as a private benefit to the land manager, such benefits also are likely to represent a higher level of sustainability of the pastoral operation due to reduced land degradation. Hence it could be argued that the increased net income estimated also avoids not only a future private income decline, but also captures some longer term sustainability impact that might benefit the public. Over the last few decades the community has been placing increasing value on environmental benefits.

Longer term benefits are often perceived by the community and by the land manger as temporal externalities in the sense that the decision makers are not the beneficiaries. This perspective is particularly relevant for leasehold land. Spatial externalities or off-site impacts are also relevant. There can also be on-site impacts on biodiversity which the community may value more highly than do land managers. As in the case of temporal externalities there may be no economic incentive to reduce off-site impacts or improve biodiversity. In this analysis, the emphasis on a catchment perspective and the community support to use that perspective to minimise negative externalities are the key drivers.

The current cost benefit analysis (CBA) attempts to more specifically value the natural resource management benefits, rather than have them viewed as an adjunct to, or embedded in, the mainstream improved net income benefits. The rationale is the promotion of a monitoring process for plant cover – a key indicator of degradation potential and biodiversity value. Alerts based on a well-validated forecast on when catchment cover is likely to decline below the 40% level critical for maintaining the pasture resource are more likely to be accepted and acted on by land managers where there is a clear incentive to be part of a community-wide effort towards more sustainable catchment management.

The response to Cover Alert can be valued therefore in terms of two benefits: the private benefit to the landholder and the environmental or societal benefit. Both are considered drivers of the changed decisions by pastoralists. There will of course be much variation in how managers perceive the distinction between the two benefits.

Investment Description

While the investment considered in this analysis is an actual investment made under MCVP1, it can be viewed as an illustrative example of the potential for NRM benefits being derived from more advanced SCF applications.

The investment analysed is that for DAN 19 entitled "*Climate science for better NRM in western NSW*". The project will not be completed until mid 2007 so that a number of assumptions have had to be made on how the results will translate to an operational system.

The objectives of the project were to:

1. Develop a capacity to predict regional trends in total ground cover, and provide early warning of potential degradation events, by linking AussieGRASS products and seasonal climate forecasts.
2. Demonstrate the potential of the PaddockGRASP model to support sustainable NRM at the property level.
3. Develop protocols to allow the Paddock GRASP model to be readily parameterised for individual properties.

This analysis is of Cover Alerts issued regionally rather than the second and third objectives refining tools for use by individual property managers. The early warnings of cover were a key part of the approach by the Western Catchment Management Authority to prevent soil erosion. The NSW Western Division has experienced major degradation episodes from overstocking and drought over more than a century. Research on more sustainable management practices and increased awareness of the impacts has contributed to a generally upward trend in landscape health in recent decades (Condon, 2002). The DAN 19 project aimed to provide the necessary evidence to support the CMA approach to maintain the trend. The Western CMA Draft Report states: '*Ground cover is a key indicator of landscape health. It reflects on grazing pressure, provides protection against erosive forces and provides habitat. 40% of designated cover is supported as a key threshold for soil protection by numerous erosion studies on both wind and water erosion.' (http://www.western.cma.nsw.gov.au/)*

Leys (1992) has shown that maintaining 40% cover is critical in preventing soil erosion. It is recognised that there will be extreme drought periods when cover inevitably will fall below 40%. However grazing pressure would generally be reduced in advance by early intervention to manage and reduce the impact.

Investment Costs

Table 1 presents a summary of the investment made in DAN19. The costs include both the MCVP investment and "other funding" from external sources such as in-kind support from the researchers. NSW Departments of Primary Industries and Infrastructure, Planning & Natural Resources contributed the major share of funding under 'Other Contributions'.

Table 1: Summary of Investment Costs for DAN19
(nominal $ terms)

Year	MCVP	Other Contributions	Total
2004/05	57,275	89,380	146,655
2005/06	75,558	184,638	260,196
2006/07	47,167	186,998	234,165
Total	180,000	461,016	641,016

Principal Outputs and Outcomes

The main initial outputs of the project are the equations for each of the main pasture types relating total dry matter (TDM) to ground cover. The TDM data for an operational system will be sourced from the AussieGRASS simulation model which has already been extensively validated for the pasture communities of Western New South Wales. AussieGRASS can then provide an additional output of estimated cover based on the equations. The Appendix shows the close agreement between measured sample and simulated TDM for the region. The agreement will give potential users confidence in the credibility of the Cover Alerts.

As also shown in the Appendix, the relationships developed between Cover and TDM have been used to check the relationship between measured cover for sampled sites and simulated cover based on specific relationships for each pasture community.

TDM levels of about 1,000 to 1,500kg/ha with 40-60% cover have been typical regional average values during the 1990s. During recent drier years typical values have been about 400 kg/ha and 40% cover. As TDM decreases below 400kg/ha % cover decreases rapidly to zero.

The operational output will be maps and other means of communicating estimates of current and forecast ground cover for Western NSW. The estimates are likely to also be in terms of the risk of cover falling below critical levels. The estimates will take into account the current levels of TDM, soil moisture, and the seasonal rainfall forecast. Actual regional stocking rates are also taken into account to some extent. The AussieGRASS model is also updated with regional information on livestock numbers and other sources of grazing pressure but there can be some lags involved.

The Western CMA has consulted with pastoralists on the use of the cover indicator as a catchment target. Inevitable shortcomings of a broad scale approach were recognised along with acceptance of the positive value of the concept in contributing to more sustainable catchment management. The impact of kangaroos as a major part of total grazing pressure was one issue raised in terms of reduced benefits from destocking domestic livestock.

The project outcomes are the benefits accruing to pastoralists and the community from early intervention by destocking to maximise the period of time when cover is maintained above the critical level of 40%. The Western CMA recognises that, for periods of time, cover levels may fall below 40% and they state '*Agricultural production and economic information demonstrate that there are improved economic returns achieved from grazing at lower stocking rates*'. In addition, environmental benefits will accrue from maintaining the land in a state where it is not irreversibly degraded with an associated loss of soil, biodiversity and landscape aesthetics.

Benefits

Economic

The economic benefits from the investment will be improved destocking and restocking decisions resulting in reduced financial losses, particularly in drought years, and therefore higher long-term average profits and reduced variability of profits. This benefit may also be associated with increased long-term productivity of the land under management and hence with the maintenance of long-term carrying capacity for farms in western NSW.

Environmental

The principal environmental benefit from the investment will be improving the condition and sustainability of soil and pasture resources in the Pastoral Zone, particularly through critical drought years. Previous simulation analyses of grazing systems have included performance criteria relevant to soil loss and pasture utilisation. In a different native pasture environment Ash et al (2000) concluded that increased animal production derived from applying a forecast is not at the expense of the resource base. Also, if the aim was more to reduce production risk rather than increase production, significant reductions in soil loss could be achieved.

Social

The principal social benefits from the investment can be described as:

- Reduced stress for woolgrowers in the Western Division of NSW from more informed processes in decision making and assisting more decisive decision making and planning ahead
- Improved personal capacity of land managers to manage climatic variability and adapt to climate change

A summary of the different types of benefits derived from the improvement in destocking decisions from use of Cover Alert information is provided in Table 2.

Table 2: Summary of Triple Bottom Line Benefits for Investment in DAN19

Economic	Environmental	Social
Increased gross margin from early destocking stimulated by Cover Alert	Reduced level of degradation of Western Division grazing lands resulting in less soil erosion, improved biodiversity and improved landscape aesthetics	Reduced stress and improved understanding and capacity to adapt and cope with impacts of drought, climate change and environmental degradation.

Quantification of Benefits

Cost of Delivery of Cover Alert

It is assumed there would be an annual operating cost of $20,000 per annum for delivery of the Cover Alert information.

Productivity Benefits

The expected value of productivity benefits due to the improved ground cover warning system leading to earlier destocking is estimated at about 3% of the Gross Margin for a grazing enterprise or $0.18 per ha per annum for Western Division grazing lands (see Appendix for detail). This is the additional benefit expected to be derived over and above that can be obtained from using AussieGRASS. The region includes 27.3m ha of grazing lands, mainly for sheep and to a lesser extent cattle and more recently some increase in managed goats. Grazing lands are 84% of the region so their status dominates landscape health in the region.

The ground cover warning or Cover Alert is expected to be issued when the forecast Cover Alert, at times over a coming period of up to six months, has a high probability of being below the critical level of 40%. This is the target level adopted by the Western CMA based on evidence in the region.

The following assumptions on which the analysis were based were provided based on experience in the region (Hacker, pers. comm., February 2007) and expectation that the Cover Alert will be widely promoted by the CMA.

- part, say 10%, of the WD is affected by 'moderate' drought (say 1-2 years duration) every year
- severe drought affecting 90% of the WD is experienced for 5 years every 40 years
- early warning of an impending soil degradation event, publicised through the CMAs, results in early destocking of an additional 10% of the affected area initially, rising to 30% after 10 years

These assumptions build on current rates of destocking assumed as a result of previous projects, particularly AussieGRASS and the Land Water and Wool project trialling and promoting seasonal climate forecasts in the western region.

The above assumptions have been simplified and used in the Appendix in conjunction with an estimate of the accuracy of forecasts to determine an overall indicative benefit from responding to the Cover Alert by destocking. The likely benefit includes both short term productivity changes and longer term benefits from maintaining the productivity of the pasture resource. The productivity benefit and recognition of the broader benefits to the catchment would be important drivers of adoption of the Cover Alert.

There are numerous uncertainties and many assumptions involved in estimating changes in productivity in grazing enterprises. Destocking in the event of a likely drought period aims to avoid likely greater losses if stock were carried through a drought and also to protect the pasture resource from overgrazing and a possible cumulative decline in productivity. There have been comprehensive studies using pasture simulation models which go some way to capturing some of the reality. Forecast accuracy is such that there will be some years when a Cover Alert is issued but actual cover does not reach critical levels. The converse is also true. The Appendix presents a much-simplified approach which does at least illustrate some of the key features.

Environmental Benefits

There are also expected to be significant environmental benefits from maintaining ground cover above a specific level. These benefits relate largely to maintaining the land in a state where it is not irreversibly degraded with an associated loss of soil, reduced offsite impacts from soil erosion, reduced biodiversity and landscape aesthetics (e.g. the loss of shrubs and the development of permanent clay pans). Another way of interpreting this benefit is preserving the options value of the land for future generations, for example for pastoralism, tourism etc.

A study by Van Bueren and Bennett estimated the willingness to pay (WTP) for improved landscape aesthetics. This choice modelling study valued the WTP of Australian households for rehabilitating degraded land on a per ha basis. This value ($0.07 per 10,000 ha per household per annum for twenty years) is used in the current analysis and assumes to apply to ‘avoidance of degraded land’ considered a surrogate for ‘countryside restoration of degraded land’.

However, the choice modelling study refers to the countryside aesthetics as relating strongly to dryland salinity where high levels of productivity were lost or at risk. Hence, due to the extensive nature of the Western Division pastoral lands, their low productivity and general absence of salinity, transferring this benefit to the Western Division requires a significant reduction.

The early destocking expected to be driven by Cover Alert is unlikely to avert 100% degradation and is unlikely to restore it to its original state. Hence, any benefit transfer from the study referred to here will require a significant reduction in the WTP value.

Based on the arguments above a correction factor of 0.01 has been applied to the value of $0.07 per 10,000 ha per households.

This benefit is assumed lagged seven years compared to the productivity benefit, that is, the environmental benefit first commences in 2014/15 rather than in 2007/08.

A summary of the assumptions made is provided in Table 3.

Table 3: Summary of Assumptions for Investment Analysis for DAN19

Variable	Value	Source
Relevant land areas		
Area of land in Western Division of NSW	32,500,000 ha	Ron Hacker, NSW DPI
Area of grazing land in Western Division of NSW	84% of 32,500,000 = 27,300,000 ha	Ron Hacker, NSW DPI
Area of grazing land initially responding to Cover Alerts	10% of 27,300,000=2,730,000 ha	Estimate by Ron Hacker, NSW DPI
Area of grazing land responding to Cover Alerts after 10 years	30% of 27,300,000 = 8,190,000 ha	Estimate by Ron Hacker, NSW DPI
Productivity benefits		
Benefit from earlier destocking driven by Cover Alert	40 year simulated income series (average increase of $0.18/ha per annum in gross margin per ha for sheep in the Western Division of NSW	Estimate by Barry White based on data provided by Ron Hacker
Commencement of benefits	Three years after initial investment (that is in 2007/08)	Agtrans Research
Environmental benefits		
Value to Australian households of rehabilitating degraded land	$0.07 per 10,000 ha for twenty years	Van Bueren and Bennett (2000 and 2004)
Value to Australian households of avoiding degraded land	$0.07 per 10,000 ha for twenty years	Agtrans Research based on value of rehabilitation
Number of households in Australia	7 million	ABS
Aggregation factor	0.45	Van Bueren and Bennett (2000)
Area that avoids degradation (due to DAN19)	10% initially rising to 30% of grazing land after 10 years	Estimate by Ron Hacker and Barry White
Dilution factor relating to the extent of Western NSW and its relative 'sameness'	0.01	Agtrans Research
Commencement of benefits	Ten years after initial investment (that is in 2014/2015)	Agtrans Research

Results

The resulting investment criteria for the prospective analysis are presented in Table 4. The period of analysis was for 40 years after the first year of investment. The results are expressed in 2006/07 $ terms and all benefits and costs are discounted to the 2006/07 year. A discount rate of 6% is used for all analyses

Table 4: Investment Criteria for Investment in DAN19 by Type of Benefits and Costs Included
(Discount rate is 6%)

Criterion	All Benefits and All Costs	MCVP Benefits and MCVP costs
Present value of benefits ($m)	17.54	4.96
Present value of costs ($m)	0.69	0.20
Net present value ($m)	16.85	4.76
Benefit-cost ratio	25.3 to 1	25.0 to 1
Internal rate of return (%)	9.3	9.3

Sensitivity Analysis

The sensitivity of the investment criteria to the percentage of grazing land area benefiting is shown in Table 5.

Table 5: Sensitivity of Investment Criteria to Percentage Grazing Land Area Benefiting (MCVP investment)

	Discount rate 6%		
	Base value 1%	**Medium Value 5%**	**Base value 10%**
Present value of benefits ($ m)	0.42	2.44	4.96
Present value of costs ($ m)	0.20	0.20	0.20
Net present value ($ m)	0.22	2.24	4.76
Benefit-cost ratio	2.1 to 1	12.3 to 1	25.0 to 1
Internal rate of return (%)	7.3	9.0	9.3

Conclusions

This investment has delivered both productivity and environmental benefits. Given the assumptions made the averted land degradation benefits contribute 68% of the total benefits and the productivity or private benefits some 32%.

The productivity benefits are exceptionally difficult to estimate. The project does not conclude until mid-2007. The outputs are likely to be strongly promoted by the Western CMA and this supports a high rate of adoption. The acceptance of seasonal forecasts as part of the Cover Alert is likely to be high given the high level of awareness of seasonal climate forecasts promoted through previous projects. Although the benefits of early destocking as a drought strategy are widely recognised in the region, the benefits are highly probabilistic, therefore variable and their estimation is difficult in a simple analysis. They depend on many assumptions on pasture productivity and on volatile livestock prices determining buying and selling transactions.

This past investment has shown that, given the assumptions made, the environmental values of the outcomes from early destocking due to the improved drought alert system are likely to be quite significant. However, difficulties exist in transferring the benefit estimate from an earlier WTP study. The confidence in the final value estimated is somewhat low.

Acknowledgements

Gratitude is expressed to Ron Hacker, NSW Department of Primary Industries, Trangie, NSW.

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Appendix: Estimating Benefits from a Ground Cover Alert Forecast for Western NSW

Barry White

This appendix summarises the calculation of the net benefits from implementing a Cover Alert Forecast. The benefits are required over a 40 year period as input to the Cost Benefit Analysis. The operational details for forecast development are currently being developed. Therefore the following is illustrative of how the system might operate and of the operating characteristics in terms of profitability and impacts on the status of the pasture resources. The example chosen is for a winter forecast based on the SOI, a time when El Niño begins to have a major impact on rainfall expectations.

The 'Betting on Rain' publication shows probabilities of exceeding median pasture growth for Western NSW (Hacker et al 2006). The probabilities are based on the pasture simulation model AussieGRASS. For example from June to September the chance of above median rain in the following three month season is typically only about 20-30% for the SOI Negative phase (indicative of an El Niño); similarly for pasture growth forecasts based on the analogue years with the SOI Negative phase. Generally pasture growth forecasts show an amplified signal compared with rainfall forecasts. Typically for pasture growth forecasts based on the analogue years with the SOI Negative phase there is about a 20% chance of above median pasture growth. The 20-30% chance is an historical average for all the years in the phase and also across the range of initial conditions at the beginning of the quarter. If the current year to date had been drier than average, the forward forecast will reflect that.

The example will consider a Cover Alert forecast based on the SOI and the pasture growth simulation. The forecast will trigger destocking. The example will estimate the possible impacts on profitability including from any decline in the condition of the pasture resource. The cover relationship with total pasture dry matter has been developed for a range of pasture communities. Figures 1 and 2 show the agreement between modelled and actual pasture dry matter and cover for the Western Catchment Management Area. The Cover Alert is based on the chances of Cover % falling below the critical 40% level over the period ahead. The critical level is based on research on pasture communities, including some in the region, by Leys (1992). The response to a Cover Alert is assumed for simplicity to be destocking although several other responses such as some feeding in sacrifice areas and agistment are often used when circumstances warrant.

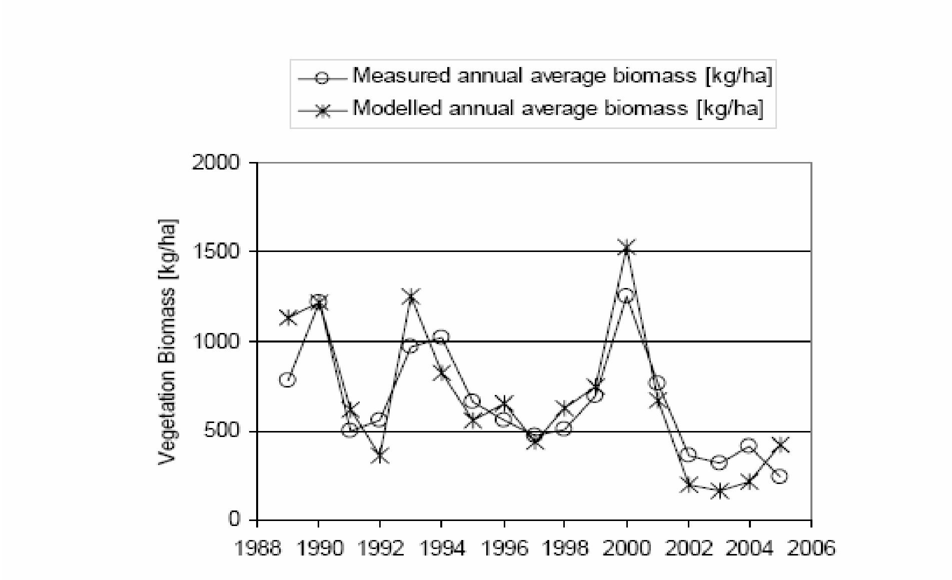

Figure 1. Annual average vegetation biomass (Total dry matter/ha) for the Western Catchment Management Area from AussieGRASS modelling and from the Rangeland Assessment Program (RAP) comprising 334 monitoring sites (NSW DPI, 2006).

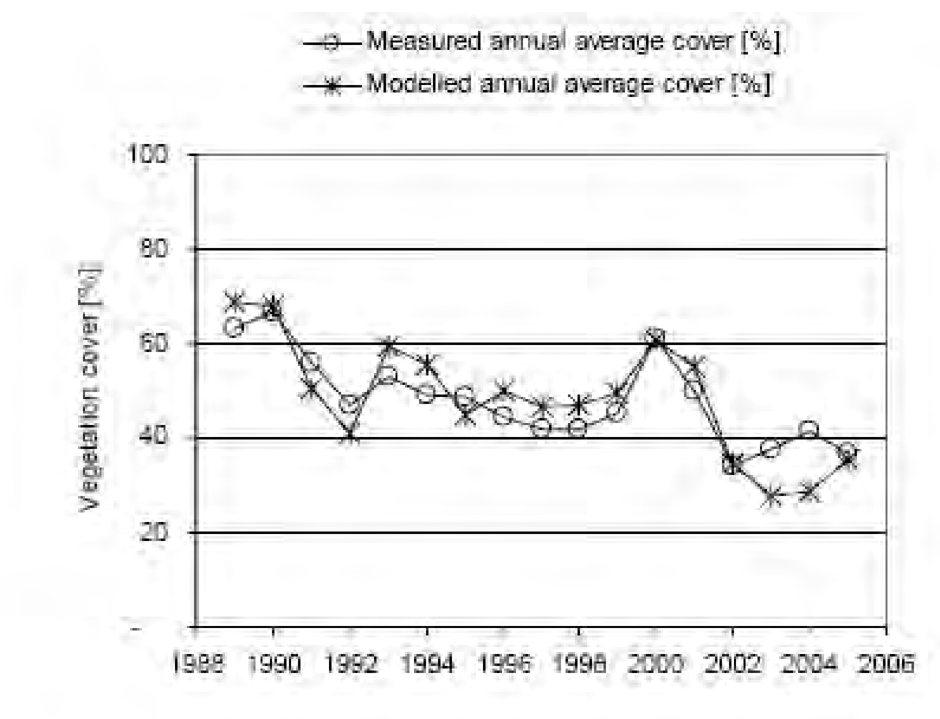

Figure 2. Annual average cover for Western Catchment Management Area from AussieGRASS modelling and from the RAP sites (NSW DPI, 2006).

The Cover Alert is implicitly also a pasture drought forecast, as it may reflect the current pasture and soil moisture conditions as well as the rainfall outlook. Information is not yet available on how the system might perform operationally in terms of the accuracy of the Alert so these will be estimated by the forecasts for rainfall. There will be years when no Alert is issued because the chance of the Cover Index falling below the critical level is low. In some years drought will eventuate but no Alert was previously issued. In that situation when rainfall is lower than expected for example, the Cover Alert Index will actually fall below the critical level, but no Alert will be issued.

There are actually four possible outcomes and impacts if an Alert is issued as shown in Table 1. These impacts need to be compared with the impacts if no Alerts are issued to assess the net benefits of the Alert system. The overall economic impact depends on the magnitude of the costs involved and their frequency.

Table 1: Scenarios and Impacts for a Cover Alert System

Outcome: Cover becomes critical	**Cover Alert Issued**		**No Alerts Issued**
	YES	NO	
YES	Destocking (drought)	Lower Income. Resource decline	Lower Income. Resource decline
NO	Destocking (no drought)	Normal Income. Resource decline	Normal Income. Resource decline

The productivity of the pasture resource will be impacted by both a current drought and previous drought exposure. The analysis assumes that if destocking always occurred prior to a drought event, then there would be no resulting drought decline in productivity. On the other hand even with a destocking strategy, there will be droughts not forecast and that will result in a stepped decline in resource productivity.

The impacts are based on a simple two-way classification. Droughts can be defined in many ways ranging from a severe and relatively rare drought definition to a less severe more frequent event. The frequencies (Table 2) have been estimated by assuming (based on local experience) that droughts for this purpose have an average frequency of about one year in four and that Cover Alerts will also be issued at the same frequency. Alerts under this assumption would be at about the same frequency as El Niño events. Many of the alerts will therefore also be in response to an El Niño forecast.

Hacker et al (2006) have shown that from mid year the probability of above median pasture growth is of the order of 20 to 30% across much of western NSW when the SOI is in a negative phase indicating an El Niño situation. To coincide with the period of high skill in El Niño forecasts, the Alert is assumed to be issued at the end of June to trigger destocking for a six month period. Some alert forecasts may result from a gradual decline in cover following a period of a few years of lower than average rainfall. Stocking rate will also be a factor. A forecast accuracy of 75% is assumed similar to the conditional accuracy of a pasture growth forecast. The two assumptions define the rest of the table. To keep frequencies as whole numbers, a total of 32 years operation needs to be considered.

Table 2: Frequency of Alerts Being Issued and their Outcomes

Outcome: Cover becomes critical?	**Cover Alert Issued?**		**No Alerts Issued**
	YES	NO	
YES	6	2	8
NO	2	22	24
Total	8	24	32

The economic impact can be determined by subtracting income in the 32 'No Alert Issued' years from that in the 32 years when a Cover Alert system was in place. A clear positive for a Cover Alert System are the reduced years of resource decline; only two years compared with eight for 'No Alerts'. The impacts of the events are cumulative so eight droughts are likely to have more than four times the impact of two droughts.

The major disadvantage for the Cover Alert system is likely to be the two years when destocking took place but was not followed by a critical cover outcome.

Table 3: Cost and Benefit Data

Average gross margin (grazing, half year, $/ha)	3.18
Gross Margin if destocking/restocking (grazing, half year, $/ha)	-2.40
Gross Margin factor for half year, No destocking, Cover alert Issued No destocking, No Cover Alert Issued	 0.75 1.08
Resource decline in productivity/drought event without restocking (%)	7

Given the assumptions in Table 3 and the frequencies in Table 2, the net impacts from implementing a Cover Alert system can be estimated from a simple simulation over the 32 year sequence. (The results for the final eight years were repeated to form the 40 year series required for the Cost Benefit Analysis). In this simplified analysis the net benefits arise from only one source – the less rapid decline in resource productivity resulting from reduced impacts of drought because destocking took place. The less rapid decline has to offset the lost income and the transaction costs involved in destocking including the cost of restocking after the six month period of the Alert is finished. A more complex analysis would need to consider rehabilitation costs for the case where no destocking takes place and productivity is substantially decreased in the long term (Green D., pers comm.).

For the 40 year period the average advantage of the destocking option, given the assumptions, is $0.18/ha or about 3% of the annual gross margin. On an annual basis the difference is small but more significant considering the difference arises from a half year period on average every four years. The time path of the benefits is typical of many investments in maintaining resource productivity. In the early years benefits are either zero or negative because of the lost income from destocking. It is not until later in the analysis that the benefits from avoiding the decline in productivity make a large enough difference for the overall strategy to be profitable.

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Appendix 3: Prospective Analysis of Increased Forecast Skill

Introduction

Surveys typically show that about one half of Australian farmers take seasonal climate forecasts (SCF) into account in their farm decisions. The principal reason given for not using SCF has usually been that, based on their experience, farmers considered the forecasts were not valuable because they were not accurate enough.

The National Research Priorities include '*Responding to climate change and variability*'. With climate change uncertainty emerging and increasing, the demand for improved information for climate risk management is likely to continue to increase. There is therefore compelling justification to assess opportunities to improve how Australians respond to the linked challenges of climate change and climate variability. Improved SCF are one of the most promising avenues to better adapt to an increasingly uncertain future.

Further investment in improving SCF therefore needs to evaluate the likelihood of improvement in accuracy that will lead to value from the farmer's perspective. Terminology will first need to be clarified before conducting a brief review of the current SCF available to farmers and of some of the issues that have been part of their development and application.

Seasonal forecasting stems from a basic need as old as humanity: to reduce uncertainty about the future. Scientific understanding of climate at the seasonal time scale developed from the late nineteenth century and accelerated from the mid 1980s, particularly in response to the 1982-83 El Niño event. From the mid 1980s statistical approaches were complemented by the development of a wide range of climate models either developed or adapted for seasonal forecasting. In Australia Nicholls (1983) demonstrated the scope to forecast droughts using statistical techniques. CSIRO also expanded their climate research program to further develop numerical models of the ocean and atmosphere to predict droughts (Voice and Hunt 1984). The following sections briefly review the evolution of the science and its application over the last century to help in evaluating the most likely avenues for further investment.

There are many approaches and varying opinions on the attributes of a good forecast. (Murphy, 1993). For example improved skill may not translate into increased value to users if the forecast is not well matched with user needs and delivered accordingly.

<u>Accuracy and skill</u> – Accuracy to a forecast user is simply the relationship between what was forecast, or thought to be forecast and what happened. The ease and usefulness of a measure of agreement clearly depends on how precise the forecast is, and how precisely the outcome can be measured. The two main SCF in use in Australia issue forecasts in map form every month of the percentage chance of rainfall for a location being greater than the median over the next three months (For convenience this forecast will be described as a GTM3 forecast). A typical forecast might be 70% GTM3. The most

typical (and not entirely accurate given it is a probability forecast) interpretation of accuracy is then to describe a forecast as accurate - a hit if rainfall is above the median, otherwise inaccurate because the outcome is a miss.

Comparisons of the forecast and the outcome for one event will be inadequate for an assessment of performance over time. How well a forecast performs on a hit or miss basis can be assessed by a skill measure of how well the forecast performs compared with the next best forecast available. Usually this evaluation is done by comparing the skill of a forecast system with what historical probabilities show (climatology). If only climatology is available, then there is a 50% GTM3. A simple skill index would then range from zero for a system no better than climatology to 100 for perfect knowledge. To avoid artificial skill that can readily arise from statistical forecast systems, skill is ideally based on independent verification of actual forecasts made after the system was developed. This assessment of an investment in SCF is built around a consideration of the skill of current forecasts and how that might be increased.

Forecast skill and value - There is a wide range of measures of forecast skill depending on the particular feature of a forecast of interest. The measure chosen for this analysis is one of the simplest and one of the easiest to understand. There are also many approaches to assessing value which depends on a further set of factors relating to how the forecast is communicated, and how the forecast relates to the user decision making process. This assessment will short cut detailed consideration of forecast value in favour of a direct approach which simply links forecast skill and the extent to which farmers take forecasts into account in decision making.

A Historical Perspective on the Development of Seasonal Climate Forecasts

A: Using statistical approaches

Any new investment can learn from experience with previous approaches and from an understanding of the changing constraints to improved forecasts. The current statistical approaches for the most widely used SCF have a lengthy heritage over the last century. Quayle (1910,1929) in a precursor of the Southern Oscillation approach linked northern Victorian spring rainfall with Darwin winter atmospheric pressure. An update by Treloar and Grant (1953) foreshadowed one of the concerns with the subsequent SOI-based approach. Correlations had decreased and this was attributed to a problem typical of statistical schemes, thought to be not well grounded in theory. Any relationship developed from the wide choice of climate predictors available will be subject to over fitting, and particularly where data is from a short series. But the Quayle relationship can now be seen as what would be expected given current understanding of the SOI. Furthermore and as reviewed by Allan (1996), later studies showed changes over time in the strength and usefulness of the relationship between the SOI and seasonal rain and historical relationships were not unusual and were related to decadal patterns of variability in sea surface temperatures (SST).

The eventual recognition in the mid twentieth century of the coupling between the SOI as an atmospheric indicator and El Niño as an ocean indicator was the next significant breakthrough in the understanding of what is now termed ENSO (El Niño Southern Oscillation), the main known source of Australian climate variability. Droughts in the 1960s, major floods in the 1970s and what was widely recognized as an El Niño drought in the early 1980s all contributed to a renewed interest in an operational SCF. The first simple models to forecast El Niño development appeared in the mid 1980s. The Bureau of Meteorology (BOM) eventually released an SOI-based rainfall forecast in 1989. Prior to that, agricultural researchers in Queensland had been doing much of the pioneering work showing the value that could be obtained from even modest forecast skill.

A variation, the SOI five phase system (Stone and Auliciems, 1992) was also widely promoted particularly in Queensland (currently issued monthly by the Queensland Department of Primary Industries and Fisheries). Subsequently, there were arguments advanced and perceptions developing that SOI-based forecasts had limited value in southern and western regions of Australia. Hayman (pers comm.) has shown that this was not supported by the long-term hindcast evidence in southern Australia although some evidence of a period of low forecast skill was evident during the 1990s in parts of Victoria. But there was strong support to develop a new improved forecast to incorporate emerging knowledge on the role of sea surface temperature changes in the Indian Ocean. With funding from a previous phase of the Managing Climate Variability Program (MCVP), the BOM developed new forecasts based on SST anomalies in specific regions of the Indian and Pacific Oceans. The rainfall forecasts were issued from October 1998 and the temperature forecasts from February 2000. Seasonal temperature forecasts are acknowledged as more skilful than rainfall, not surprisingly given the reduced variability of temperature patterns compared with rainfall.

The potential to improve SCF was reviewed by Drosdowsky and Allan (2000). They concluded that there had been constraints before that time but these were now much reduced. Improvements had been restricted by the lack of:

- Long series of data,
- Adequate statistical methodologies,
- Computing power, and
- Scientific knowledge of underlying mechanisms.

Over the last two decades there have been many attempts to develop new SCF using statistical approaches. Some have performed better than expected by chance when tested by rigorous cross –validation approaches but none have appeared as likely to displace existing approaches.

Drosdowsky and Allan did identify three possibilities for further development of statistical approaches. They were:

- Different target seasons, for example the 30-90 day ‘intraseasonal oscillation’ now developed operationally as the Madden-Julian Oscillation (40 day wave),
- Increased lead times, however it has now been confirmed that for most seasons and locations SOI-based skill declines rapidly, and

- Predictions of parameters other than rainfall, already achieved for temperature forecasts and for other key agricultural variables such as wheat yields but limited by skill.

The last point is particularly important in demonstrating relevance and value of forecasts to users of forecasts. Experience has shown that the transfer process needs to be embedded in the SCF research process. The information that influences decisions can range from the basic probability forecast to a forecast interpreted for example in terms of wheat yields for particular locations. There can be substantial increase in forecast skill when the decision variable represents an integration of rainfall over a three month forecast season. McIntosh (2005) showed that even a perfect rainfall forecast was not as skilful as a forecast of days of pasture growth using a simple simulation model.
In summary, efforts to develop improved statistical approaches have a long history with no major changes in the last two decades. The absence of any marked improvement can not simply be attributed to any major constraints. Therefore there is no case in general for significant funding of new statistical approaches. Some flexibility to fund specific applications on their merits may be justified from time to time.

B: Using Climate Modelling Approaches
Since the mid-1980s many models have been developed by research institutions around the world to forecast the development of El Niño as measured by SST in the eastern equatorial Pacific. Outputs of these models have generated much media interest and inevitably some confusion given the number and variety of the forecasts. A major limitation has been that users are left to interpret the implications for rainfall at a particular location given a probability of an El Niño developing. (This involves combining two probabilities in ways that are not intuitive).

Coupled models of the ocean and atmosphere have sought to overcome limitations of the simpler models. Initially ocean modelling was constrained by the limited data available. There has been a rapid increase in the range and quality of ocean data in recent decades.

Over the last two decades seasonal forecasting has increasingly become a spinoff benefit from climate modelling with predominately climate change or weather forecasting objectives. Over that period the main research agencies were the BOM and the CSIRO Divisions of Marine and Atmospheric Research (now amalgamated as DMAR). The research over the early part of the last two decades had been fragmented and essentially of a basic or strategic nature as evidenced by the very limited application of seasonal forecasts from any of the modelling programs.

Following the initial funding by the Australian Government in 1989, research on climate change became a major priority for climate research. The aim of the Greenhouse Research Program was to improve Australia's capability for the prediction of regional climate change. Improving the core modelling capacity of CSIRO and BOM was a major focus of the core program. In 2004 the Australian Government announced renewed program funding of $30.7 million over four years. The effect of this funding is magnified by contributions of equal value from partners, CSIRO and the BOM.

During the 1990s the Climate Variability in Agriculture Program (CVAP) gave some SCF priority to strategic ocean research and to projects that integrated and efforts between the three major climate research agencies. The ocean priority was aimed at accelerating understanding of the Indian Ocean and how it impacted on Australian rainfall variability. CVAP also was a part funder from 1999 to 2001 of the POAMA model, the Bureau's current operational dynamical seasonal prediction system. This system was developed jointly with CSIRO Marine Research and consolidated expertise in ocean modelling. The model couples the atmosphere and the oceans and to date has been mainly used for long-range forecasts of El Niño development.

The POAMA-1 forecasting system performs well and forecasts are as good as, if not superior to, other models (Bureau of Meteorology, 2006). The POAMA forecasts were the first to predict the rapid decay of the 2002/3 El Niño. New versions are being released to forecast new products including, for the first time, Australian rainfall. A statistical/bridging approach will be used as a simpler alternative to downscaling that would be required because of the resolution of the atmospheric model.

The concluding MCVP includes two major continuing projects on SCF, one on forecasting the northern wet season and the other the southern grain regions. The southern project aims to advance SCF from coupled models as part of the South-Eastern Australian Climate Initiative (SEACI), a collaboration between the Murray Darling Basin Commission (program managers), the Australian Greenhouse Office (AGO), the Victorian Department of Sustainability and Environment and MCVP through Land and Water Australia. Research providers CSIRO and the Bureau of Meteorology are providing matching support, bringing the total value of the research to just over $7 million over 3 years finishing in 2008.

The SEACI project has themes on the current climate, climate change, and SCF. The forecasting theme will assess:

- skills of different types of forecasts (dynamical, statistical-physical and hybrid) at different lead times and forecast periods compared with current forecasts;
- applications forecasting crop yields and stream flow and involving downscaling.

The above projects involving coupled modelling for SCF are only a small part of major Australian research activity on the use of coupled models, particularly operations and research with a weather or climate change focus. Activities are being increasingly rationalised and coordinated through the Australian Community Earth System Simulator (ACCESS), an initiative involving the AGO, CSIRO, BOM and Australian Universities.

ACCESS is essentially a framework to reduce duplication and develop key generic modules of value for different applications. For example, many of the components of future POAMA versions for SCF are now being developed as part of the ACCESS project. Other ACCESS stakeholders are heavily dependent on ocean modelling. Thus some POAMA activity on ocean modelling is essentially generic and some is undertaken specifically to advance SCF. POAMA develops also by taking tools from ACCESS and adapting and combining them as needed for POAMA.

Overall the ACCESS goal of a comprehensive climate and earth system simulator requires the coupling of component model codes together including those for the ocean and sea ice, the atmosphere, and the land surface. Contributions to the Fifth Assessment by the Intergovernmental Panel are a high priority. A major advantage of ACCESS is that the framework makes it much simpler to achieve coordination internationally.

ACCESS should provide a world class climate modelling system for Australian applications including for example the main drivers and forcings which affect Australia's climate. Drivers include ENSO and MJO (Madden Julian Oscillation). Forcings include aerosols, ozone and greenhouse gases.

Investment Rationale

A priority investment is proposed that will contribute to the National Research Priority '*Responding to climate change and variability*'. The demand for improved information for climate risk management is likely to continue to increase. Improved SCF are one of the most promising avenues to better adapt to an increasingly uncertain future. The current generation of statistical forecasts will be increasingly challenged to provide Australians with adequate levels of skill in climate risk management.

The likely scale of an MCVP investment is small in relation to the Australian climate research portfolio. The only promising avenue to improve forecast is through coupled models that are dynamic representations of the oceans and atmosphere. Previous phases of MCVP have funded some of the key projects that contributed to improved understanding of the Indian Ocean and to strengthening coordination between the major agencies. POAMA was one strategic research investment by a previous phase of MCVP. Since funding ceased in 2002 POAMA has continued to slowly develop applications and is currently moving beyond promising forecasts of El Niño development to forecasts of Australian rainfall.

In the short term, the SEACI program will further develop seasonal forecasts from coupled models. There is a much expanded Australian effort on the use of coupled models, particularly operations and research with a weather or climate change focus. Recently, through the ACCESS initiative, there is now the framework and the resources to provide a world class climate modelling system for Australian applications. MCVP priorities will be covered to some extent by the inclusion of the main drivers and forcings which affect Australia's climate. ENSO is a major driver and there are forcings now of interest additional to greenhouse gases.

The knowledge base on Australia's climate is expanding rapidly. Australia has major global climate responsibilities because of its unique location. Australia is in an isolated position globally and cannot depend on spinoff from the massive research effort on climate change which inevitably is concentrated in the northern hemisphere. The increased scope of Australian climate research to include influences not previously subject to intensive research increases the opportunities for skill increases in regions and seasons additional to the current ENSO-dominated patterns. Understanding of the Indian Ocean role is increasing as data limitations are being overcome. Projects such as SEACI and the similar project on south west Western Australia (Indian Ocean Climate Initiative) have laid the base for more broadly based gains. The underlying mechanisms driving the unusual and persisting patterns of current rainfall anomalies are being sought. The patterns that have become entrenched in the last fifteen years are of major national concern. The north west of the continent has been above average and there have been persistent below average periods in the south-east, south, and south west (National Climate Centre, 2006).

MCVP is unlikely to achieve significant benefits unless it takes the initiative to lead an expanded effort. Research on climate variability and improved forecasting will not advance rapidly without external funding. The preferred strategy for MCVP is clearly to build on the existing infrastructure and to be a catalyst and lead stakeholder in a research consortium to benefit agriculture, water and natural resource managers. ACCESS is essentially a framework to reduce duplication and develop key generic modules of value for different applications and it is already strengthening the development of POAMA. An investment in POAMA will need to recognize the need to support both the underpinning generic framework and more targeted research of benefit to MCVP stakeholders.

The magnitude of the investment required is a challenge for a small program such as MCVP. There are numerous potential beneficiaries. There are strong arguments for public good funding, in particular:

- the generic nature of the research,
- the transaction costs involved in attracting funding from the range of beneficiaries, and
- the existence of free riders with no incentive to contribute.

Arguments against seeking a high proportion of public funding include delays and confusion in relation to other research agendas such as climate change. A small program such as MCVP is particularly vulnerable to resources needed for improved SCF being leveraged by other funding sources. MCVP funding will ensure that the research resources can be maintained and the outputs be targeted for maximum benefit to MCVP.

Challenges for the Next Generation of Seasonal Forecasts

In the almost two decades since seasonal forecasts based on ENSO first became available, experience has accumulated on challenges for new SCF. Seven priority specifications are listed below.

***A significant improvement in overall skill* –** current forecasts are generally regarded as of low to moderate skill. They do have considerable if occasional value in many locations when they significantly change rainfall probabilities for some months during major ENSO events. Without a significant and demonstrable improvement over current approaches, a new forecast will simply add to and compete with the current suite.

***A significant improvement in skill spatially and seasonally* –** current forecasts have skill for some months in some years. Skill is conditional. For example there may be an increased chance of a drought during an El Niño event, but that still leaves many droughts in non El Niño years where there is negligible forecast skill.

***Clearer communication of forecasts of significant skill* –** current forecasts are issued for all Australia for all months even though a majority of forecasts are essentially of climatology. New forecasts could assess advantages from limiting forecasts to areas of significant skill. For example the current SOI forecast (negative phase) shows large areas of the Murray Darling Basin with a 60 to 70% chance GTM3. However the difference from climatology is not significant (Source: Australian RAINMAN analysis).

***Forecasts delivered in formats to meet user requirements* –** demonstrations of value of SCF have relied on simulation models to evaluate alternative decisions using long term historical records of key daily climate data. There is a substantial increase in skill compared with rainfall forecasts when agriculturally relevant indicators such as wheat yield are used, similarly for streamflow. Analogue years that have a common forecast outlook have been of particular value for SOI-based forecasts. The current Bureau Seasonal Outlook forecasts have not been translated to an analogue format and that limits opportunities to assess their value. New forecasts will need to continue to provide national products of rainfall and temperature forecasts as at present and will need to be consistent with more detailed regional forecasts that may be provided by downscaling or other techniques.

***Improved skill at critical decision times and at longer lead times* –** farmers consistently seek better information in autumn for example for winter crop planting and marketing decisions. The Bureau Outlook currently has some limited skill at that time from Indian Ocean SST. Current skill overall is limited to a three month lead time which is a minimum lead time for most important seasonal decisions in agriculture, water and natural resource management.

***Forecast stability over time by the incorporation of climate change* –** current forecasts may be subject to reduced skill if their relationships have been changed by climate change given this is likely to increase. In any case, even if it is difficult to show a reduction because of limited data, the perception of a decline is likely to increase. The current forecasts may also be subject to decadal patterns as has happened with the relationship between the SOI and Australian rainfall.

***Forecasts presented to achieve seasonal and spatial coherence* –** Current forecasts can have substantial discontinuities, either spatially or seasonally that are unlikely to have a mechanistic explanation. For example maps of SCF probabilities based on limited smoothing of data generated from small historical samples can show numerous confusing outliers.

The Investment Description

The potential benefits and the range of existing activities and stakeholders justify a major collaborative project. The project will need to make an equitable contribution to the underpinning generic research effort. The project will readily build on the SCF activities being pioneered in the SEACI program.

The proposal can leverage off the major investments aimed at achieving other objectives, particularly those related to climate change.

The proposal is to build on Australia's current developing expertise in coupled models for SCF. POAMA forecasts of ENSO are as good as, if not superior to, international efforts. The POAMA forecasts were the first to predict the rapid decay of the 2002/3 El Niño. The first trial forecasts of Australian rainfall are currently being made notwithstanding CVAP finished funding in 2001. The time scales involved in model development are of the order of three year cycles, often two cycles are needed to achieve two phases of model development.

There has been considerable strategic investment in coupled models to improve SCF over the last two decades. Operational products have yet to emerge. The major new factors indicating that success is ever closer are:

a) the substantial investment in coupled models, particularly for climate change research, and
b) a rationalised national effort through ACCESS reducing duplication.

An indication of the type of investment needed can be gathered from the scope of the models and the need to include a wide range of generic and targeted projects, for example:

- investigating the impact of global warming on predictability,
- data assimilation techniques,
- how the land surface is modelled and initialised at the start of a model run,
- applying downscaling methods to the model output so that results are more relevant at regional scales, and

- improving connections with risk management tools and working with potential users to refine techniques and communication activities.

The tasks require a project of a minimum of six years duration to maximise the chances of achieving a significant difference in forecast skill. A small difference will not be enough to displace current approaches.

Investment Costs

Table 1 presents a summary of the prospective investment costs for attempting to improve the skill level of SCF in Australia. The costs are indicative and include both the MCVP2 prospective costs and "other funding" from external sources as well as in-kind support from researchers. The funding is on the basis of what is required rather than what might be achieved.

Table 1: Summary of Prospective Investment Costs by Year
for Improving Skill (2007/08 $ terms)

Year	MCVP2	Other Contributions	Total
2007/08	333,333	666,666	1,000,000
2008/09	333,333	666,666	1,000,000
2009/10	333,333	666,666	1,000,000
2010/11	333,333	666,666	1,000,000
2011/12	333,333	666,666	1,000,000
2012/13	333,333	666,666	1,000,000
Total	2,000,000	4,000,000	6,000,000

Principal Outputs and Outcomes

Outputs

- SCF at lead times of three months and longer developed from coupled models in formats suitable for major user groups in regional applications in agriculture, water and natural resource management
- National products in map form of improved forecasts for rainfall and temperature at longer lead times
- Evidence of a significant increase in skill above current statistical forecast systems
- Demonstrations of the ease of use of the forecasts in applications with simulation models used in agriculture and hydrology
- Evidence that the forecast skill is not unduly influenced by climate change

Outcomes

At the level of National Research Priorities, the development of improved SCF will make a major and unequalled contribution to the priority relating to '*Responding to climate variability*'.

Managing the season ahead is one of the major challenges for Australian farmers and water resource managers because of exceptional rainfall variability. There are few opportunities to offset the risks. Therefore improved forecasts will potentially be one of the most useful ways to reduce income volatility, increase profits and tailor operations to those more in harmony with the season. Water managers, both urban and rural will be major beneficiaries of improved SCF.

Current skill levels of forecast have been identified as the main constraint on farmers using forecasts. This proposal has shown that a significant increase is feasible and will result in increased uptake of forecasts in all major industries.

Benefits Associated with the Investment

Increased use of SCF

Farmers have continually stated since SCF were first introduced two decades ago that use of SCF is limited by poor skill and the associated lack of confidence users have in their value. Skill is used in a technical sense as a measure of the extent to which forecasts do better than a random or no-skill forecast. There is some variation in skill levels between industries because of the geographic pattern of skill. Surveys show that farmer use of forecasts is related to skill. The relationship is likely to be reinforced by higher levels of support for research and training in areas where skill is highest, for example in the cotton and sugar industries.

A simple index of current skill levels can be developed from the extent of the shift in probabilities associated with the major ENSO events which account for much of current forecasting skill. The index (range 0 –100) as shown in a later section of this analysis shows the extent to which current forecasts approach perfect forecasts. The current forecasts average 23 on the index showing they have low to moderate skill and that there is ample scope for improvement.

A 20% increase in skill is seen as a feasible output by climate researchers given a well funded project of six years duration. The relationship developed between skill and farmer use suggests that such an increase in skill would result in a substantial increase in the number of farmers using forecasts.

Improvement in profit capture

An increase in skill will increase adoption/use levels (adoption measured as the number of farmers that take the forecasts into account in their decision making). However, taking account of SCF will not always translate into additional profits. With increased skill the likelihood of profit increases occurring for those taking SCF into account will most likely increase.

No improvement in profit level

The key assumption used in evaluating CVAP and MCVP was that the use of seasonal forecast information allows average profits for those who can use it appropriately to be increased by approximately 10% per annum. The 10% was based on a range of simulation-based analyses which show optimal returns for some specific decisions when there are significant shifts in probabilities. The level has been maintained rather than increased, given that there will be new farmers involved and in new regions and industries where significant learning may be required.

NRM benefits

No explicit allowance has been made for NRM benefits because of the difficulties in estimating gains at a national level. In many cases NRM benefits are likely to be embedded with increased profitability from operations more in harmony with the season. Improved SCF for example can achieve a better balance between feed supply and demand in a grazing system. Improved ground cover, a key indicator of biodiversity, will result in further benefits. Cropping patterns more in harmony with likely soil water storage can reduce runoff and deep drainage.

A summary of the different types of benefits derived from the improvement in forecasting skill attained for SCF is provided in Table 2.

Table 2: Summary of Triple Bottom Line Benefits for Investment in Forecast Skill

Economic	Environmental	Social
Increased adoption of SCF leading to improved profitability in agriculture and decreased farm income variability	Improved sustainability of land and pasture resources from cropping and grazing systems more attuned to expected rainfall variability	Reduced uncertainty and stress for land and water managers due to more objective processes in decision making and being able to plan ahead.
Higher proportion of those adopting SCF (taking notice of forecasts) who can capture long-term profits from SCF use	Improved understanding of the patterns of climate variability to inform natural resource management decisions	Improved personal capacity of land managers to manage climatic variability and adapt to climate change
Offsetting the reduction in statistical model forecasting skill due to climate change	Improved success rate for tree planting for natural resource management purposes	
Improved management of water storages for irrigators	Improved allocation of water to the environment	
Benefits to a wide range of climate-sensitive industries from improved seasonal forecasts	Improved forecasting for bushfires	
Improved planning for agribusiness (e.g. physical inputs)		
More efficient and effective government policies for delivery of drought support		

Quantification of Benefits

The counterfactual scenario will contain the set of assumptions used to estimate investment criteria for MCVP1. The investment in improving accuracy is assumed to commence in the next year and be part of MCVP2.

Derivation of increased adoption from a given increase in skill (Barry White)

A simple skill measure was developed using Australian Rainman for 24 stations around Australia. Selections were made to give a representative sample for each industry sector. SOI<-7 and >+7 are approximate indicators of El Nino and La Nina conditions and these conditions account for much of the forecast skill of the SOI. For a specific station and month, Rainman shows the probability of three monthly rainfall being above median for the years with the SOI in the three previous months averaging in one of the three ranges as defined by SOI<-7,-7 to +7 and >+7. Note that for simplicity and stability the skill measure uses the three month mean SOI for the period before the three month period of the rainfall forecast. This is a simple default option in RAINMAN to analyse the broad characteristics of the ENSO signal. The SOI 5 phase system uses trends and levels in the two previous months. A more complex analysis would have been needed if the standard SOI 5 phase forecasts had been used. Two of the five phases have correspondence with the high and low SOI categories used here.

The average absolute deviation from the 50% median probability gives a measure of the influence of the SOI in changing the odds, and is thus a measure of forecast skill. The skill concept is simply the extent to which the forecast is better than chance. If only the climatological records were available, then the chance of above median rainfall can only be determined as 50%.

For Narrabri (Figure 1) the average absolute deviation for the twelve months for SOI<-7 and SOI>+7 is about 11%. Months with SOI<-7 and SOI>+7 account for about 45% of all months. The typical frequency of El Niño and La Niña events (corresponding SOI<-7 and SOI>+7 respectively) is about one year in four, or about one half of all years in total. The graph shows that substantial deviations only occur over about one half the year when there are El Niño and La Niña events. Thus the 11% average absolute deviation is mainly contributions from one half of the time in one half of all years.

The analysis excludes the neutral years when SOI is in the range from –7 to +7. There are a few locations and months for which an SOI in the range –7 to +7 may be a significant and useful indicator of a shift in the probabilities but for simplicity this analysis does not include them.

A simple skill measure needs to consider the extent to which deviations may simply be due to chance. Two indicators are:

a) A statistical test for each month in isolation which will take into account sample size to determine if any SOI group is different, and

b) Whether the deviation for the month is part of a consistent and expected seasonal pattern, for example the ENSO influence giving the main seasonal pattern of departures as shown for Narrabri.

The average absolute deviations are similar for the eastern grain region as would be expected from the SOI patterns and the stronger ENSO influence in spring. The corresponding figure and the pattern for Birchip in Victoria are about the same as for Narrabri. An example for Birchip (Figure 2) shows that about one half the months have deviations that can be regarded as statistically significant and not due to chance. This gives confidence that a simple skill index can be developed from the deviation measure but that small values will indicate the skill is most likely due to chance. For Narrabri the extreme deviation is about 30% in July. A perfect forecast would state a 100% chance of rainfall being greater than the median, that is, a deviation of 50%. A simple skill index with a scale of zero (no skill) to 100 (perfect skill) can be developed by doubling the average absolute deviation for the two SOI classes for each of the 12 months, or equivalently simply summing all 24 absolute deviations. The overall skill index for Narrabri is thus twice the mean absolute deviation of 11% or a value of 22. The skill index should then be interpreted as skill relative to perfect knowledge of 100.

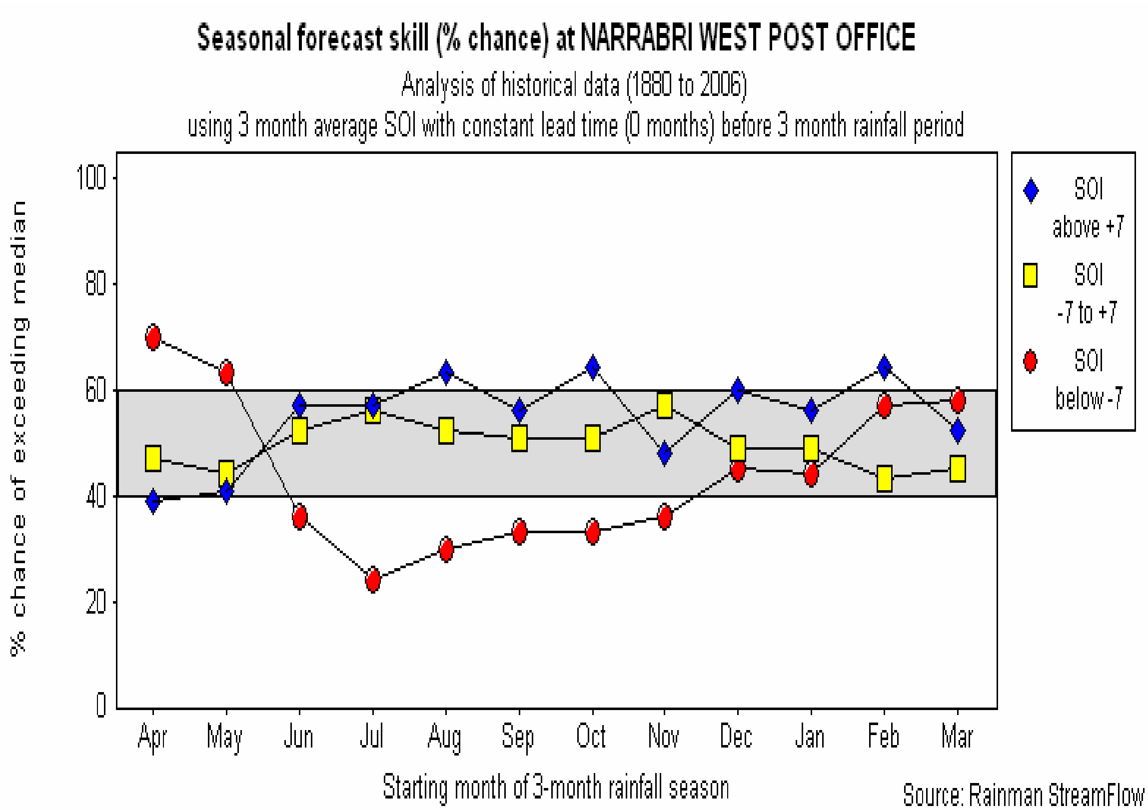

Figure 1: Example of Seasonal Forecast Skill as measured by % Chance of Rainfall exceeding the median for different levels of SOI in the preceding period.

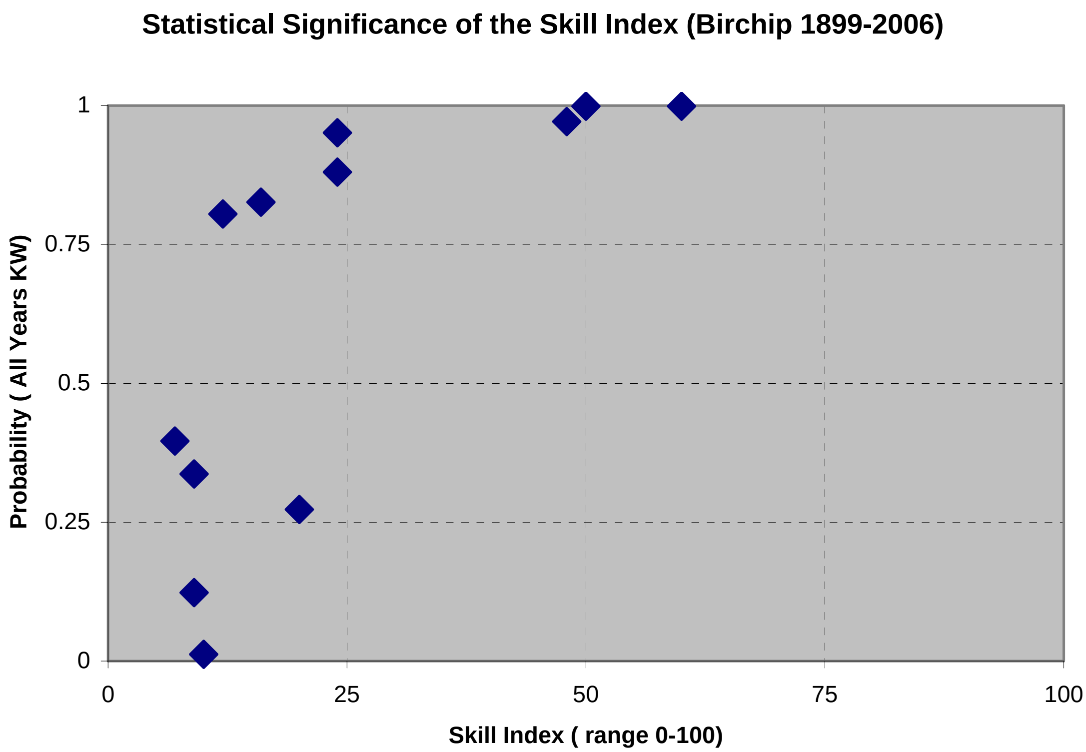

Figure 2: Example of the statistical significance of the skill index based on the average SOI for the 12 monthly seasonal forecasts at Birchip.

The probability is for the KW (Kruskal Wallis) test, a standard non-parametric statistical test of significance. It tests whether at least one group has values that are different from those of the other groups (Source: a RAINMAN analysis).

Survey data is available for 2,500 Australian farmers on use of seasonal forecasts for the years 2000 and 2002 (Climag 2005 based on data from a AAA survey). A standard question on the use of SCF was used in both surveys. The telephone survey asked farmers if they were aware of seasonal forecasts that predict the chance of rain over the next few months. Those who were aware were then asked whether they took the seasonal forecasts into account in their farm decisions. The response data have been classified by industry. For example the cotton industry was the highest response with 65 per cent responding that they took SCF into account.

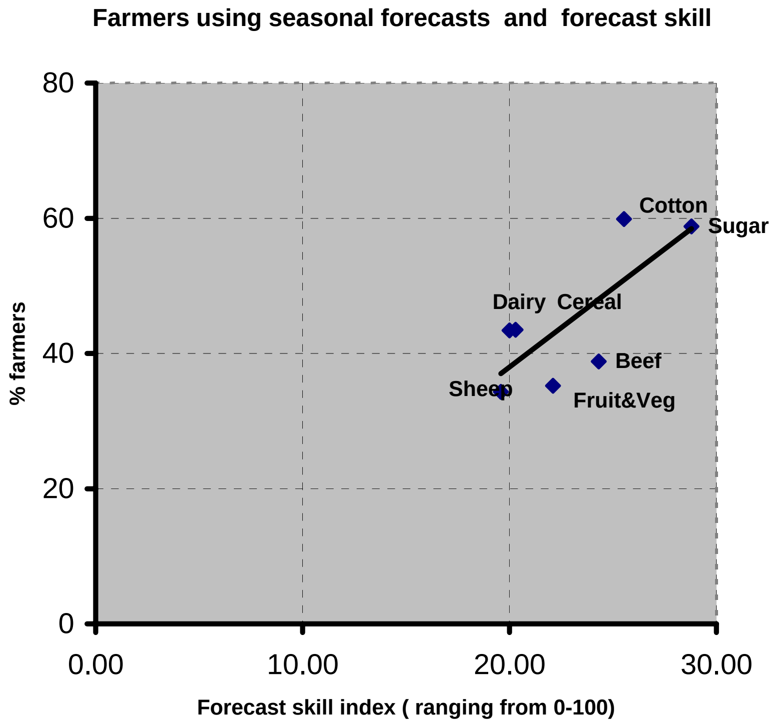

Figure 3: Farmer Use of Seasonal Forecasts in Relation to their Industry and its Forecast Skill Index
Source: Climag (2005) from an analysis using the AAA survey data 2000 and 2002.

As shown for the Narrabri example (Figure 1), RAINMAN can readily provide the information needed to develop a skill index for any of the 3,800 locations available for Australia. As the index is an average for all months the spatial pattern will not show a high degree of variability, particularly for stations with a long period of record. The index was determined for 30 locations. Several stations were then selected to give adequate spatial coverage of each of the seven industries. For example 17 were used for the sheep industry and some of these were used again for 14 representative grain locations.

Figure 3 shows the relationship between the adoption measure and the skill index. The data for the seven industries show increasing use by farmers as the skill index increases. The question is to what extent the relationship can be used to show the additional farmer use from an overall level of increase in the skill index, in particular an increase resulting from an investment in an improved SCF system.

There are of course many other factors determining farmer uptake of SCF. Some obvious ones are the strength of the research and extension effort in the industry. But to some extent industries or regions with higher forecast skill have had major climate risk management programs over longer periods. For example the increased range of research and training activities by the Queensland Government from the early 1990s included significant activity in the sugar and cotton industries.

Farmer consultation has consistently shown that increased skill is the key to increased adoption. There is considerable evidence that farmers only respond to major shifts in forecast probabilities. This will be more frequent and valuable as skill increases. Leith (2006) showed that with current forecasts as experience developed, a relatively small shift in probabilities was seen as useful in decision making. Another finding was that seasonal forecasts were also used as one indicator of future market conditions in addition to their role in assessing on-property climate risk. Increased skill in one region will therefore increase uptake in other regions if there is a market factor involved.

Increased capture of financial benefits
Given the skill level assumed in the analysis for CVAP and MCVP, the "capture" of added profits was assumed to be 10% of those farmers that took SCF into account in their decision making. An increase in skill is therefore likely to not only increase the proportion of farmers taking account of SCF but also the proportion who actually turn the information into long-term profits. The proportion is therefore assumed to increase to 12.5% with the increased skill level assumed.

Maintenance of SCF skill notwithstanding climate change
Benefits attributed to CVAP and MCVP have previously been reduced by a risk factor for benefits due to forecasting deterioration. The risk factor accounts for the impacts of climate change on the current SCF. They are based on historical relationships likely to be already changing. The risk factor is assumed to begin operating from 2012/13. The new forecasts are based on coupled models that will incorporate current climate change in a dynamic way to the extent they include the major climate forcings contributing to climate change. The assumption is made that 60% of the benefits are recovered.

A summary of the assumptions made is provided in Table 3.

Table 3: Summary of Assumptions for Investment Analysis of MCVP

Variable	Value	Source
Income		
Five year average net value of Australian farm production	$8.73 billion	ABARE Commodity Statistics (Table 17, Dec 2006) for five years ending June 2006, expressed in 2007/08 dollar terms
Skill level changes due to investment		
Skill level improvement	20% over the current skill index of 23 (=4.6 units)	Agtrans Research and Barry White
Benefits to Existing Adopters of SCF		
Proportion of Australian farmers taking seasonal climate forecasting into	55%	Agtrans Research and Barry White

account at current level of skill		
Potential increase in profits at current level of skill	10%	Agtrans Research and Barry White
Proportion of farmers taking seasonal forecasting into account that benefit at current level of skill	10%	Agtrans Research and Barry White
Proportion of farmers taking seasonal forecasting into account that actually benefit at new level of skill	12.5%	Agtrans Research and Barry White
First year of increased net benefits due to increased skill	2015/16	Agtrans Research and Barry White
Phase in of gains	Over 10 years to 2024/25	Agtrans Research and Barry White
Risk factor for benefits due to forecasting deterioration	0.5 from 2012/13	Agtrans Research and Barry White
Benefits to New Adopters due to improved skill		
Relationship between increased skill level in SCF and adoption	Adoption increase (absolute %) = 2.4%/unit increase in skill* 4.6=11%	Barry White, pers.comm., Jan 2007
New adoption level for farmers that take seasonal climate forecasting into account	55+11= 66%	
Potential increase in profits with increased accuracy	10%	Agtrans Research and Barry White
Proportion of farmers taking seasonal forecasting into account that benefit with new skill level	12.5%	Agtrans Research and Barry White
First year of increased net income	2015/16	Agtrans Research and Barry White
Phase in of gains	Over 10 years to 2024/25	Agtrans Research and Barry White
Risk factor for benefits due to forecasting deterioration	0.5 from 2012/13	Agtrans Research and Barry White
Benefits from Reduced risk of SCF skill deterioration		
Proportion of benefits lost due to climate change impact on SCF recovered due to the improved models (applies to existing and new adopters)	60%	Advances in Global Climate Models so the SCF more fully incorporate climate change.

Results

The resulting investment criteria for the prospective analysis are presented in Table 4. The period of analysis was for 40 years after the first year of investment. The results are expressed in 2007/08 $ terms and all benefits and costs are discounted to the 2007/08 year. A discount rate of 6% is used for all analyses.

Table 4: Investment Criteria for Increasing Skill Level for SCF by Type of Benefits and Costs Included
(Discount rate is 6%)

Criterion	All Benefits and All Costs	MCVP2 Benefits and MCVP2 costs
Present value of benefits ($m)	133.33	44.44
Present value of costs ($m)	5.21	1.74
Net present value ($m)	128.11	42.70
Benefit-cost ratio	25.6 to 1	25.6 to 1
Internal rate of return (%)	31.9	31.9

The proportion of total discounted benefits contributed by each of the three benefit sources is:

Existing adopters of SCF	31%
New adopters of SCF	31%
Retention of skill otherwise compromised by climate change	38%

Sensitivity Analysis

For the MCVP2 investment the sensitivity of the investment criteria to the level of skill improvement is shown in Table 5.

Table 5: Sensitivity of Investment Criteria to Assumption of Percentage Increase in Skill Level in Seasonal Forecasting
(MCVP investment)

	Discount rate 6%		
	Low Value 5%	Base value 20%	High value 50%
Present value of benefits ($ m)	10.28	44.44	127.80
Present value of costs ($ m)	1.74	1.74	1.74
Net present value ($ m)	8.54	42.70	126.06
Benefit-cost ratio	5.9 to 1	25.6 to 1	73.6 to 1
Internal rate of return (%)	17.9	31.9	45.0

Table 6 shows the sensitivity of the investment in skill improvement to the assumption regarding the avoidance of the loss of benefits due to climate change.

Table 6: Sensitivity of Investment Criteria to Assumption of Percentage Loss Avoided from SCF Deterioration due to Climate Change
(MCVP investment)

	Discount rate 6%		
	Low Value 10%	**Base value 60%**	**High value 100%**
Present value of benefits ($ m)	30.55	44.44	55.55
Present value of costs ($ m)	1.74	1.74	1.74
Net present value ($ m)	28.82	42.70	53.82
Benefit-cost ratio	17.6 to 1	25.6 to 1	32.0 to 1
Internal rate of return (%)	27.9	31.9	34.5

Conclusions

The analysis demonstrates that an investment of the type proposed can be highly profitable with a most likely benefit cost ratio of greater than 25 to 1. Further, this conclusion is not particularly sensitive to major changes in key assumptions. Even a skill increase of one quarter of that proposed remains profitable. The fundamental reason is because the investment is generic. The use of SCF will increase and be of benefit nationally at a time when there is an increasing demand for improved products to manage climate-related risks.

Current SCF have two decades of use with little change in their intrinsic skill. They are accepted as of only low to moderate skill although they do for many locations and times indicate significant changes in the chances of above or below rainfall during ENSO events. Climate change is likely to be increasingly perceived as eroding the existing skill levels. SCF are one of the most effective ways for climate sensitive industries to adapt as the risks and uncertainties change.

This prospective analysis has shown the feasibility of a significant improvement in current skill levels and that this will increase the proportion of farmers using and benefiting from the opportunities the forecasts bring for improved risk management. The benefits are evenly spread between three sources, new users, greater benefits from existing users, and from arresting the impact of climate change on forecast quality.

Acknowledgements

Several leading Australian climate researchers who commented on the feasibility of achieving a significant increase in forecast skill.

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Appendix 4: Prospective Analysis of Further Investment in Yield Prophet

Introduction

Improved management of climate risk has been the focus of MCVP and its predecessor programs since their inception. GRDC as a key partner in MCVP has invested in projects that have developed the understanding and the tools to turn new developments in climate science into practical management. This analysis is of a possible MCVP investment in YieldProphet, a computer-based tool for understanding and managing climate risk for grain crops. The YieldProphet approach is viewed as an opportunity for MCVP to capitalise on the tools now available and take improved climate risk management to a major segment of the grains industry.

An initial investment by MCVP in YieldProphet has demonstrated benefits of collaborative projects linking R&D and science to agribusiness and to farmers. This is a key strategy for future investment in MCVP regarding its investment in applications of climate science. The merits of the strategy can be illustrated by a case study evaluating benefits of a possible new investment by MCVP in YieldProphet.

The benefits that will result from an MCVP investment in YieldProphet can only be determined by the incremental gain the investment will make compared with the situation without the investment. For a subscribing farmer, the benefit is the increase in profitability compared with the cost of the service, for example from adapting inputs and marketing decisions to the emerging season. For MCVP, the increased profitability to the farmer and the service provider need to be reduced by the profitability that would result in the absence of the MCVP investment. The two possibilities are:

a) an alternative investor to MCVP would become involved (resulting in possibly zero additional benefits from an MCVP investment) or,
b) YieldProphet support will cease and then farmers would use one of the next best approaches to climate risk management.

In either case an adjustment to the profitability of the investment to the farmer and the service provider needs to be made from the MCVP viewpoint. The adjustment simply reflects the extent to which the additional profitability would have been achieved anyway. The analysis can incorporate both possibilities by using a risk factor.

The following section briefly reviews the origins of YieldProphet and a related but more general purpose product WhopperCropper, also promoted by MCVP, and most likely to be the product even more widely used as an alternative if YieldProphet was not available.

Climate Risk Management in the Grain Industry

Demand for improved information on climate risk management is increasing. The drought experience over the last decade and more recently the increased awareness of climate change as a possible major current issue, have been two key factors. The Climate Supplement (GRDC, 2007) in the GRDC publication *Ground Cover* distributed to all graingrowers demonstrates new concerns with climate risk management.

Stephens (2002) has shown how climate variability impacts on regional cropping performance. The main impact is through yield variability and the increasing level of risk associated with a high-input, high-yield, farming system. The high rates of productivity gain being achieved in the grain industry demand more skilled management. As shown by Stephens (2002) the best performing shires in terms of yields consistently increased N fertiliser application and crop diversity. Alexander and Kokic (2005) have shown that increased productivity is related to many factors including education levels and involvement in training. In Victoria other indicators included crops planted at the optimum time, use of nutrition budgets and yield forecasting.

In southern and western cropping regions, key decisions on planting and fertiliser application are guided by tools that can indicate potential yield and water use efficiency (WUE) given the season to date and possible outcomes for the remainder of the season. The French and Schultz (1984) approach has been widely used to estimate WUE. Approaches based on identifying improved strategies using simulation models were pioneered in northern Australia. The capacity to examine the possible outcomes from alternative cropping strategies was the initial focus for research. Seasonal climate forecasting was added some two decades ago to help determine the best strategy given the likely season ahead. Soil moisture at planting was also recognised as a critical decision variable.

Over the last few years the simulation approach has now been shown to be of value in southern and western cropping regions despite key differences in the environments. In the northern region, summer rainfall dominance and soils of high moisture capacity contrast with the lighter soils in the southern and western areas of mainly winter rainfall.

The challenge of interpreting climate risk as shown by simulation models in ways useful for farmers has been met in two ways in recent MCVP projects. Both are based on the APSIM model (Keating *et al* 2003) (http://www.apsim.info/).

YieldProphet is a web interface for the crop production model. It simulates crop growth based on paddock-specific inputs of soil type, pre-sowing soil water and nitrogen, rainfall, irrigation and nitrogen fertiliser applications, and climate data. YieldProphet was developed by BCG (Birchip Cropping Group) in collaboration with APSRU (CSIRO) as a risk management tool for dryland farming systems in the Victorian Wimmera and Mallee, with an emphasis on decision support for nitrogen fertiliser inputs. It was first used for wheat at BCG trial sites in 2002, and its early predictions of the likely failure of that season generated sufficient interest and credibility to allow a commercial release to BCG members in 2003 as a monthly fax-out service. Continuing demand resulted in the development of the YieldProphet web-interface, which allowed a larger number of subscribers to receive up-to-date crop information and forecasts at will in 2004. The first year of general commercial release of the service was in 2005; 338 paddocks were subscribed to the service from all over Australia. Over 6,800 reports were generated during the season.
(http://www.yieldprophet.com.au/yp/wflogin.aspx)

The BCG project was one of several linked projects targeting improved climate risk in the grain industry. The project '*Horses for courses: using the best tools for managing climate risk*' by the Mingenew-Irwin Group trialled approaches including YieldProphet for managing climate risk for a farmer group in Western Australia. The comparison was with PYCAL, a product supported by the Department of Agriculture and Fisheries, Western Australia. The conclusion was that the choice of decision support tool will depend on how much precision and detail individuals want. For the extent of the trial, YieldProphet had a small advantage over PYCAL in accurate yield prediction but that need to be assessed against cost and convenience factors.

In addition to the YieldProphet approach based on farmer groups and paddock specific information, there has also been substantial investment by MCVP and GRDC in a similar product WhopperCropper, most recently the current MCVP project QPI54 '*National Whoppercropper - delivering risk management to agricultural advisors*'. Both approaches had their origins in Queensland and are based on APSIM. They were successfully developed and refined as a discussion-support process for the northern grain region. The approaches are complementary in that they differ in their approach to delivery.

WhopperCropper will be most used by public sector advisers working regionally and by private sector advisers. WhopperCropper is essentially a very large database of accurate and locally validated runs of the APSIM crop simulation model designed for use, for example by public and private sector advisers in regions around the grain industry. It generates risk information on yield and economic outcomes for desired crop scenarios by modelling the combined effects of existing resources (e.g. soil water at sowing), farm management inputs (e.g. crop type, N fertiliser rate), and climate forecast (SOI phase). The QPI54 project is facilitating technology adoption by contracting a private commercial-delivery partner. Nutrient MS was chosen because it has contacts Australia-wide and a long-established training record especially in the crop nutrition field.

As reported by Cox (GRDC, 2007), there are parallels with YieldProphet, for example both are underpinned by APSIM. The approaches can be viewed as complementary. Some farmers may start with WhopperCropper and either change to YieldProphet or use both. The opposite scenario is also possible. The two alternatives do offer different perspectives and to that extent they are also competitive products. WhopperCropper uses less detailed preset options for input levels but is likely to be quicker, cheaper and easier to use. The emphasis is on pre-season planning. This makes it easier to look at a wide range of situations about crop or variety choice and inputs in relation to the likely season. In contrast to YieldProphet where the emphasis is on farmers working through a consultant and the Internet, WhopperCropper has a more general audience and will be widely available as a CD for a specific district via an annual subscription.

The recent experience with the BCG project and WhopperCropper has been invaluable in demonstrating that climate risk assessment based on simulation models can be of significant practical value across southern Australia. This outcome is a breakthrough given the widespread view of only a decade ago that seasonal forecasts and cropping models would be of limited use in a winter rainfall environment with soils of generally lower water holding capacity than in northern grain regions. Key issues for the evaluation are the market penetration that can be achieved and sustained given the products have only recently been promoted in southern and Western Australia.

Investment Description

This analysis is of a possible MCVP investment in YieldProphet, a computer-based tool for understanding and managing climate risk for grain crops. The proposed investment follows on from where the YieldProphet project, BCG1 finished. The final report for the Birchip project BCG1 states: '*YieldProphet is considered to have high commercial potential and is currently being delivered on a commercial basis Australia wide. BCG is currently developing a business plan through external consultants. The current plan is to establish a commercial arm to the BCG named Agri Prophet which will deliver YieldProphet on a commercial basis*.'

This evaluation is of the MCVP investment to support the wider commercial potential of YieldProphet building on the BCG Business Plan.

A small part of the investment is likely to be for further model development. The earlier investment in YieldProphet (BCG1) further developed the simulation model (APSIM) already embedded in YieldProphet by the addition of modules for risks relating to yield, nitrogen and climate, nitrogen profit and soil water. The success of YieldProphet is illustrated by there being 5,000 requests for YieldProphet reports during 2005. Further, the earlier investment (BCG1) produced procedures and parameters to aid the adoption of YieldProphet by farmer groups across the grain industry.

MCVP has recently provided some bridging funding for YieldProphet to expand its capabilities for farmers' risk management (BCG2). The project includes:

a) Expanded functionality of YieldProphet for the 2007 season based on user demand
b) A designed package of future expansion for YieldProphet, and identification of parameterisation and validation data required to assure robustness and credibility
c) Improved representation of probability in YieldProphet
d) An additional seasonal forecast based on output from the POAMA atmospheric general circulation model (dependent on a planned release of data by Bureau of Meteorology).

Another recent investment by GRDC included improving soil water data. The data will have many uses but will be needed to successfully run YieldProphet at an accurate level for estimating farm yield. Plant Available Water Capacity (PAWC) is a key parameter. The project '*Training growers to manage soil water*' will be completed in 2009.

The project will run action learning activities on the soil water balance with growers and agribusiness. The project expects to engage about 800 farmers and agribusiness in workshop activities in southern and Western Australia. As a follow-up activity to the workshop, participants will be encouraged to work as a group to identify and characterise the local agriculturally important soils. Data collected from these exercises will be checked by the project and incorporated into the national PAWC database for general use.

The PAWC project and the bridging project provide the underpinning for an investment in YieldProphet to expand the number of farmers involved beyond the current level of 270. The basic strategy is to promote YieldProphet through consultants. The product and its benefits have had a high level of exposure. BCG has a high level of credibility in the grains industry and a successful record in innovation.

Investment Costs

Table 1 presents a summary of the prospective investment costs for further supporting YieldProphet. The costs include an estimate of both the MCVP2 prospective costs and "other funding" from internal sources as well as in-kind support from researchers.

Table 1: Summary of Prospective Investment Costs for Further Investment in YieldProphet
(2007/08 $ terms)

Year	MCVP2	CSIRO	Other Contributions (BCG)	Total
2007/08	200,000	75,000	33,000	308,000
2008/09	150,000	75,000	33,000	258,000
2009/10	150,000	50,000	34,000	234,000
	500,000	200,000	100,000	800,000

Principal Outputs and Outcomes

The outputs of YieldProphet include a wide range of simulations to give farmers better information on a per paddock level on the likely implications of various management decisions. Information is presented in a risk management context to show the variability in yields and prophet for the coming cropping season as determined by the key factors including type of crop, the variety, soil moisture and nitrogen fertiliser strategy. The most important aspect of the information is that it is specific to the farmer's situation and uses local parameters for example for soil moisture capacity. It is expected that most farmers will access information through existing farmer group networks and will have input from an agronomic consultant to develop greater understanding of the options presented by YieldProphet.

The major outcome is the improved profitability of grain cropping resulting from decisions which are closer to optimal for the farmer's particular circumstances. With the capacity of the APSIM model being enhanced to provide improved information on environmental outcomes, some environmental benefits will also result in terms of reduced fertiliser leaching and deep drainage.

Benefits Associated with the Investment

The investment will increase benefits primarily by making YieldProphet more widely available across Australian cropping regions. The major benefits compared to existing approaches flow from the improved quality of information, in particular of likely yields for various assumptions. More accurate yield forecasts enable farmers to make more reliable decisions on inputs and other strategies relating to marketing and storage.

In southern and western cropping regions, key decisions on planting and fertiliser application are guided by tools that can indicate potential yield and water use efficiency (WUE) given the season to date and possible outcomes for the remainder of the season. The French and Schultz (1984) approach has been widely used to estimate WUE. An analysis by Hochman (personal communication, March 2007) prepared to support this evaluation showed the substantial gains in forecast accuracy that YieldProphet offers over the French and Schultz approach.

Data is derived from paddocks spread throughout the Australian Grain Zone from northern NSW through to Victoria, South Australia and Western Australia. The results of a comparison of observed and predicted yield of 240 wheat crops over 4 seasons showed that Yield Prophet accounted for 79% of the variability. The residual mean square deviation (RMSD) was 0.65 t/ha compared with 1.44 t/ha for the French and Schultz model

A summary of the different types of benefits derived from the further investment in YieldProphet is provided in Table 2.

Table 2: Summary of Triple Bottom Line Benefits for Further Investment in YieldProphet

Economic	Environmental	Social
Increased use of YieldProphet across Australia	Improved use of nitrogen resulting in reduced extent of leaching and deep drainage	Improved capacity of cropping farmers to manage initial inputs, crop management and grain storage and marketing
More accurate yield forecasts translating into improved planning and responses, culminating in higher profits		

Quantification of Benefits

The benefits from any new investment by MCVP will be those additional to benefits that will accrue in the "without new investment" or counterfactual scenario. If MCVP does not invest, assumptions are also needed on likely investments by BCG and APSRU and outcomes likely to be achieved in terms of additional profits.

As outlined previously the most likely counterfactual scenarios are:

1. an alternative investor to MCVP would become involved (resulting in possibly zero additional benefits from a MCVP investment) or,
2. YieldProphet support will cease and then farmers would use the next best approaches to climate risk management.

The two scenarios are mutually exclusive. The weight given to the two alternatives would be to some extent determined by the reasoning behind the assumption that MCVP would not invest. The two possibilities have been assessed as equally likely scenarios in the event that MCVP did not fund the investment. The scenarios are:

1. MCVP judges the investment will be low risk and highly profitable: MCVP investment would therefore be superfluous. If that view was shared by other possible investors, the likelihood of an alternative funder to MCVP would be high.
2. MCVP considers that WhopperCropper is likely to be widely adopted thus limiting the gains possible from YieldProphet. The WhopperCropper project is near completion and may not require further MCVP funding to rapidly expand its market. For this scenario, it is assumed that one half of those adopting YieldProphet would have adopted WhopperCropper and would have gained half the benefits per ha compared with YieldProphet.

The benefits from any new investment by MCVP will therefore be those additional to benefits that will accrue in the "without new investment" situation. It is assumed that the new MCVP investment funds an improved and more widely applicable version of YieldProphet. Additional assumptions are needed on the likely magnitude and timing of further investment by MCVP as well as the additional benefits (and their timing) that may accrue due to new adopters and any added gains per ha applicable to both new and existing users of YieldProphet.

The added operational costs of YieldProphet for each of the years in the analysis are estimated in Table 3.

Table 3: Projected Operational Costs for Yield Prophet ($)

Year	Number of Users	Cost to Users ($500 per user)	BCG costs (a)	CSIRO	Total
2007/08	270	135,000	225,000	30,000	390,000
2008/09	360	180,000	225,000	30,000	435,000
2010/11	600	300,000	225,000	30,000	555,000
2010/11	900	450,000	225,000	30,000	705,000
2011/12	1,300	650,000	225,000	30,000	905,000
2012/13	1,600	800,000	225,000	30,000	1,055,000
2013/14	1,900	950,000	225,000	30,000	1,205,000
2014/15	2,200	1,100,000	225,000	30,000	1,355,000
2015/16	2,500	1,250,000	225,000	30,000	1,505,000
2016/17	2,800	1,400,000	225,000	30,000	1,655,000
2017/18	3,100	1,550,000	225,000	30,000	1,805,000
2018/19	3,400	1,700,000	225,000	30,000	1,955,000
2019/20	3,700	1,850,000	225,000	30,000	2,105,000
2020/21 and after	4,000	2,000,000	225,000	30,000	2,255,000

(a) Assumes 75% of total overhead costs of $300,000 per annum are allocated to YieldProphet

Assumptions on the phase-in period of the added benefits are consistent with other MCVP analyses. A risk factor has been added to depreciate benefits from 2012/13 due to erosion of forecast skill from climate change.

The $10 per hectare profit is aggregated to a farm level by assuming that the average cropping farm has 652 ha cropped on average (ABARE farm surveys). Based on experience to date, farmers typically only get YieldProphet outputs for some paddocks but the data is used as a representative sample to allow improved information for all of the farm area.

A summary of the assumptions made is provided in Table 4.

Table 4: Summary of Assumptions Used in the Analysis

Variable	Value	Source
Target market – potential users of YieldProphet	The target market is the top 20% of the 30,900 grain farmers in Australia (~ 6,000)	ABARE
Average cropped area per grain farmer	652 ha	Weighted average of crop area per farm for (i) wheat and other crop and (ii) mixed livestock farms for years ended June 2000 to June 2005 (ABARE farm surveys)
Without Further MCV Investment		
Capital Investments in new projects over 2007-09	BCG and APSRU - no investment planned without major external support	BCG/APSRU
Actual number of farmers using YieldProphet (2007)	270	BCG/APSRU
Actual number of farmers using YieldProphet (2010)	0 (BCG and APSRU will not provide the service if there is no external investment)	BCG/APSRU
Actual number of farmers using YieldProphet (2019)	0 (BCG and APSRU will not provide the service if there is no external investment)	BCG/APSRU
Improvement in information from using YieldProphet	Compared with French and Schultz alternative, accuracy in estimating potential yield more than doubled.	BCG/APSRU
Increased profit from current version of YieldProphet	Conservative $10/ha based on cost studies of yield increases and cost savings over drier than average years.	BCG/APSRU /Agtrans /Barry White
Probability of external investor support (not MCVP)	0.5	Agtrans/Barry White
Probability of no external support but WhopperCropper supplying 50% of the perceived benefits	0.5	Agtrans/Barry White
With Further Investment by MCVP		
Additional capital investments in new projects over 2007-09 (see separate table for by years)	BCG: $100k for science development MCV: $500k for R&D APSRU: $200k for R&D	BCG/APSRU
Phase in of gains	2008-2019	Agtrans
Operating costs 2007-2019 (excluding farmer costs)	BCG $225k per annum APSRU $30k	BCG/APSRU
Additional number of new farmers using YieldProphet by 2019	2007 – 270 2010 – 900 2019 – 4000 (2/3 of potential)	BCG/APSRU
Increased profit from using	$10 /ha	BCG/APSRU

YieldProphet		
Farmer cost to access YieldProphet	$500 annually	
Factor for reduction in benefits from SCF skill deterioration	0.5 from 2012/13 onwards	Agtrans

Results

The resulting investment criteria for the prospective analysis are presented in Table 5. The period of analysis was for 40 years after the first year of investment. The results are expressed in 2007/08 $ terms and all benefits and costs are discounted to the 2007/08 year. A discount rate of 6% is used for all analyses

Table 5: Investment Criteria for Further Investment in YieldProphet by Type of Benefits and Costs Included
(Discount rate is 6%)

Criterion	**All Benefits and All Costs**	**MCVP2 Benefits and MCVP2 costs**
Present value of benefits ($m)	30.20	18.90
Present value of costs ($m)	0.76	0.48
Net present value ($m)	29.44	18.42
Benefit-cost ratio	39.8 to 1	39.8 to 1
Internal rate of return (%)	No solution	No solution

Sensitivity Analysis

For the MCVP2 investment the sensitivity of the investment criteria to the profit per ha is shown in Table 6. The break even benefit is $1.9 per ha.

Table 6: Sensitivity of Investment Criteria to Additional Profit per ha
(MCVP investment only)

Criterion	**Discount rate 6%**		
	$2 per ha	**$5 per ha**	**Base Value ($10 per ha)**
Present value of benefits ($ m)	0.66	7.50	18.90
Present value of costs ($ m)	0.48	0.48	0.48
Net present value ($ m)	0.18	7.02	18.42
Benefit-cost ratio	1.4 to 1	15.8 to 1	39.8 to 1
Internal rate of return (%)	8.7	87.8	No solution

The sensitivity of the investment criteria to the eventual number of users is shown in Table 7. The break even eventual number of users for the investment to break even at a discount rate of 6% was 228.

Table 7: Sensitivity of Investment Criteria to Eventual User Numbers
(MCVP investment only)

Criterion	**Discount rate 6%**		
	400 users	**800 users**	**Base Value (4000 users)**
Present value of benefits ($ m)	1.32	3.27	18.90
Present value of costs ($ m)	0.48	0.48	0.48
Net present value ($ m)	0.84	2.80	18.42
Benefit-cost ratio	2.8 to 1	6.9 to 1	39.8 to 1
Internal rate of return (%)	13.9	30.3	No solution

Conclusions

The analysis demonstrates the very high returns possible from a decision support tool that can provide risk management information directly relevant to the production risks faced by individual farmers. The principal difficulty with this analysis is deciding on the assumptions to make if MCVP does not fund the further development of the model. Based on the assumptions made the investment appears very profitable. This is so, even though approximately 75% of the benefits from Yield Prophet are likely to be captured anyway if MCVP does not fund the investment. Thus, the benefits assumed for the MCVP investment are those additional to those in this without scenario.

The investment criteria show that far fewer than 4,000 users need to be involved for the investment to make a positive return.

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