Queensland Government
Department of Primary Industries

Project Series QO02012

# THE VALUE AND BENEFITS OF USING SEASONAL CLIMATE FORECASTS IN MAKING BUSINESS DECISIONS: A REVIEW

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November 2002

**Department of Primary Industries • Queensland**

QO02012
ISSN 0727-6281
Agdex 020/800
November 2002

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# ACKNOWLEDGEMENTS

Contributions by the following officers are gratefully acknowledged:

- Belinda Cox, Scientist, Department of Natural Resources and Mines (NR&M);
- Cecelia McDowall, Senior Librarian, Department of Natural Resources and Mines;
- Ken Brook, Manager, Climate Impacts and Natural Resource Systems, NR&M;
- Cover illustrations from 'The Long Paddock' Internet site (NR&M);
- Michael Gutteridge, Project Officer, Department of Natural Resources and Mines; and
- Roger Stone, A/Director, Qld Centre for Climate Applications.

# EXECUTIVE SUMMARY

## Introduction

Australia has one of the most variable climates in the world with the largest variability being in the north-east of the continent. Periodic droughts have significant intermittent impacts on primary production. A typical major drought reduces the gross value of agricultural production by about 10%, and the Gross National Product by about 1%.

Seasonal climate forecasts (SCFs) are becoming more accurate, and have considerable potential to enable managers in climate-affected industries to reduce unwanted impacts and take advantage of expected favourable climatic conditions. However, the potential benefits of SCFs vary considerably because of many physical, biological, economic, social and political factors.

## Use of Seasonal Climate Forecasts

Managers involved in primary industries are now using seasonal-climate-forecast information in making business decisions in many areas. The use of a seasonal climate forecast in making a particular business decision may increase the confidence of that decision-maker, and be perceived as having insurance value by a risk-averse manager. However, many decision-makers have indicated that they require more confidence in using SCFs. Actions that need to be taken to address this issue are listed in the Discussions section.

In order to put a value on a particular seasonal forecast, it is necessary to consider the net economic, environmental and social benefits resulting from the use of that forecast in making a wide range of business decisions. The value of climate forecasts is sensitive to economic conditions as well as forecast characteristics. In any specific decision, the full range of possible outcomes from using the forecast needs to be recognised. Some outcomes are more desirable than others to the decision-maker, and therefore need to be given a higher weighting in the valuation process. It is important to remember that an inappropriate response to a forecast, or using a ‘wrong’ forecast, may be worse than not using the forecast – a financial loss may occur.

Many managers involved in primary industries are attempting to use SCFs fruitfully in their businesses. The two ingredients for using a seasonal climate forecast in decision-making are: exploring options for alternative decisions based on the likelihood of possible outcomes; and a comparative evaluation of the alternatives in terms of the decision-maker’s goals.

## Benefits of Using Seasonal Climate Forecasts

The outputs of SCFs have a wide range of potential uses in our community. Studies estimating the value or benefits of them have to date been based on case studies at scales ranging from enterprise level to national-economy level. Usually some production and/or economic simulation models have been used, and some assumptions are made on the impacts and/or client responses to different climate scenarios.

The research findings described in the following sections give a broad appreciation of the current documented benefits, and potential benefits, from using climate forecasts in business decision-making. The papers quoted give many ‘snapshots’ of the usefulness or calculated value of various SCFs in particular case studies, or in other analyses involving various assumptions. However, similar case studies (using different methods and/or assumptions) may produce significantly different values of the SCF.

Some macro-economic studies are quoted which give estimates of the costs of climate variability. Such estimates help to justify the development of SCF systems, and provide a context within which the use of a climate forecast system can be valued. Other studies have assessed the potential benefits of using SCFs in a particular region of the world. Alternatively, there are studies that compare the value of two or more SCF systems.

The Queensland Centre for Climate Applications (QCCA) produces SCFs and climatic risk assessments that are used mainly by the following industries: beef, wool, cereals for grain, sugar and cotton.

Considering the grazing industries alone, the cost of QCCA represents only 5-10% of the total benefits to Queensland's economy (Queensland Centre for Climate Applications, 2002).

Unfortunately, where SCFs are being used in management decisions there is no guarantee that the most likely climate scenario will actually occur. The client needs to know that the forecast system has worthwhile accuracy, and that the probability of the most likely climate scenario is significantly different from that expected by examining the all-years historical record. Forecast credibility is a fragile thing, and can suffer considerably due to perceptions that the forecast was 'wrong' resulting in a financial loss.

Results from a number of surveys are also quoted. These give some feedback on clients' perceptions of value in seasonal forecasts – information required, ease of use in decision-making and outcomes from decisions using the information.

There are also case studies that examined the value of SCFs in managing a particular enterprise in a specific region. Financial benefits claimed in such studies include: increased profitability; reduced risk to the enterprise; and reduced income and cash-flow variability. Potential environmental benefits include reduced risk to the resource base.

Using SCFs can act as a catalyst/motivator for a manager to improve overall management of his/her business, for example by demanding improvements in monitoring, infrastructure/equipment, and the adoption of up-to-date technology. Modern farming involves greater precision through better monitoring of the production system, quantitative comparisons of management options, and sufficient flexibility in operations to implement the preferred response to a SCF. Pasture and crop growth simulation models can be used to evaluate alternative management options, and quantify the likely effects on farm income and production risk.

However, when trying to increase the profit from a production system, the result is often some increase in risk. For example, the tactical use of seasonal climate forecasts in cropping often involves increasing cropping intensity in selected years. However, decisions made on crop choice and management in one season have ramifications on the sequencing of crops in subsequent seasons, and on the potential for resource degradation.

It is more difficult to calculate/observe the benefits of using seasonal climate forecasts in grazing industries compared with cropping industries. The dynamics of animal-pasture interactions are more complex, and usually the benefits/increased profits are received over a longer period of time. Computer packages such as Grassman, Range-pack and Dynama can be used to help in making such decisions.

SCFs have the potential for providing considerable benefits to:

- Wholesalers and retailers of production inputs (for example, improved marketing strategies, inventory management and advice to clients);
- Grain/fibre handling and marketing organisations, and processors (better forecasts of production and quality);
- Forward sellers and purchasers of products (more accurate estimations of future prices); and
- Water resource management.

While it may be difficult to value environmental benefits, a number of environmental indicators can be used to determine whether a decision will result in a change in sustainability of the production system. For example, soil erosion, soil organic matter, salinity, changes in key pasture species, weed populations and changes in ground cover.

There is some evidence that the provision of SCFs may result in large net public benefit rather than predominantly a private-benefit outcome. For example, in a study of the value of seasonal forecasts in corn production in the Corn Belt of U.S.A. (Mjelde, Penson and Nixon, 2000), it was found that consumers were the clear winners and producers were the losers over the entire 10 years of the study.

## Forecasts and Government Policies/Assistance

Government policy/decisions can significantly influence the value of seasonal forecasts. Mjelde and Hill (1999) reported that recent changes to the US Federal Farm Program may increase the value of improved climate forecasts because of the elimination of most planting restrictions, acreage reduction, and disaster assistance. The addition of catastrophic crop insurance appears to decrease the value of improved climate forecasts.

While government policies and their effects are different in Australia, it is likely that drought and other disaster assistance by federal and State governments will reduce the value of climate forecasts. Similarly the proposed introduction of all-risks crop insurance, by the State Government in Western Australia, may have a similar effect.

## Extension/Communication

There are many aspects of risk management from which producers could benefit before forecasting becomes the limiting factor in management. However, a seasonal forecast with current skill has some value for production and resource protection when used to trigger appropriate responses.

Many primary producers could make significant improvements through better application of knowledge of climatic variability, and basic crop/pasture management principles/technology, before improving decisions further through the use of seasonal climate forecasts. Also, the order of adoption may be important, with some farmers preferring to adopt other practices/technologies before seriously attempting to use SCFs profitably.

There is a need to focus more on users' perspectives of SCFs, and their climate-related information needs. Some decision-makers claim that they lack any quantitative basis for evaluating forecast credibility. In addition, forecast formats can affect the ease, accuracy, and reliability of interpretation.

## Realising the Value of Seasonal Climate forecasts

The communication aspects of SCFs warrant greater priority if the potential benefits of using SCFs are to be realised. In some cases there are simply poor linkages between the information available and on-farm decision-making. However, one major constraint to the effective use of climate forecasts is the considerable difficulty people have in estimating and dealing in probabilities, risk and uncertainty. Communicating probability-based information in a form to encourage confident responses by decision-makers is a continuing research and extension challenge.

Some other problem areas in communicating forecasts are:

- Targeting different user groups;
- Users' incomplete knowledge of how El Nino-Southern Oscillation affects their region;
- Problems of forecasting for adjacent or overlapping periods (resulting in perceptions of inconsistencies);
- Messages that are distorted over space and time;
- The lag between forecasts and dissemination; maladaptive responses; and
- False alarms.

More rapid adoption by farmers, the major user group, depends on their greater involvement in research. Research needs to be more focused on increased confidence in the use of forecasts, and demonstrations of the value of forecasts relevant to the decisions of individual farmers. Understanding and effectively communicating decision risks are important keys to successful applications of climate prediction. Advances of the future will be made by better connecting agricultural scientists and practitioners with the science of climate prediction. One attempt to do this is the FARMSCAPE program of participatory research with the farming community of north-east Australia (Carberry and others, 2002).

## Conclusions

It is necessary to evaluate progress made in using outputs of SCFs in various climate-affected industries, and to identify what research, development and extension activities are required to add further value to SCFs. The following conclusions can be made:

- Australia has one of the most variable climates in the world, and SCFs have considerable potential to enable managers in climate-affected industries/activities to reduce unwanted climatic impacts and take advantage of expected favourable conditions.
- It is essential that SCFs be *integrated into overall business risk management*, and used over many seasons to be confident of benefiting from them.
- The *benefits* received from issuing SCF information *vary considerably* due to the influences of physical, biological, economic, social and political factors. Some of the factors that affect the value of a SCF in a particular situation are: disaster insurance/government assistance may decrease the value of SCFs; government policy/decisions can significantly influence the value of seasonal forecasts; the value of SCFs usually increases as planting conditions move towards the optimum; and the value of SCFs is more likely to increase with risk aversion.
- *Many managers* involved with climate-affected industries are *currently using SCFs* in making major management decisions, with varying success, at scales ranging from enterprise level to national-economy level.
- *Quantitative estimates of the value* or benefits of SCFs have often been based on *case studies*. Usually some production and/or economic simulation models were used, and some assumptions were made on the impacts and/or client responses to different climate scenarios. Some findings were:
    - Surveys in Queensland have shown that seasonal climate forecasting is used by 35-40% of graziers, 70% of sugar producers and 30% of cotton growers. The estimated total benefit of SCFs and climatic risk assessment to grazing industries alone, from 1991/92 to 2002/03 was in the range of $600M-1200M (Queensland Centre for Climate Applications, 2002).
    - Instead of applying a standard dressing of 40kg.of nitrogen/ha/year to a wheat crop in southern Queensland, it is worth an extra $18/ha/year overall (at a 10% risk of making a loss) to apply tactical dressings based on the SOI in the two months before planting (Paltridge, 2001).
    - Management of wheat in southern Queensland, according to the SOI Phase, yielded a long-term average economic value of less than, or equal to, the economic value of 1mm of extra plant-available soil moisture at planting (Robinson and Butler, 2002).
    - A study by Petersen and Fraser (2001), in the Merredin agricultural region of Western Australia, estimated that SCFs had the potential to provide an accumulated annual benefit to farmers in the region of approximately $2 million.
    - Jury (2002) assessed the economic impacts of climate variability in South Africa and development of resource prediction models. He estimated that over U.S.$1 billion could be saved annually through uptake of timely and reliable long-range forecasts.
    - Fifteen users of the QDPI's SOI Hotlines made an average net profit of $1933, over the previous 12 months, from using SOI information (Paull and Peacock, 2002).
    - A 'failed' SCF issued in autumn 2000 resulted in an estimated loss of US$1.1 billion in Midwest USA (Changnon, 2002).
    - Hammer (2000) quotes a case study of tactical management of row configuration in a cotton crop on the Darling Downs, Queensland, based on the SOI phase; the average increase in profit was 11%.
    - Hammer and others (2000) compared four forecasting systems in relation to their value in managing a cropping system in northern Australia. The best forecast systems gave a 20% increase in gross margin, a 30% decrease in soil erosion, but an increased risk of making a financial loss.
    - Jones and others (2000) estimated the potential economic value of climate forecasts for farm-scale management decisions in Southeast USA for comparison with results previously obtained for the Pampas region of Argentina. Predicted benefits to the farm of adjusting crop mix to ENSO phase averaged from US$3-6/ha in USA and US$9-35/ha in Argentina. Varying maize management by ENSO phase resulted in predicted forecast values of US$13 and US$15 per hectare for USA and Argentina respectively.
    - Carberry and others (2000) conducted a study involving changing between fallow-cotton, sorghum-cotton or cotton-cotton rotations based on the SOI phase in the August-September period preceeding the next two summers. Average gross margins for the two-year period increased by 14% over a standard fallow-cotton rotation, soil erosion was reduced by 23% and cash flow was improved in many years. However, the risk of economic loss increased from 5% of years to 9%.

  - Costello and others (1998) found that a perfect El Nino forecast for the coho salmon fishery resulted in an annual welfare gain of approximately $1 million, while imperfect forecasts led to smaller gains.
  - Changnon and others (1999) report on a case study incorporating ENSO information into a strategy for purchasing natural gas. The selected strategy saved Northern Illinois University (NIU) approximately US$500,000.
  - A study was conducted to determine the impact of perfect growing-season forecasts for corn produced in the Corn Belt region of USA over a 10-year period (Mjelde, Penson and Nixon, 2000). The expected present value of changes in net surplus varied from US$1.270 to $2.917 billion from the use of perfect forecasts over different 10-year planning periods.
- Similar case studies (using different methods and/or assumptions) may produce significantly different values of the SCF. There is a need to obtain consensus on *how best to calculate the value of a climate forecast*, given the uncertainties associated with the forecast, the managerial response to it, and the outcome of the decision. Ultimately, it is best if the individual decision-maker decides the assumptions that are made in calculating forecast value. In any case, simulation models will be required to enable examination of a range of options and their likely outcomes.
- There is a need to develop *more accurate forecasts* with longer lead times. The client needs to know that the forecast system has worthwhile accuracy in his/her district at that time of year, and that the probability of the most likely climate scenario is significantly different from that expected by examining the all-years historical record. Usual management should only be changed where there is a relatively high probability of a different climate scenario to normal, otherwise gains from a correct forecast will be cancelled by losses when the forecast is ‘wrong’.
- Unfortunately, where SCFs are being used in management decisions there is no guarantee that the most likely climate scenario will actually occur. Therefore it is best if the probabilities are presented in such a way that *clients* perceive that they use them to *make their own forecasts*. Forecast credibility is a fragile thing, and can suffer considerably due to perceptions that the forecast was ‘wrong’ resulting in a financial loss.
- Research, development and extension programs need to be more focused on increasing the *confidence of clients* in using SCFs in business decision-making. More rapid adoption by farmers, the major user group, depends on improving their *understanding* of climate prediction , demonstrations of the value of forecasts relevant to the decisions of individual farmers, and more *involvement of farmers in research*. The use of an interdisciplinary systems approach has considerable merit for connecting disciplinary knowledge in a manner most suited to decision-makers, for example using the FARMSCAPE program of participatory research with the farming community.
- There is a need to provide reliable information on the relative forecasting skills of different forecasting systems for each district and month of the year, in a manner that makes it relevant to the end-user. Many decision-makers claim that they lack any quantitative basis for *evaluating forecast credibility*. That is because the evaluations currently available typically reflect forecasters’ perspectives rather than those of users, or are not available in forms that users can easily obtain or understand.
- It is important to determine the *climate information* that is *required* by each client group, and (if possible) to supply it.
- There is a need to *customise climate information* at district or local-government area so that it is perceived as relevant by clients. Forecast characteristics that are important include:
  - Provide forecast outputs in the *presentation format* that is preferred by each client group (that is, can be easily understood and used in decision-making);
  - Provide brief high-quality *interpretive comments* with the climate-related products that are distributed; and
  - *Deliver* forecasts by the *methods* preferred by each client group.
- It is important to maintain good *quality control* in the production and distribution of forecast outputs, so that clients receive accurate, timely and unambiguous forecast information.
- There is a need to understand better, and document, the *processes and tools* for integrating climate risk management into overall business management.
- *Using SCFs can act as a catalyst/motivator* for a manager to improve overall management of his/her business, for example by demanding improvements in monitoring, infrastructure/equipment, and the adoption of up-to-date technology. Modern farming involves greater precision through better monitoring of the production system, quantitative comparisons of

management options and likely outcomes, and sufficient flexibility in operations to implement the preferred response to a SCF. Pasture and crop growth simulation models can be used to evaluate alternative management options, and quantify the likely effects on farm income and production. From the perspective of the forecast user, the likely climatic impacts and the formats of the forecast products both influence the management option chosen - and the final economic value of the forecast system in that instance. In addition, there are often trade-offs between forecast quality and the economic value of the forecast system.

- When using SCFs to increase profits from a production system, some risks may increase while others may decrease.
- There is a need for *multiyear modelling* in cropping and pastoral enterprises when examining the potential impact of using improved climate forecasts.
- SCFs have the potential for providing considerable benefits to *agribusiness* such as:
    - Wholesalers and retailers of production inputs (for example, improved marketing strategies, inventory management and advice to clients);
    - Grain/fibre handling and marketing organisations, and processors (better forecasts of production and quality); and
    - Forward sellers and forward purchasers of products (more accurate estimations of future prices).
- Planning and decision-making may be improved by access to reliable *forecasts of ecosystem state*, ecosystem services, and natural capital. Interdisciplinary linkages are necessary in order to develop a capacity to provide such forecasts; this is because of the climate and societal controls on ecosystems, the feedbacks involving social change, and the decision-making relevance of forecasts.
- Many primary producers could make significant improvements to their businesses through *better application of knowledge of climatic variability*, and basic crop/pasture management principles/technology, before needing to use climate forecasts to further improve the quality of management decisions.
- There is some evidence that the provision of seasonal climate forecasts may result in large net *public/consumer benefit* rather than mainly a private-benefit outcome.
- The communication aspects of SCFs (that is, communicating decision risks) warrant greater priority if the potential benefits of using the forecasts are to be realised. In some cases there are simply poor linkages between the information available and on-farm decision-making. However, *communicating probability-based information* in a form to encourage confident responses by decision-makers is a continuing research and extension challenge. Greater attention needs to be given to forecast content and communication, including visualization, expression of probabilistic forecasts and presentation of ancillary information.
- Some other problem areas in communicating forecasts are:
    - Presenting forecasts to specific clients for the periods of greatest importance;
    - Prior knowledge assumptions in presentation of forecasts; and
    - Problems of forecasting for adjacent or overlapping periods (resulting in perceptions of inconsistencies).
- One major constraint to the effective use of climate forecasts is the considerable difficulty people have in estimating and dealing in probabilities, risk and uncertainty. Some of this difficulty arises from problems known as *cognitive illusions or biases*. The optimum use of climate predictions requires providers of forecasts to understand these difficulties, and to make adjustments for them in the way forecasts are prepared and disseminated.
- Understanding decision risks is one of the keys to successful applications of climate prediction. For example, end-users of SCFs need to know how El Nino-Southern Oscillation affects their region. There is a need for further *training* to increase the awareness and understanding of decision-makers, analysts, and scientists in the profitable use of SCFs.

# INTRODUCTION

This publication is a review of current knowledge on the value and benefits of using seasonal climate forecasts in making business decisions. This information is required in order to justify the resources being directed into research, development and extension on climate forecasts and applications of the forecast outputs. In addition, we need to know how various client groups are using forecast outputs, and barriers to making profitable use of them.

The underlying source of climate variability affecting the Australian economy is the fluctuations in agricultural production related to rainfall. Drought in the grain and extensive grazing industries is the prime contributor. Notwithstanding the relatively small size of the farm sector, the impacts of drought can have significant but infrequent flow-on effects to the rest of the economy, and on major macro-economic aggregates such as economic growth and the volume of exports (White, 2000).

Anderson's (1979) review highlighted the decline in economic impacts of climate variability as the level of aggregation increased from farm to industry to national level. He concluded that the impact of a major drought was a macro-shock likely to be a 1-2% decline in Gross National Product. He showed that about 40% of the temporal variation in the net value of agricultural production was attributable to climate risk. About 20% of Australia's total exports were provided by the farm sector.

The typical impact of a major Australian drought has been about 10% reduction in gross value of agricultural production. Also there has been a reduction of about 1% in the Gross National Product, and this can be significant given typical growth rates for the economy up to a few percent. The potential to forecast droughts offers opportunities to adjust macro-economic policies to reduce impacts on national economic objectives (White, 2000).

An analysis by McTaggart and Hall (1993) concluded that the Southern Oscillation Index (SOI) was a dominant influence on Australian economic activity. This emphasises the potential importance of seasonal climate forecasts (SCFs) in economic policy development.

Climatic variability leads to economic and food security risks throughout the world because of its major influences on agriculture. Accurate forecasts of climate 3-6 months ahead of time can potentially allow farmers and others in agriculture to make decisions to reduce unwanted impacts or take advantage of expected favourable climate. However, potential benefits of climate forecasts vary considerably because of many physical, biological, social and political factors (Jones and others, 2000).

# USE OF SEASONAL CLIMATE FORECASTS

Seasonal climate forecasts are being increasingly used to benefit decision-making in the more climate-sensitive sectors of the economy. Farmers are the major group of potential users and they have identified more confident use of forecasts as a priority for research (White, 2000).

Managers involved in primary industries are now using seasonal-climate-forecast information in business decisions in the following areas:

- Policy decisions/policy support/government planning;
- Buying/selling/agisting livestock/stocking rates;
- Pasture management;
- Planting crops/pastures;
- Water supplies;
- Cash-flow budgeting;
- Capital expenditure/property development;
- Pest and disease control;
- Feed/seed supplies;
- Agribusiness – inventory management/selling strategies/crop forecasts/effects on contractors;
- Marketing/prices/forward selling;
- Enterprise selection/mix;
- Production goals;

- Adjusting production inputs; and
- Extension/consultancy activities (Paull, 2001).

An effective application of a seasonal climate forecast is defined as use of forecast information leading to a change in decision that generates improved outcomes in the system of interest (Hammer, 2000). However, many managers are currently using climate forecasts as 'background information', so it is often difficult to ascertain whether the information changed a decision or not.

Seasonal climate forecasting must be integrated into the whole decision-making process, as one of many management tools, and used consistently for many seasons to truly benefit from it (Meinke and Hochman, 2000). This is because SCFs are issued as probabilities, and there is no guarantee that a climate scenario with a high probability will occur in a particular season. In addition, a manager must consider factors other than climatic risks and opportunities when making a business decision.

The potential value of climate forecasts in Australia is huge, but there is concern that Bureau of Meteorology forecasts for drought in 1997, based on El Nino indicators, have cost some farmers dearly (Taylor, 1998). Thus a financial loss can be incurred by a person attempting to use SCF information, and the forecast may be perceived as being 'wrong'.

# VALUING SEASONAL CLIMATE FORECASTS

SCFs can provide benefits to individuals, organisations, governments and the whole community through their use in making a range of management decisions. Valuing of forecasts needs to cover a range of possible benefits, including increased profitability and reduced risk to the enterprise and its resource base (White, 2000).

Various factors may affect the potential value of SCFs. For example, White states that the value of forecasts is likely to be dependent on monitoring systems being in place. In a water resource system, a low or no-risk water release policy will constrain the value of a forecast, whilst in extensive grazing operations the frequency of mustering is likely to be a constraint.

Further case studies are required to increase our understanding of how to use SCFs and the value of them. However, White states that one constraint on the scope for case studies is the development costs of the simulation models required for a rigorous comparison of outcomes from alternative decisions. Also the inherent predictability (a few months ahead), of many agricultural and hydrological systems compared to climate systems, needs to be accounted for in studies of forecast value.

The prospect of increased profit was seen by Ridge and Wiley (1996) as the practical key for unlocking an improved decision-making process based on seasonal forecasts. The two ingredients for using a seasonal climate forecast in decision-making were: exploring outcomes for alternative decisions based on the likelihood of possible outcomes; and a comparative evaluation of the alternatives in terms of the decision-maker's goals.

In a 1998 survey of 217 graziers around Australia (Paull and Hall, 2000) 81% of respondents said that judgements of future climatic conditions were 'very important' or 'moderately important' in their decision-making; 75% did not use long-term climatic records to assist in decision-making; 44% said that probability-based information was 'moderately useful' to 'very useful' in the management of their business; and 37% of participants used seasonal climate forecasts in decision-making.

In a survey of users of information on SOI Hotlines by Paull and Peacock (2002), 56% of respondents indicated that they we involved in non-cropping primary production, 22% in cropping and 16% in agribusiness. A total of 45% of respondents was in Queensland and 42% in NSW.

Stafford Smith and others (1977) evaluated SOI forecasts in simulated grazing systems in northern Australia. The studies suggested limited value of the forecasts for the simulations undertaken, but improved forecast skill had considerable potential to improve economic returns and to help protect the resource base.

A dynamic programming model was utilised to determine the value of seasonal climate forecasts in corn production in east-central Illinois (Mjelde and others, 1988). Results indicate that the value of climate forecasts is sensitive to economic conditions as well as forecast characteristics. A trade-off between forecast accuracy and lead time exists; a less accurate forecast received earlier in the production process may be more valuable than a more accurate forecast received later.

Robinson and Butler (2002) outline an alternative method for assessing the value of the Southern Oscillation Index (SOI). Previous studies had identified extra profit that could result from selecting management options according to particular phases of the SOI. Those studies identified optimal decisions for each phase and the value of these decisions. However, this may have overestimated the value of SOI-based management through a lack of data for independent evaluation. The study compared the previous approach with a new method based on a simple sampling technique (analogous to leave-one-out cross validation) that estimates the range of future outcomes when independent validation data are not available. The new method gave much-improved estimates of the mean and variance of the value of the SOI for management. In studies involving wheat-growing in southern Queensland, this method indicated that management according to the April-May SOI phase yielded either small long-term increases (in 4 of 6 cases) or decreases (in 2 of 6 cases) in profit. There was considerable heterogeneity among phases, and the annual variance of the outcomes was large relative to the long-term average value in all 6 cases. Consequently, unless a strategy is applied long term (at least 10 years), there is a relatively high likelihood of higher or lower profit than for non-strategic management. The likelihood of increased and decreased short-term profit is approximately equal. In all 6 case studies, the long-term average economic value of SOI-adjusted management was less than, or equal to, the economic value of 1 mm of extra plant-available soil moisture at sowing.

Katz and Murphy (1997) used cost/loss models to establish the existence of a threshold for forecast quality below which the forecast value was zero. The cost/loss approach can also be simplified, and expressed as rules-of-thumb.

Palmer (2002) investigated the economic value of ensemble forecasts as a tool for risk assessment. Despite the revolutionary development of numerical weather and climate prediction (NWCP) in the second half of the last century, quantitative interaction between model developers and forecast customers has been rather limited.

However, ensemble forecasts provide a qualitative tool for the assessment of weather and climate risk for a range of user applications and on a range of time-scales, from days to decades. Examples of the commercial application of ensemble forecasting, front electricity generation. ship routeing, pollution modelling, weather-risk finance, disease prediction and crop-yield modelling are shown from all these time-scales.

A generic user decision model, described by Palmer, allows one to assess the potential economic value of numerical weather and climate forecasts for a range of customers. Using this, it is possible to relate analytically, potential economic value to conventional meteorological skill scores. A generalised meteorological measure of forecast skill is proposed which takes the distribution of customers into account. It is suggested that when customers' exposure to weather or climate risk can be quantified, such more generalised measures of skill should be used in assessing the performance of an operational NWCP system.

## BENEFITS OF USING SEASONAL CLIMATE FORECASTS

The outputs of SCFs have a wide range of potential uses in our community. Studies estimating the value or benefits of them have to date been based on case studies at scales ranging from enterprise level to national-economy level. Usually some production and/or economic simulation models have been used, and some assumptions are made on the impacts and/or client responses to different climate scenarios.

The research findings described in the following sections give a broad appreciation of the current documented benefits, and potential benefits, from using climate forecasts in business decision-making.

## General Benefits

Findings include:

- In Queensland, since 1991 $36 million was spent by the Queensland Government on research on climate forecasting and climatic risk assessment (including DPI oncosts of $10 million). This figure includes the provision of a super-computer and recurrent hardware (Queensland Centre for Climate Applications, 2002). The resultant seasonal climate forecasts are used in the following industries (gross value of production is shown for 1999/2000): beef $2276M; wool $165M; cereals for grain $593M; sugar $813M; and cotton $581M. Surveys have shown that seasonal climate forecasting is used by 35-40% of graziers, 70% of sugar producers and 30% of cotton growers.

  QCCA states that the estimated total benefit to grazing industries alone, from 1991/92 to 2002/03 was in the range of $600M-1200M. In addition, land degradation costs in Australia are estimated at $1150M per year which represents 5% of the total value of agricultural production. Therefore even a small reduction in degradation (for example, 10%) would be of considerable economic benefit (that is, $115M per year). Thus considering the grazing industries alone, the cost of QCCA represents only 5-10% of the total benefits to Queensland's economy.

- Effective application of forecasts involves their use to improve decisions. This requires development of management skills based on an understanding of how the forecast might interact with potential decision options. While weather and climate-related decisions in agriculture occur on both short and long time-scales, seasonal climate forecasts are less relevant to the very short and long time-scale decisions (Clewett and others, 2000).

- The potential benefits of seasonal climate forecasts vary considerably because of many physical, biological, economic, social and political factors (Jones and others, 2000).

- There are few studies on research evaluation that also include the benefits from reduced income variability (Harrison and others, 1991).

- Chen and others (2002) studied whether the value of the agricultural responses can be enhanced by releasing more detailed ENSO information. They evaluated the implications for projected agricultural welfare under release and adaptation to the Stone-and-Auliciems five-phase definition of ENSO states as opposed to the more standard three-phase definition. This value was estimated using a stochastic, U.S./global agricultural model representing 22 climate years. The results indicated that the release and exploitation of the more-detailed ENSO phase definition almost doubled the welfare impact. The results also indicated that there was room for up to another doubling of information value through further refinements.

- Chen and McCarl (2000) investigated the value of considering the full distribution of ENSO phase strength effects as opposed to average ENSO phase strength effects, as well as the implications of considering ENSO impacts on the rest of the world (ROW). A stochastic U.S. agricultural sector model linked with a global trade model was used to assess the value of ENSO phase information. When the full distribution of ENSO phase strength was considered, the value of phase information increased twofold with respect to the average ENSO effects.

- A study by Petersen and Fraser (2001) aimed to improve the methodology for assessing the value of seasonal climate forecasting technology prior to its development, using the meteorological records in the Merredin agricultural region of Western Australia, for the period 1907-95, as an illustration. Results suggest that a seasonal forecasting technology that provides a 30% decrease in seasonal uncertainty increases annual profits by approximately 5%. The accumulated annual benefit to farmers in the Merredin region (an area with 754 farm holdings over 35 500 $km^2$ of land) is approximately $2 million. Hence, support is given for the development of seasonal forecasting techniques in Western Australia.

- Jury (2002) assessed the economic impacts of climate variability in South Africa and development of resource prediction models. He estimated that over U.S.$1 billion could be saved annually through uptake of timely and reliable long-range forecasts.

- In a survey of users of the QDPI's SOI Hotlines, Paull and Peacock (2002) asked: 'During the last 12 months, roughly how much additional profit or loss did you make from using the information?' Out of 63 respondents to the survey, 14 stated that it was too difficult to calculate, and 15 made an average net profit of $1933 (10 made no profit, and the remainder ranged from profit of $30 000 to loss of $10 000).

- Changnon (2002) studied the effects of a 'failed' forecast. In autumn 2000 NOAA issued long-range forecasts indicating that an existing Midwestern drought would continue and intensify through the upcoming summer. These forecasts received extensive media coverage and wide public attention. However, in late May, June, and July heavy rains fell throughout most of the Midwest, ending the drought in most areas and revealing that the forecast was incorrect for most of the Midwest. Assessment of the agricultural and water management sectors revealed notable commonalities. Most people surveyed were aware of the drought forecasts, and the information sources were diverse. One-third of those surveyed indicated they did nothing as a result of the forecasts. The decisions and actions taken by others as a result of the forecasts provided mixed impacts. The water resource actions resulted in little cost and were considered to be beneficial. However, in the three areas of agricultural impacts (crop production shifts, crop insurance purchases, and grain market choices), mainly negative outcomes occurred. The March issuance of the forecast was too late for producers to make sizable changes in production practices or to alter insurance coverage greatly, and most forecast-based actions taken in these two areas were considered to be negative but financially minor losses. However, 48% of the 1017 producers sampled altered their normal crop marketing practices, which in 84% of the cases led to sizable losses in revenue. This loss can be extrapolated as $1.1 billion for the entire Midwest if the sample statistics are representative of the region. A common result of the failed drought forecast among its users was a loss of credibility in climate predictions and a reluctance to use them in the future. Credibility is a fragile commodity that is difficult to obtain and is easy to lose.

- Chen and others (2001) studied the economic damages in the agricultural sector arising from a shift in El Nino Southern Oscillation (ENSO) event frequency and strength due to climate change. The damage estimates reported are in the context of the global agricultural system. Annual damages in the U.S.$300-400 million range were found if only the frequency of ENSO events changes. However, annual damages rise to over $1 billion if the events also intensify in strength. Event anticipation and crop-mix adaptation on the part of farmers can help offset the damages but cannot fully alleviate them.Adams and others (1999) developed estimates of the economic consequences of El Nino and La Nina events on US agriculture. Both phases result in economic damages to US agriculture - a $1.5 to $1.7 billion loss for El Nino and a $2.2 to $6.5 billion loss for La Nina. The range in these damage estimates reflects assumptions concerning the relationship between yields and ENSO weather patterns, and how farmers respond to these potential yield differentials.

## Cropping Benefits

### *General*

Findings include:

- Profitability in farming comes from making an exceptionally profit in the good years – usually associated with a positive SOI. Many farms make a loss from cropping in the poor years – usually associated with a negative SOI. Attitudes to opportunity and risk are a personal characteristic, but ignoring the SOI increases the chance of a wrong decision (Partridge, 2001).

- Hammer (2000) quotes an example of tactical management of row configuration in a cotton crop on the Darling Downs, Queensland. The profit outcomes with a fixed (all years the same) decision, or a tactical decision based on the SOI phase, or perfect knowledge of the season were compared using a crop simulation study. Over the complete historical climate record, the tactical approach gave an average profit increase of 11%. Adopting a tactical approach, however, did not give increased profit in every year. In 80% of years, adopting a tactical approach was as good as or better than not adopting it, but in 20% of years the manager would have been worse off.

- A dryland grain/cotton farmer on the southern Darling Downs found that since he started following and using the seasonal climate outlook his whole thinking about crop and cropping-systems management had changed; the speed and thoroughness of the implementation of water-conserving strategies were greatly affected by the forecast (Meinke and Hochman, 2000).

- Based on historic rainfall records in conjunction with dynamic crop-simulation models, producers can evaluate alternative management options and quantify the likely effects on farm income and production risk (Meinke and Hochman, 2000).

- Hammer and others (2000) compared four forecasting systems in relation to their value in managing a cropping system in northern Australia. They were the SOI Phase system, SOI patterns over the previous 9-month period, Pacific Ocean sea-surface temperatures and projected SOI patterns from GCM runs. All forecasting systems showed some value in improving management decisions over the two-year period examined in the dryland cropping system. In all cases this was associated with increasing the intensity of cropping in specific forecast year types, either by introducing a sorghum crop or cotton to replace the fallow in the second year of the rotation. The best outcome was associated with the forecasting systems based on either the five-month SST patterns or the nine-month SOI patterns, which gave a 20% increase in gross margin, a 30% decrease in soil erosion, but an increased risk of making a financial loss. The other two forecasting systems gave a gross margin increase of about 13%. There were some differences in relation to financial risk and erosion outcomes among forecasting systems.

- Jones and others (2000) estimated the potential economic value of climate forecasts for farm-scale management decisions in Southeast USA (Tifton, GA) for comparison with results previously obtained for the Pampas region of Argentina. The same crops are grown in both regions but at different times of the year. Firstly, the expected value of tailoring the crop mix to El Nino–Southern Oscillation phases for a typical farm in USA was estimated. Secondly, the potential values for adjusting management of maize to different types of climate forecasts (perfect knowledge of: ENSO phase; growing season rainfall categories; and daily weather) were estimated for USA and Argentina. Predicted benefits to the farm of adjusting crop mix to ENSO phase averaged from US$3-6/ha over all years, depending on the farmer's initial wealth and aversion to risk. Values calculated for Argentina were US$9-15/ha for Pergamino and up to US$35/ha for other locations in the Pampas. Varying maize management by ENSO phase resulted in predicted forecast values of US$13 and US$15 per hectare for Tifton and Pergamino respectively. The potential value of perfect seasonal forecasts of rainfall tercile on maize profit was higher than for ENSO-based forecasts in both regions (by 28% in USA and 70% in Argentina). Perfect knowledge of daily weather over the next season provided an upper limit on expected value of about US$190 /ha for both regions. However, there are a number of challenges to realise these benefits, that are generally related to the uncertainty of climate forecasts and to the complexities of agricultural systems.

- Three economic models varying in aggregation, crops analysed, and regions modelled were used to determine potential impacts of the use of improved climate forecasts on US agriculture (Mjelde and Hill, 1999). Different regions and crops both within a region and between regions may be affected differently. Expected values of variables such as costs, yields, input usage, etc., may increase or decrease with the use of improved climate forecasts. Further, current changes in the US Federal Farm Program may increase the value of improved climate forecasts because of the elimination of most planting restrictions, acreage reduction, and disaster assistance. The addition of catastrophic crop insurance appears to decrease the value of improved climate forecasts.

## *Summer Crops*

Findings include:

- The effects of the spring SOI on profits from grain sorghum in southern Queensland are more pronounced than the effects on yield. These effects are even more serious in crops that have higher costs of production (Partridge, 2001).

- Carberry and others (2000) quoted the results of a simulated case study which demonstrated that the SOI contributed some skill to improving management decisions over a two-year rotation. By changing between fallow-cotton, sorghum-cotton or cotton-cotton rotations based on the SOI phase in the August-September period preceding the next two summers, average gross margins for the two-year period increased by 14% over a standard fallow-cotton rotation. At the same time, soil loss from erosion was reduced by 23% and cash flow was improved in many years because an extra crop was sown. The SOI-based strategy did however increase the risk of economic loss from 5% of years for the standard fallow-cotton rotation to 9%, but this risk was considerably less than the 15% for sorghum-cotton and 19% for cotton-cotton rotations.

## *Winter Crops*

Findings include:

- In winter crop production, the influence of the autumn SOI on winter rainfall may be less important than the amount of water stored in the soil at planting. When the gross margins for tactical dressings of nitrogenous fertiliser are compared with fixed dressings each year, there is a small chance of making less money but a good chance of making much more. Thus more money can be made with less risk, by adjusting the rate of nitrogenous fertiliser according to the SOI trend in the two months prior to planting. An example was calculated for a wheat crop planted on a soil at two-thirds moisture capacity at Goondiwindi in southern Queensland. Instead of applying a standard dressing of 40kg.of nitrogen/ha/year, it is worth an extra $18/ha/year overall (at a 10% risk of making a loss) to apply tactical dressings based on the SOI in the two months before planting (Paltridge, 2001).

- The software program called Wheatman can use the SOI to assess the probabilities associated with its effects on yield, protein content and gross margin of winter crops (Partridge, 2001).

- The value of using a seasonal forecasting system (based on identification of phases of the Southern Oscillation) in wheat management at Goondiwindi in southern Queensland, was investigated by Marshall (1996). Earlier methods have been improved by accounting for interdependence of decisions regarding planting date, nitrogen fertiliser and cultivar, by investigating the sensitivity of the value of the forecasting system to variation in planting conditions, by using expected utility theory, by testing the sensitivity of estimated values to degree of risk aversion, and by accounting more completely for post-planting tactical options that allow a grower to reduce climatic risk. In decisions relating to nitrogen applications, cultivar choice and whether to harvest grains or graze, seasonal forecasts had mean values of $3.52 to$3.83 per hectare per year. The results also indicated that as planting conditions move towards the optimum, the value of forecasting usually increases and is more likely to increase along with risk aversion.

- Hill and others (2000) compared SOI-based forecasting methods to determine which one was more valuable to Canadian and US wheat producers. The most commonly used three-phase method of El Nino, La Nina and other was compared to a five-phase system. Because of differences in growing season and yearly SOI classification schemes, two different three-phase methods were used. The five-phase system is based on the level and rate of change of the SOI over a two-month period. Phases are consistently negative, consistently positive, rapidly falling, rapidly rising and near zero. As expected, results vary by the method used. Winter wheat producers in Illinois placed no value on either of the SOI-based forecast systems. Producers at seven of the thirteen sites prefered the five-phase method to either of the three-phase methods. The value of the five-phase approach was up to 70 times more valuable than the three-phase approach. Producers growing spring wheat in Saskatchewan and Montana, along with winter wheat producers in Ohio and Kansas value the three-phase approach more than the five-phase. In this case, the value of the three-phase system is up to two times more valuable than the five-phase system. Depending on the expected price and region, the values of the SOI-based forecasts were 0-22% of the value of perfect forecasts. Economic value and distributional aspects of the value of climate forecasts have implications for producers, policy makers, and meteorologists. Finally, the results clearly suggested all producers will not prefer one forecast type.

- Stone and Hammer (1994) illustrated the value of on-farm application of management decisions and crop simulation based on seasonal forecasting by a case study of a wheat crop at Goondiwindi Queensland. Results indicate that most high-yielding years follow rapidly-rising SOI in late autumn, most low-yielding years follow a consistently–negative SOI in late autumn, and yields following SOI values near zero are similar to the all-years distribution. General Circulation Models (GCMs) also have their poorest skill in autumn but because this fact is not well known, many farmers who have used GCM forecasts for crop planning have suffered economic losses.

- Mjelde and Dixon (1993) investigated how the value of climate forecasts for maize production changes as a function of when they are received. The value of climate forecasts is highly sensitive to the expectations of the decision-maker at the beginning of the planning horizon. A procedure is developed which allows a decision-maker to anticipate the issuance of forecasts in a dynamic programming framework. This procedure is contrasted with a previous methodology in which the decision-maker was unaware that a climate forecast would be issued until the forecast was received. Results show that using the 'unaware' methodology may overstate the value of receiving forecasts earlier.

## Grazing Benefits

### *General*

Findings include:

- Preliminary studies on the use of seasonal climate forecasts (SCFs) indicate potential for better management decisions such as:
    - Herd management – by forecasting rates of reproduction and mortalities.
    - Pasture management and management of stocking rate – using various approaches including 'safe' carrying capacity, adjusting animal at end of growing season, rapid rotation of stock, and 'tactical rest' (Johnston and others, 2000).

      It is rarely possible to assess the value of climate forecasting by directly comparing historical SOI time series with grazier records. Using a systems approach, involving developing and utilising simulation models of components of the grazing system, long-term historical climate records can be transformed into simulated records of physical, biological and financial variables. These links between simulated variables and the forecasting system can then be evaluated and better decision rules derived (Johnston and others, 2000).

- The following research findings have contributed to our understanding of how to fruitfully use SCFs in grazing industries:
    - Some skill exists in forecasting summer pasture growth (November to March) using the SOI from August to October;
    - Spring SOI <-5 provides warning of years when resource damage is most likely to occur;
    - Annual steer growth and wool-cut per head were highly correlated with the proportion of the year that plant-growth or soil-moisture indices exceeded a given threshold, rather than the total amount of plant growth;
    - Pregnancy rate of mature lactating cows in north-east Queensland, measured in June-July, was correlated with the previous August-October SOI;

  - Some forecasting skill is available in predicting pasture growth following spring burning; and
  - Limit sowing of the legume Stylosanthes to years when the SOI Phase is consistently positive or rising (Johnson and others, 2000).

- Jochec and others (2001) investigated the potential for west Texas ranchers to increase the profitability of their enterprises (by becoming more proactive in their management practices by using seasonal climate forecasts) through using a focus group and ecological-economic modeling. The focus group felt forecasts could potentially be used in making decisions concerning stocking rates, brush control, and deer herd management. Further, the focus group raised concerns about the potential misuse of 'value-added' forage forecasts. These concerns necessitate a revisiting of the value-added concept by the climate-forecasting community. Using only stocking-rate decisions, the potential value of seasonal forage forecasts was estimated. As expected, the economic results suggested the value of the forecasts depended on the restocking and destocking price along with other economic factors. More important, the economic results and focus-group reactions to these results suggested the need for multiyear modeling when examining the potential impact of using improved climate forecasts.

## ***Beef***

Findings include:

- Ash and others (2000) used a forage-animal production model in the Dalrymple Shire to evaluate the production and resource implications of grazing management and five SCF strategies (spring SOI, spring SOI Phases, an SOI Phase System 'tuned' to Charters Towers rainfall, winter Pacific Ocean SST (EOF analyses), and winter Pacific and Indian Ocean SSTs (EOF analyses). Stocking rates were adjusted annually. Results from these analyses show that:

  - SCFs provide more benefit to animal production when the forecasting information is available in June rather than November;
  - The relative value of forecasting is greater for constant grazing strategies than for flexible ones;
  - Increased animal production derived from applying a forecast is not at the expense of the resource base, and if increased animal production is not the desired aim of the forecast then significant reductions in soil loss can be achieved;
  - Using localised forecasts does not provide any extra skill in production simulations.

- Stafford Smith and others (2000) highlight the importance of assessing the value of forecasts in the context of the whole management system. They used linked models of pasture growth, herd dynamics and property economics to simulate whole-enterprise management of a cattle station in north-eastern Queensland. They used a constant stocking rate and a trading-reactor strategy over the weather record, and then added six- or 12-month forecast information to the farmers' decision-making. Findings were:

  - In general the optimum level of response to a forecast (increasing stock numbers in good years and decreasing them in bad) increased with increasing certainty. An inappropriate response to the forecast could be worse than no response, highlighting the sensitivity of forecasting advice to this factor. The differences in cash-flow between different levels of response to a forecast could be considered larger than the difference between strategies.
  - At the optimal response levels, forecasts provided a modest benefit in cash-flow over baseline strategies, with more benefit to be gained from a 12-month forecast than a six-month forecast. The same level of cash-flow could be achieved for a much lower risk of environmental degradation with forecasting; however, if advantage was taken of increased cash-flow, then the risk of soil loss changed little. The benefits found in production per unit area do not translate to economic output at the whole-enterprise level in a simple way.
  - The outcomes were sensitive to changes in market prices. In general, trading strategies (reactor, and six- or 12-month forecasts) were relatively more favoured over a constant stocking rate strategy as sale prices rose, and especially as the margins between sale and

purchase prices increased. Higher stocking rates were also favoured at higher prices in reactor strategies.

There are many other aspects of risk management from which producers could benefit before forecasting becomes the limiting factor in management. However, a seasonal forecast with current skill has some value for production and resource protection when used to trigger appropriate responses.

## *Sheep and Wool*

Findings include:

- Bowman and others (1995) used a simulation model of a breeding ewe flock to make a preliminary assessment of the value of climate forecasting for wool-producing enterprises in Victoria. Stocking and selling policies were modified in response to the SCF. This resulted in a reduction in the death rate of adult ewes and their progeny. Timely action when adverse conditions were imminent resulted in an increase in pasture cover during autumn and winter and minimum liveweight loss of the sheep. Gross returns were increased on average by more than 5%. Much of this increase was contributed by higher wool returns associated with the increase in size of the flock during favourable conditions. Expenditure on sheep purchases was lower for the traditionally-managed farms; however, knowledge of forthcoming conditions did allow stock numbers to be reduced before pasture reserves were depleted in poor seasons, which in turn reduced the requirement for supplementary feed.

  Where the forecast was accurate in only eight years in 10 or six years in 10, the benefits of altering the stocking and selling policies were reduced, but the average cash operating surplus was higher than that achieved using the traditional management regime. However, in individual years, inappropriate policies adopted due to an incorrect forecast resulted in reductions in financial returns of up to 64%. Accurate forecasts can improve land care and animal welfare by changing pasture and animal management, particularly by reducing stock numbers. However, since the profitability of sheep enterprises in Victoria is highly dependent on the choice of stocking rate, recommendations to reduce stock numbers without considering the financial viability of sheep enterprises may go unheeded.

  The study highlighted a number of prerequisites for long-range climate forecasting to be of value to farmers. A very high level of accuracy of forecasting is required to ensure that most of the financial benefits gained through correct forecasts are not subsequently lost in years when the forecasts are in error. Buying and selling strategies for livestock need to be determined well in advance of adverse seasons, and seasonal forecasts need to provide quantitative information on the effect of forthcoming climatic conditions on pasture production to accurately predict carrying capacity over the autumn and winter. The value of reduced damage to soils and vegetation through destocking prior to drought must be included in the final analysis, and is a prerequisite to attaining more sustainable agricultural systems as part of a holistic approach.

## Marketing Benefits

Findings include:

- Mjelde and others (1989) examined the complex nature of the process of economically valuing climate/weather forecasts. Integration of both micro- (farmer) and sector (market) economic issues is necessary to obtain the overall value of current or improved climate/weather forecasts. Previous studies had predominantly been concerned with valuing climate/weather forecasts at the producer level. By considering only producer-level effects, the estimates of the value of climate/weather forecasts ignore market adjustments and the potential biases from doing so.

- Rosenthal and others (1998) found that reliable Shire and State grain sorghum production estimates can be generated by combining crop simulation and geographic information system technologies. The procedure is suitable for further development for use in real-time. By updating estimates as a season progresses, improved timeliness and accuracy of production forecasts could be achieved.

- Potgieter and others (2002) researched spatial and temporal patterns in Australian wheat yield and their relationship with ENSO. Year type groupings that were identified were tested for association with indicators of ENSO. Significant associations were found for all zones in the Australian wheatbelt. Associations were as strong or stronger when ENSO indicators preceeding the wheat season (April-May phases of the Southern Oscillation Index) were used rather than indicators based on classification during the wheat season. Although this association suggests an obvious role for seasonal climate forecasting in national wheat crop forecasting, the discriminatory power of the ENSO indicators, although significant, was not strong. By examining the historical years forming the wheat yield analog sets within each zone, it may be possible to identify novel climate system or ocean-atmosphere features that may be causal and, hence, most useful in improving seasonal forecasting schemes.

## Other Industries

In some industries/business enterprises, other considerations are much more important than a possible climate impact. Add to this the uncertainty associated with the climate forecast. However, as the use of decision-support systems using models increases, SCFs may become more valuable in some circumstances.

### *Fisheries*

Findings include:

- Costello and others (1998) developed a bioeconomic model of the coho salmon fishery and derive the value of information from improved El Nino forecasting ability. They found that a perfect El Nino forecast resulted in an annual welfare gain of approximately $1 million, while imperfect forecasts led to smaller gains. Results also suggested that optimal management in the face of uncertainty involved a ‘conservative’ management strategy, resulting in lower harvest, higher wild fish escapement, and lower hatchery releases than management in the absence of such uncertainty.

### *Water Resources*

Findings include:

- In general, water authorities consider SCFs unreliable and insufficiently specific for their needs (Long and McMahon, 1996). The currently used simplistic methods which tend to underestimate available water resources could be replaced by more sophisticated exploratory methods.

- Ploughman (1999) stated that there had been a number of fundamental reforms to water policies that would enhance drought management, including the introduction of water trading, strategies for the management of groundwater and the use of climate forecasts to improve management decisions.

- Pagano and others (2002) investigated the factors affecting seasonal forecast use in Arizona water management. In interviews with key personnel from a broad array of agencies responsible for emergency management and water supply, they investigated where information was acquired, how it was interpreted and how it was incorporated into specific decisions and actions. In addition, technical and institutional barriers to forecast use were explored. Study findings emphasised the need for special handling of tailored forecast products on a regional scale, the need for systematic regional forecast evaluation and the potential for climate information to directly affect water management decisions through integrating climate forecasts into water supply outlooks where appropriate.

- Hartmann and others (2002) conducted a survey of weather, climate, and hydrologic forecasting for the US Southwest. During the survey period, users faced a complex and constantly changing mix of forecast products. The abundance of forecasts was not matched in the provision of corresponding interpretive materials, documentation about how the forecasts were generated, or reviews of past performance. Potential existed for confusing experimental and research products with others that had undergone a thorough review process. Contrasts between the state of meteorologic and hydrologic forecasting were notable, especially in the former's greater operational flexibility and more rapid incorporation of new observations and research products. Greater attention should be given to forecast content and communication, including visualization, expression of probabilistic forecasts and presentation of ancillary information. Regional climate models and use of climate forecasts in water supply forecasting offer rapid improvements in predictive capabilities for the Southwest. Forecasts and production details should be archived, and publicly available forecasts should be accompanied by performance evaluations that are relevant to users.

- Chen and others (2001) investigated the effects of climatic change on regional water demand and supply as well as the economy in the San Antonio Texas Edwards Aquifer region. This was done using a regional model that portrayed both hydrological and economic activities. The overall results indicated that changes in climatic conditions reduce water resource availability and increase water demand. Specifically, a regional welfare loss of \$2.2-\$6.8 million per year may occur as a result of climatic change. Additionally, if springflows are to be maintained at the currently desired level to protect endangered species, pumping must be reduced by 9-20% at an additional cost of \$0.5 to \$2 million per year.

### *Insurance*

Findings include:

- Martin and others (2001) studied developing and pricing precipitation insurance. Their findings showed a potential for weather derivatives to serve niche markets within U.S. agriculture.

- Stern (2001) also investigated the application of weather derivatives to mitigate the financial risk of climate variability and extreme weather events. He presents an approach to the pricing of weather derivatives that employed a combination of empirical data including forecast verification data, regional synoptic classification data, and data associated with climate indices on a global scale, such as the Southern Oscillation Index.

### *Energy*

Findings include:

- Changnon and others (1999) report on a case study incorporating ENSO information into a strategy for purchasing natural gas. The strategy selected saved Northern Illinois University (NIU) approximately \$500,000, and aided in the university's decision to hire a full-time applied meteorologist to provide advice on a continuing basis.

## Ecological/Environmental Benefits

While it may be difficult to value environmental benefits, a number of environmental indicators can be used to determine whether a decision will result in a change in sustainability of the production system. For example, soil erosion, soil organic matter, salinity, changes in key pasture species, weed populations and changes in ground cover.

Findings include:

- There is a trade-off between pastoral production and environmental damage. A simulation study by McKeon and others (2000) highlighted the potential value of achieving in June, the skill from seasonal forecasting that is now available in November using average SOI in the August-October period as the indicator of season type. Such an improvement in forecasting may improve production and/or reduce damage.

- Clark and others (2001) stated that planning and decision-making can be improved by access to reliable forecasts of ecosystem state, ecosystem services, and natural capital. Availability of new data sets, together with progress in computation and statistics, will increase our ability to forecast ecosystem change. An agenda that would lead toward a capacity to produce, evaluate, and communicate forecasts of critical ecosystem services requires a process that engages scientists and decision-makers. Interdisciplinary linkages are necessary because of the climate and societal controls on ecosystems, the feedbacks involving social change, and the decision-making relevance of forecasts.

### Social/Community Benefits

Findings include:

- A general equilibrium model was linked to a decision model to determine the impact of perfect growing season forecasts for corn produced in the Corn Belt region of USA over a 10-year period (Mjelde, Penson and Nixon, 2000). Five different timing scenarios were examined to determine the effect of different orderings in the occurrence of good and bad crops over this period. The use of climate forecasts is shown to have both positive and negative financial and economic effects depending on the specific year within any given scenario. The expected present value of changes in net surplus (consumer plus producer surplus) varied from US$1.270 to $2.917 billion from the use of perfect forecasts over different 10-year planning horizons. Consumers are the clear winners (positive values) and producers are the losers over the entire horizon.

- Biot (1991) states that crop production forecasting, in the Sahel and Sub-Saharan Africa, can be used to give production forecasts 4-6 weeks before harvest and 3-6 months before famines.

- Murphy and others (2001) review the use of seasonal forecasts for climate hazards, including a critical evaluation of the utility of seasonal forecasts centres on vulnerability, communication channels, and effective responses. In contrast to short-term prediction, seasonal forecasts raise new issues of preparedness and the use of information.

## FORECASTS AND GOVERNMENT POLICIES/ASSISTANCE

Findings include:

- Mjelde, Thompson and Nixon (1996) examined the impact of USA government institutions on the value of improved climate forecasts. Federal tax law had only a moderate influence. However, the disaster program decreased the value of improved climate forecasts. The Farm Program may decrease or increase the value of climate forecasts depending on the situation.

- Eakin (2000) studied the decisions of smallholder farmers in Mexico which are intricately tied to the political-economic circumstances in which they are made. He argued that political-economic uncertainty outweighed climatic uncertainty as a determinant of their production strategies. In those circumstances, the farmers are unlikely to use new SCFs.

- Naylor and others (2002) discuss the use of models linking ENSO-based climate variability to Indonesian cereal production, in order to improve food policy planning.

## EXTENSION/COMMUNICATION

Findings include:

- Despite the demonstrated benefits to pastoral industries of using a forecasting strategy based on the SOI, there is considerable reluctance amongst producers to adopt such forecasts. A producer survey indicated that even if more reliable forecasts were developed, most would wait until extreme events had an impact on their enterprise before making critical stocking decisions. Even in the absence of seasonal forecasts, grazing management in the rangelands of Australia could be vastly improved through better incorporating existing understanding of climate variability into stocking decisions. Further value may be added through the application of seasonal forecasting, but perhaps this added sophistication should only be contemplated after basic grazing management principles are incorporated into whole property planning (Ash and others, 2000).

- Hayman and Alston (1999) conducted a survey of 400 wheat farmers in northern New South Wales in April 1997 to assess how they made decisions about nitrogen fertiliser. It revealed that many had recently changed their fertiliser practices. Although most respondents had been growing wheat since the 1960s, regular applications of nitrogen only commenced in the mid 1980s. Initially only low rates of nitrogen were applied, but in the last 2-5 years, the nitrogen rates have been substantially increased. These changes are notable because until this decade, most were content to rely mainly on mineralisation of soil organic nitrogen, whereas, now, half the respondents in the survey plan to add as much nitrogen in fertiliser in one year as was removed in the previous year's wheat crop. Farmers were asked to rate the importance of a number of factors that have been promoted as means of tactically adjusting fertiliser rates. This study found a disparity between the level of measurement and precision suggested by the majority of research, development and extension programs compared with the methods used by farmers. In general, the respondents to the survey had rejected, or are yet to adopt, regular soil testing, the use of climate forecasts and decision-support programs. Rather, they rely on simple rules of thumb based on readily accessible data such as past grain protein content and cropping history.

- The Property Management Planning (PMP) process provides the context for developing seasonal climate knowledge and skills within a strategic planning and farm decision-making framework. There is a need to develop training tools/processes that enable analysis of decision options in conjunction with seasonal forecast information and other factors (Clewett and others, 2000).

- Cobon (1999) modelled the comparative impact of three Southern Oscillation Index (SOI) classes on wool production and profitability in western Queensland. Although the results showed clear relationships between SOI and rainfall, pasture growth and profit pastoralists had not adjusted stocking rate accordingly. It is suggested that the complexities of forecasting from SOI classes may limit practical application of the method. Providing simple diagrammatic explanations of the likely opportunities and risks of adjusting management decisions to climate forecasts may be a useful addition.

- A study was conducted by Hayes and others (2001) to examine the decision-making processes of Victorian dairy farmers, and the ways they used climate information within those processes. It found that most farmers do not have confidence in climate forecasts and view estimates of probabilities as of no value to practical decision-making. Dairy farmers have the perception that climate forecasts are unreliable and inaccurate, media reporting of climate forecasts is often inconsistent and conflicting, that current climate information is not specific to local areas, and that information on the internet is scattered across many sites and farmers are frustrated trying to find the particular indicators relevant to their area and situation. The study supports the view that the limited ability of Victorian dairy farmers to use probabilistic climate information in farm management decision-making is one of the major limitations to the use of climate forecasts by them. Unless these abilities are improved and farmers can be convinced that they are able to benefit from the use of climate information, there will be little effective demand for such information.

- Hartmann and others (2002) evaluated seasonal climate forecasts from user perspectives. Decision makers stated that they lacked any quantitative basis for evaluating forecast credibility. That is because the evaluations currently available typically reflect forecaster perspectives rather than those of users, or are not available in forms that users can easily obtain or understand. Seasonal climate forecasts were evaluated from the perspective of distinct user groups, considering lead times, seasons, and criteria relevant to their specific situations. Examples showed how results targeted for different user perspectives can provide different assessments of forecast performance. In addition, forecast formats can affect the ease, accuracy, and reliability of interpretation.

- Letson and others (2001) also investigated user perspectives of climate forecasts: crop producers in Argentina. A survey of 200 farmers identified climate forecast scale and the reliability of the source of forecast as critical obstacles to adoption. Users' incomplete knowledge of how El Nino-

Southern Oscillation affects their region may also pose an obstacle to greater use of climate information. A related problem is that users sometimes confuse the different time scales of weather and climate forecasting. Research and outreach to downscaling forecasts temporally and spatially toward user communities would help close the gap of expectations between forecast user and provider, and would facilitate the trust building process between the two that must precede adoption.

- Sherrick and others (2000) studied decision-maker expectations and the value of climate prediction information. They examined the commonly-used assumption that decision-makers possess accurate prior probability information about climate events that affect their well-being, and illustrated the impact of that assumption on the valuation of prediction information. A survey of large producers in the Mid-western United States was used to recover their prior beliefs about climate variables. It was found that producers systematically misrepresented the probabilities of climate events that materially affect their well-being. In particular, the most common form of the miscalibration between actual and subjective probabilities was to overstate the likelihood of adverse events and understate the likelihood of favourable events. As a result, common methods for valuing prediction information were likely to understate the true value when recipients began with less accurate prior beliefs.

- Bohn (2000) studied the ENSO signal in terms of its relevance to commercial agriculture in southern and eastern Africa. Analysis reveals, however, that the ENSO signal shows great variability both within and between events with obvious implications for the use of climate information by potential users. Information requirements also vary substantially from user to user. The results showed that the use of climate information varies considerably between companies. A preliminary assessment highlights certain constraints on use, primarily in terms of forecast timing and scale. Recommendations for further work included a thorough exploration of the constraints issue as well as economic assessment of the perceived value of forecasts, including how these estimates were reached.

- Washington and Downing (1999) studied the use of seasonal forecasts in southern and eastern Africa. Their utility depended on the linkages between geophysical, economic and social aspects of resource use. Progress in rainfall forecasting was placed in the context of the use of seasonal predictions in Africa, with a particular emphasis on ameliorating vulnerable livelihoods. Targeting users, reaching vulnerable livelihoods, messages that were distorted over space and time, the lag between forecasts and dissemination, maladaptive responses and false alarms were difficulties that could be expected in many developing countries.

## REALISING THE VALUE OF SEASONAL CLIMATE FORECASTS

The communication aspects of SCFs warrant greater priority if the potential importance of the forecasts in improving risk management is to be realised. Communicating probability-based information in a form to encourage confident responses by decision-makers is a continuing research challenge, and an integral component of a balanced research program (White, 2000).

The review of the Rural Adjustment Scheme (DPIE, 1997) stated that seasonal forecasts have not yet had a great impact on the risk management practices of Australian farmers. Poor links between the information available and on-farm decision-making was seen as the principal reason.

In the review of the CVAP Program (Hassall and Associates, 1997) more rapid adoption by farmers, the major user group, was seen to depend on their greater involvement in research. Further, research needed to be more focused on increased confidence in the use of forecasts, and demonstrations of the value of forecasts relevant to the decisions of individual farmers. Two neglected areas were taking advantage of forecasts of favourable seasons and improved management of natural resources.

One major constraint to the effective use of climate forecasts is the considerable difficulty people have in estimating and dealing in probabilities, risk and uncertainty. Some of this difficulty arises from problems known as cognitive illusions or biases. The optimum use of climate predictions requires providers of forecasts to understand these difficulties and to make adjustments for them in the way forecasts are prepared and disseminated (Nicholls, 1999).

Mjelde and others (1993) examined trade-offs between climate forecast quality and economic value from the perspective of the forecast user. Various scenarios for climate forecast quality were applied to corn production in east-central Illinois. A stochastic dynamic programming model was used to obtain the expected value of the various scenarios. As anticipated, the results demonstrate that the entire structure of the forecast format interacts to determine the economic value of that system. Additional results indicated two possible preferred directions for research concerning climate forecasting and economic applications such as corn production in Illinois. First, increasing forecast quality by decreasing the error between the observed condition and the forecast condition may be preferred to increasing quality by increasing the number of predictions in the correct category. Second, corn producers may prefer research to increase the quality of forecasts for 'poorer' climatic conditions, rather than research directed toward increasing the quality of forecasts for 'good' conditions.

Broad and others (2002) investigated effective and equitable dissemination of seasonal-to-interannual climate forecasts in the Peruvian fishery. They identified: potential constraints on the realisation of benefits, such as limited access to and understanding of information, and unintended reactions; and the need for an appropriately detailed definition of societal benefit, considering whose welfare counts as a benefit among various groups. They argued that consideration of who benefits, and an understanding of potential socioeconomic constraints and how they might be addressed, should be brought to bear on forecast dissemination choices.

Hammer and others (2001) stated that skill in climate prediction offered considerable opportunities to managers via its potential to realise system improvements (that is, increased food production and profit and/or reduced risks). Realising these opportunities, however, was not straightforward as the forecasting skill is imperfect and approaches to applying the existing skill to management issues was not developed and tested extensively.

From the case studies quoted, Hammer and others noted some general lessons. Foremost was the value of an interdisciplinary systems approach in connecting disciplinary knowledge in a manner most suited to decision-makers. This approach often included scenario analysis based on simulation with credible models as a key aspect of the learning process. Interaction among researchers, analysts and decision-makers was vital in the development of effective applications - all of the players learn. Issues associated with balance between information demand and supply as well as appreciation of awareness limitations of decision-makers, analysts, and scientists were highlighted. It was argued that understanding and communicating decision risks was one of the keys to successful applications of climate prediction.

They considered that advances of the future will be made by better connecting agricultural scientists and practitioners with the science of climate prediction. Professions involved in decision making must take a proactive role in the development of climate forecasts if the design and use of climate predictions were to reach their full potential.

Carberry and others (2002) describe FARMSCAPE which is a program of participatory research with the farming community of north-east Australia. It initially involved research to explore whether farmers and their advisers could gain benefit from tools such as soil characterisation and sampling, climate forecasts and, in particular, simulation modelling. Its current focus is facilitating the implementation of commercial delivery systems for these same tools, in order to meet industry demand for their access. The FARMSCAPE team employed a Participatory Action Research approach to explore whether farmers could value simulation as a decision-support tool for managing their farming system and if so, could it be delivered cost-effectively. Initial scepticism by farmers and commercial consultants about the value of APSIM systems simulator was addressed by testing its performance. Simulation sessions usually evolved into participants interactively inquiring of the model the consequence of alternative management options. These 'What if' questions using APSIM were contextualised using local climate and soil data, and the farmer's actual or proposed management rules. The active participation of farmers and their advisers, and working in the context of their own farming operations, were the key ingredients in the design, implementation and interpretation of the FARMSCAPE approach to decision support. The attraction of the APSIM systems simulator to farmers contemplating change was that it allowed them to explore their own system in a manner equivalent to learning from experience. Current efforts are focused on the training, support and accreditation of commercial agronomists in the application of the FARMSCAPE approach and tools.

# DISCUSSION

Australia has one of the most variable climates in the world with the largest variability being in the north-east of the continent. Periodic droughts have significant intermittent impacts on primary production. A typical major drought reduces the gross value of agricultural production by about 10%, and the Gross National Product by about 1%.

Seasonal climate forecasts (SCFs) are becoming more accurate, and have considerable potential to enable managers in climate-affected industries to reduce unwanted impacts and take advantage of expected favourable climatic conditions. However, the potential benefits of SCFs vary considerably because of many physical, biological, economic, social and political factors.

## Use of Seasonal Climate Forecasts

Managers involved in primary industries are now using seasonal-climate-forecast information in making business decisions in many areas. The use of a seasonal climate forecast in making a particular business decision may increase the confidence of that decision-maker, and be perceived as having insurance value by a risk-averse manager. However, many decision-makers have indicated that they require more confidence in using SCFs. Actions that would help to address this issue include:

- Develop more accurate forecasts with longer lead times;
- Provide reliable information on the relative forecasting skills of different forecasting systems for each district and month of the year;
- Provide forecast outputs in the presentation format that is preferred by each client group (that is, can be easily understood and used in decision-making pertaining to their enterprise);
- Customise the information at district or local government area so that it is perceived as relevant by clients;
- Provide brief high-quality interpretive comments with the climate-related products that are distributed;
- Maintain good quality control in the production and distribution of forecast outputs, so that clients receive accurate, timely and unambiguous forecast information; and
- Deliver forecasts by the methods preferred by each client group.

In order to put a value on a particular seasonal forecast, it is necessary to consider the net economic, environmental and social benefits resulting from the use of that forecast in making a wide range of business decisions. The value of climate forecasts is sensitive to economic conditions as well as forecast characteristics. In any specific decision, the full range of possible outcomes from using the forecast needs to be recognised. Some outcomes are more desirable than others to the decision-maker, and therefore need to be given a higher weighting in the valuation process. It needs to be remembered that an inappropriate response to a forecast, or using a ‘wrong’ forecast, may be worse than not using the forecast – a financial loss may occur.

Many managers involved in primary industries are attempting to use SCFs fruitfully in their businesses. For example, in a survey of graziers around Australia in 1998 (Paull and Hall, 2000), 37% of respondents indicated that they used SCFs in their decision-making. The two main components of using a seasonal climate forecast in decision-making are: exploring options for alternative decisions based on the likelihood of possible outcomes; and a comparative evaluation of the alternatives in terms of the decision-maker’s goals (Ridge and Wylie, 1996).

## Benefits of Using Seasonal Climate Forecasts

The research papers quoted in the above review give many ‘snapshots’ of the usefulness or calculated value of various SCFs in particular case studies, or in other analyses involving simulation with various assumptions. However, similar case studies (using different methods and/or assumptions) may produce significantly different values of the SCF. For example in the case studies quoted, the long-term value of SCFs in wheat production in inland southern Queensland ranged from very little value to $18/ha./year. There is a need to obtain consensus on how best to calculate the value of a climate forecast given the uncertainties associated with the forecast, the managerial response to it, and the outcome of the decision.

Ultimately, it is best if the individual decision-maker decides the assumptions that are made in calculating forecast value. In any case, simulation models will be required to enable examination of a range of options and their likely outcomes.

Some macro-economic studies are quoted which give estimates of the costs of climatic variability. Such estimates help to justify the development of SCF systems, and provide a context within which the use of a climate forecast system can be valued. For example, estimates of the economic consequences of El Nino and La Nina events on U.S. agriculture are: US$1.5 to 1.7 billion loss for El Nino, and US$2.2 to 6.5 billion loss for La Nina (Chen and others, 2001).

Other studies have assessed the potential benefits of using SCFs in a particular region of the world. For example, it was estimated that SCFs had the potential to increase annual profits by $2 million in the Merredin agricultural region of WA (Petersen and Fraser, 2001); and that over US$1 billion could be saved annually in South Africa through uptake of timely and reliable long-range forecasts (Jury, 2002).

Alternatively, there are studies that compare the values of two or more SCF systems. For example, a USA study by Chen and others (2002) found that the five-phase SOI Phase System almost doubled the welfare impact of the three-phase SOI System, and concluded that there was room for another doubling of information value through further refinements. In eastern Australia, the experimental SPOTA-1 System promises to provide some of this additional value through greater accuracy and lead time (Day and others, 2001).

In another USA investigation (Hill and others, 2000), graingrowers at seven of the thirteen study sites preferred the five-phase SOI Phase System to either of the three-phase methods (that is, SOI and SOI Phase). The value of the five-phase approach was up to 70 times more valuable than the three-phase approach. However, producers growing spring wheat in Saskatchewan and Montana, along with winter wheat producers in Ohio and Kansas, valued the three-phase approach more than the five-phase. In this case, the value of the three-phase system was up to two times more valuable than the five-phase system. Depending on the expected price and region, the values of the SOI-based forecasts were 0-22% of the value of perfect forecasts. These results emphasise that forecast information needs to be tailored to specific regions, and the needs of specific client groups.

Unfortunately, where SCFs are being used in management decisions there is no guarantee that the most likely climate scenario will actually occur. The client needs to know that the forecast system has worthwhile accuracy, and that the probability of the most likely climate scenario is significantly different from that expected by examining the all-years historical record. Forecast credibility is a fragile thing, and can suffer considerably due to perceptions that the forecast was ‘wrong’ resulting in a financial loss. An example of such a situation occurred in 2000 in the Midwest of USA, when a failed forecast resulted in an estimated total loss of US$1.1 billion by farmers (Changnon, 2002).

Results from a number of surveys are also quoted. These give some feedback on clients’ perceptions of value in seasonal forecasts – information required, ease of use in decision-making and outcomes from decisions using the information. For example, in a survey in 1995 (Paull and Peacock, 2002), fifteen primary producers in Queensland and NSW reported an average net profit of $1933 in a 12-month period using SOI-based information. However, the spread of net financial outcomes ranged from a profit of $30 000 to a loss of $10 000.

There are also case studies that examined the value of SCFs in managing a particular enterprise in a specific region. For example, tactical management of row configuration in a cotton crop in southern Queensland, according to the SOI phase, gave an average profit increase of 11% in one study (Hammer, 2000). Financial benefits claimed in such studies include: increased profitability; reduced risk to the enterprise; and reduced income and cash-flow variability. Potential environmental benefits include reduced risk to the resource base.

Another study simulated the growth of a wheat crop planted on a soil (at two-thirds moisture capacity) at Goondiwindi in southern Queensland. Instead of applying a standard dressing of 40kg.of nitrogen/ha/year, it was worth an extra $18/ha/year overall (at a 10% risk of making a loss) to apply tactical dressings based on the SOI in the two months before planting (Partridge, 2001).

In Southeast USA, predicted benefits to the farm of adjusting crop mix to ENSO phase averaged from US$3-6/ha over all years, depending on the farmer's initial wealth and aversion to risk (Jones and others, 2000). Values calculated for Argentina were US$9-35/ha. Similarly varying maize management by ENSO phase resulted in predicted forecast values of US$13 in USA and US$15 per hectare in Argentina.

Using SCFs can act as a catalyst/motivator for a manager to improve overall management of his/her business, for example by demanding improvements in monitoring, infrastructure/equipment, and the adoption of up-to-date technology. Modern farming involves greater precision through better monitoring of the production system, quantitative comparisons of management options, and sufficient flexibility in operations to implement the preferred response to a SCF. Pasture and crop growth simulation models, together with economic models, can be used to evaluate alternative management options, and quantify the likely effects on farm income and production risk.

Unfortunately, when trying to increase the profit from a production system, the result is often some increase in risk. For example, the tactical use of seasonal climate forecasts in cropping often involves increasing cropping intensity in selected years. However, decisions made on crop choice and management in one season have ramifications on the sequencing of crops in subsequent seasons, and on the potential for resource degradation. Hammer and others (2000) showed that the best SOI-based forecasts, in managing a cropping system in northern Australia, gave a 20% increase in gross margin, a 30% decrease in soil erosion, but an increased risk of making a financial loss. In another study pertaining to cotton rotations in southern Queensland, an SOI-based strategy increased the risk of economic loss from 5% of years (for the standard fallow-cotton rotation) to 9%. The case study quoted by Carberry and others (2000), indicted that the SOI-based strategy used to select a crop rotation increased the risk of making an economic loss when compared with the rotation commonly used.

In another study (Marshall, 1996), as planting conditions moved towards the optimum, the value of seasonal climate forecasting usually increased. It was also more likely to increase as the degree of risk-aversion in the manager increased.

It is more difficult to calculate/observe the benefits of using seasonal climate forecasts in grazing enterprises compared with cropping enterprises. The dynamics of animal-pasture interactions are more complex, and usually the benefits/increased profits are received over a longer period of time. Computer packages such as Grassman, Range-pack and Dynama can be used to help in making such decisions.

In a study in Texas, USA, by Jochec and others (2001) the potential value of seasonal forage forecasts in making stocking-rate decisions was estimated. As expected, the economic results suggested the value of the forecasts depended on the restocking and destocking prices along with other economic factors. More important, the economic results and producer-group reactions to these results suggested the need for multiyear modelling when examining the potential impact of using improved climate forecasts.

A study in north Queensland (Ash and others, 2000) used a forage-animal production model to evaluate the production and resource implications of grazing management and five SCF strategies. Results from the strategies showed:

- SCFs provide more benefit to beef cattle production when the forecasting information is available in June rather than November;
- The relative value of forecasting is greater for constant grazing strategies than for flexible ones;
- Increased animal production derived from applying a forecast is not at the expense of the resource base, and if increased animal production is not the desired aim of using the forecast then significant reductions in soil loss can be achieved; and
- Using localised forecasts does not provide any extra skill in production simulations.

Another similar study by Stafford Smith and others (2000) simulated whole-enterprise management of a cattle station in north Queensland. In general the optimum level of response to a forecast (increasing stock numbers in good years and decreasing them in bad) increased with increasing certainty. An inappropriate response to the forecast could be worse than no response, highlighting the sensitivity of forecasting advice to this factor. The differences in cash-flow between different levels of response to a forecast could be considerably larger than the differences between strategies. At the optimal response levels, forecasts provided a modest benefit in cash-flow over baseline strategies, with more benefit to be gained from a 12-

month forecast than a six-month forecast. With forecasting, the same level of cash-flow could be achieved for a much lower risk of environmental degradation.

An assessment of the value of climate forecasting for wool-producing enterprises in Victoria was made by Bowman and others (1995). Stocking and selling policies were modified in response to the SCF. The study highlighted a number of prerequisites for long-range climate forecasting to be of value to graziers. A very high level of accuracy of forecasting was required to ensure that most of the financial benefits gained through correct forecasts are not subsequently lost in years when the forecasts are in error. Buying and selling strategies for livestock need to be determined well in advance of adverse seasons, and seasonal forecasts need to provide quantitative information on the effects of forthcoming climatic conditions on pasture production to accurately predict carrying capacity over the autumn and winter. The value of reduced damage to soils and vegetation through destocking prior to drought must be included in the final analysis, and is a prerequisite to attaining more sustainable agricultural systems as part of a holistic approach.

By considering only producer-level effects, the estimates of the value of climate/weather forecasts ignore market adjustments and the resultant potential biases. Rosenthal and others (1998) found that reliable Shire and State grain sorghum production estimates can be generated by combining crop simulation and geographic information system technologies. Such estimates may cause rapid changes in the price of grain sorghum.

Potgieter and others (2002) researched spatial and temporal patterns in Australian wheat yield and their relationship with ENSO. They found that the discriminatory power of the ENSO indicators, although significant, was not strong. By examining the historical years forming the wheat yield analogue sets within each zone, it may be possible to identify novel climate system or ocean-atmosphere features that may be causal and, hence, most useful in improving seasonal forecasting schemes.

Costello and others (1998) developed a bioeconomic model of the coho salmon fishery and derive the value of information from improved El Nino forecasting ability. They found that a perfect El Nino forecast resulted in an annual welfare gain of approximately US$1 million, while imperfect forecasts led to smaller gains. Results also suggested that optimal management in the face of uncertainty involved a ‘conservative’ management strategy.

SCFs have the potential for providing considerable benefits to:

- Wholesalers and retailers of production inputs (for example, improved marketing strategies, inventory management and advice to clients);
- Grain/fibre handling and marketing organisations, and processors (better forecasts of production and quality); and
- Forward sellers and purchasers of products (more accurate estimations of future prices).

Findings from an investigation by Pagano and others (2002) into the factors affecting the use of seasonal forecasts in water management (in USA) emphasized: the need for special handling of tailored forecast products on a regional scale; the need for systematic regional forecast evaluation; and the potential for climate information to directly affect water management decisions through integrating climate forecasts into water supply outlooks where appropriate.

A survey of climate-related forecasting for Southwest U.S.A. (Hartmann and others, 2002) found that an abundance of forecasts was not matched in the provision of corresponding interpretive materials, documentation about how the forecasts were generated, or reviews of past performance. Potential existed for confusing experimental and research products with others. Greater attention needed to be given to forecast content and communication, including visualization, expression of probabilistic forecasts and presentation of ancillary information. Publicly-available forecasts needed to be accompanied by performance evaluations that are relevant to users.

The effects of climate change are influencing the accuracy of some SCF Systems and the outcomes of some decisions based on them. For example, a study was conducted of the economic effects of climate change on water demand and supply in the San Antonio Texas Edwards Aquifer region of U.S.A. (Chen and others, 2001). A regional welfare loss of US$2.2-$6.8 million per year may occur as a result of climatic change. Additionally, if springflows are to be maintained at the currently desired level to protect endangered species, pumping must be reduced by 9-20% at an additional cost of US$0.5 to $2 million per year.

While it may be difficult to value environmental benefits, a number of environmental indicators can be used to determine whether a decision will result in a change in sustainability of the production system. For example, soil erosion, soil organic matter, salinity, changes in key pasture species, weed populations and changes in ground cover.

Clark and others (2001) stated that planning and decision-making can be improved by access to reliable forecasts of ecosystem state, ecosystem services, and natural capital. Interdisciplinary linkages are necessary in order to develop a capacity to provide such forecasts; this is because of the climate and societal controls on ecosystems, the feedbacks involving social change, and the decision-making relevance of forecasts.

There is some evidence that the provision of SCFs may result in large net public benefit rather than predominantly a private-benefit outcome. For example, in a study of the value of seasonal forecasts in corn production in the Corn Belt of U.S.A. (Mjelde, Penson and Nixon, 2000), it was found that consumers were the clear winners and producers were the losers over the entire 10 years of the study.

## Forecasts and Government Policies/Assistance

Government policy/decisions can significantly influence the value of seasonal forecasts. Mjelde and Hill (1999) reported that recent changes to the US Federal Farm Program may increase the value of improved climate forecasts because of the elimination of most planting restrictions, acreage reduction, and disaster assistance. The addition of catastrophic crop insurance appeared to decrease the value of improved climate forecasts.

Similarly, Mjelde, Thompson and Nixon (1996) examined the impact of USA government institutions on the value of improved climate forecasts. Federal tax law had only a moderate influence.

While government policies and their effects are different in Australia, it is likely that drought and other disaster assistance by federal and State governments will reduce the value of climate forecasts. Similarly the proposed introduction of all-risks crop insurance, by the State Government in Western Australia, may have a similar effect.

Eakin (2000) studied the decisions of smallholder farmers in Mexico which are intricately tied to the political-economic circumstances in which they are made. He argued that political-economic uncertainty outweighed climatic uncertainty as a determinant of their production strategies. In those circumstances, the farmers are unlikely to use new SCFs.

Political considerations may sometimes result in climate-related information being suppressed. For example, a ‘Drought Alert’ was not issued by QDPI in autumn 1997 because of fear that graziers in the high-risk areas would think they were eligible for government drought assistance.

## Extension/Communication

There are many aspects of risk management from which producers could benefit before forecasting becomes the limiting factor in management. However, a seasonal forecast with current skill has some value for production and resource protection when used to trigger appropriate responses.

In contrast to short-term prediction, seasonal forecasts raise new issues regarding preparedness and the use of information. For example, a producer survey (Ash and others, 2000) indicated that even if more reliable forecasts were developed, most would wait until extreme events had an impact on their enterprise before making critical stocking decisions. Even in the absence of seasonal forecasts, grazing management in the rangelands of Australia could be vastly improved through better incorporating existing understanding of climate variability into stocking decisions. Further value may be added through the application of seasonal forecasting, but perhaps this added sophistication should only be contemplated after basic grazing management principles are incorporated into whole property planning.

A study in northern NSW (Hayman and Alston, 1999) found a disparity between the level of measurement and precision suggested by the majority of research, development and extension programs compared with the methods used by farmers. In general, the respondents to the survey had rejected, or are yet to adopt, regular soil testing, the use of climate forecasts and decision-support programs. Rather, they rely on simple rules of thumb based on readily accessible data such as past grain-protein content and cropping history.

This finding is similar to that from the survey of graziers quoted by Ash and others; many farmers could make significant improvements through better application of basic crop management principles/technology, before improving decisions further through the use of seasonal climate forecasts. Also, the order of adoption may be important, with some farmers preferring to adopt other practices/technologies before seriously attempting to use SCFs profitably. Perhaps outputs from SCFs could be incorporated into the rules of thumb that many managers use.

Cobon (1999) modelled the comparative impact of three Southern Oscillation Index (SOI) classes on wool production and profitability in western Queensland. Although the results showed clear relationships between SOI and rainfall, pasture growth and profit, pastoralists had not adjusted stocking rate accordingly. It is suggested that the complexities of forecasting from SOI classes may limit practical application of the method. Providing simple diagrammatic explanations of the likely opportunities and risks of adjusting management decisions to climate forecasts may be a useful addition.

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Letson and others (2001) also investigated user perspectives of climate forecasts. A survey of 200 farmers in Argentina identified climate forecast scale and the reliability of the source of forecast as critical obstacles to adoption. Users' incomplete knowledge of how El Nino-Southern Oscillation affects their region may also pose an obstacle to greater use of climate information. A related problem is that users sometimes confuse the different time scales of weather and climate forecasting. Research and outreach to downscaling forecasts temporally and spatially toward user communities would help close the gap of expectations between forecast user and provider, and would facilitate the trust building process between the two that must precede adoption.

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Washington and Downing (1999) studied the use of seasonal forecasts in southern and eastern Africa. Their utility depends on the linkages between geophysical, economic and social aspects of resource use. Difficulties experienced include targeting users, reaching vulnerable livelihoods, messages that are distorted over space and time, the lag between forecasts and dissemination, maladaptive responses and false alarms.

There is a need for some users of SCFs to have a better understanding of forecast systems and their limitations. For example, General Circulation Models (GCMs) have their poorest skill in autumn, but because this fact is not well known, many farmers in eastern Australia who have used GCM forecasts for crop planning have suffered economic losses (Stone and Hammer, 1994).

## Realising the Value of Seasonal Climate forecasts

The communication aspects of SCFs warrant greater priority if the potential benefits of using SCFs are to be realised. In some cases there are simply poor linkages between the information available and on-farm decision-making. However, communicating probability-based information in a form to encourage confident responses by decision-makers is a continuing research and extension challenge.

One major constraint to the effective use of climate forecasts is the considerable difficulty people have in estimating and dealing in probabilities, risk and uncertainty. Some of this difficulty arises from problems known as cognitive illusions or biases. The optimum use of climate predictions requires providers of forecasts to understand these difficulties and to make adjustments for them in the way forecasts are prepared and disseminated (Nicholls, 1999).

Some other problem areas in communicating forecasts are:

- Presenting forecasts to specific clients for the periods of greatest importance;
- Prior knowledge assumptions in presentation of forecasts; and
- Problems of forecasting for adjacent or overlapping periods (resulting in perceptions of inconsistencies).

In the review of the CVAP Program (Hassall and Associates, 1997) more rapid adoption by farmers, the major user group, was seen to depend on their greater involvement in research. Further, research needed to be more focused on increased confidence in the use of forecasts, and demonstrations of the value of forecasts relevant to the decisions of individual farmers. Two neglected areas were taking advantage of forecasts of favourable seasons and improved management of natural resources.

Often in making decisions, the outputs from simulation models can be more important than the actual climate forecast. For example, the effects of the spring SOI on profits from grain sorghum in southern Queensland are more pronounced than the effects on yield. These effects are even more serious in crops that have higher costs of production (Partridge, 2001).

Mjelde and Dixon (1993) found that the value of climate forecasts is highly sensitive to the expectations of the decision-maker at the beginning of the planning horizon. Thus, it is important that the decision-maker expects a forecast (before it is received) in order to respond quickly and appropriately (that is, to obtain full benefit from the forecast).

Mjelde and others (1993) examined trade-offs between climate forecast quality and economic value from the perspective of the forecast user. The results demonstrate that the entire structure of the forecast format interacts to determine the economic value of that system. Additional results indicate two possible preferred directions for research concerning climate forecasting and economic applications such as corn production in Illinois. First, increasing forecast quality by decreasing the error between the observed condition and the forecast condition may be preferred to increasing quality by increasing the number of predictions in the correct category. Second, corn producers may prefer research to increase the quality of forecasts for ‘poorer’ climatic conditions, rather than research directed toward increasing the quality of forecasts for ‘good’ conditions.

Broad and others (2002) investigated effective and equitable dissemination of seasonal-to-interannual climate forecasts in the Peruvian fishery. They identified: potential constraints on the realisation of benefits, such as limited access to and understanding of information, and unintended reactions; and the need for an appropriately detailed definition of societal benefit.

From the case studies that they quoted, Hammer and others (2001) note some general lessons. Foremost is the value of an interdisciplinary systems approach in connecting disciplinary knowledge in a manner most suited to decision-makers. In addition, issues associated with balance between information demand and supply as well as appreciation of awareness limitations of decision-makers, analysts, and scientists are highlighted. It is argued that understanding and communicating decision risks is one of the keys to successful applications of climate prediction. They considered that advances of the future will be made by better connecting agricultural scientists and practitioners with the science of climate prediction.

FARMSCAPE is a program of participatory research with the farming community of north-east Australia (Carberry and others, 2002). Its current focus is facilitating the implementation of commercial delivery systems for a range of decision-support tools, in order to meet industry demand for their access. A Participatory Action Research approach is used to explore whether farmers could value simulation as a decision-support tool for managing their farming system and if so, could it be delivered cost-effectively. Initial scepticism by farmers and commercial consultants about the value of the APSIM systems simulator was addressed by testing its performance. Simulation sessions usually evolved into participants interactively inquiring of the model the consequence of alternative management options. These 'What if' questions using APSIM were contextualised using local climate and soil data, and the farmer's actual or proposed management rules. The active participation of farmers and their advisers, and working in the context of their own farming operations, were the key ingredients in the design, implementation and interpretation of the FARMSCAPE approach to decision support. The attraction of the APSIM systems simulator to farmers contemplating change was that it allowed them to explore their own system in a manner equivalent to learning from experience. Current efforts are focused on the training, support and accreditation of commercial agronomists in the application of the FARMSCAPE approach and tools.

# CONCLUSIONS

It is necessary to evaluate progress made in using outputs of SCFs in various climate-affected industries, and to identify what research, development and extension activities are required to add further value to SCFs. The following conclusions can be made:

- Australia has one of the most variable climates in the world, and SCFs have considerable potential to enable managers in climate-affected industries/activities to reduce unwanted climatic impacts and take advantage of expected favourable conditions.
- It is essential that SCFs be integrated into overall business risk management, and used over many seasons to be confident of benefiting from them.
- The benefits received from issuing SCF information vary considerably due to the influences of physical, biological, economic, social and political factors. Some of the factors that affect the value of a SCF in a particular situation are: disaster insurance/government assistance may decrease the value of SCFs; government policy/decisions can significantly influence the value of seasonal forecasts; the value of SCFs usually increases as planting conditions move towards the optimum; and the value of SCFs is more likely to increase with risk aversion.
- Many managers involved with climate-affected industries are currently using SCFs in making major management decisions, with varying success, at scales ranging from enterprise level to industry/national-economy level.
- Quantative estimates of the value or benefits of SCFs have often been based on case studies. Usually some production and/or economic simulation models were used, and some assumptions were made on the impacts and/or client responses to different climate scenarios. Some findings were:
    - Surveys in Queensland have shown that seasonal climate forecasting is used by 35-40% of graziers, 70% of sugar producers and 30% of cotton growers. The estimated total benefit of SCFs and climatic risk assessment to grazing industries alone, from 1991/92 to 2002/03 was in the range of \$600M-1200M (Queensland Centre for Climate Applications, 2002).

  - Instead of applying a standard dressing of 40kg.of nitrogen/ha/year to a wheat crop in southern Queensland, it is worth an extra $18/ha/year overall (at a 10% risk of making a loss) to apply tactical dressings based on the SOI in the two months before planting (Paltridge, 2001).
  - Management of wheat in southern Queensland, according to the SOI Phase, yielded a long-term average economic value of less than, or equal to, the economic value of 1mm of extra plant-available soil moisture at planting (Robinson and Butler, 2002).
  - A study by Petersen and Fraser (2001), in the Merredin agricultural region of Western Australia, estimated that SCFs had the potential to provide an accumulated annual benefit to farmers in the region of approximately $2 million.
  - Jury (2002) assessed the economic impacts of climate variability in South Africa and development of resource prediction models. He estimated that over U.S.$1 billion could be saved annually through uptake of timely and reliable long-range forecasts.
  - Fifteen users of the QDPI's SOI Hotlines made an average net profit of $1933, over the previous 12 months, from using SOI information (Paull and Peacock, 2002).
  - A 'failed' SCF issued in autumn 2000 resulted in an estimated loss of US$1.1 billion in Midwest USA (Changnon, 2002).
  - Hammer (2000) quotes a case study of tactical management of row configuration in a cotton crop on the Darling Downs, Queensland, based on the SOI phase; the average increase in profit was 11%.
  - Hammer and others (2000) compared four forecasting systems in relation to their value in managing a cropping system in northern Australia. The best forecast systems gave a 20% increase in gross margin, a 30% decrease in soil erosion, but an increased risk of making a financial loss.
  - Jones and others (2000) estimated the potential economic value of climate forecasts for farm-scale management decisions in Southeast USA for comparison with results previously obtained for the Pampas region of Argentina. Predicted benefits to the farm of adjusting crop mix to ENSO phase averaged from US$3-6/ha in USA and US$9-35/ha in Argentina. Varying maize management by ENSO phase resulted in predicted forecast values of US$13 and US$15 per hectare for USA and Argentina respectively.
  - Carberry and others (2000) conducted a study involving changing between fallow-cotton, sorghum-cotton or cotton-cotton rotations based on the SOI phase in the August-September period preceeding the next two summers. Average gross margins for the two-year period increased by 14% over a standard fallow-cotton rotation, soil erosion was reduced by 23% and cash flow was improved in many years. However, the risk of economic loss increased from 5% of years to 9%.
  - Costello and others (1998) found that a perfect El Nino forecast for the coho salmon fishery resulted in an annual welfare gain of approximately $1 million, while imperfect forecasts led to smaller gains.
  - Changnon and others (1999) report on a case study incorporating ENSO information into a strategy for purchasing natural gas. The selected strategy saved Northern Illinois University (NIU) approximately US$500,000.
  - A study was conducted to determine the impact of perfect growing-season forecasts for corn produced in the Corn Belt region of USA over a 10-year period (Mjelde, Penson and Nixon, 2000). The expected present value of changes in net surplus varied from US$1.270 to $2.917 billion from the use of perfect forecasts over different 10-year planning periods.
- Similar case studies (using different methods and/or assumptions) may produce significantly different values of the SCF. There is a need to obtain consensus on how best to calculate the value of a climate forecast, given the uncertainties associated with the forecast, the managerial response to it, and the outcome of the decision. Ultimately, it is best if the individual decision-maker decides the assumptions that are made in calculating forecast value. In any case, simulation models will be required to enable examination of a range of options and their likely outcomes.
- There is a need to develop more accurate forecasts with longer lead times. The client needs to know that the forecast system has worthwhile accuracy in his/her district at that time of year, and that the probability of the most likely climate scenario is significantly different from that expected by examining the all-years historical record. Usual management should only be changed where there is a relatively high probability of a different climate scenario to normal, otherwise gains from a correct forecast will be cancelled by losses when the forecast is 'wrong'.

- Unfortunately, where SCFs are being used in management decisions there is no guarantee that the most likely climate scenario will actually occur. Therefore it is best if the probabilities are presented in such a way that clients perceive that they use them to make their own forecasts. Forecast credibility is a fragile thing, and can suffer considerably due to perceptions that the forecast was 'wrong' resulting in a financial loss.
- Research, development and extension programs need to be more focused on increasing the confidence of clients in using SCFs in business decision-making. More rapid adoption by farmers, the major user group, depends on improving their understanding of climate prediction , demonstrations of the value of forecasts relevant to the decisions of individual farmers, and more involvement of farmers in research. The use of an interdisciplinary systems approach has considerable merit for connecting disciplinary knowledge in a manner most suited to decision-makers, for example using the FARMSCAPE program of participatory research with the farming community.
- There is a need to provide reliable information on the relative forecasting skills of different forecasting systems for each district and month of the year, in a manner that makes it relevant to the end-user. Many decision-makers claim that they lack any quantitative basis for evaluating forecast credibility. That is because the evaluations currently available typically reflect forecasters' perspectives rather than those of users, or are not available in forms that users can easily obtain or understand.
- It is important to determine the climate information that is required by each client group, and (if possible) to supply it.
- There is a need to customise climate information at district or local-government area so that it is perceived as relevant by clients. Forecast characteristics that are important include:
    - Provide forecast outputs in the presentation format that is preferred by each client group (that is, can be easily understood and used in decision-making).
    - Provide brief high-quality interpretive comments with the climate-related products that are distributed.
    - Deliver forecasts by the methods preferred by each client group.
- It is important to maintain good quality control in the production and distribution of forecast outputs, so that clients receive accurate, timely and unambiguous forecast information.
- There is a need to understand better, and document, the processes and tools for integrating climate risk management into overall business management.
- Using SCFs can act as a catalyst/motivator for a manager to improve overall management of his/her business; for example, by demanding improvements in monitoring or infrastructure/equipment, and the adoption of up-to-date technology. Modern farming involves greater precision through better monitoring of the production system, quantitative comparisons of management options and likely outcomes, and sufficient flexibility in operations to implement the preferred response to a SCF. Pasture and crop growth simulation models can be used to evaluate alternative management options, and quantify the likely effects on farm income and production. From the perspective of the forecast user, the likely climatic impacts and the formats of the forecast products both influence the management option chosen - and the final economic value of the forecast system in that instance. In addition, there are often trade-offs between forecast quality and the economic value of the forecast system.
- When using SCFs to increase profits from a production system, some risks may increase while others may decrease.
- There is a need for multiyear modelling in cropping and pastoral enterprises when examining the potential impact of using improved climate forecasts.
- SCFs have the potential for providing considerable benefits to agribusiness such as:
    - Wholesalers and retailers of production inputs (for example, improved marketing strategies, inventory management and advice to clients);
    - Grain/fibre handling and marketing organisations, and processors (better forecasts of production and quality); and
    - Forward sellers and forward purchasers of products (more accurate estimations of future prices).
- Planning and decision-making may be improved by access to reliable forecasts of ecosystem state, ecosystem services, and natural capital. Interdisciplinary linkages are necessary in order to develop a capacity to provide such forecasts; this is because of the climate and societal controls on ecosystems, the feedbacks involving social change, and the decision-making relevance of forecasts.

- Many primary producers could make significant improvements to their businesses through better application of knowledge of climatic variability, and basic crop/pasture management principles/technology, before needing to use climate forecasts to further improve the quality of management decisions.
- There is some evidence that the provision of seasonal climate forecasts may result in large net public/consumer benefit rather than mainly a private-benefit outcome.
- The communication aspects of SCFs (that is, communicating decision risks) warrant greater priority if the potential benefits of using the forecasts are to be realised. In some cases there are simply poor linkages between the information available and on-farm decision-making. However, communicating probability-based information in a form to encourage confident responses by decision-makers is a continuing research and extension challenge. Greater attention needs to be given to forecast content and communication, including visualization, expression of probabilistic forecasts and presentation of ancillary information.
- Some other problem areas in communicating forecasts are:
    - Presenting forecasts to specific clients for the periods of greatest importance;
    - Prior knowledge assumptions in presentation of forecasts; and
    - Problems of forecasting for adjacent or overlapping periods (resulting in perceptions of inconsistencies).
- One major constraint to the effective use of climate forecasts is the considerable difficulty people have in estimating and dealing in probabilities, risk and uncertainty. Some of this difficulty arises from problems known as cognitive illusions or biases. The optimum use of climate predictions requires providers of forecasts to understand these difficulties, and to make adjustments for them in the way forecasts are prepared and disseminated.
- Understanding decision risks is one of the keys to successful applications of climate prediction. For example, end-users of SCFs need to know how El Nino-Southern Oscillation affects their region. There is a need for further training to increase the awareness and understanding of decision-makers, analysts, and scientists in the profitable use of SCFs.

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