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3 Plain English summary

3.1 Background

The success of agricultural industries relies on the weather which means being able to accurately predict the weather is crucial. The Rural R&D for Profit Program project “Improved use of seasonal forecasting to increase farmer profitability” aimed to bridge the gap between seasonal climate forecasts (SCFs) and farm business decisions to improve productivity and profitability.

3.2 Objectives and methodology

The objectives of this project were to:

- Identify critical seasonal climate risks by sector, type of decision and region (“Valuing the Forecast”)
- Identify and develop support tools, products, services, information and training to overcome the barriers to adoption of SCFs by farmers and advisers in farm business decisions (Using the Forecast)
- Improve the SCF abilities of Australia’s primary forecasting model ACCESS-S, by correcting biases that introduce errors into the current forecasts (“ACCESS-S Model Enhancement”)

These objectives were met through a range of activities that predominately related to stakeholder engagement and exploration of the barriers to adoption of SCFs, but also assessments of the models used for producing SCFs in Australia and addressing issues that limited the accuracy of the predictions.

3.3 Outcomes and Conclusions

There were a number of barriers to the adoption of SCFs by farmers and advisors in Australia, and they predominately related to perceived and real inaccuracies in the forecasts which leads to lack of trust in the SCFs and therefore, lack of adoption. Climate illiteracy was also a recurrent theme, and this lack of understanding of SCFs, and how and when to use them, notably impacted on whether SCFs were used, and if they were used, the efficacy of their application in farm business decisions. However, the forecast requirements requested by farmers in most regions can and would have been forecast by almost any SCF system currently used, however there was low awareness that the forecasts existed.

The establishment of a community of practice (CoP) on the use of SCFs brought together farmers, advisers and key SCF support who discussed and shared information, knowledge and opportunities for improving the use of SCFs. The success of the CoP is evident in its continuation post the conclusion of this project. A significant number of resources to support improved knowledge and application of SCFs by farmers and advisers were produced and utilised in forums beyond just the CoP, and predicted to have reached thousands of stakeholders.

While the overall skill level of SCF systems could be considered modest to reasonable, higher forecast skill levels are more obvious and accurate during El Niño and La Niña events (collectively known as ENSO periods), especially in many regions of southern and eastern Australia. Therefore, a range in
forecast value was found within various case studies with the value primarily dependent on the environmental and economic settings of the decision and the skilfulness of the forecast.

Further, experiments to improve the forecasting ability of models currently used in Australia were successful in reducing long-standing issues and as a result, the models produced more realistic representations. These changes will require further development and testing.

### 3.4 Implications for industry/primary farmers

Although all farmers are aware of climate risk, there is variability in the adoption of SCFs to manage that risk. Farmers are best to avoid forecasts during periods when the skill of the model is known to be low and seek them out during periods when they’re known to be high, however farmers generally require assistance in making these assessments. The CoP and supporting materials that were developed as part of this project provided a significant opportunity for improving the adoption of SCFs in agricultural management, and there are plans to continue the CoP and utilisation of materials beyond the completion of this project. This project also improved engagement and communications between government departments, farmers, advisers and other stakeholders.

### 3.5 Recommendations for further research and improved adoption

A number of recommendations for further research were identified in this project, and adoption of SCFs in farm business decisions will improve as more information and opportunities for knowledge sharing are explored, and those established as part of this project, continued. The Rural R&D for Profit Program project “Forewarned is Forearmed Extremes” project covers extremes in rainfall and temperature which accounted for the majority of issues raised by farmers and advisers during this project. Therefore, continuation of the CoP and maintenance of support materials developed in this project are recommended to be continued in-line with the Forewarned is Forearmed Extremes project.
4 Abbreviations

ACCESS-S - Australian Community Climate and Earth Science Simulator-Seasonal

BCG - The Birchip Cropping Group

BoM – Bureau of Meteorology

CoP - Community of Practice

DAFWA - Department of Agriculture and Food, Western Australia

DEDJTR - the Victorian Department of Economic Development, Jobs, Transport and Resources

DPIRD – Department of Primary Industries and Regional Development

ECMRWF - European Centre for Medium-Range WeatherForecasts

ECPC- Experimental Centre for Climate Prediction

ENSO - El Niño/Southern Oscillation

GCM - General Circulation Models

IOD - Indian Ocean Dipole

LEPS - Linear Error in Probability Space

MCV - Managing Climate Variability Program

MJO - the Madden Julian Oscillation

NSW DPI - New South Wales Department of Primary Industries

POAMA - Predictive Ocean Atmosphere Model for Australia

SAM - Southern Annular Mode

SARDI - South Australia Research and Development Institute

SCF – Seasonal Climate Forecasts

SME – Subject Matter Expert

SSF – Statistical Seasonal Forecast

SWWA – South-west Western Australia

USQ- University of Southern Queensland
5 Project rationale and objectives

The objective of the Rural R&D for Profit Program is to realise productivity and profitability improvements for primary producers through:

- Generating knowledge, technologies, products or processes that benefit primary producers;
- Strengthening pathways to extend the results of rural research and development, including the barriers to adoption; and
- Establishing and fostering industry and research collaborations that form the basis for ongoing innovation and growth of Australian agriculture.

This project aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability. It delivered this by:

- Identifying the critical information requirements relating to seasonal climate risks for primary industries by their sector, type of decision and region;
- Enabling farmers to realise the potential in existing seasonal climate forecasts by developing tools, products, services, information, training and other methods to skill farmers and advisers to better understand the use of seasonal forecasts in farm business decision making; and
- Improving seasonal forecasting capabilities of Australia’s primary forecasting model (POAMA2.4/ACCESS-S) by analysing and reducing the main errors that negatively impact the quality of seasonal predictions for use by farmers and advisers.

5.1 Project 1- Valuing the Forecast

Project 1 will undertake case studies to demonstrate the value of seasonal forecasts by region and commodity (Appendix 1). This aspect of the Rural R&D for Profit Program will also determine the relative ‘power’ of the General Circulation Models (GCMs) by region, commodity and key decision points.

5.1.1 Project 1a- Case Studies

Insufficient evidence regarding the value of climate forecast is continually considered as a major factor limiting the adoption of seasonal forecasting as a resource in Australia and other countries. As such, the focus of the case studies in this research project has been to provide robust assessments of forecast value by looking at decision making environments across a diverse range of agricultural industries and locations within Australia.

Within this context, the aim of these case studies is to identify the unrealised potential in current seasonal forecast information and apply that information in a structured and efficient format to improve decision making in farm businesses. This will help farmers translate imperfect information from climate forecasts into practical risk management, which can reduce losses during poor seasons and improve production in good seasons.

The aims of Project 1a have been delivered through the completion of the following activities:
• The completion of a comprehensive literature review. A literature review demonstrating the value of seasonal forecasts has been completed (Parton and Crean, 2016) (Appendix 1).
• The definition of seasonal climate information needs by sector and region.
• Bio-economic modelling which will draw on the standard economic approach to valuing forecasts.
• Development of industry and region-specific case studies based on the results from the other activities outlined in Project 1a.

5.1.2 Project 1b- General Circulation Model (GCM) Analysis

There are currently several GCMs producing seasonal climate forecasts that Australian farmers can access. However, little work has been completed to identify which model produces the best forecast for a given industry section, within a given region, at a given time of year. Drawing on the outputs of Project 1a, Project 1b will focus on the special and temporal requirements of forecasts relevant to the target sectors and access the skill of GCMs to provide forecasts to meet these requirements.

The aim of this analysis is to identify the seasonal forecast models that provide the greatest skill to relevant industry sectors in a given region at a particular time.

The aims of Project 1b have been delivered through the completion of the following activities:

• Based on the case studies performed in Project 1a (Appendix 1), key decision points have been identified in regards to the production processes that will require (or benefit from) seasonal climate information being a part of farmer decision making.
• A review of the ‘power’ of operational, dynamic and relevant statistical seasonal climate forecasting models.
• The key decision points identified regarding production processes have been aligned with the relevant seasonal climate forecasting models.
• The development of a framework for mapping seasonal and sub-seasonal climate information needs, and existing information, with the inclusion of each forecast model.

5.2 Project 2- Using the Forecast

Improving the use and usefulness of seasonal climate forecasts requires farmers, along with the public and private advisors, to understand the relative value of the forecast and share ideas, concepts and approaches to using climate information. This will enhance the long-term sustainable use of climate forecasts, which must recognise both the uncertainty in the forecast and the fact that few decisions are based on climate information alone. Access to the relevant forecast information, in as many forms as possible, must also be improved.

5.2.1 Project 2a- Community of Practice

A community of practice (CoP) is a group of willing practitioners with a common sense of purpose, who agree to work together to solve problems, share knowledge, cultivate best practice and foster innovation. Agricultural CoP’s are developed on peer-reviewed, research-based, unbiased content development and educational delivery aimed at adoption of practices and changes in behaviour.
Programs and products are developed by teams of content specialists and support professionals, constantly interacting with the clientele served. Most of these engagements are conducted virtually, however, an element of face-to-face contact is important.

With these principles in mind, the ‘Australian seasonal climate forecasting CoP’ aimed to improve collaboration, derive greater value from existing expertise and resources, improve the flow of science to advisors and farmers, and create new, more open discussion channels for SCF projects that can better serve the industry.

The aim of Project 2a is to increase a farmer's ability to manage in a variable climate by establishing a group of people that share a common interest in seasonal climate forecasts and their use in farm decision making.

The aims of Project 2a have been delivered through the completion of the following activities:

- The identification of people to be engaged within the CoP, including a project leader, forecast users, practice specialists and climate practitioners.
- A review of the technologies and systems used to facilitate the engagement between participants.
- The identification of enabling factors and barriers to the adoption of seasonal climate forecasts by farmers and advisors.
- The engagement and education of stakeholders, including an annual stakeholder workshop.

5.2.2 Project 2b- Develop and Tailor Products, Tools and Services

The outputs of Project 1 will be considered in terms of farmer and advisor information needs. From this, products, tools and services will be developed in collaboration with farmers, advisors and extension specialists, in order to meet their needs.

Project 2b was made possible through collaboration of The Birchip Cropping Group (BCG) with the Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR), South Australia Research and Development Institute (SARDI), Department of Agriculture and Food, Western Australia (DAFWA) and the New South Wales Department of Primary Industries (NSW DPI).

The aim of this project was to provide the resources required to enable information to be packaged and presented in ways that maximise uptake by farmers and advisors.

The aims of Project 2b have been delivered through the completion of the following activities:

- The outputs of all of the previous projects outlined above have been considered, and consolidated, in regards to the information required by farmers and advisors, the best way to deliver this information, and the best way to incorporate this information into existing systems.
- From these outputs, information packages were created that considered innovative communications, R&D for Profit program outputs and legacy systems.
- Tools, products and services developed in the program have been tested using existing channels, and existing tools, products and services were assessed to determine whether or not the new information could be incorporated within them.
5.3 Project 3- ACCESS-S Enhancement

The main goal of this project is to understand and reduce the main systematic errors in the ACCESS-S model that negatively impact the quality of seasonal predictions for use in farming. This was achieved by developing improvements to the treatment of convection in the ACCESS-S model, evaluating these improvements, and implementing those with the largest target positive effect in the subsequent operational version of ACCESS-S.

The aim of this project was to improve the predictive capabilities of the ACCESS-S model, particularly in relation to rural Australia, by reducing the model biases related to Indian Ocean and tropical atmospheric convection.

The aims of Project 3 have been delivered through the completion of the following activities:

- The diagnosis of the key systematic errors that influence seasonal prediction for farming.
- The improvement of the treatment of convection in the ACCESS-S model.
- The testing of the model improvements through case studies.
6   Method and Project Locations

6.1   Project 1a

Project 1a was completed by the University of Southern Queensland (USQ), in partnership with NSW DPI.

USQ developed the skill testing framework used to evaluate the accuracy and efficiency of seasonal forecast systems, by using the techniques outlined by Fawcett and Stone (2010) and Power (BoM) (more detailed descriptions can be found in these resources). The system analyses both the ‘hit rates’ and the Linear Error in Probability Space (LEPS) assessments of a region. The ‘hit rates’ (‘percent correct’ or ‘percent consistent’) scores a forecast system if the forecast and actual rainfall (or temperature) was correct in regards to the median. LEPS assessment is based on forecasts that are ‘rewarded’ for forecasting more extreme deciles of rainfall recorded in a region, especially in regards to 30 day and 60 day shorter term sub-seasonal forecasts requested by users.

Over twenty user-focussed workshops and follow up interviews were conducted in northern regions of Australia, with the aim of carefully establishing core user needs and determining whether seasonal climate forecast outputs would have met some, or all, of these needs. In addition, major weather events experienced in the past have been identified and an assessment was made as to whether our current suite of seasonal climate forecasting outputs would have provided value in making management decisions relevant to the occurrence of those events.

NSW DPI outlined a range of case studies (Appendix 1) that were aimed at assessing where, when and how seasonal climate forecasts (SCFs) offer value in agricultural production systems. These case studies provide an example of the potential value of a forecast based on a particular production system, at a specific time of year and at a specific location with its own historical climate variability. While the case studies reflect climate sensitive management decisions identified by engagement with industries, they were not designed to be statistically representative or assess the potential value of SCFs to a sector as a whole.

The case study approach was undertaken to provide a more systematic and largely comparable assessment of the value of SCFs. This common, inter-comparison methodological approach has not previously been applied to several different agricultural sectors. Together, the case studies aim to improve the broader understanding of the value of SCFs to Australian agriculture.

A total of nine case studies were conducted, which covered Southern Beef, Northern Beef, Prime Lamb, Southern Grains, Northern Grains, Western Grains, Cotton, Sugar and Rice.

A key aspect of the case studies was the intentional and explicit focus on farm decision environments, and the potential value of SCFs within these systems. A common approach was utilised for each of the nine case studies by following three key steps:

- Through industry consultation, identify key decision points within the production system potentially sensitive to SCF information.
- The use of biophysical modelling to represent important features of the production system and the key decision point.
The use of economic modelling to evaluate the value of SCFs at each decision point within the described production system.

To assess the value of SCFs, probabilistic climate forecasts from a hypothetical forecast system were adopted. This approach was chosen because there are multiple providers of operational climate forecasts, which are regularly updated to reflect improvements in the understanding of climate and weather systems and rapid developments in computing and analytical capabilities. The main benefit of assessing a hypothetical forecast, rather than an operational forecast, is that key aspects of forecast quality (e.g. skill) can be systematically valued. For most case studies, three discrete climate states were identified based on the lower, middle and upper tercile of rainfall received at the case study site using historical climate data. Each year was classified as belonging to one of these climate states; dry, average or wet.

Agricultural production levels (e.g. pasture growth, crop yields) for each of these climate states were obtained from outputs created by biophysical production models. These outputs were combined with production costs and prices and built into an economic model to capture the links between climatic conditions and agricultural production.

Agricultural systems are inherently dynamic, and the approach taken with these case studies attempts to strike a balance between highly specific farm-level analyses and very limited, wider applicability and coarser level general analyses, which can miss important features of production systems that may influence results. The economic model was used to select the most profitable decision under a wide variety of scenarios. The analysis of the model included the interplay between forecast and non-forecast variables in influencing forecast value.

6.2 Project 1b

Important aspects of seasonal climate forecast ‘skill’ have been consolidated and assessed as to how exactly seasonal forecast development can fit the key decision-points of industry and users. Utilisation of SCFs in decision making needs to be provided in a way that aligns it to key industry decision points. This activity is important for understanding the timing and application of key decision points in the agricultural management cycles in order to customise forecasts for use at key decision points.

For Project 1b, USQ partnered with the NSW DPI and the Department of Agriculture and Fisheries WA (DAFWA) through industry engagement and case studies to identify key decision points in all industries. USQ then mapped the key decisions using a matrix and identified the important sub-seasonal and seasonal forecasts needed as part of the decision making process. USQ has led the northern component (beef, sugar, grains), NSW DPI the southern Australia component (beef, grains, cotton, rice), and DAFWA the western component (grains).

6.3 Project 2a and 2b

The Birchip Cropping Group (BCG) led project 2a, ‘community of practice’ and project 2b, ‘development and tailoring of products, tools & services’. These activities were conducted with support from other project agencies, including: the Victorian Department of Economic Development, Jobs, Transport and Resources (DEDJTR); South Australia Research and Development Institute (SARDI); Department of Agriculture and Food, Western Australia (DAFWA); and the New South Wales Department of Primary Industries (NSW DPI).
By the completion of the project, BCG established and oversaw the ongoing management of a successful seasonal climate forecasting community of practice (CoP), which will continue to meet beyond the finalisation of the project.

BCG aimed to fulfil the project objectives by progressing through a three-phased membership approach to forming the CoP, which is outlined in the CoP Implementation Plan. This approach included:

- Phase 1 – core project and subject matter personnel;
- Phase 2 – invited expansion (leveraging networks of core personnel);
- Phase 3 – open membership.

Three key pieces of work were conducted in project 2, which have improved understandings of barriers and opportunities for industry adoption of SCFs. These are:

- Opportunities and barriers to the use of SCFs (Activity 5, output 5a).
- The adoption of SCFs in Australian agriculture (Activity 5, output 5a).
- The application of the CSIRO ADOPT tool to SCFs, using the results of the case studies (Activity 5, Output 5b).

### 6.4 Project 3

Project 3 was completed by Monash University. This was achieved by developing improvements to the treatment of convection in the ACCESS-S model, evaluating these improvements, and implementing those with the largest target positive effect in the subsequent operational version of ACCESS-S.
7 Project Outcomes

7.1 Project 1a and 1b (June 2015- June 2018)
The University of Southern Queensland
Roger C. Stone, Torben Marcussen, Shahbaz Mushtaq and Christa Pudmenzky

Plain English Summary

Background

The success of agricultural industries relies on the weather, which means the ability to accurately predict the weather is crucial. The Rural R&D for Profit Program, "Improved use of seasonal forecasting to increase farmer profitability", aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

There are several models (called ‘General Circulation Models’) that the Australian Bureau of Meteorology (BoM) has used since the 1980s to produce seasonal climate forecasts (SCFs) for regions across Australia. Recently, the BoM adopted an optimised model system, POAMA 2.4, and the accuracy (‘skill’) of POAMA 2.4 has been assessed extensively, particularly in relation to its ability to provide useful forecast information for key industry decision making.

Objectives and methodology

Projects 1a and 1b aimed to identify the seasonal forecast models that provide the greatest skill to relevant industry sectors in a given region at a particular time. Forecast-user workshops were designed to identify core needs, which included an assessment of whether the forecasts from various models would have met some, or all, of these needs.

Outcomes and conclusions

- The forecast requirements requested by farmers in most regions (except South West Western Australia and parts of Tasmania) can and would have been forecast by almost any seasonal climate forecast system in operational use, however there was low awareness that the forecasts existed.
- Use of forecasts during low skill periods impacted on farmers’ trust of future forecasts.
- While the overall skill level of seasonal forecasting systems could be considered modest to reasonable, higher forecast skill levels are more obvious and accurate during El Niño and La Niña events (collectively known as ENSO periods), especially in many regions of southern and eastern Australia.
• POAMA 2.4 performs very well throughout most of Australia, except for some years in south west Western Australia, where other models performed better.
• Newly developed 30-day and 60-day, shorter-term and monthly to sub-seasonal forecast systems appear to provide very useful forecast skill for many regions of Australia.

Implications for industry/farmers

Each of the various SCF systems appear to have its own merits for varying regions and periods of time. This suggests that farmers should assess forecasts from all available models to gain an overall perspective of the skill being provided to meet their needs. Farmers are best to avoid forecasts during periods when the skill of the model is known to be low and seek them out during periods when they’re known to be high, however, it was found that farmers generally require assistance in making these assessments.

Recommendations for further research and improved adoption:

• It is strongly recommended that the varying skill of models to make forecasts is made clearly known to farmers, and not to issue SCFs during periods of known likely low skill;
• The “Forewarned is Forearmed Extremes” project covers extremes in rainfall and temperature, which were the majority of aspects raised by farmers, therefore collaboration with this project is recommended;
• Fine tuning of forecasts is required over 30-day and 60-day periods, especially to northern Australian industries;
• Improvements to the skill of models for predicting the combination of wet and cold periods in winter (or summer) is needed to prevent massive stock losses;
• Improvements to the skill of models regarding the start of first frost in the season, the end of the frost season and severity of the frost season is needed to limit crop damage caused by frost;
• Differing forecasts issued for the same period within two weeks of each other is an issue. POAMA2.4 may provide varying forecasts for the same coming season within a matter of weeks, making decision making difficult for some farmers faced with this conflicting information (from the same source).

Included in this report; delivery of KPI 6.5, report demonstrating contribution to delivery of KPI 6.1, 6.3, 6.6, 6.7, 6.8, 6.9. All KPI’s have been completed.

7.1.1 Background

The ‘Improved Use of Seasonal Forecasting to Increase Farmer Profitability’ project has focussed on investigating the value of the forecasts (Project 1a), assessing the reliability or skill of the forecasts (Project 1b), improving the use of the forecasts (Project 2) and improving the skill of the forecasts (Project 3). A literature review demonstrating the value of seasonal forecasts has been completed (Parton and Crean 2016) (Appendix 1) as part of Project 1a.

This project milestone also concentrates upon conducting further in-depth consultation with all industries and users involved, with an aim of consolidating frameworks. This includes more
substantive workshop activity and open discussion with key stakeholders, especially for the supply chain in the northern beef and sugar industry groups.

Important aspects of seasonal climate forecast ‘skill’ have now been consolidated and assessed as to how exactly seasonal forecast development can fit the key decision-points of industry and users.

As mentioned in previous reports, utilisation of seasonal climate forecasts in decision making needs to be provided in a way that aligns it to key industry decision points. This activity is important for understanding the timing and application of key decision points in the agricultural management cycles in order to customise forecasts for use at key decision points.

The University of Southern Queensland (USQ) has worked with the New South Wales Department of Primary Industries (NSW DPI) and Department of Agriculture and Fisheries WA (DAFWA) through industry engagement and case studies to identify key decision points in all industries, to map the key decisions using a matrix, and identify the important sub-seasonal and seasonal forecasts needed as part of the decision making process. USQ has led the northern component (beef, sugar, grains), NSW DPI the southern Australia component (beef, grains, cotton, rice), and DAFWA the western component (grains).

This report presents findings from our industry engagement and case studies mainly in northern regions, but also incorporates southern and western industries. The report identifies the key decision points in the annual management cycles for beef, grains, sugar, cotton and rice in the different regions, and identifies the important sub-seasonal and seasonal forecasts likely to have the greatest impact and potential value to the respective industry.

### 7.1.2 Summary of Skill Analyses (KPI 6.5)

The World Meteorological Organisation (WMO) has officially designated 13 Global Producing Centres for Long-Range Forecasts (GPCLRFs);

- Beijing: China Meteorological Administration (CMA)/Beijing Climate Centre (BCC)
- Brazil: Centre for Weather Forecasts and Climate Studies (CPTEC)/National Institute for Space Research (INPE)
- United Kingdom: European Centre for Medium-Range Weather Forecasts (ECMWF) Exeter: Met Office
- Melbourne: Bureau of Meteorology (BoM), Australia
- Montreal: Meteorological Service of Canada (MSC)
- Moscow: Hydrometeorological Centre of Russia
- Offenbach: Deutscher Wetterdienst (DWD)
- Pretoria: South African Weather Services (SAWS)
- Seoul: Korea Meteorological Administration (KMA)
- Tokyo: Japan Meteorological Agency (JMA)/Tokyo Climate Centre (TCC)
- Toulouse: Météo-France
- Washington: Climate Prediction Centre (CPC)/National Oceanic and Atmospheric Administration (NOAA), United States of America.

In addition to the institutions referenced above, WMO has also designated the following Lead Centres;

- WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble (LC-LRFMME), jointly coordinated by KMA and CPC/NOAA [Download WMO LC-LRFMME flyer]
7.1.3 General Circulation Model (GCM)

A general circulation model (GCM) (Figure 1) is a type of climate model that employs a mathematical model of the general circulation of a planetary atmosphere or ocean. It uses the Navier–Stokes equations on a rotating sphere, with thermodynamic terms for various energy sources (radiation, latent heat). These equations are the basis for computer programs used to simulate the Earth’s atmosphere or oceans. Atmospheric and oceanic GCMs (AGCM and OGCM), sea ice and land-surface are all key components.

7.1.4 S2S Data

The S2S (sub-seasonal to seasonal) prediction project is a WWRP/THORPEX-WCRP joint research project established to improve forecast skill, understand the sub-seasonal to seasonal time scale, promote its uptake by operational centres, exploitation by the applications community and provides input into the assessments made in this report (Appendix 2).

7.1.5 Ensembles

Ensemble forecasting is a method used in numerical weather prediction. Instead of making a single forecast of the most likely weather, a set (or ensemble) of forecasts is produced. This set of forecasts
aims to give an indication of the range of possible future states of the atmosphere and is a form of Monte Carlo analysis. The multiple simulations are conducted to account for the two usual sources of uncertainty in forecast models; (1) the errors introduced by the use of imperfect initial conditions, amplified by the chaotic nature of the evolution equations of the atmosphere (often referred to as sensitive dependence on the initial conditions); and (2) errors introduced because of imperfections in the model formulation, such as the approximate mathematical methods to solve the equations. Ideally, the verified future atmospheric state should fall within the predicted ensemble spread, and the amount of spread should be related to the uncertainty (error) of the forecast. In general, this approach can be used to make probabilistic forecasts of any dynamical system and not just weather prediction.

Examples and calculations of statistics of ‘actual forecast skill’ using the selection of previously tested systems for Australia are provided in Appendix 3.

### 7.1.6 Skill and timeliness of climate forecasts in industry clusters over time

Growers, producers and agribusiness may have access to a number of seasonal climate forecast outputs from a number of national and international forecast and research centres, which produce different forecasting system outputs but may be used to assist with on-farm decision making. These systems have varying degrees of skill (skill refers to the accuracy of the forecast system) at different times and for different regions and the final result may cause some confusion for users applying this type of information in ‘real world’ decision making. Although seasonal climate forecasting systems were initially statistically based, major advances in meteorological sciences means they are now primarily dynamically based General Circulation Models (coupled ocean-atmosphere models).

As part of the ‘Improved Use of Seasonal Forecasting to Increase Farmer Profitability’ project, USQ has identified the seasonal forecast systems that provide useful skill to various industry sectors in a given region at a particular time, relevant to key management decisions points.

Updated findings on the skill and timeliness of forecasts for the sugar industry cluster as an example of the analysis is outlined in Appendix 4.

USQ developed the skill testing framework to evaluate the skill and timeliness of seasonal forecast systems using the techniques based on Fawcett and Stone (2010) and Power (BoM).

The forecast systems that are assessed in detail in this updated report (relevant to KPI 6.5) are:

- **BOM Australia (POAMA 2.4)**
  - Time range: 0-62
  - Resolution: T47L17
  - Ens.Size: 33
  - Frequency: 2/week
  - Re-forecasts: fix
  - Rfc length: 1981-2013
  - Rfc frequency: 6/month
  - Rfc size: 33
Volume of real-time forecast per cycle: 6 TB

- ECMWF (Europe)
  - Time range: d 0-46
  - Resolution: T639/319 L91
  - Ens. Size: 51
  - Frequency: 2/week
  - Re-forecasts: on the fly
  - Rfc length: past 20 years
  - Rfc frequency: 2/week

- UKMO
  - Time range: d 0-60
  - Resolution: N216L85
  - Ens. Size: 4
  - Frequency: daily
  - Re-forecasts: on the fly
  - Rfc length: 1993-2015
  - Rfc frequency: 4/month
  - Rfc size: 3

Each forecast has a ‘Real Time’ forecast, which is forecasting ‘forward’ as well as producing a set of ‘reforecasts’ (rfc); where the run the same model ‘backwards’ for a period, which can be used to detect any bias in the model. These can also be used as ‘hindcasts’.

Queensland Government statistical seasonal climate forecasts

Reference is also made to the statistical, SOI-based, seasonal forecast system for comparison purposes. This system is currently made available by the Queensland Government under its LongPaddock web site and extension networks (published by Stone at el., 1996), and is incorporated in a number of decision-support systems, such as Rainman, ClimateARM, Whopper-Cropper, etc.

To evaluate the skill and timeliness of these forecast systems, comparisons between forecast seasonal conditions with observed seasonal conditions have been conducted. To achieve this, historical forecasts and observed data have been correlated.

To evaluate skill for each forecast system, the rainfall forecast has been compared with the observed rainfall and a subsequent ‘hit rate’ was then calculated. For example, if above average (median) rainfall is forecast for a grid cell and the grid cell then receives above median rainfall, a ‘hit’ (or 1) is recorded. Conversely, if the rainfall is below median a ‘miss’ (or 0) is recorded. Appendix 5 outlines the hit scores for POAMA 2.4 forecasts. The proportion of ‘hits’ across all the grid cells has been tallied across the cluster region. The resolution of the POAMA forecasts are 2.5 x 2.5 degrees. In addition, the actual rainfall is interpolated on this grid scale to compare.

Figures in Appendix 5 show a high ‘hit’ score during strong La Niña and El Niño events in many regions, while the forecasting skill of the models is often markedly reduced during neutral events.
7.1.7 Monthly to sub-seasonal scale forecasts (30-day and 60-day)

An assessment of GCM-based monthly to 60-day forecasts has been made, in keeping with user/workshop requests for shorter term break of season and wet season commencement forecasts. A mapped example of output is provided below in Figure 2, and an overview of the forecast assessment (‘hit rates’ and LEPS scores) are provided in Appendix 6 (system and method shown in each figure).

![Figure 2: A mapped assessment of GCM-based monthly to 60-day forecasts using a) BoM, b) ECMWF, c) METEO, and d) HMCR.](image)

The information produced from this skill-testing framework can now provide critical information for producers, growers, and the industry value-chain, by potentially allowing users to vary the degree of confidence they place in different forecast systems in regards to the ‘hit rate’ in a particular region during a given timeframe. Following further validation and grower feedback, this could provide greater confidence in industry decision-making, particularly for predicted El Niño and La Niña conditions, which have the potential to impact heavily on production.

Attributes of the forecast required for skill and timeliness analyses are outlined in the case study descriptions included as part of partner milestone submissions (USQ and NSW DPI). These case studies are conducted to provide robust assessments of the value of seasonal climate forecasts by investigating the decision-making environments for a range of agricultural industries at specific locations.
Further results regarding the skill and timeliness of climate forecast were reported by USQ in conjunction with NSW DPI in the following outputs:

- Output 3(c): Conduct consultation and feedback workshops with each industry’s stakeholders and experts to test and validate draft frameworks developed under Output 3(b) and review the relative skill of all major climate forecast information sources.
- Output 3(d): Report on the results of the skills review of forecast information sources under Output 3(c) against the seasonal climate information needs of each industry.

Projects 1a and 1b have developed strong linkages with Project 2 (led by Birchip Cropping Group) through the Community of Practice. Following completion of Output 3(d), Birchip Cropping Group will seek to use the skills analysis and each industry’s information requirements to assist with the development of farmer extension and training products as per Output 6(c), due 31/05/2018.

7.1.8 Seasonal climate forecast skill pertaining to the key decision points for industry in Australia

The seasonal climate forecasting systems were analysed in respect to time series of skill values in Australia and key northern grazing region, as well as assessing their relationship to the decision-making frameworks already identified by grazing industry users. The key points are listed below.

- The core seasonal climate forecast systems that were tested displayed high capability in seasonal rainfall and temperature forecast skill during the onset, duration and decay of El Niño/Southern Oscillation (ENSO) events. However, they varied considerably (and generally lower) in skill during non-ENSO periods.
- This project has ascertained that the Bureau of Meteorology POAMA 2.4 model provides high overall skill levels. Systems such as ECMWF and GLOSEA5 also produce high skill levels (except GLOSEA5 in 2015/16), but only tend to provide actual forecast outputs during ENSO periods.
- Seasonal forecast outputs for the South West of Western Australia and Central Tasmania tend to have low skill for all systems tested, which remains a challenge for the generation of seasonal forecast systems and products.
- The POAMA 2.4 system performed considerably better than the SOI phase statistical system in terms of forecast skill for the late autumn (May to July) period. It is already known that statistical systems have far less skill during this time of year.
- This project has learnt that GCMs provide much more advanced lead times in seasonal forecasting and forecast more accurately climate extremes. For example, in the summer of 2010/11, the ECMWF GCM output provided warning as early as April of the upcoming extremely high risk, above average rainfall for the ensuing 10 months in Australian sugar regions.
- A key outcome from this project is that the forecast skill for most of Australia varies considerably from year to year, largely as a result of whether or not major climate drivers (such as El Niño or La Niña) are active in the equatorial Pacific or Indian Oceans. Therefore, terms such as ‘average skill’ are believed to be somewhat meaningless and misleading to users, as this term tends to mask the high variability
in skill that can range from 100% accuracy to as low as 10% or 0% accuracy over successive years. Also, as it is known when periods of higher or lower skill are likely to occur, we recommend that seasonal forecasting not be used during the periods of likely poor skill – i.e. when major climate drivers are not present.

A summary of the enterprise, key decisions, relevant weather intra-seasonal and seasonal climate systems, and the timing needs for beef, grains, sugar, cotton and rice in northern, southern and western regions in Australia can be found in Appendix 7, which also provides further updated information from more recent workshops in the northern grazing and sugar industries, with the relevant seasonal forecasting capability highlighted. A list of associated websites and support systems are outlined in Table 1.

Table 1: Web sites and decision-support systems of value to farmers and producers.

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Web Site Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOI phase and similar outputs (e.g. SPOTA), with links to associated pasture production forecasts</td>
<td><a href="https://www.longpaddock.qld.gov.au/">https://www.longpaddock.qld.gov.au/</a> (Queensland Government ‘Long Paddock’ web site)</td>
</tr>
<tr>
<td></td>
<td><a href="https://www.ecmwf.int/en/forecasts/charts/catalogue/">https://www.ecmwf.int/en/forecasts/charts/catalogue/</a> (click twice) (ECMWF – European Centre for Medium Range Weather Forecasting)</td>
</tr>
</tbody>
</table>

Appendix 8 outlines case study events and periods of concern (links to framework/matrix of decision systems identified through user workshops) to provide details of appropriate forecast systems now tested and available to users. Appendix 9 summarises further detailed discussions and workshops with northern Australian industry groups.
7.1.9 Additional project details

- Full hind-cast data-set outputs are available on:

- Listing of skill maps by season and forecast source (example shown are outputs provided since 2010) are provided in Appendix 10. Each figure provides an assessment of the forecast skill for each of the periods analysed when assessed for each grid square across Australia. Each figure provides the detail (including original forecasts and actual rainfall maps) to provide hit rates for POAMA2.4, ECMWF, and UKMO since 2010. These figures highlight the varying temporal skill of these forecast systems - an issue that needs to be addressed for all forecast systems.

7.1.10 References


Plain English Summary

Background

The success of agricultural industries relies on the weather, which means the ability to accurately predict the weather is crucial. The Rural R&D for Profit Program, “Improved use of seasonal forecasting to increase farmer profitability”, aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

Seasonal climate forecasts (SCFs) provide opportunities for farmers to combine farm management with knowledge of the pending climate, so they can select appropriate crop types, varieties, stocking rates and nutrient inputs that are better suited to the forecasted climate conditions. This provides farmers with greater certainty and the potential for greater economic value during key decision making periods. Insufficient evidence on the value of SCFs is a barrier to their adoption by farmers in Australia and other countries.

Objectives and methodology

The objective of the project undertaken by the NSW DPI was to develop a range of case studies to better understand the barriers to SCF adoption by farmers, by assessing where, when and how SCFs offer value in agricultural production systems. While the case studies reflect climate sensitive management decisions identified by engagement with industries, they were not designed to be statistically representative or assess the potential value of SCFs to a sector as a whole. A total of nine case studies were conducted, which covered Southern Beef, Northern Beef, Prime Lamb, Southern Grains, Northern Grains, Western Grains, Cotton, Sugar and Rice with the intentional and explicit focus on farm decision environments, and the potential value of SCFs within these systems.

A common approach was utilised for each of the nine case studies by following three key steps:

- Through industry consultation, identify key decision points within the production system potentially sensitive to SCF information.
- The use of biophysical modelling to represent important features of the production system and the key decision point.
- The use of economic modelling to evaluate the value of SCFs at each decision point within the described production system.

To assess the value of SCFs, probabilistic climate forecasts from a hypothetical forecast system were adopted. This approach was chosen because there are multiple providers of operational climate forecasts, which are regularly updated to reflect improvements in the understanding of climate and weather systems and rapid developments in computing and analytical capabilities. The main benefit of assessing a hypothetical forecast, rather than an operational forecast, is that key aspects of forecast...
quality (e.g. skill) can be systematically valued. For most case studies, three discrete climate states were identified based on the lower, middle and upper tercile of rainfall received at the case study site using historical climate data. Each year was classified as belonging to one of these climate states; dry, average or wet.

An economic model was used to select the most profitable decision under a wide variety of scenarios. The analysis of the model included the interplay between forecast and non-forecast variables in influencing forecast value.

Typically, a total of 11 skill levels were assessed (0%, ...100%), with 0% skill representing climatology (the historical average) and 100% skill reflecting a perfect forecast of the climate states.

**Outcomes and Conclusions**

A range in forecast value was found within each case study (below table), and the value was primarily dependent on the environmental and economic settings of the decision and the skilfulness of the forecast. Certain settings provided significant value, whilst others yielded nil value.

**Range in forecast value for each case study.**

<table>
<thead>
<tr>
<th>CASE STUDY</th>
<th>RANGE IN FORECAST VALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTHERN BEEF</td>
<td>$0 to $29/ha</td>
</tr>
<tr>
<td>NORTHERN BEE</td>
<td>$0 to $14/steer</td>
</tr>
<tr>
<td>PRIME LAMB</td>
<td>$0 to $54/ha</td>
</tr>
<tr>
<td>SOUTHERN GRAINS</td>
<td>$0 to $20/ha</td>
</tr>
<tr>
<td>NORTHERN GRAINS</td>
<td>$0 to $204/ha</td>
</tr>
<tr>
<td>WESTERN GRAINS</td>
<td>-$24.4 to $18.5/ha</td>
</tr>
<tr>
<td>COTTON</td>
<td>$0 to $517/ha</td>
</tr>
<tr>
<td>SUGAR*</td>
<td>$0 to $2,358/ha</td>
</tr>
<tr>
<td>RICE**</td>
<td>$0 to $120/ha</td>
</tr>
</tbody>
</table>

*Upper range is for finer forecasts (8.3% probability as opposed to 33.3%), lower values are weighted by forecast probability across all forecasts.  
**Perfect weather forecast value.

A general finding was forecasts that led to decisions that were contrary to the direction of conditions provided the most value. Using the southern beef case study as an example, a dry forecast under high level of initial standing pasture tended to be the most valuable, as a decision was made to depart from holding to selling stock. This finding illustrates that the 'newsworthiness' of information is a critical determinant of its value.

**Implications for industry/primary farmers**

A skilful seasonal climate forecast is potentially valuable if it helps farmers make an informed decision, instead of making decisions based on historical average rainfall amounts. It is important to recognise that the decisions investigated in each of the case studies only represent part of the risk farmers manage; each case study represented a single site and one production system. Other sites, other systems and other decisions may find different results. It is likely that the general findings around the circumstances for which forecast value was found will provide insights for the use and value of SCFs for farmers more widely.
7.2.1 Background

The broad methodology used to evaluate the potential value of seasonal climate forecasts (SCFs) was carried out in three steps. First, the relevant industry was consulted to describe each case study farm and climate sensitive decision points. This engagement gleaned specific climate and non-climate drivers of the decision points. Typically, this included the forecast window (e.g. rainfall April to October), important environmental conditions (e.g. initial standing pasture) and economic conditions (e.g. relative crop prices). Second, biophysical modelling was conducted to represent the farm and decision; this utilised a range of tools including APSIM and AusFarm. Third, assessment of the value of SCFs within the system was analysed using economic modelling.

Specific details of the methodology used in each case study is contained in the attached case study reports. Table 2 provides a list of the case study sites, noting it is likely that the general findings around the circumstances for which forecast value was found will provide insights for the use and value of SCFs for industry on a wider scale.

Table 2 Case study locations.

<table>
<thead>
<tr>
<th>CASE STUDY</th>
<th>CASE STUDY SITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SOUTHERN BEEF</td>
<td>Holbrook, NSW</td>
</tr>
<tr>
<td>NORTHERN BEEF</td>
<td>Charters Towers, QLD</td>
</tr>
<tr>
<td>PRIME LAMB</td>
<td>Holbrook, NSW</td>
</tr>
<tr>
<td>SOUTHERN GRAINS</td>
<td>Birchip, VIC</td>
</tr>
<tr>
<td>NORTHERN GRAINS</td>
<td>Gunnedah, NSW</td>
</tr>
<tr>
<td>WESTERN GRAINS</td>
<td>Merredin, WA</td>
</tr>
<tr>
<td>COTTON</td>
<td>Bungunya, QLD</td>
</tr>
<tr>
<td>SUGAR</td>
<td>Ayr, QLD</td>
</tr>
<tr>
<td>RICE</td>
<td>Deniliquin, NSW</td>
</tr>
</tbody>
</table>

Figure 3 provides an example of the methodology undertaken to value SCFs, using the southern beef case study to illustrate the process. The potential value of SCFs was evaluated through maximising returns of the system by selecting the most profitable decision under various system conditions. Four key components were provided to the economic model, which then evaluated the potential value of SCFs.
The link between climatic conditions and agricultural production was captured through detailed biophysical modelling. The production costs of the system were input using various sources of costs of production. For example, the production costs for the southern beef case study was based on the NSW DPI Farm Enterprise Budget Series. Key output and input prices were obtained from appropriate sources for each case study, with output prices drawn from historical price series. Again, using the southern beef case study as an example, stock prices were sourced for 2006-2015 for the Wagga Wagga saleyards and adjusted to real prices based on movements in the Consumer Price Index (2014-15 used as the base year).

To assess the value of SCFs, a probabilistic climate forecast system was adopted. In general, three discrete climate states were identified based on the lower, middle and upper tercile of rainfall for the climate forecast period identified (e.g. April to October) over the historical dataset (more than 100 years). Each year was classified as belonging to one of these climate states; dry, average or wet. Agricultural production levels (e.g. pasture growth, animal weight, crop yield) for each of these climate states were obtained from outputs created by the biophysical production model. The resulting yearly data for each state was then averaged to represent each climate state within the economic model. This categorisation is a critical part of the approach, as variations in production across climate states provide the necessary, but not sufficient, conditions for forecasts to offer value in decision making. These biophysical outputs were combined with production costs and built into an economic...
model to capture the links between climatic conditions and agricultural production. The economic model was used to select the most profitable decision from a wide variety of scenarios.

The economic model took the form of a discrete stochastic programming approach. This was considered to have a number of strengths in the context of valuing seasonal climate forecasts. First, because production in each state of nature is explicitly recognised, it is straightforward to assess the consequences of different decisions in each state. This is an important feature when considering the value of imperfect forecasts. Second, the modelling reflects the ability of farmers to consider state-contingent responses (i.e. respond to rainfall state), something readily observed in practice. Third, with operational forecasts generally probabilistic in nature, some farmers will interpret probabilistic forecasts as a shift in the odds. This can be readily reflected through the assignment of posterior probabilities to each state based on forecast skill.

A specific interest of this project was to understand how forecast and other important non-forecast decision variables interplay to influence forecast value. The utilisation of a biophysical model allowed the capture of different environmental and economic settings, and outcomes to be explored in dry, average and wet climate states.

In order to systematically assess the value of forecast skill, a total of 11 skill levels were assessed (0% ...100%), with 0% skill representing climatology (the historical average) and 100% skill reflecting a perfect forecast of the three climate states. Increasing forecast skill resulted in a higher probability of a particular climate state evolving, which provided more certainty about future conditions.

The value of the forecast was analysed in the context of the decision environment settings (e.g. standing pasture or crop price). Four key analyses were conducted; i) decision made without forecast, ii) perfect (100% skilful) dry, average and wet climate state forecast decision, iii) the perfect dry, average and wet climate state forecast value, and iv) imperfect forecast value for dry, average and wet climate states.

7.2.2 Project Outcomes

Progress against KPI's in the current reporting period are outlined in Appendix 11. The nine case studies investigating the potential value of seasonal climate forecasting to Australian agriculture are embedded within the table. These case studies meet the broader project objectives of:

- Defining the critical seasonal climate risk information required by Australian farmers.
- Improving the understanding of the usefulness of seasonal climate forecasts and how to incorporate these into business decision making. NSW DPI’s primary contribution to the project was to develop nine industry specific case studies to evaluate the potential value of seasonal climate forecasts (SCFs) to the Australian agricultural industry. These case studies meet several of the overall programs’ objectives.

Each case study provides a robust analysis of an industry determined decision that was deemed sensitive to SCFs. Through this process, there is a need to define environmental and economic settings that also influence the decision. This exploration of the decision point prior to assessment of the value of SCF was critical. Informal feedback from participants in the southern beef and prime lamb case studies indicated that this process was illuminating, and they would be incorporating these findings.
into further work. A paper has been compiled that illustrates this process (Cashen and Darbyshire, 2017) and the methodology can be used by other practitioners, consultants and farmers to better understand their decision settings and to determine if SCFs may or may not provide potential value.

The range of industries investigated is, in itself, is a notable contribution, as the majority of previous research focussed on the grains industry only, primarily in relation to nutrient management. Furthermore, the methodology is largely comparable, which allows for cross-industry investigation of forecast value.

The robustness of the methodological approach highlighted some potential causes for the perceived relatively low adoption rates of SCF information among Australian farmers. Not all conditions are suitable for SCF to provide economic value to decision making. For example, forecasts of average climate conditions were generally found to be of little value, as they provide minimal additional information compared with historical average (which decisions can be made from in the absence of forecast information). Furthermore, other conditions, such as soil moisture and level of initial pasture, reduces the sensitivity of the decision to in-season rainfall lowering the value of the forecast in some instances.

7.2.3 Resources and Publications


Rebecca Darbyshire and Anwar Muhuddin, ”What value are seasonal climate forecasts for dryland cotton?”, Australian Cotton Grower Magazine, April-May 2017.


Plain English Summary

Background

The success of agricultural industries relies on the weather, which means the ability to accurately predict the weather is crucial. The Rural R&D for Profit Program, “Improved use of seasonal forecasting to increase farmer profitability”, aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

Seasonal climate forecasts (SCFs) provide farmers with critical knowledge of the weather that impact on key farm decisions, such as crop types. Groups of farmers and other support (e.g. advisors) with expertise in SCFs and related products share knowledge to improve adoption and use of SCFs in farm management decisions, however, they are often disparate with little collaboration between them.

Objectives and methodology

This project, undertaken by the Birchip Cropping Group (BCG), with support from other project partners, aimed to establish a community of practice (CoP) for members with existing products, services and industry networks to use information and introductions gained through SCF activities. This was performed to further effectively extend SCF key messages, and to develop resources that maximise uptake of SCFs by farmers and advisers. This was underpinned by assessments of the application of the CSIRO ADOPT tool to SCFs (using the results of the case studies), opportunities and barriers to the use of SCFs, and the adoption of SCFs in Australian agriculture.

Outcomes and Conclusions

The CoP was established through monthly meetings, where information was presented on a diverse range of topics selected by CoP members. This allowed for projects, products, concepts, research and professional development opportunities to be presented to the CoP, raising awareness of existing industry initiatives and identifying opportunities for feedback, support and collaboration. As a result of input by members of the CoP, a monthly technical webinar with the Bureau of Meteorology was also developed to discuss current climate events.

There were 73 members in the CoP at the end of the project.

Implications for industry/primary farmers

By the completion of the project, BCG established and oversaw the ongoing management of a successful SCF CoP, which will continue to meet beyond the finalisation of the project. This provides significant opportunity for improving the adoption of SCFs in agricultural management.
Recommendations for further research and improved adoption

Three key issues related to adoption of SCFs were identified in farm management decisions:

- **Adoption of SCFs will take a long time, and only a small percentage of the target audience will adopt their use in decision making.**
  The application of the CSIRO ADOPT tool, which evaluates and predicts the likely level of adoption and diffusion of specific agricultural technologies and practices with a target population in mind, suggests that even if a ‘perfect’ forecast exists, the peak level of adoption (for the southern grains case study) would be 97 per cent and would take eight years to achieve.

- **The accuracy and presentation of forecasts, plus farmer understanding of climate drivers, need continuous investment if adoption is to improve.**
  CoP member experiences that had opportunities and barriers to the use of SCFs identified that the accuracy and guidance from the forecast was generally seen as limiting. Additionally, although it is likely that there would be universal awareness of weather forecasts, the SCFs are an innovation that has emerged within the working life of many farmers and so the application has differed across regions and industries. Formats that are more likely to lead to a correct assessment should be adopted to ensure that SCFs are presented in a way that leads to favourable use of the system.

- **Communicating SCFs should be conducted at a time and decision point when they can provide the most value.**
  For some decisions, a SCF will not be relevant and should not be communicated to avoid confusion.

**7.3.1 Background**

BCG’s predominant focus in this project was driving collaboration between disparate groups that were aware of each other and their agricultural SCF products and services but had not always collaborated. Facilitated collaboration between project partners through the CoP ensured ideas were shared and developed into new products and services, or existing products and services were improved and better promoted. This allowed for more consistent communication and quicker time to delivery, which resulted from shared learnings from prior experiences and a strong focus on farmer needs. The intention of the CoP was for members with existing products, services and industry networks to use information and introductions gained through SCF activities to further effectively extend SCF key messages.

**Project 2a- Community of Practice**

A CoP is a group of willing practitioners with a common sense of purpose, who agree to work together to solve problems, share knowledge, cultivate best practice and foster innovation (Appendix 12). Agricultural CoP’s are developed on peer-reviewed, research-based, unbiased content development and educational delivery aimed at adoption of practices and changes in behaviour. Programs and products are developed by teams of content specialists and support professionals, constantly
interacting with the clientele served. Most of these engagements are conducted virtually, however, an element of face-to-face contact is important.

With these principles in mind, the ‘Australian seasonal climate forecasting CoP’ aimed to improve collaboration, derive greater value from existing expertise and resources, improve the flow of science to advisors and farmers, and create new, more open discussion channels for SCF projects that can better serve the industry.

The CoP was built on the following principles:

- **Engagement** – the CoP provided the mechanisms by which subject matter experts (SME’s) can engage;
- **Knowledge** – provided a body of new and existing knowledge to farmers, advisors and others that adds value, or increases profitability, encourages participation and increases engagement over time;
- **Shared Resources** – this project developed a range of resources that can be used by farmers and advisors to understand their SCF information needs, the climate information that's available and how to better utilise it. The CoP provided access to these resources.

The CoP was the conduit by which the project engaged with the project ‘consumers’; farmers and farm advisors. It identified and engaged the necessary and relevant expertise, coordinated relevant activities and services, provided feedback loops across the range of participants and managed the development of products, tools and services. It had a clear focus on the needs of farmers and advisors and was careful to ensure efficient cross-sectoral and cross-jurisdictional representation.

Fundamentally, the CoP approach differed from conventional communication or extension activities, which attempt to take specific information and ‘broadcast’ it to a wider target audience, whereas the CoP attempted to take relevant information and ‘narrowcast’ that information to a specific individual or group.

The project was supported through the excellent extension and adoption resources made available to the project from Agriculture Victoria, SARDI, DPIRD, NSW DPI and USQ. A key aspect of bringing together this expertise is to generate a level of trust in the system that was required to give farmers and advisers sufficient confidence in the information and how to use it.

**Project 2b – Develop and Tailor Products, Tools & Services**

The aim of this component of the project was to provide the resources required to enable information to be packaged and presented in ways that maximise uptake by farmers and advisers.

To adequately achieve this, the project needed to develop a clear understanding of the enablers and barriers to the use of seasonal climate information to on-farm decision making (Appendix 13). The capacity for adoption by the target audience (activity 5) (Appendix 14) was also required, and current issues that prevent adoption include:

- Low farmer trust in reliability of the forecast;
- Low model skill at key decision-making times;
- Low farmer understanding of climate drivers impact on a given region;
• Limited farmer ability to understand and correctly interpret probabilistic forecasts.

In addition to understanding barriers and enablers, understanding the potential audience size and time required to reach peak adoption was considered as part of the project, to help design and evaluate effective extension methods. The CSIRO Adoption and Diffusion Outcome Prediction Tool (ADOPT) was used to provide this data.

To specifically design and deliver appropriate products and services, the project drew on the extension and adoption expertise and existing products made available through MCV, BoM, BCG, DEDJTR, SARDI, DAFWA, NSW DPI and USQ. Together they provided great guidance in developing and improving products, tools and services that encourage adoption by farmers (Appendix 15).

This component of the project was cognisant of findings of the MCV Program V, ‘A Research and Development Operational Plan’, developed by Christian Jakob, Andy Pitman, David Karoly and Peter McIntosh (Appendix 16).

This report suggests:

“There were quite a number of comments about the complexity of the information landscape for producers and their advisors. There are 46 decision support tools listed on the Climate Kelpie web site (MCV 2016) alone after a rigorous selection procedure. In addition to these tools, climate and weather information is available on a wide variety of web sites, both within Australia and overseas. However, very few of the decision support tools incorporate climate forecasts.

The general consensus seemed to be that producers don’t need more tools, but rather that climate forecasts should be incorporated into existing tools so that this additional information could be utilised in a familiar setting.

Most decision support tools appear to focus on a single management decision, such as fertilizer application or stocking rate. While it is initially important to fully understand the impact and value of these individual decisions, ultimately a farmer is operating in a complex decision-making environment and juggling many factors.” – MCV V Operational Plan.

This formed part of the core focus of the CoP when considering project 2b, ensuring greater value from within existing expertise and resources and expanding promotion of existing resources to derive greater value.

This meant the focus of the project became about ensuring existing tools had maximum impact and were widely shared, continuously improved and, where possible, customised for each region and industry, rather than developing new tools and contributing to the current state of producer ‘information overload’.

7.3.2 Method and Project Locations

Project 2a followed the implementation strategy outlined below. This strategy enabled the CoP to ensure legacy after the project.

Phase 1:
A CoP ‘core’ was established and consisted of all project personnel, as well as a small number of representatives external to the project. This included other climate/seasonal forecasting organisations
and agricultural operators with an interest in seasonal forecasting. This phase was completed by the end of 2016.

This core was responsible for agreeing upon Terms of Reference that meet both project and member objectives, user testing potential platform/s and identifying issues and mitigating risks prior to the CoP becoming available to a wider audience.

**Phase 2:**
Phase two commenced in 2017, allowing time for sufficient project related products, tools and services to be made available. These resources acted as a strong incentive for participation.

This phase expanded on the networks of individuals within the CoP, where ‘core’ members invited peers who they felt could positively and actively contribute to, and learn from, the CoP.

Additionally, participants in project activities (workshops, farm advisory groups, case studies etc.) were invited. This provided a mechanism for participants to continue learning and further engage with the project following initial contact.

Finally, developers of SCF related products and services were invited to present and receive feedback on their outputs, allowing shared learnings from similar offerings, improved industry awareness and opportunities for cross-promotion.

**Phase 3:**
Phase three commenced in 2018 and sought to operationalise the CoP, and access is currently available to any interested party. During phase 3, CoP evaluation and legacy was discussed, and active CoP members were invited to take on roles within the CoP after the end of the project. Phase three has been mindful that the CoP will be transitioning to a new RR&D4P project (Forewarned is Forearmed: Managing the Impacts of Extreme Climate Events) after the project is finished. As this will bring in a new ‘core’, CoP activities and promotion have been developed with this transition in mind.

The full implementation strategy is available as an (Appendix 1). The CoP met monthly, presenting a diverse range of topics selected by CoP members. This allowed for projects, products, concepts, research and professional development opportunities to be presented to the CoP, raising awareness of existing industry initiatives and identifying opportunities for feedback, support and collaboration.

Based on CoP member feedback, an additional CoP activity was developed and operated throughout the life of the project. Bureau of Meteorology (BoM) and seasonal climate forecasting communicators participate in a monthly, in-depth discussion regarding current climate drivers and their effects on the various industries. As per the CoP meetings, this was conducted via webinar and coincides with the release of the BoM monthly seasonal climate outlook.

All of the participants in this webinar have excellent agricultural networks within their respective sector/region, and the webinar is allowing effective and targeted extension of SCF information. Additionally, BoM presenters receive industry feedback and insight into the different issues affecting producers.

Evaluation of the CoP was conducted annually, with surveys of participants being undertaken to collect feedback.
3.3.3 Project Outcomes

Appendix 17 outlines the KPI’s that were completed within this report.

7.3.4 Contribution to Program Objectives

The Birchip Cropping Group component of the Rural R&D for Profit project, along with the development and ongoing maintenance of the Seasonal Climate Forecasting Community of Practice (CoP) and activities arising from the CoP, have been pivotal in fostering collaborations between industry and research. Monthly meetings of SCF professionals, including many personnel not funded by the project, have provided the opportunity for:

- Leading SCF research is presented to industry professionals, allowing for quicker and more scientifically rigorous extension to producer end-users;
- Feedback to forecast providers from industry regarding producer needs, current experiences and relevance of the forecast to on-farm decision making;
- Raising awareness of existing projects, research, products and services to identify opportunities for collaboration, and to share learnings across sectors/regions to minimise time to delivery for similar offerings;
- Feedback/user testing of SCF products and services, such as industry presentations, producer online training modules, decision support tools, communications products and experimental forecast products;
- Professional development through the presentation of producer market research results and topics, such as user experience, decision support tool design and development and the use of social media;
- Cross promotion and sharing of SCF products and services to producer audiences.

The CoP was also used to regularly engage CoP members (both internal and external to the project) in project developments to engage members in project progress, seek member feedback and expertise and leverage industry networks.

CoP members are comprised of 73 representatives from state departments, grower groups, federal departments, research development corporations, universities, TAFEs and private enterprises.

The CoP approach has enhanced relationships between research and industry and provided researchers with a greater understanding of producer needs, while simultaneously upskilling SCF extension professionals understanding of the subject matter. This has allowed for more accurate and timely dissemination through their producer networks.

The monthly webinar between BoM staff and agricultural SCF extension professionals involves BoM staff delivering a ‘behind the scenes’ look at the monthly climate outlook, on the day it is released by the bureau. This activity has:

- Fostered relationships between the numerous BoM staff that have presented and industry extension providers;
- Improved the understanding of how outlooks are developed;
- Allowed two-way conversation regarding influences of climate drivers on different sectors and regions.
CoP members, through evaluation exercises, have provided the following feedback on their involvement in CoP activities:

“It has provided me with a better understanding of what is happening weather wise and has helped me better understand the forecasts provided by the BoM. I have incorporated some of this into the ‘Weather Or Not’ communications I have been writing for the Farmlink grower group throughout 2017.”

“It is important for me when working with seasonal climate forecasts to be aware of current forecasts and current developments in forecasting. The webinars are useful means of achieving these objectives.”

“Hearing latest modelling, plus opportunity to ask dumb questions about climate issues, which helps lift our level of understanding about both the forecasts but also the climate system.”

“I think each presenter offers a slightly different spin on the content which gives a better all-round understanding.”

This enhanced collaboration has ensured that researchers and industry are delivering SCF products and services that are relevant to producer requirements at a given point in the season, while also ensuring that the information is based on the best available scientific information and presented in formats conducive to a producer audience. By bringing together the diversity of members as seen in this CoP, relationships have been established that will ensure the development of future efforts a collaborative and end user focused approach, minimising the risk of duplication and increasing efficiencies and time to delivery.
Plain English Summary

Background

The success of agricultural industries relies on the weather, which means the ability to accurately predict the weather is crucial. The Rural R&D for Profit Program,"Improved use of seasonal forecasting to increase farmer profitability", aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

A key barrier to the adoption of seasonal climate forecasts (SCFs) by Australian farmers to improve farm management decisions, is access to resources that support maximum uptake of SCFs by farmers and farm advisers.

Objectives and methodology

DEDJTR supported the Birchip Cropping Group to develop a range of potential techniques to increase the effectiveness of SCF understanding and their use by farmers in southeast Australia.

Stakeholder collaborations across agriculture and improvement links with a range of private industry agronomy & extension providers were critical to the success of this project, as they enabled piloting SCF products and defining the needs of users.

Outcomes and Conclusions

SCF products and presentations were designed and presented to 62 agriculture events, targeting 3923 participants over 3 years. Most of these events were held in South Australia, NSW & Tasmania, in order to test if approaches used within Victoria’s seasonal risk program would translate across regions. The strong demand from interstate agricultural stakeholders suggested that this approach does work across southeast Australia.

In September 2017, a seasonal forecasting workshop training session was developed for the National Fertiliser Australia conference. Working closely with Fertiliser Australia enabled the testing of a new workshop session, where 94 participants listened to expert presenters and were then able to make their own interpretations of various seasonal forecast products.

Implications for industry/primary farmers

The outputs and outcomes from this project have, and will continue to, improved adoption of SCFs by Australian farmers which result in improved farm management decisions and subsequently, improved economic outcomes.
Recommendations for further research and improved adoption

Several additional resources have been identified that could be developed or improved to further improve adoption of SCFs, including website/webpages, workshop, webinar series' and tools. However, the key themes required to be continued and improved for success are:

• **Working with users’ needs and customise the seasonal forecast information and products as required.**
  Working with service providers is critical to reach new audiences, and the presence of a seasonal climate speaker at an industry event was much more successful than trying to arrange a seasonal climate event on its own.

• **Expanding on local historical rainfall records.**
  Explanations were provided on the key climate drivers of seasonal variability and their impact on past local seasons. This brings the farmers own history & experience together with the latest science, which creates confidence regarding how and where their local seasons are influenced by these key drivers both in the past, and in the future.

• **Continue the SCF community of practice (CoP).**
  The CoP created as part of the broader “Improved use of seasonal forecasting to increase farmer profitability” project provided a unique space for seasonal risk extension deliverers to meet online, share stories of what works and what doesn’t, and most importantly, allowed access to the latest monthly climate outlook updates from the Bureau of Meteorology. These sessions were powerful in both sharing the science behind the current forecasts, but also in allowing agriculture staff to ask questions, which allowed for improved climate literacy and better understanding about the capacity of the forecast models. These discussions were critical in providing important content on the latest forecasts, which extension agents could then use to develop their messages for communication to rural audiences.

### 7.4.1 Background

Project 2b was led by the Birchip Cropping Group, and the primary role of DEDJTR was to support them in delivering:

• Identifying the enablers and barriers to the use of seasonal climate information to on farm decision making, and
• Skilling farmers and advisors to best apply climate data in their decision making.

Within this project, the outputs of Project 1 were considered in terms of farmer and adviser information needs. From this, products, tools and services were developed in collaboration with farmers, advisers and extension specialists to meet those needs.

This project is fortunate to be able to draw on the extension and adoption expertise made available through BCG, DEDJTR, SARDI, DAFWA, NSW DPI and the recently engaged resources at USQ. Together, they provided great guidance in developing products, tools and services that encourage the adoption of seasonal climate forecasting by farmers.

The aim of this project was to provide the resources to enable information to be packaged and
presented in ways that maximise uptake by farmers and advisers.

The outputs of previous projects, including the literature review and case studies from Project 1a, the GCM analysis from Project 1b, the information needs of farmers and advisers from Project 2a and the model improvements from Project 3, were considered in terms of three issues: 1) What information do farmers and advisers need?; 2) What is the best delivery method for this information?; and 3) How can the information be incorporated into existing systems or delivery mechanisms to maximise the projects legacy?

Each information package was also considered in relation to:

**Innovative communications**
This drew on the success of products like the DEDJTR ‘Climate Dogs’ communication exercise, which has shown that complex issues (such as key drivers of Australian climate) can be conveyed in an entertaining and effective manner. Communication tools were designed and tested to convey the use of seasonal climate forecasts in risk management. The aim of this communication was to break down some long-held reservations about the appropriate use of uncertain, but still skillful, climate forecasts.

**Program outputs**
The outputs of activities, such as the bio-economic modelling, decision making frameworks and GCM analysis, were considered to determine whether products, tools, or services can be designed to assist farmers and advisers in utilising the knowledge in a meaningful and practical way.

**Legacy systems**
This aspect of the project will be conducted for a finite period, but the knowledge developed will provide a legacy into the future. This can be enhanced by encapsulating the knowledge in learning systems that will be accessible into the future, which will include investigating inclusion in current agriculturally-related curriculums, developing online tools such as workbooks and videos, and adding tools and products to existing websites or other platforms.

Tools, products and services developed in this project will be tested using existing channels, such as training programs, producer groups and RDC networks. Existing tools, products and services will also be assessed to determine if new information can be incorporated within them. This development will include:

- Working with the Vocational Education and Training sector to ensure that any nationally recognised training packages (e.g. Certificate IV) that focus on seasonal climate risk management incorporate the best knowledge and are contextualised in relation to business decision making and farm profitability.
- Products based around working with each of the contributing RDCs and tailoring products and services that include seasonal climate information, while retaining a focus on farm profitability (e.g. ‘More lambs more often’).
- Testing and piloting several learning products and service delivery mechanisms that have audience suitability and learning impact. Priority will be given to concepts that maximise the reach of the project to people with minimal opportunity for direct interaction with the training delivery.
7.4.2 Methods and Project Locations

Milestone 1 was to achieve KPI 1.8 & 1.9, which was led by Birchip Cropping Group and involved the establishment of a new Community of Practice (CoP). DEDJTR staff Dale Grey & Graeme Anderson provided initial support and discussions on the value and design of a CoP and have since been regular participants in attending CoP webinars and have presented on a number of occasions.

DEDJTR staff attended all project team meetings, workshops and webinar events. However, most activity by DEDJTR has been based on working with agriculture stakeholders to develop and test approaches that help them better understand and apply seasonal forecasts in their decision making.

DEDJTR presented seasonal forecast presentations and products to 62 agriculture events to 3923 farmers and advisors over the last 3 years. Most of these events were in South Australia, NSW & Tasmania.

Even though contracts with all collaboration partners were delayed in establishing this new project in 2015, DEDJTR Victoria staff had commenced piloting seasonal forecasting products in good faith and approached delivery in July 2015. This early start was crucial, as agriculture stakeholders were actively seeking advice on the seasonal outlook due to a forecast El Nino event in the spring of 2015. DEDJTR staff took this opportunity to rapidly develop and test pilot seasonal forecasting talks and products, which became in demand as the season unfolded.

The 2015/16 El Nino provided a useful opportunity to engage with key agricultural advisory networks and test approaches and products that could help them make sense of, and increase confidence, in the use of seasonal forecasts in their farm decision making. Farmers and advisors responded very well to explanations of El Nino, Southern Oscillation and Indian Ocean Dipole when it was demonstrated how these climate drivers had affected their local winter & spring rainfall in previous seasons. This builds confidence in the link between climate drivers, oceans and local rainfall outlooks.

The 2016 season saw a shift from El Nino and dry weather, towards one of the wettest winter/springs in southeast Australia’s record. The strong negative phase of the Indian Ocean Dipole helped bring the wetter conditions and provided a valuable opportunity to engage with key agricultural advisory networks. Most workshops where DEDJTR presented had farmers who had experienced incredible variability within the prior 12 months; from extremely dry/hot spring in 2015 to a productive spring in 2016. A survey of 600 people showed a knowledge gain and growing confidence in using seasonal forecast tools once there was a better understanding of how forecasts are made, and what drivers’ cause variability in each district. These insights were shared with project collaborators via the Community of Practice presentation sessions in November 2016.

Also, following the 2016 growing season with the wet spring associated with the strong negative phase of the Indian Ocean Dipole, there was some increasing recognition of the role and value of seasonal forecasts by stakeholders. Both the dry spring in 2015 and wetter spring in 2016 were forecast as increased likelihood via analysis of the DEDJTR Fast Break global model outlook comparison table, which showed in both years the majority of global forecast models had a drier (2015) or wetter (2016) signal for Victoria. This is believed to be a useful format and approach that can add value to only using the single probability forecast from BoM POAMA/Access-S outlooks.
DEDJTR’s Dale Grey also developed a pilot product that showed Australian wide rainfall forecast outlook maps (rainfall) from several global climate models, which add further context to BoM POAMA model outlooks. This was well received at the Wagga Wagga project team meeting and BCG investigated how this style of product could be created on the MCV project web pages in future.

It was also discovered that local monthly rainfall charts developed for specific El Nino or IOD years proved to be a great value for some farmers and agronomists. Rather than just hearing about how previous El Nino events were usually drier, the monthly charts showed how past local rainfall during El Nino events had varied, with around one third of years close to average or wetter. Interestingly, the agronomists found great value in seeing the ‘season finishes’ in previous El Nino springs, and in most cases, it helped them reassess their crop management. For some NSW agronomists who had reasonable soil moisture levels, they realised that they risked losing crop yield unless they adjusted their fertiliser rates, as the outlooks they had assumed for an El Nino season were at the driest end of the scale, which had only occurred 2 or 3 times in history. By looking through the monthly charts, they had better information regarding the range of finishes possible, which helped them to readjust their crop management advice. One leading agronomist said that by assuming the worst (rather than looking at the finder details of all El Nino finishes), they risked losing one tonne per hectare of potential yield by not providing sufficient crop nitrogen in areas with good soil moisture levels.

DEDJTR also developed a new method of communication via a facilitated workshop on seasonal forecasting at the National Fertiliser Australia Conference. The session had 94 participants from across Australia and involved 3 key presenters, as well as an interactive workshop where participants from each state learned how to read several forecast model outputs, tested their performance for their region in the winter of 2017 and then looked into the model outlooks for next 3 months. Participants rated the session 8.7/10 and 100% stated they would recommend it to others.

Throughout this project, DEDJTR staff provided advice and support to the Birchip Cropping Group project activities for the development of the Community of Practice, through regular attendance at CoP meetings, attendance at project meetings and workshops and providing input to the ADOPT scenarios developed by the BCG team.

**7.4.3 Project Outcomes and Contributions**

DEDJTR can report on evaluation data related to the many seasonal forecast presentations delivered. All these activities were undertaken at events and forums that were organised and arranged by other industry stakeholders, and as such, data was not always collected or evaluated from events that DEDJTR attended. However, the ratings and satisfaction is consistent with the data reported below, as many stakeholders thought highly enough of DEDJTR’s approach that they often invited us to deliver follow up seasonal forecast updates to their clients. It is usually a good sign when private or industry service providers present an invitation to speak to their clients, it suggests that they value the information and approach and believe it will not harm their own reputation with their clients. In that sense, the feedback from the DEDJTR seasonal forecasting talks were very well received.

Representative satisfaction ratings taken from within the 62 DEDJTR presentations were always above 8 out of 10, such as:

- **GRDC workshop presentation at Griffith NSW** - (Anderson) 40 farmers, 17 advisors forecasting presentation - Satisfaction score averaged 8.3/10;
• **GRDC Wagga Advisors Update, Feb 2016** - (Grey) 74 attendees - Satisfaction score averaged 8.6/10;

• **GRDC - NSW MOAMA Research Update, July 28, 2016** - (D Grey) 91 participants on seasonal forecasting - Satisfaction score averaged 9.1/10;

• **South Australia, Adelaide, Independent Advisors & Consultants Workshop, 20 October 2016** - Making Sense of Climate & seasonal forecasting session lead by G Anderson & P Hayman - 35 advisor participating (grains & livestock) - Evaluation satisfaction rating 4.1 out of 5;

• **National Conference Fertiliser Australia, Torquay, September 2017** – Customised 90-minute seasonal forecasting workshop by Graeme Anderson, Dale Grey and Andrew Watkins included 94 participants who took part in the session and gave a rating of 8.7/10 for satisfaction and 100% said they would recommend the session to a colleague.

Importantly, when it comes to how seasonal forecasting information is used by farmers, a June 2016 survey of DEDJTR “The Break” subscribers showed high customer satisfaction (637 farmer responses) indicating:

- 94% responded it has improved their ability to manage seasonal variability and risk;
- 96% responded it has improved their knowledge and understanding of seasonal climate variability;
- 90% responded it provides them with information they can't find elsewhere;
- 59% of respondents had also seen a face to face presentation from the DEDJTR seasonal risk team at regional industry forum.

“I have said in the past and still say that in terms of commercial impact on grain growers, “The Break” and its derivatives are the best thing to come out of the Australian Government Department of Agriculture and Water Resources in the last 20 years. Keep up the good work. The webinars provide valuable insight that cannot be presented in the brief Break format. Essential viewing for all involved in production risk management.” Kate Burke, Managing Director, Think Agri Pty Ltd.

The DEDJTR component of $25k/year was a small, but important contributor to the whole project. AgriFutures Australia (formerly RIRDC) is in the best position to incorporate the entirety of project participant contributions, and DEDJTR have supported them in meeting the overall program outcomes in an efficient and timely manner.
Plain English Summary

Background

The success of agricultural industries relies on the weather, which means the ability to accurately predict the weather is crucial. The Rural R&D for Profit Program, “Improved use of seasonal forecasting to increase farmer profitability”, aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

A key barrier to the adoption of seasonal climate forecasts (SCFs) by Australian farmers to improve farm management decisions is adequate trust in, and understanding of, SCFs. This is particularly relevant in the South West corner of Western Australia (the Grainbelt in WA), as the climate drivers that impact on the Australian continent have little influence here. This creates doubt in WA farmers regarding the use of SCFs.

Objectives and methodology

The Department of Primary Industries and Regional Development (DPIRD) in WA developed a unique seasonal forecast for the Grainbelt of WA, ‘The Statistical Seasonal Forecast’ (SSF), which has better skill than the Bureau of Meteorology’s POAMA model for that region. The objective of this project was to promote the SSF to a wider audience using a variety of pathways, both existing and those developed as part of the broader, “Improved use of seasonal forecasting to increase farmer profitability” project, and the DPIRD monthly newsletter, ‘Seasonal Climate Outlook’.

Outcomes and conclusions

Through this project there were numerous publications and communication opportunities to promote the decision tools developed and extensive support available through DPIRD for farmers. These opportunities included Dowerin Field Days, two spring field days, 24 publications of DPIRD’s Seasonal Climate Outlook newsletter, Various Newspaper publications, one Research Updates Paper (Guthrie and Evans, 2018) and several web pages published on the DPIRD website.

The number of subscribers to the ‘Seasonal Climate Outlook’ in April 2016 was 283, with 35% having opened the email and 22% clicked on a link in the email summary. By April 2018, the number of subscribers had grown to 402, with 37% having opened the email and 27% clicking on a link in the email.

This project provided opportunity for open communication between government departments and farmers and sharing of information on climate variability.
Implications for industry/primary farmers

Seasonal Forecasting in WA has limited ‘skill’ (accuracy) due to lack of influence from climate drivers that impact on the Australian continent. Therefore, growers need to be wary when using SCFs, although, the tools, support and programs available through DPIRD can significantly improve the use of climate information for farm management decisions in the Grainbelt of WA.

Recommendations for further research and improved adoption

There is a need for different climate indications to be assessed for improving the forecasts for the WA climate.

7.5.1 Background

The Bureau of Meteorology's Predictive Ocean Atmosphere Model for Australia (POAMA) has reportedly had low skill in three areas of Australia; southwest Western Australia (SWWA), Queensland and Tasmania. A locally-developed statistical seasonal forecast (SSF) (DAFWA 2016) in SWWA is considered more useful than POAMA, and, as such, SSF is used by DPIRD in their agricultural applications. BoM’s Australian Community Climate and Earth Science Simulator-Seasonal prediction model (ACCESS-S1), which is scheduled to be launched mid2018, will improve forecast skill in SWWA for temperature but not so much for rainfall (McIntosh 2016).

Evaluation of David Stephens Global ENSO Sequence System (ESS) (Tennant and Fairbanks 2004) and BoM’s statistical system (Fairbanks, 2006) found that the international models Experimental Centre for Climate Prediction (ECPC) and European Centre for Medium-Range Weather Forecasts (ECMRWF) were better at seasonal forecasting than ESS and the BoM model. The SSF that was developed for SWWA has better skill than ESS and POAMA, as it looks at local climate indices like the Indian Ocean sea surface temperature and mean sea level pressure over SWWA, as well as conditions in the Pacific Ocean. A six-year review of POAMA and SSF has found that the SSF has more success in the northern and central Grainbelt of Western Australia (Guthrie and Evans 2018).

Since 2012, DAFWA has been producing three-month seasonal outlooks for the Wheatbelt and SWWA with the SSF model. The outlook gives a probability of exceeding the median rainfall for the next three months, as well as for the growing season (May to October). The outlook gives a probable decile ranking, which is more valuable than an above, or below median forecast. The model allows users to click on a rainfall station that can provide more detailed information, including the likelihood of receiving certain rainfall amounts.

2010 had a poor yield in the SWWA region and following on from droughts in 2006/2007 for some areas of the Grainbelt, it is assumed that farmers are more aware of seasonal forecasting and now consider it as beneficial to their business management. In 2006, the Managing Climate Variability Project, AcCLIMATise, showed that seasonal climate information was a priority to Western Australian farmers. AcCLIMATise surveyed 190 farmers from 66 shires about their attitude to climate/weather data and tools and whether they use it. Of these, 87 readily accessed weather data and 34 of the 190 actively sourced climate information. Therefore, a similar survey of 14 farmer groups conducted in 2017 by the e-Connected Grainbelt project (funded through Royalties for Regions), found that seasonal climate information was scored as the 5th highest priority of 22 topics, after soil water,
predicted yield, extreme weather events and rainfall to date (DAFWA Fiona Evans pres., comm). These surveys demonstrate that climate and weather information is of interest to Western Australian grain growers. However, further work is required to educate growers in the application of seasonal climate information to their business. Dealing with seasonal climate forecasts requires clear thinking on how to incorporate imperfect information into planning; this clarity of thinking, if translated into practical risk management, is likely to have significant pay-offs (Hayman et al., 2007).

Climate change is an issue that will severely impact farmer profit and there has already been a significant change to May–July SWWA rainfall since 1975 (IOCI, 2012). However, a recent report from CSIRO found that, in general, people’s attitudes to climate change has not altered (this was a national study and did not focus entirely on farmers).

Climate scientists and extension offices have an integral role in helping farmers to better understand their regional climate and how to gain information from seasonal forecasts. Hayman et al. (2007) reports that seasonal climate forecasts seem to be ill-suited to decision making, and decision making ill-suited to probabilistic seasonal forecasts. Although farmers are used to making decisions under uncertainty, it is difficult to know how to use a probabilistic forecast.

The Seasonal Climate Outlook is a monthly newsletter published by DPIRD, which reports on seasonal outlooks for SWWA from SSF and POAMA. It also gives commentary on current climate conditions and other modelled forecasts of the likely influence of future climate. Many farmers are interested in what will happen in spring, even before they seed, and there is an increasing trend to dry-seeding some of their programs early, to either spread their risk or start their ever-increasing programs. The subscription rate of the newsletter increased by 5% in 2017, due to a dry season in the northern Grainbelt, and DPIRD’s involvement in this project has allowed for further promotion of the newsletter.

Previous work by Peter McIntosh (Climag edition 24, May 2015), identified four tips for WA farmers who want to use forecasts:

- Look at all the information and models you can get;
- Do not weigh all the information equally. Some models and forecasts are more skilful and reliable than others. You should account for this when comparing different forecasts;
- Look for consistency between the forecasts and models you have collected. If everything is telling you the same thing, then it’s more likely to happen. If there is variation, then there is increased uncertainty;
- Get used to the fact that no forecast is certain. The information is telling you which way to lean, not which way to jump.

“If you follow a forecast for long enough, it will eventually bring you dollars. It’s the same as if you went to a casino and knew a coin was biased. You may not pick the first toss, but if you keep playing you’ll learn which side is weighted and can take advantage of your insider knowledge.”

-Peter McIntosh, 2015.

Studies have found that there is a limited influence on ENSO (specifically, SOI) on SWWA rainfall (England et al 2006: Fairbanks and Foster 2007). As ENSO has limited influence on SWWA rainfall, and because chocolate wheels emphasise the gambling aspect to farming, the science behind the wheel is not remembered. However, this is not the case with other areas, for example, in South Australia Peter
Hayman uses chocolate wheels successfully and Dale Grey and Graeme Anderson have success with them in Victoria.

Understanding the skill of a model is a barrier to using the seasonal climate, which was a main point of discussion at the second monthly CoP meeting in June 2016. If someone wants to use a model as a categorical forecast (which most people do i.e. > 50% chance of above average = wet and < 50% chance of above average = dry), then a 50% consistent accuracy means that every second outlook will be wrong.

Averaged across Australia and across the seasons, BoM’s rainfall outlooks are approximately 60% consistent overall. If people use them more in a risk management fashion, as they should be, then reliability is a more important measure of skill. Good reliability is achieved when a certain percentage chance of occurrence is forecast, and that percentage of outcomes is observed over a long period of time (i.e. a 60% chance of above average rainfall means that 60% of rainfall totals over a period should be above average). BoM doesn’t publish these metrics, but considers the outlooks as generally reliable, though certainly not perfect (Glenn Cook, Bureau of Meteorology, Perth, pers. comm).

Some consultants comments have included;

“I like the idea of statistical seasonal forecasting, statistics is very interesting.”
John MacDonald, Wickepin, WA.

“DAFWA’s Statistical Seasonal Forecast is the forecast we find most useful. It incorporates the Southern Annular Mode and sea surface temperatures that we also look at independently when making decisions throughout the growing season.”
John Scotney, West Midlands, WA.

“Improved seasonal forecasting will assist farm decision making, but fundamental challenges, such as severe frost events, require agronomic answers from our scientists.”
Simon Wallwork, Corrigin, WA.

“DAFWA’s Statistical Seasonal Forecasting has provided added confidence in farming decisions about how to ‘play the season’ when used in association with a range of other agronomic facts. Gives me a bit of confidence in my fertiliser decisions.”
Camray Gethin, Merredin, WA.

The objectives of Project 2, ‘Using the Forecast’, was to improve the use and usefulness of seasonal climate forecasts by;

- Setting up a Community of Practice, which includes forecast users, practice specialists and climate practitioners, and,
- Develop and tailor products, tools and services.

### 7.5.2 Methods and Project Locations

Extension of seasonal forecasting information and related material took place in various locations of the Western Australian Grainbelt (Figure 4).
Figure 4: Various locations of the Western Australian Grainbelt where research took place for this report.

7.5.3 Project Outcomes

The monthly newsletter (KPI 6.1), ‘Seasonal Climate Outlook’, DPIRD publication is the most effective method of communicating the current climate and model outlooks for the Western Australian grains industry. This project has allowed DPIRD to promote this publication by word of mouth at events, such as Research Updates, Dowerin Field Days and Grower Group Spring Field Days.

The number of subscribers in April 2016 was 283, with 35% having opened the email and 22% clicked on a link in the email summary. By April 2018, the number of subscribers had grown to 402, with 37% having opened the email and 27% clicking on a link in the email.

The enabling factors and barriers to the adoption of climate forecasts in farm business decision making (KPI 6.6) are outlined below:

- Enabling factors include, ease of use, accessibility, no cost and it comes with contact information if there are further questions or enquiries;
- If consultants and agronomists use them then it is a plus;
- Subscription of DPIRD’s monthly seasonal climate newsletter increased to 400, up by 5% in 2017, a year when there was a declared dry season;
- Barriers to adoption include low skill levels, especially in the southwest of WA, which is supported by Peter McIntosh and the paper Guthrie and Evans 2018;
- Climate forecasts of April and May rainfall have limited skill given that the climate drivers, such as ENSO and Indian Ocean Dipole, are inactive at this time of the year;
• ENSO phase transition often occurs during April and May and most forecasting models have their lowest skill during this time (Webster and Yang, 1992), therefore this period has been described as the 'predictability barrier';
• Lack of promotion, as indicated at Dowerin Field Day;
• There is some confusion as to what climate drivers are important in SWWA, for example, one farmer in Tambellup, Great Southern Grainbelt in WA, follows the Southern Oscillation Index, which has little correlation to rainfall in the west;
• There is also some confusion between a three-month seasonal climate outlook and the weather forecast- some growers are still confused about weather and climate.

The innovation associated with DPIRD’s involvement in this project included the adoption of a seasonal forecast that provides information targeted at the decision to forward sell wheat in July for the SWWA region. This innovation was piloted in a case study by Dr Rebecca Darbyshire, with grain growers in a WA medium-low rainfall zone, specifically Burraoppin, but is relevant to farmers who forward sell in WA (which is the majority). The main results of this case study are outlined in Table 3, and Figures 5-7.

Table 3: The predicted adoption levels of seasonal forecasting in the SWWA region.

<table>
<thead>
<tr>
<th>Level of adoption</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Predicted peak level of adoption</td>
<td>29%</td>
</tr>
<tr>
<td>Predicted years to peak adoption</td>
<td>13</td>
</tr>
<tr>
<td>Predicted years to near-peak adoption</td>
<td>10</td>
</tr>
<tr>
<td>Year innovation first adopted or expected to be adopted</td>
<td>N/A</td>
</tr>
<tr>
<td>Year innovation adoption level measured</td>
<td>N/A</td>
</tr>
<tr>
<td>Adoption level in that year</td>
<td>N/A</td>
</tr>
<tr>
<td>Predicted adoption level in 5 years from start</td>
<td>17%</td>
</tr>
<tr>
<td>Predicted adoption level in 10 years from start</td>
<td>28.6%</td>
</tr>
</tbody>
</table>

n.b. 1 The predictions of ‘Peak Adoption Level’ is a numeric output that is provided to assist with insight and understanding, and like any forecasts, should be used with caution. 2 The prediction of ‘Time to Peak Adoption Level’ is a numeric output that is provided to assist with insight and understanding, and like any forecasts, should be used with caution. 3 ‘Time to Near Peak Adoption’ represents the time to 95% of the maximum predicted adoption level.
Figure 5: The effects on Peak Adoption Level and time to Peak Adoption of single step changes regarding a survey of grain farmers in the SWWA region.
Figure 6: Chart indicating how the S-Curve is predicted to change when a single step change is made to the most sensitive question(s) with respect to Peak Adoption Level.

Figure 7: Chart indicating how the S-Curve is predicted to change when a single step change is made to the most sensitive question(s) with respect to Time to Near Peak Adoption.

The above predictions are based on information entered into the Adoptability and Diffusion Outcome Prediction Tool (Appendix 14).

DPIRD has several decision support tools available to clients. This includes the Australian Government Department of Agriculture and Water Resources Seasonal Statistical Forecast, which is located on the Seasonal Climate Information page. Also located here are informative maps, which include, soil water maps, potential yield maps and frost risk maps. The soil water and potential yield maps have proven
popular with external clients and forms part of the GIWA (Grains Industry Western Australia) monthly crop reports.

The eConnected Grainbelt ‘Royalties for Regions’ project has developed a number of tools to help farmers understand climate variability. These tools include rainfall to date tool (Figure 8), potential yield tool, soil water tool, and extreme weather events tool (Figure 9). These tools have helped farmers to better understand their seasons and provide vital information to the agricultural industry and Government regarding the location of climate risks.

Figure 8: Rainfall to date graph showing Merredin rainfall from 1 January to 12 March. This is one of the tools from the eConnected Grainbelt project.
DPIRD offers formal farm business planning, called 'Plan, Prepare, Prosper'. The program was developed under the Pilot of Drought Reform Measures, a joint initiative between the Australian and Western Australian Governments. The Plan, Prepare and Prosper workshop is a free, five-day training program designed to assist farm enterprises develop strategic plans that will assist in decision making in times of risk and opportunity. The training is intended to strengthen farm businesses, sustain farming families and build resilient rural communities. At the end of the workshop, participants will have completed a strategic business plan, undertaken practical exercises that will improve business skills and developed an understanding about how other farm businesses are managing their challenges. Included in the farm planning is a workshop on climate and production systems (Appendix 18).

The objective of the program is to realise significant productivity and profitability improvements for primary producers, through generating knowledge, technologies, products or processes that benefit primary producers, strengthening pathways to extend the results of rural R&D, including understanding the barriers to adoption, and establishing and fostering industry and research collaborations that form the basis for ongoing innovation and growth of Australian agriculture.

Seasonal Forecasting in Western Australia has limited skill due to it being only slightly influenced by ENSO and IOD. Therefore, growers need to be wary when they look at seasonal forecasting. A recent paper by Guthrie and Evans, 2018, found that DPIRD’s seasonal forecast has more skill than BoM’s POAMA model. Research by McIntosh has suggested that the new ACCESS-S model will improve forecast skill in SWWA for temperature, but not so much for rainfall. Therefore, different climate indications need to be looked at to better forecast the WA climate. This was not within the scope of this project.
7.5.4 References


IOCI (2012), Milestone report 4 Project 1.2 south-west Western Australia’s regional surface climate and weather systems (accessed 18 December 2014).

McConnell G. (2011), Bridging the yield gap survey of high profit farmers. Department of Agriculture and Food, Western Australia.


7.6 Project 2a and 2b (December 2015 – May 2018)
South Australian Research and Development Institute
Peter Hayman (SARDI), Jemma Pearl (BCG) and Chris Souness (BCG)

Plain English Summary

Background

The success of agricultural industries relies on the weather, which means the ability to accurately predict the weather is crucial. The Rural R&D for Profit Program, “Improved use of seasonal forecasting to increase farmer profitability”, aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

A spectrum of barriers exist that prevent the use of seasonal climate forecasts (SCFs), which range from the nature of the forecast, to the capacity of farmers to use the forecast. Although individual awareness is likely to accumulate over time, resources are also required to maintain awareness as new entrants come into the industry (especially as advisers).

Objectives and methodology

This project explored and considered the opportunities and barriers to the use of SCFs through the various forums, literature reviews, the establishment of a community of practice (CoP; as part of the broader “Improved use of seasonal forecasting to increase farmer profitability” project) and surveys. This included specifically exploring farmer and advisor understanding (or lack thereof) of climate drivers and probabilities in an attempt to better understand ways to build confidence in the use of SCFs for farm management decisions and to develop tools to support this.

Outcomes and Conclusions

Based on the literature relating to the adoption of SCFs, industry experience and discussion with farmers and advisers, a spectrum of barriers ranging from the nature of the forecast to the capacity of farmers to use the forecast were identified and considered:

- Inaccuracy of forecasts (low skill),
- Lack of definitive forecasts,
- The spatial precision is too broad,
- The wrong parameters are forecast,
- There is insufficient lead time,
- The decision is being made at a time of poor skill,
- There are a restricted set of choices to the farmer,
- Farmers and advisers may be too busy,
- Forecasts are not effectively communicated,
- Farmers may not understand probabilities,
- Farmers may not trust the Bureau of Meteorology,
- Farmers and advisers may not know how to use probabilities.
There is a high general awareness of SCFs in Australia, however, farmers can encounter problems associated with an oversupply of information wherein farmers and their advisers have access to an overwhelming range of websites and media reports on climate information. A major task of the community of practice (CoP) is to build an informed awareness of sources of climate information and supply information regarding the reasons behind the climate information.

Further, probabilities were found to present a challenge for communication and confidence within the Australia agricultural industry. A key concept in SCFs is that the future climate is uncertain and can be represented as a sampling of the historical distribution. However, understanding probabilities is not the same as using probabilities in decision making.

Implications for industry/primary farmers

The increased awareness and confidence in understanding the climate drivers, and decreased emphasis on probabilities, can contribute to overconfidence and causal thinking. Although all farmers are aware of climate risk, not all are highly dissatisfied with their current approaches to managing risk and/or convinced by the value proposition of SCFs. Of the farmers and agronomists who are wanting to use probabilistic climate information, a barrier might lie in the absence of the next step to take.

Recommendations for further research and improved adoption

It is clear from the comments from respondents received through the consultations that there is still a lot of work required in increasing awareness and understanding of climate drivers, and that probabilities remain a significant communication challenge.

7.6.1 Background

SARDI played a support role in the project, 'Improved use of seasonal forecasting to increase farmer profitability', with tasks that were led by the Birchip Cropping Group (BCG). The following report reflects the minor role played by SARDI in the wider project, with the more modest reporting requirement agreed upon with Mark Letfuss, RIRDC (now trading as AgriFutures Australia) and subsequent reports accepted by AgriFutures Australia. Peter Hayman, Principal Scientist at SARDI Climate Applications was funded for 0.07 FTE.

The contracted milestone for SARDI is a report that demonstrates:

- Contribution to Activity 1, 'Project Management', which includes this report and the provision of material for the final report for AgriFutures Australia. This includes KPI 6.1, 'Final Report', and KPI 6.3, 'Final Financial Report'.
- Contribution to Activity 5, 'Identifying the enablers and barriers to the use of seasonal climate information to on-farm decision making'. This includes KPI 6.6, 'Factors affecting the adoption of climate forecasts in farm business decision making', and KPI 6.7, 'The application of the ADOPT tool'.
- Contribution to Activity 6, 'Skilling farmers and advisers to best apply climate data in their decision making'. This includes KPI 6.8, 'Reporting on farmer and adviser guides and decision
support tools, products and services developed and road tested with farm advisory groups’, and KPI 6.9, ‘Training and other materials, outcomes summary and report on final event’.

The remaining portion of this report contains the following information:

- Report on the enablers and barriers to the use of SCF, which addresses Activity 5;
- Report on SARDI contribution to working with farmers and advisers to best apply climate data, which addresses Activity 6;
- Papers published;
- Presentations.

### 7.6.2 The Opportunities and Barriers to the use of Seasonal Climate Forecasts

#### Introduction

An underlying assumption in this project is that the actual use of seasonal climate forecasts (SCFs) falls short of the potential. This report captures the response of project members and some BCG staff to the barriers and opportunities to adopting SCFs in on-farm decision making. The results should not be read as an industry survey, but rather as a collation of findings from the research conducted.

If research on social issues is ‘organised common sense’ (Punch 2013), then an important early step is to systematically categorise the barriers to the use of SCF. Adoption theory usefully distinguishes between the characteristics of the innovation (SCF) and the characteristics of the target populations (farmers and advisors in the Australian grains, livestock, rice and sugar industries). The characteristics of the decision context were considered as a third component in this project. The decision context included, when the decision was being made, the desired outcomes and the required climate information, which includes lead time and forecast period. In one sense, the decision context is just part of understanding the target population and it is difficult to neatly separate the decision context from the real-world actions of the decision maker. However, separating the decision allows clear thinking to the limits on the decision maker (time, trust, understanding, risk appetite) and the decision context (options available, profit and risk).

Based on the literature relating to the adoption of SCFs, the authors’ industry experience and discussion with farmers and advisers, we considered a spectrum of barriers ranging from the nature of the forecast to the capacity of farmers to use the forecast. These barriers include:

- Inaccuracy of forecasts (low skill),
- Lack of definitive forecasts,
- The spatial precision is too broad,
- The wrong parameters are forecast,
- There is insufficient lead time,
- The decision is being made at a time of poor skill,
- There are a restricted set of choices to the farmer,
- Farmers and advisers may be too busy,
- Forecasts are not effectively communicated,
- Farmers may not understand probabilities,
• Farmers may not trust the Bureau of Meteorology,
• Farmers and advisers may not know how to use probabilities.

Although these barriers interact, it is useful to evaluate each one individually. For example, to pose the question, “What if a forecast was well communicated to a farmer who set aside adequate time and trusted the source?”. It may still be that the forecast is of modest benefit to the farmer, as the decision may be made during a time of low skill forecasting. In this example, it would be unwise to spend time and resources on capacity building and communication. The detailed responses regarding barriers and enablers can be found in Appendix 19.

Common themes for decisions include, nutrition, crop choice, manipulation of phenology by sowing time, cultivar for annual crops and pruning for wine grapes (details provided in Appendix 20). Livestock decisions involve matching feed supply and demand, including stocking rates, culling and weaning.

In most cases, respondents answered ‘yes’ to the question of decision flexibility, in other words, they did not view the decision context as a limiting factor. It is to be expected that respondents would select tractable decisions when it was perceived that the decision maker had flexibility to respond to forecasts. The accuracy and guidance from the forecast is generally seen as limiting, and in many cases, this was due to the decision being made at a low skill period or inadequate spatial precision.

Respondents were asked to estimate the change over the last five years regarding awareness, understanding of climate drivers, and understanding of probabilistic SCFs. As shown in Figure 10, awareness was ranked much higher than understanding of climate drivers, with the understanding of probabilities consistently ranked as the lowest.

![Figure 10: Estimates of the change in understanding over the last 5 years](image)

**Figure 10: Estimates of the change in awareness, climate drivers and confidence in using probability. There were 13 responses for awareness and 12 for climate drivers and probability, respectively.**

Awareness by farmer and advisers is obviously a precursor to use, although, it is likely that there would be universal awareness of weather forecasts. The seasonal climate forecasts are an innovation that has emerged within the working life of many farmers and the application has differed across regions and industries.
Comments from respondents regarding how awareness has changed in the last 5 years include:

“2017 was a dry season for the northern and central WA Grainbelt, so awareness of seasonal forecasting increased. This project enabled me to talk to more growers and get more exposure.”

“It is getting better but varies depending on the year. Good commentary from The Break is great. It is best to be sceptical when using them and make decision on what is known.”

“In my job, I’ve seen a big increase over the last 3-4 years in the number of producers who are aware of the 3-month climate outlook from BoM and are referring to the information.”

“I’m uncertain of this, I suspect that awareness has increased but there remains considerable scepticism about their accuracy and usefulness among the cropping sector in northern Australia.”

“There’s not a lot of funding for climate work in the north for the last decade.”

“There is a lot more focus on BoM SCF. Livestock markets now wait for their release.”

“People have experienced larger variations in production and are seeking out better ways to manage and anticipate their business, knowing this extreme variation exists.”

“In the sugar industry, following the 2010 La Nina, the industry from farmers to marketers saw very significant economic losses. Immediately, or in a couple of years after the event, I might have scored high (3-4) as several climate risk workshops to increase climate literacy and use of forecasts were sponsored by the industry. I think awareness may have diminished slightly since then. It is very difficult to generalise across the industry when the spectrum of awareness is highly variable.”

“There appears to have been an increase in the awareness of SCF over the last 5 years. BoMs monthly video is being broadcast on Landline on Sunday morning and this has enhanced the awareness of the forecast, but we have not quantified the reach to specific industries.”

Seasonal climate forecasting seems well established within sections of the rural media, especially the ABC Landline, but also in newsletters focussed on SCF (e.g. the Break) or more general newsletters (BCG newsletter). Although individual awareness is likely to accumulate over time, resources are required to maintain awareness as new entrants come into the industry (especially as advisers).

**Understanding of Climate Drivers**

SCFs have been available in Australia since the 1990s, with earlier forecasts based on ENSO just as current forecasts are. Recent decades have seen increased attention and commentary on other drivers, including the Indian Ocean Dipole (IOD), the Madden Julian Oscillation (MJO), the position of the subtropical ridge and the Southern Annular Mode (SAM).


Awareness and understanding of climate drivers is influenced by recent experience, an example of which is outlined in Figure 11, which shows April to October rainfall for Blythe in the mid-north of South Australia. Growers and advisers have memories of the Millennium drought (2002-2009), with 2006 experiencing an El Nino and IOD positive event. The widespread rainfall associated with the
2010 La Nina dramatically ended the drought. During the life of this project, El Nino was discussed through 2014, and the dry 2015 was attributed to an El Nino followed by a much wetter 2016, which attributed to a La Nina that turned into a strong IOD negative. By contrast, 2017 had no clear climate drivers but was dry in many regions. For example, at Blythe the April to October rainfall was 192mm.

Figure 11: Time series of climate rainfall coloured by IOD and ENSO phase (Darren Ray, SA BoM).

Respondents were asked whether they thought that understanding of climate drivers had increased, and responses include:

“This hasn’t changed. Farmers are still confused about the influence of ENSO and SOI in WA, which is minimal. This needs to be talked about more on the BoM website”.

“4 out of 5. Each year I learn something new, eg, in 2014 El Nino didn’t happen, but it was bone dry, 2015 El Nino happened, and it was bone dry, 2016 had IOD negative and was a great year, 2017 was ok, but forecasts weren’t clear due to no clear drivers.”

“There is still limited understanding about the limitation of forecasts, which ones are best to use when and why.”

“This is a bit harder to estimate, but at a guess, I would say a 3 (1-5). I think general understanding of the major climate drivers would have increased largely due to initiatives such as ‘climate dogs’, the VIC DPI ‘Fast Break’ and general commentaries and explanations of climate drivers within the BoM video updates.”

“Some growers are becoming more aware of things like the IOD. A lot still focus on ENSO, even though ENSO years don’t seem to have that much influence on the growing season for viticulture.”

“Sugar 3 out of 5, beef, cotton, horticulture and grain 2 out of 5, and the others a 1 out of 5.”

“People know a bit about what they see and hear, but still don’t really understand them or which ones are most relevant to them.”
“4 out of 5. Largely due to The Break etc in Victoria.”

“Some growers go to the next level to understand causation, but the majority are only interested in probability maps or coloured forecasts.”

“In Queensland early in that period would have been a high 3-4 out of 5, but perhaps has dropped off again to 2-3 out of 5. It is very difficult to generalise across the industry when the spectrum of understanding is highly variable.”

“There appears to have been a general increase in the understanding and literacy of climate drivers, but it is not something that we have been able to quantify, and not something we have tested extensively. There has been a general increase for more services around ENSO, SOI and MJO, which suggests an increase in understanding of the drivers.”

**Understanding of Probabilities**

SCFs are commonly expressed as shifts in probabilities, and there is ample psychology literature and anecdotal evidence available that suggests that communication and the use of probabilities in decision making is challenging.

Comments from respondents regarding how understanding of probabilities has changed in the last 5 years include;

“It hasn’t changed, and I think farmers in WA know this.”

“I’m not sure if many people understand what to do with probabilities. They need to have a range of ways to frame what forecasts are trying to tell us.”

“I would estimate a 3 out of 4. I find that producers still struggle to understand the ‘change of above median’ rainfall charts and what this actually means. Quite often I’ll refer to the ‘chance of at least X mm’ chart, as this is much easier to comprehend.”

“I’m unsure. I think lots of growers just do the same thing every year. Again, there isn’t a specific forecast for viticulture, so no one really bothers to explain probabilistic forecasting to the industry.”

“I assume growers are still finding this a difficult thing to grasp, particularly when most forecasts are only reported as a 50-70% likelihood.”

“Sugar 3 out of 5, beef, cotton, horticulture and grain 2 out of 5, and the others a 1 out of 5.”

“I still think it is a difficult concept for many to grasp, and saying things like, “a 50% chance of average rainfall”, leads people to discount them.”

“3 out of 5. Growers seem to want deterministic forecasts and probabilistic forecasts and awareness is still quite low.”

“1-2 out of 5. This area is still highly challenging, and I would say that it has not increased significantly, broadly across the industry.”

“I don’t think there has been a noticeable change in the understanding of probabilistic information used in the forecasts. We did some work prior to the upgrade of the Climate Outlooks service that showed low
to average levels of understanding. Subsequent work, while not as quantified, has not shown a significant increase in the understanding of probabilistic information. This is also an issue in weather forecasting for the 0-7 days service, particularly for the chance of rainfall.”

As shown in Figure 11, respondents are optimistic about the changes in awareness (about twice as many votes for 3&4 than 1&2), cautious about changes in understanding climate drivers (about as many votes for 3&4 as 1&2), and pessimistic about grasping probabilities (about three times as many votes for 1&2 than 3&4). It was expected that awareness of SCF and understanding climate drivers exceeds the ability to understand probabilities. Not only has there been a greater emphasis on understanding climate drivers than use of probabilities, there is plenty of evidence to show that probabilities are a barrier to the use of information. Probabilities encourage risk management, and as the French mathematician and philosopher, Laplace, stated, “Probability is relative in part to our ignorance, in part to our knowledge.” The increased awareness and confidence in understanding the climate drivers, and decreased emphasis on probabilities, can contribute to overconfidence and causal thinking.

Some of the issues of probability in medicine is addressed in the popular book, Bad Science by Ben Goldacre. He suggests several ways to improve the communication and use of probabilities, primarily by using frequencies rather than percentage. Frequencies have been used by the climate forecasting community in the past and were one of the communication advantages of analogue years. Dryland farmers are familiar with deciles, which seem to be interpreted as frequencies, that is to say, a decile 3 year is understood as a year in which 7 out of 10 years are wetter and 2 out of 10 are drier, rather than saying, “30% chance of getting at least X amount of rainfall”.

It is clear from the thoughtful comments from respondents outlined in this report that there is still a lot of work required in increasing awareness and understanding of climate drivers, and that probabilities remain a significant communication challenge.

### 7.6.3 SARDI Use and Testing of Profit by Deciles Framework

**Building Farmers and Advisors Confidence in SCFs**

Building confidence in SCFs involves an understanding what is available, where to go for reliable sources, the basis of the climate science and climate drivers, and the probabilistic nature of the forecast.

There is a high general awareness of SCFs in Australia, however, farmers can encounter problems associated with an oversupply of information, or information dazzle, wherein farmers and their advisers have access to an overwhelming range of websites and media reports on climate information. A major task of the community of practice (CoP) is to build an informed awareness of sources of climate information and supply information regarding the reasons behind the climate information.

There has been a long history of communicating climate information to agricultural industries in Australia, primarily led by the Queensland Department of Primary Industries and CSIRO (as part of the Agricultural Production Research Unit in the 1990s), followed by Climate Application groups in NSW, WA and South Australia. An early Managing Climate Variability (MCV) Program on delivering climate information was led by Jim Egan from South Australia, with partnerships from WA, Qld and NSW.
Much of the recent innovation is coming from Victoria, led by Graeme Anderson, Chris Souness and Dale Grey. This has emphasised the importance of trusted sources of information that add meaning and explanation, while utilising modern technology for communication, such as video conferencing.

A further development within Australian agriculture has been the increased role of private agricultural advisers (opposed to government funded advisers), not only in numbers, but also as ‘gate keepers’ and trusted sources of information for decision making. However, there has always been an ongoing challenge associated with the probabilistic nature of the forecast.

**Representing the Confidence and Uncertainty of the Forecast**

Probabilities present a challenge for communication and confidence within the Australia agricultural industry, and one method that has proven to effectively communicate this is a spinning disk, where the pattern on the wheel changes (a.k.a. the chocolate wheel).

A challenge with seasonal forecasting is the concept that a seasonal forecast involves a revision of a probability distribution, and then random sampling from this distribution. A key concept in SCFs is that the future climate is uncertain and can be represented as a sampling of the historical distribution. This is often shown as a spinning disk with 100 nails and terciles that represent the driest third, middle third and wettest third of a given years. For example, a forecast that predicted that an El Nino is developing, may adjust the driest third of years from the 33rd percentile to the 50th percentile and the wettest third of years from the 67th percentile to the 85th percentile. The wheel is spun to show that, although there is an increased chance of being in the driest tercile, there is no guarantee.

This simple illustration has been used widely in Australia and in overseas programs to convey the fact that while climate science has a high degree of confidence in the change on the pattern of the wheel, there is still a random sampling of this distribution.

**Appreciation for the Benefits of SCFs**

For an end-user, appreciating the need for climate science to communicate forecasts as probabilities, does not solve the greater challenge of using probabilities for decision making. An important point was recently made by an Australian agronomist, who said, "That's a nice talk on probabilities, but in the real world people have to make decisions".

Most people have a basic understanding of probability and enjoy the simple illustration of the spinning disk in the chocolate wheel model. Although people have commented on how they like the illustration, almost no one has challenged the basic concept that it is problematic when a change in the pattern of the wheel is replaced with a simple statement, for example, it will be dry (wheel all red), or it will be decile 7 a revision from 10% to 100% chance of a decile, or it will be 107 mm (land on a single nail).

Further, understanding probabilities is not the same as using probabilities in decision making. A common notion is that a farmer needs to use the forecast to decide on the most likely outcome and then put on the appropriate rate of fertiliser. This view ignores the many areas of modern life such as health, finance, insurance, aviation safety and building codes that use probabilities to make decisions every day.

In a related project on the use of POAMA for nitrogen topdressing, we tried to probe root causes for the lack of use of SCF (Figure 12).
There are a group of farmers and advisors who are unaware of developments in SCF, and they are likely to either become aware and unsure of the usefulness, or aware and dismissive. Obviously, this group will not respond to awareness campaigns, and although some of this group may be open to waiting until forecasts improve, others will remain dismissive.

There are also farmers and advisors that are aware of the forecasts but are unsure on how to use them. For this group, there are several reasons as to why they are unsure of the adoption of SCFs, and it is reasonable for some to decide that they are too busy. Farming is becoming increasingly complex with competing demands for time, and psychology research has shown that good managers recognise that cognitive effort is a limited resource.

We found that even for the relatively straightforward decision of topdressing N, the problem as an investment decision under uncertainty is poorly defined. This means that even if there was a forecast that was well communicated, for the farmers we spoke to, developing a framework to utilise the probabilistic information remained a challenge.

### 7.6.4 Methods

A link between the spinning disk and decision making will help in communication, which is an area that SARDI is keen to explore as a process for learning and discussion about the use of SCFs.

The aim was to explore a straightforward decision framework that started with a decision under the current climate. The first step is for the end user to provide information for a low risk low return plan (e.g. not topdressing), with a higher risk and higher return plan (e.g. topdressing). As shown in the Table 4, the cost of topdressing is $50, and the partial gross margin will be a loss of $50 in the driest season, and a gain of $200 in the best season. Although no nitrogen is added, the returns under the low risk option of topdressing are still responsive to climate, they are just much less responsive than the high risk and high return.

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**Figure 12:** Flow chart outlining the root causes limiting the adoption of SCFs in the Australian agricultural community.
Table 4: Example of a straightforward decision framework for adopting SCFs in on-farm decision making, with the outline of both a Plan A and a Plan B for financial investment. The information is based on topdressing for a given year in Australia.

### Plan A - no topdressing

<table>
<thead>
<tr>
<th></th>
<th>Income</th>
<th>Cost</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRIEST</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>BELOW NORMAL</td>
<td>25</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>NORMAL</td>
<td>50</td>
<td>0</td>
<td>50</td>
</tr>
<tr>
<td>ABOVE NORMAL</td>
<td>75</td>
<td>0</td>
<td>75</td>
</tr>
<tr>
<td>WETTEST</td>
<td>100</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

### Plan B - topdressing

<table>
<thead>
<tr>
<th></th>
<th>Income</th>
<th>Cost</th>
<th>Profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRIEST</td>
<td>0</td>
<td>50</td>
<td>-50</td>
</tr>
<tr>
<td>BELOW NORMAL</td>
<td>40</td>
<td>50</td>
<td>-10</td>
</tr>
<tr>
<td>NORMAL</td>
<td>100</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>ABOVE NORMAL</td>
<td>200</td>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>WETTEST</td>
<td>250</td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

The information from Table 4 is also shown as a graph (Figure 13), with profit plotted against rainfall deciles. The user can adjust the information as required.

![Graph showing profit against rainfall deciles for Plan A and Plan B](image)

Figure 13: Example of a straightforward decision framework for adopting SCFs in on-farm decision making, with the outline of both a Plan A and a Plan B for financial investment. The information is based on topdressing for a given year in Australia.
There are several key points raised in discussion of the example provided in Table 4 and Figure 13:

- Figure 13 shows rainfall deciles against profit, whereas most of the literature and many decision support systems, such as YieldProphet, show probability of exceedance on the vertical axis and profit or yield on the horizontal axis. These are both valid conventions, however, it is more common for probability to be on the vertical axis in economics in the field of stochastic dominance. In other disciplines, such as hydrology, it is not uncommon for probability to be on the horizontal axis, for example, in the GRDC Farm Business handbook, there are farm plans plotted with deciles on the horizontal axis. In our experience, it is more intuitive for deciles to be on the horizontal axis because the most normal convention is that X causes Y, in other words, changes in rainfall causes changes in profit.

- There is a cross over. A farmer or adviser can quickly see that in dry years the low risk and low return option is favoured (Plan A), whereas in wet years topdressing pays off.

- The probability weighted average of topdressing (Plan B) at $65 is higher than not topdressing at $50. Under these assumptions, someone who farmed for 100 years would be wealthier if they were to top-dress. In the driest year, the loss from topdressing will be -$50 and the driest 21% of years are a loss.

An El Nino forecast can be represented as a change in the probability wheel, where the chance of being drier than the lowest tercile is now 50% (Figure 14). This change in the wheel is reproduced in the shape of the graph, with points shifting to the right for a drier forecast and shifting to the left for a wetter forecast.

Figure 14: Example of a straightforward decision framework for adopting SCFs in on-farm decision making during an El Nino event, with the outline of both a Plan A and a Plan B for financial investment. The information is based on topdressing for a given year in Australia.

Figure 14 shows that, although not topdressing is the superior choice 63% of the time, topdressing still has a higher probability weighted average, but the difference is small ($46 compared to $42). The
chance of a negative return from topdressing has increased from 21% to 31%.

7.6.5 Results and Discussion

A simple exercise has been used in GRDC update meetings in Adelaide February 2017, and Bendigo and Clare in March 2017, and with the MVC Champions in Melbourne November 2016. The organisers of the climate champions were allocated two hours, which provided the opportunity to work through a livestock and a cropping example.

Not all participants are comfortable representing the outcomes in this format, but for some, this approach makes a lot of sense. One of the climate champions, 2016, said, "I have always thought that the only progress was to have much more accurate forecasts, but this shows that we are always dealing with risk and any information is helpful". Perhaps the key preliminary finding is the value in having decision makers explore how their different plans work across rainfall deciles with current climatic odds, before considering how revised odds might change this. It becomes evident to users that most of the information is displayed in misleading curves on a graph, where the cross over and distance between the curves may not be correct until they are adjusted by a forecast.

Studies on the value of forecasts may alert farmers to situations where climate forecasts are more valuable, however, these studies are more likely to be used to assess the benefits of RD&E in the science and application of SCFs. While farmers and their advisers are interested in the studies, they don’t answer the question of how to make efficient decisions in the coming season with a given forecast. They may provide a motivation to change, but they don’t provide the next step.

A simple model for change is the Beckhard-Harris Change Model, '(DxVxF)>R’, where D = dissatisfaction, V = Value proposition, F = first or next step and R = resistance. This model acknowledges that there is always resistance to change. Although SCFs are freely available, there is a substantial cost in terms of time to get the latest update, and more importantly, understand the forecast. Overcoming this resistance requires a level of dissatisfaction with the existing situation and confidence in an alternative. Although all farmers are aware of climate risk, not all are highly dissatisfied with their current approaches to managing risk and/or convinced by the value proposition of SCFs. Of the farmers and agronomists who are wanting to use probabilistic climate information, a barrier might lie in the absence of the next step to take.

7.6.6 References


Plain English Summary

Background

The success of agricultural industries relies on the weather, which means the ability to accurately predict the weather is crucial. The Rural R&D for Profit Program, "Improved use of seasonal forecasting to increase farmer profitability", aimed to bridge the gap between seasonal climate forecasts and farm business decisions to improve productivity and profitability.

The Bureau of Meteorology (BoM) has recently made a major upgrade to the operational sub-seasonal to seasonal (S2S) forecasting system, by implementing ACCESS-S1 (the Australian Community Climate and Earth-System Simulator-Seasonal prediction system). This system includes substantial enhancements in horizontal and vertical resolutions, as well as a very different model physics compared to the previous operational system, POAMA2.4. However, there remains scope for improving the model that underpins ACCESS-S1, as it exhibits several systematic errors, especially in rainfall over the Indo-Pacific warm pool region.

Objectives and methodology

The primary objective of this project was to understand tropical rainfall biases and, where possible, reduce these biases in ACCESS-S1 and, in doing so, enhance the forecasting capability of future operational systems on a sub-seasonal to seasonal timescale. As the model produces most of the dry bias over the tropical landmasses, an experiment aimed at enhancing tropical convection over the land regions would be of great interest. The effect of enhanced convection over land, including the islands of the Maritime Continent, is the primary topic of this report. The key experiments involve modifications to the model’s convective parameterization to improve the quality of the forecasts.

Outcomes and Conclusions

A sensitivity experiment is conducted in atmosphere-only and ocean-atmosphere coupled ACCESS by enhancing the convective efficiency over the land-region in the convective parameterization of model. This modification reduces the dry bias over the land region and the seasonal mean precipitation bias over the tropics. This is one of the long-standing issues of the model, and it is found to be reduced in both versions of the experiment. The reduction in the WIO and Maritime Continent precipitation bias also appears to result in better MJO propagation over the Indian Ocean and this improvement supports to improve the MJO forecast skill during initial few days.

Implications for industry/primary farmers

Our experiment highlights the potential for reduction of systematic biases in ACCESS-S1, through improved treatment of tropical convection, especially over tropical coastal regions. As a result, a more
realistic representation of coastal convection is now under development and will be available for testing in the near future.

7.7.1 Background

The Bureau of Meteorology (BoM) has recently made a major upgrade to the operational sub-seasonal to seasonal (S2S) forecasting system, by implementing ACCESS-S1 (the Australian Community Climate and Earth-System Simulator-Seasonal prediction system). This system includes substantial enhancements in horizontal and vertical resolutions, as well as a very different model physics compared to the previous operational system, POAMA2.4. These advances also improve the forecasting capability of the system in multi-week to multi-seasonal timescales (Hudson et al. 2017; Marshall and Hendon, 2018). However, there remains scope for improving the model that underpins ACCESS-S1, as it exhibits several systematic errors, especially in rainfall over the Indo-Pacific warm pool region. ACCESS-S1 produces excessive rainfall over the western Indian Ocean (WIO) and south Pacific convergence zone (SPCZ) regions, while a substantial dry bias is evident over the Maritime Continent and northern Australia. The impact of these biases is not only limited over these tropical regions, but they also influence the weather/climate prediction over other regions through atmospheric teleconnections, especially over southern Australia. The primary objective of this project was to understand tropical rainfall biases and, where possible, reduce these biases in ACCESS-S1 and, in doing so, enhance the forecasting capability of future operational systems on a sub-seasonal to seasonal timescale.

In previous reports, we presented results from a set of sensitivity experiments that made changes to the cumulus parameterization of the model. Despite many different attempts to reduce the tropical rainfall biases, most of the sensitivity experiments only showed limited improvements in the model rainfall. We often find compensating effects through the coupling of the large-scale circulation, with the result that our changes to the convective parameterizations produce only minor changes in precipitation over the WIO region and Maritime Continent. For example, frequently, the reduction of the convective precipitation in one of our sensitivity experiments is strongly compensated by an increase in large-scale precipitation, especially over the equatorial region. However, we noted that the reduction of the convective strength over the WIO might be a key to modifying the precipitation distribution in the model.

ACCESS-S1 also exhibits key deficiencies in the depiction of the eastward propagating Madden-Julian Oscillation (MJO; Madden and Julian, 1971, 1972). The MJO is a source of sub-seasonal predictability and it produces large impacts on rainfall, temperatures, and tropical cyclones in the Australian region. Rather than depicting the observed eastward propagation of enhanced convection with a spatial scale ~10000 km, a period of ~40 days and a phase speed ~5 m s⁻¹, which are characteristic of the MJO, ACCESS-S1 tends to produce stationary convective anomalies on the intra-seasonal timescale, developing and decaying over the western/central Indian Ocean and with limited extension eastward across the Maritime Continent into the western Pacific. Neale and Slingo (2003) argued that the systematic rainfall biases over the Maritime Continent islands might have a profound impact on the excess precipitation over the WIO, as well as on the depiction of the MJO. As the model produces most of the dry bias over the tropical landmasses, an experiment aimed at enhancing tropical convection over the land regions would be of great interest.

The effect of enhanced convection over land, including the islands of the Maritime Continent, is the primary topic of this report. Forecast experiments in the atmosphere-only model version of ACCESS-
S1 indicate that some of the model biases in rainfall are considerably reduced when rainfall over land is increased. This motivates us to perform this experiment in the coupled ocean-atmosphere ACCESS-S1 S2S prediction framework. The details of the experiments and their results are discussed in the following sections.

### 7.7.2 Model Details and Experiments

ACCESS-S1 is based on the UK Met Office's (UKMO) atmospheric Unified Model (UM; e.g. MacLachlan et al. 2015), the Nucleus for European Modelling of the Ocean (NEMO; e.g. Mogensen et al. 2009, 2012), the JULES land surface model (Best et al. 2011; Walters et al. 2017) and the CICE sea ice model (Rae et al. 2015). The atmospheric component of ACCESS-S1 has horizontal resolution of N216 (about 60 km over mid-latitudes), with 85 vertical levels, while the ocean model has a 25 km horizontal resolution with 70 vertical levels. The initial conditions for the atmosphere are obtained by interpolating model level ERA-Interim (ERA-I) re-analyses (Dee et al. 2011) onto the UM grid. The ocean initial conditions are taken from the Forecast Ocean Assimilation Model (FOAM) analyses at the UKMO (Blockley et al. 2013), which uses the NEMO variational assimilation system, ingesting available subsurface temperatures and salinity and satellite observed sea level. Further details of the ACCESS-S1 system is available in Hudson et al. (2017).

All model changes proposed in this report are initially tested in the single column model (SCM) of ACCESS-S1 and then, based on their merits, additional experiments are carried out in the uncoupled atmospheric GCM (AGCM) at N216 resolution. We use the Global Atmosphere 6.0 (GA6.0) model, which is the AGCM component of Global Coupled configuration 2 (GC2), ocean-atmosphere coupled model for the ACCESS-S1 system. The SCM simulations use sea surface temperatures (SST) and the initial profiles of temperature, moisture, horizontal and vertical winds based on the Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA-COARE) observation (Webster and Lukas, 1992) of 9th January 1993 over the Western tropical pacific “warm pool” region (2°N, 156°E).

The SCM simulation is performed for 10 days with a time-step of 12 minutes. The AGCM runs are initialised with November 1 atmospheric initial conditions during 2006-2010, and the observed SST is prescribed at the lower boundary of the model. Sensitivity experiments using the most promising model changes are also performed in the full atmosphere-ocean coupled ACCESS-S1 system initialized on November 1 for 23 years (1990-2012), using three ensemble members and a single unperturbed ensemble member initialized on August 1 for the same 23 years. The model performance is evaluated against observed datasets, e.g. GPCP precipitation, AVHRR outgoing long-wave radiation (OLR) and ERA-Interim reanalysis, the results of the sensitivity studies are then compared to the standard ACCESS-S1 (CTRL) hindcasts.

The key experiments involve modifications to the model’s convective parameterization. The convective parameterization of the model is based on the bulk mass flux scheme developed by Gregory and Rowntree (1990). It comprises three major components; a trigger, a cloud model and a closure. In the triggering section, an undiluted test parcel is lifted from the top of the surface layer with the mean surface temperature and humidity of that level. The possibility of convection and its type is decided based on the level at which the parcel reaches zero buoyancy. We previously found that the model often fails to trigger any type of convection, as the parcel is unable to reach the cloud base due to a lack of buoyancy, which leads to intermittent convective triggering and excessive precipitation production in the model. In an attempt to enhance convection over land, an extra temperature perturbation of
~2K is added to the parcel in the trigger calculation over the land-points of the GCMs. For consistency, the same perturbation is also added to the updraft parcel temperature at the cloud base when the final updraft calculation is performed. This change is intended to enhance the convective efficiency over the land regions, in particular, over the Maritime Continent islands where the model shows large negative rainfall biases (Figure 15). We hypothesize that increasing rainfall in this important region may also reduce rainfall in the Western Indian Ocean (WIO) through circulation feedbacks.

Figure 15: (a) Observed seasonal (DJF) mean rainfall and circulation based on GPCP/ERA-Interim reanalysis. (b) Ensemble mean precipitation bias for the same season at 1-month lead from ACCESS-S1 hindcast relative to the observation.

### 7.7.3 Results

Figure 15a shows the seasonal (December-February, DJF) mean precipitation and the lower level (850 hPa) circulation in observation. Figure 15b depicts the associated mean errors in the ACCESS-S1 hindcasts at 1-month lead time relative to the observation. In the observations, precipitation maxima occur over the eastern Indian Ocean, Maritime Continent and the convergence zones north and south of the equator over the tropical Pacific Ocean (Figure 15a). Consistent with the precipitation maxima, a large-scale cyclonic circulation resides over the Maritime Continent/western Pacific region. ACCESS-S1 underestimates the observed rainfall maxima over the Indo-Pacific warm-pool region, especially over the islands of the Maritime Continent and northern Australia. In contrast, it produces a wet bias over the WIO, western Pacific and SPCZ regions. Generally, the model produces excessive rainfall over oceanic regions and underestimates the rainfall over the land regions, except over the southern part of Africa.

To identify the potential source of the model biases, short lead forecast with the uncoupled and coupled versions of ACCESS-S1 were carried out and revealed that most of the systematic biases evolve within first few days of the forecast (details on request). The early development of these
systematic model biases is likely to be associated with the local interaction between the physical processes in the model, while the large-scale teleconnection may play a secondary role at that early stage. In view of the early development of the systematic biases in this forecasting system, we set up several sensitivity experiments that aimed at resolving these systematic tropical rainfall biases and improving the prediction skill in sub-seasonal to seasonal timescale.

**Single Column Model experiment**

We began our investigation by testing the impact of the convective efficiency modification (adding 2K to the parcel temperature) in SCM simulations, using the TOGA-COARE case introduced above. No land-ocean convective treatment difference is included in the SCM due to its single grid-point limitation. As previously mentioned, the SCM equivalent of ACCESS-S1 does not diagnose any type of convection for the majority (~80%) of the time-steps. In contrast, a substantial increase in number of convective time-steps is noted in the experiment; convection of any type is diagnosed in about 93% cases. The performance of the experiment relative to the CTRL is summarised in Table 5. It is readily seen that the experiment provides a more realistic frequency, as convection of some type was almost always observed during TOGA COARE. It is worth noting, the dominance of shallow convection over the deep convective time-steps in the experiment, while the opposite occurs in the CTRL.

**Table 5: Convective diagnosis in 10-day SCM simulation (total 1200 time-steps).**

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Deep</th>
<th>Shallow</th>
<th>No Convection</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTRL</td>
<td>1200</td>
<td>142</td>
<td>67</td>
<td>991</td>
</tr>
<tr>
<td>Experiment</td>
<td>1200</td>
<td>84</td>
<td>1028</td>
<td>88</td>
</tr>
</tbody>
</table>

We found that the enhanced shallow convection transports additional boundary layer moisture into the cloud levels, leading to gradual increase in the lower level instability in the model. As a consequence, the SCM diagnoses a relatively drier boundary layer but moist layers above the cloud base in the experiment.

**AGCM experiments**

To further evaluate the impact of the modification, we conducted experiments in the atmosphere only model (GA6.0), forced with daily observed SST at its lower boundary. Figure 16 shows the Austral summer mean precipitation from the observation, CTRL and the experiment. Additionally, the model biases relative to the observation and differences from the control experiment are also shown. The observed precipitation distribution follows the location of the Inter Tropical Convergence Zone (ITCZ) and the rainfall activity is found to be enhanced to the south of the equator, with its maxima over the equatorial Indo-Pacific warm pool region. In the control case, excessive precipitation maxima occur over the WIO and western Pacific region, while the rainfall amount is considerably underestimated over the eastern Indian Ocean, northern Australia and the Maritime Continent Islands.
These biases are largely consistent with the coupled ocean-atmosphere GC2 precipitation bias in Figure 15. In contrast, the wet bias over the WIO and the western Pacific and the dry bias over the eastern Indian Ocean and the Maritime Continent, are considerably reduced in the experiment. Although rainfall overestimations are noted over the Africa, northern Australia and South America, this experiment provides a useful insight into underlying problems of the model, with a potential solution to this long-standing issue. It is noteworthy that most of the precipitation changes in this experiment are contributed by the convective rainfall, while the large-scale rainfall remains nearly constant, largely consistent with the results in SCM.

Next, the spatio-temporal behaviour of MJO events is examined using lag-correlation analysis (Figure 17), following the Climate Variability and Predictability (CLIVAR) Research Program MJO Working Group (CLIVAR Madden–Julian Oscillation Working Group, 2009).
A pair of Real-time Multivariate MJO (RMM) indices (Wheeler and Hendon, 2004) is computed by projecting daily anomalies of equatorially averaged OLR, 850 hPa and 200 hPa zonal winds onto the leading pair of observed empirical orthogonal functions (EOFs) of these combined fields. Following Rashid et al. (2011), the forecast anomalies are computed by removing the forecast climatology, and the influence of interannual variability is excluded by subtracting the previous 120-day mean from the anomalies.

The behaviour of the MJO is diagnosed by lag-correlation of observed and forecasted OLR anomalies relative to the time series of RMM1-RMM2 index. The systematic eastward propagation associated with the MJO, starting from the Indian Ocean to the dateline at a phase speed of about 5° per day, is evident in the observed OLR anomalies. Additionally, the observed MJO shows about a 40-day periodicity. In CTRL, the MJO appears to be weaker, faster, and mostly confined to the Indian Ocean sector. It also shows a much less periodic behaviour than observed. Comparatively, the experiment slightly improves the phase speed and the periodicity of the MJO. It produces correlations closer to those in the observations; but, the correlation still considerably weakens across the Maritime Continent.

Despite some success in improving the key rainfall biases in the AGCM, the experiment still shows limitations in forecasting seasonal mean rainfall and the MJO. Many previous studies (e.g. Kemball-
Cook et al., 2002; Inness and Slingo, 2003; Sperber et al., 2005) suggested that air-sea coupling improves the organization and propagation characteristics of the MJO, compared with the atmosphere-only components of the same models. The observed intra-seasonal SST variation exhibits a phase relationship with convection, whereby warmer SSTs preceding the convective maxima by about a week. This coherent air-sea coupling might be a key for realistic MJOs in the ocean-atmosphere coupled model. This motivates us to conduct a similar experiment with the coupled version of ACCESS-S1.

**Fully coupled experiments**

We repeated the AGCM experiments above in the fully coupled ocean-atmosphere ACCESS-S1 framework and evaluated the coupled model performance in producing seasonal mean rainfall and SST, as well as their interannual and intra-seasonal variability. In Figure 18, the DJF mean precipitation distribution from ACCESS-S1 is compared with the observation. Consistent with the results in Figure 15, the rainfall overestimation from the control forecasts is evident over most of the tropical ocean basins, especially over the WIO, western Pacific regions, while the dry biases are noted over the central Africa, the Maritime Continent, and Amazon basin. In the experiment, some of these dry biases over the land-masses are found to be reduced, however, the rainfall biases over the tropical oceans persist, with some even becoming worse in the experiment. Intriguingly, some of the benefits seen in the atmosphere-only experiments, such as the reduction of the WIO rainfall bias, are absent when the model is coupled to the ocean.

![Figure 18: (Top panels) DJF mean precipitation (in mm/day) from observation (GPCP), ACCESS-S1 (CTRL) and the experiment. The corresponding biases are shown in the bottom panels.](image)

The above analysis indicates that the performance of the experiment using our convection changes worsens with the introduction of the air-sea coupling with the AGCM. Within this context, it would be interesting to know the impact on the underlying ocean temperature in the experiment. Figure 19
shows the DJF mean SST distribution from the observation, CTRL and the experiment. The CTRL produces colder SST relative to the observation over the tropics, with a maximum negative bias over the central/eastern equatorial Pacific. A significant cold bias is also noted over the north/west Indian Ocean. This north Indian Ocean cold bias is marginally improved in the experiment; however, a weak cold bias is now evident over the eastern Indian Ocean, south of the dry bias over the region. Additionally, the cold tongue bias over the Pacific has worsened and extends further westward, while a warm bias is noted along the east coast of Australia. The cold (warm) SST bias over the Indian Ocean/west Pacific may be responsible for some of changes in the dry (wet) bias in the model compared to its atmosphere-only version.

Figure 19: (Top panels) DJF mean SST distribution (in °C) from observation (ERSST) ACCESS-S1 (CTRL) and the experiment. The corresponding biases are shown in the bottom panels.

The strengthening of the cold tongue bias in the experiment might influence the global weather and climate through impacts on the El Nino – Southern Oscillation (ENSO), which is the strongest climate driver of inter-annual variations in the tropics. To estimate the ENSO teleconnection in the model, a correlation between Nino3.4 (120°W-170°W, 5°N-5°S) SST index and SST and rainfall anomalies globally are shown in Figure 20. All the correlations displayed in Figure 20 are significant at the 90% confidence level. Apart from the maximum correlation with the local observed SST over the Nino3.4 region, a strong negative correlation is evident over the western Pacific, associated with the Southern Oscillation. Otherwise, a moderate positive correlation is noted over the western/central Indian Ocean. These teleconnections are largely reproduced both in CTRL and the experiment with slightly stronger amplitude over the Indian Ocean.
The observed rainfall correlation mostly follows the SST correlation pattern over the Pacific (Figure 20, right column), but the negative correlation over the western Pacific extends too far west in the model. Compared to observation, the CTRL precipitation correlation over the Pacific is confined over the equatorial region and the correlations are considerably weaker over eastern Indian Ocean/north-western Australia. Instead, an erroneous negative correlation is evident over the eastern and south-east Australia, indicating too strong an influence of ENSO on the rainfall distribution over eastern Australia. These problems appear to be resolved in the experiment, which clearly captures the ENSO induced rainfall changes over north-western Australia and successfully reduces the excessive ENSO influence over the eastern Australia. However, the negative correlation over the western Pacific and sub-tropical western Australia is too weak in the experiment.

Improving intra-seasonal variability is one of the primary objectives of this project, as it is an important source of sub-seasonal predictability. The MJO propagation is once again evaluated based on the lag-correlation between OLR anomalies and the RMM1-RMM2 index, similar to Figure 17. Note, the differences in the observed behaviour of the MJO in Figures 17 and 20 are entirely a result of the years sampled in both. In Figure 21, the observed MJO propagates from the WIO to the dateline with about 5° longitude per day phase speed and associated convective anomalies show a roughly 40-day periodicity.
In CTRL, the air-sea coupling did not alleviate its faster propagation characteristics and the convection decays across the Maritime Continent. The forecasted MJO largely exhibits similar characteristics to that in the uncoupled AGCM. The phase speed of the MJO is better captured in the experiment, consistent with the results from AGCM. This improvement is likely associated with the increase in shallow convection and slow moistening processes, which are thought to be fundamental to the MJO (Benedict and Randall, 2007). However, the periodic behaviour of the MJO convection is not well captured in the experiment, and the correlation significantly weakens across the Maritime Continent.

Encouraged by the somewhat improved MJO behaviour in the experiment, we investigated the impact on the predictive skill of the MJO by projecting the forecast data onto the observed MJO patterns, in order to produce predicted values of the RMM indices. The predicted indices are then compared to the observed indices using bivariate correlation and root mean square error (RMSE). To reduce the uncertainty due to the initial condition errors, the experiment is initialised by taking subset of 3 ensemble members of ACCESS-S1 for 30-day forecasts during 1990-2012.

The bivariate correlation and RMSE using the two RMM indices at different lead time of \( \tau \) days are outlined in Figure 22.
Here, $R_1(\tau)$ and $R_2(\tau)$ are observed RMM indices and $r_1(t, \tau)$ and $r_2(t, \tau)$ are the forecasted RMM indices for ensemble forecasts starting at time $t$ for a lead time of $\tau$ days, and $N$ is the number of forecasts. We compute $Corr$ and $RMSE$ for November 1 start dates over the entire hindcast period 1990-2012 for 30 lead times. For a climatological forecast (i.e. predicted RMM anomalies equal to zero), the RMSE would be $\sqrt{2}$ as the standard deviation of each of the observed RMM indices is 1 (Rashid et al. 2011). A forecast can thus be considered useful for normalised RMSE < 1 and $Corr > 0.5$, where the normalization factor is $\sqrt{2}$.

Figure 23 displays the MJO forecast skill for the available 11 ensemble members of CTRL and 3 ensemble members of the experiment at different lead times. Based on above threshold values, the CTRL produces skillful MJO forecasts to about 25 days out. A slightly more skillful MJO prediction in the experiment is apparent during the first few days of the forecast, but the initial improvement doesn’t persist beyond 1 week when both the CTRL and the experiment show comparable prediction skills. This limitation of the model could be attributed to the development of systematic biases, which fully develop within 5-7 days of forecast (Hendon et al. 2000) and they grow faster when MJO heating anomalies weaken. The averaged bivariate observed and forecasted MJO amplitude, defined as $5RMM^0 + RMM^0$, are shown at different lead time. Both the CTRL and the experiment maintain its amplitude closer to the observation for first few days of forecast and they considerably weaken after 1 week. Nevertheless, the experiment shows some potential to improve the MJO forecast skill during initial few days of the forecast, although a firmer conclusion would require more cases and ensemble members.

The experiment is also analysed for the mean austral spring season (September- November, SON) using hindcasts from a single unperturbed ensemble member initialized on August 1 for the years 1990-2012. The Indian Ocean Dipole (IOD), one of the important climate drivers for Australian rainfall, typically attains its peak during this season. It is characterized by an anomalous SST gradient between the tropical western and eastern Indian Ocean. The Dipole Mode Index (DMI, Saji et al. 1999), calculated as the anomalous SST difference between the western (50°–70°E; 10°S–10°N) and eastern (90°–110°E; 10°S–EQ) tropical Indian Ocean, is used to monitor the IOD activity. Recent studies (e.g. Cai et al. 2011) showed that the emanation of Rossby wave trains from the Indian Ocean region induces change in winter-spring rainfall distribution over the south-east Australia, through the changes in mid-latitude westerlies. Thus, the errors in representing variability over the tropical Indian Ocean likely have a negative impact on the climate prediction over this region.
ACCESS-S1 shows reasonable skill (correlation > 0.8) in predicting the winter-spring IOD variability when initialized on August 1 (Hudson et al. 2017). To assess the impact of the IOD in the model, we compute partial regression onto the DMI index when the effects of NINO3.4 are removed (Figure 24). This technique removes the linear dependence of Nino3.4 from both the predictand and DMI. Compared to observation, the IOD is relatively stronger in ACCESS-S1 initialized on August 1 for the subsequent SON period. It appears that weaker SST anomalies over the western Indian Ocean and higher SST over the eastern Indian Ocean result in a stronger anomalous SST gradient in CTRL. This issue gets worse in the experiment with the eastern Indian Ocean anomalous SST signal extending further westward into the central Indian Ocean. The precipitation variability associated with the IOD
shows an east-west dipole pattern over the Indian Ocean. Additionally, an in-phase relationship is apparent between eastern Indian Ocean and south-eastern Australian rainfall, indicating the tropical influence on extra-tropical rainfall variability through Rossby wave trains (Cai et al. 2011). The CTRL largely captures the rainfall variability associated with the IOD with some overestimation over north-western Australia. Consistent with the unusually asymmetric SST dipole, the eastern Indian Ocean rainfall anomalies appear to be stronger and have a wider structure in the forecast. The overestimation of the IOD teleconnection over north-western Australia is resolved in the experiment, however, the strong eastern Indian Ocean rainfall problem further worsens in the experiment, presumably due to stronger SST gradient over the Indian Ocean. This also produces out-of-phase relationship between eastern Indian Ocean and south-eastern Australian rainfall.

**Figure 24: Partial regression of (left) SST and (right) precipitation onto DMI index when NINO3.4 index has been removed for the Austral spring season (SON). The observation is shown in the top panel, while middle and bottom panels show CTRL and experiment hindcasts initialized on August 1 during 1990-2012.**

**Follow-up AGCM Experiment**

The limited success of the experiment in improving sub-seasonal to seasonal forecast further motivates us to implement the convective efficiency modifications in a more controlled system. In a stand-alone atmosphere initialized experiment, the convective efficiency is enhanced only over the land regions of Maritime Continent and northern Australia, between 15°S-15°N and 90°-160°E. Figure 25 shows DJF mean precipitation difference relative to observation and CTRL. This experiment shows potential to reduce the biases present in our previous experiment. The rainfall overestimation over the landmasses south of the Equator, over Africa, northern Australia, South America is considerably reduced this experiment. Moreover, the remaining dry bias over the Maritime Continent appears to be reduced further. Based on these noticeable improvements in this experiment, we may therefore expect further improvement in seasonal forecast with this adjustment in ACCESS-S.
7.7.4 Conclusion

A sensitivity experiment is conducted in atmosphere-only and ocean-atmosphere coupled ACCESS by enhancing the convective efficiency over the land-region in the convective parameterization of model. This modification reduces the dry bias over the land region and the seasonal mean precipitation bias over the tropics. This is one of the long-standing issues of the model, and it is found to be reduced in both versions of the experiment. The reduction in the WIO and Maritime Continent precipitation bias also appears to result in better MJO propagation over the Indian Ocean and this improvement supports to improve the MJO forecast skill during initial few days. However, some of the improvements in AGCM are weakened or even removed in the fully ocean-atmosphere coupled ACCESS-S1, mainly due to the presence of SST biases in the model. While improving the teleconnection to north-western Australia, the stronger than observed IOD forecast during the Austral spring season reduces the Rossby wave tropical teleconnection over south-eastern Australia. Our experiment highlights the potential for reduction of systematic biases in ACCESS-S1, through improved treatment of tropical convection, especially over tropical coastal regions. As a result, a more realistic representation of coastal convection is now under development and will be available for testing in the near future.

7.7.5 References


Inness, P. M., and J. M. Slingo (2003), Simulation of the MJO in a coupled GCM, I: Comparison with observations and an atmosphere-only GCM. J. Clim., 16, 345–364.


Madden, R. A., and P. R. Julian (1972), Description of global-scale circulation cells in the tropics
with a 40–50 day period. J. Atmos. Sci., 29, 1109–1123.


Mogensen K, Balmaseda MA, Weaver AT. (2012), The NEMOVAR ocean data assimilation system as implemented in the ECMWF ocean analysis for System 4. Tech Rep TR-CMGC-12-30. CERFACS Toulouse France.


8 Collaboration

8.1.1 NSW DPI Collaborations

This project was designed to collaborate with formal industry partners, through the Managing Climate Variability program that supports the project proposal. Project partners included researchers across Australia, specifically, NWS DPI, USQ, SARDI, Agriculture Victoria, Birchip Cropping Group, Monash University and WA Agriculture and Food.

Many other collaborations were developed throughout the project. Connections with CottonInfo were developed with two farmer visits, specifically for their seasonal climate workshops, plus two invitations to speak at climate updates and one invitation to speak at the 2018 Australia Cotton conference. These connections allowed for input into the cotton case study development, and refinements were incorporated to better reflect grower practice.

Stronger links were formed with CSIRO scientists that research climate variability. This was forged through invitations to discuss CSIRO modelling of POAMA for use in the cotton industry. NSW DPI were also invited to participate in the CSIRO ‘LaunchCamp’ workshop with the Bureau of Meteorology (BoM) to investigate the use of weather data and information to improve farm productivity and profitability (“Weather stuff for Growin’ Stuff”). CSIRO and BoM have indicated their interest in the outcomes of this project for potential integration into their research and applications.

The sheep CRC were contacted regarding their development of the ‘Wellbeing and Productivity’ application (app). This app contains a component to integrate seasonal forecast information into broader sheep decision points. NSW DPI provided the opportunity to participate in testing this product to BCG, as this provided a good option to contribute to Project 2.

Relations have been strengthened with the newly formed agriculture group in BoM. This included sharing of BoM’s national workshop series that collated information regarding farmer use of seasonal climate forecasts in decision-making and regular updates of NSW DPI case study findings to BoM’s agriculture group. BoM had indicated that ongoing collaboration with NSW DPI would improve activities of the team, with potential co-location of NSW DPI staff subsequent to the completion of this project.

Further, greater bonds with Local Land Services (LLS) (South East) have occurred as a result of the project. LLS shared their approach on communicating seasonal climate forecasting information to livestock producers with NSW DPI and more widely through the CoP. This linkage has highlighted key times of year and different options to present information to farmers that is currently well received. This provided another opportunity to contribute to the success of Project 2. NSW DPI has input into the further refinement of LLS provision of seasonal climate information to producers, which will continue into the future.

Through collaborations within NSW DPI, the rice case study created greater exposure to the industry and introduced the industry to our skill set. As a result, a pilot study was completed that investigated modelling to predict panicle initiation, and funding of further work to improve prediction of panicle initiation has been successful.
8.1.2 Birchip Cropping Group Collaborations

The CoP provided a coordinated series of activities to allow for collaboration to occur and has been so instrumental in supporting participants in their roles, that members (including people external to the project) have supported continuation beyond the life of this project. The CoP will continue post this project, transitioning into a new Rural R&D for Profit funded project. New members will be invited to join in the next iteration and almost all of the existing members who are not part of the future project have indicated that they will continue their membership.

The CoP, and subsequent project activities, have provided a platform to communicate, engage and meet likeminded individuals, who have the same goal in increasing producer profitability through SCFs. It has also regularly brought together project personnel to provide support across projects and ensure consistency in outputs.

The CoP approach as part of a project is novel, but has proven successful in:

- Ensuring regular project updates, fostering collaboration between project personnel and keeping all personnel abreast in all aspects of the project;
- Allowing people external to the project to be aware of the project and its outputs, fostering further industry promotion and identifying additional avenues for collaboration;
- Allowing the development and continual improvement of products and services;
- Easily identifying avenues for support and troubleshooting;
- Further upskilling SME's, ensuring that extension activities are consistent in communication and are based on current and technically sound information;
- Sharing understandings of barriers and enablers to ensure appropriate targeting of products and services;
- Identifying potential successors to current SME's (who are limited in number and predominantly later in their careers).

In a survey conducted of CoP participants, 80% said they have, or would, recommend other people to participate in the CoP.

Examples of collaboration, as identified by CoP members in evaluation activities, include:

"Helps a lot to hear what others are doing that works or doesn’t work."

"Connections with other researchers and access their details and a way to connect."

"Amidst the various presentations, there has been some great information sharing that translates well across the country."

"Meeting and being a part of a national network has been very beneficial, being part of this project and knowing Graeme Anderson gave me an opportunity to teach at Murdoch University as he has lectured here in the past by video and was able to give the lecturer my name so I can do it in person. Knowing that there are other people in other states doing similar work is encouraging."

"Expanded the network."

"Great people and build meaningful relations with them."
This collaboration and learning will continue as the CoP transitions into the Rural R&D4Profit project, ‘Forewarned is Forearmed: Managing the Impacts of Extreme Climate Events’, where further industries and individuals will continue to grow the membership.

Extension and communication activities were also able to leverage off the networks and relationships formed as part of this project. For example, Seasonal climate forecaster, Catherine Ganter, and Meteorologist, Tom Fejes, attended the BCG Future Farmers Expo in 2017 to present on the Southern Annular Mode, a climate driver which has received less exposure to producers in that region than other climate drivers. While in Birchip, the project arranged for them to stay with a BCG farmer member, which provided further insight to the needs of local producers.

An article was also produced as part of the project, entitled ‘December 2017 mega storm, observed outcomes’, which was developed as a result of facilitating conversation between BoM and producers, in regard to a forecast that many producers felt BoM got wrong. This allowed for further upskilling of farmers as to how forecasts are produced and demonstrated BoM visibility at a producer level.

These relationships and networks will be maintained, which will enable further projects, products and services to capitalise on them.

8.1.3 DEDJTR Collaborations

A critical component to DEDJTR delivery for this project regarded the number of stakeholder collaborations undertaken in the course of piloting seasonal forecasting products since July 2015.

Dale Grey and Graeme Anderson developed links with a range of private industry agronomy & extension providers and developed customized products on seasonal forecasts that could be utilised as part of their everyday business services provided to farmers. These events were organized by the various industries and agronomists involved (grains, meat & livestock, dairy, viticulture, horticulture etc).

These collaborative working relationships were critical in providing DEDJTR the ability to deliver seasonal forecast presentations and products at 62 events to 3923 participants.

In September 2017, a seasonal forecasting workshop training session was developed for the National Fertiliser Australia conference. Working closely with Fertiliser Australia enabled the testing of a new workshop session, where 94 participants listened to expert presenters and were then able to make their own interpretations of various seasonal forecast products.

The target audience was managers of supply chains for farmer inputs/outputs, whose key role is managing seasonal variability, and therefore require the literacy to understand seasonal forecast products and language. Offers were also made to industry stakeholders that DEDJTR was willing to educate on the Fast Break seasonal risk multi-model outlooks, so that other regions could develop their own multi-model table for forecasting.

Perhaps the most effective development, is the decision made by the GRDC (South) to establish a new tender for seasonal forecast extension services to be delivered direct to their farmers and advisors in South Australia and Tasmania (a number of whom were exposed to seasonal forecast...
talks via this project). At the time of writing this report, DEDJTR is in discussions with GRDC to deliver seasonal forecast extension products to the whole of the GRDC south region. This is an exciting new phase for seasonal forecasting extension in Australia, as investment by key industries to services provided directly to their growers enables future education regarding the next phase of improving the use of seasonal forecasts for profit in Australian agriculture.
9 Extension and adoption activities

9.1 USQ

N/A

9.2 NSW DPI

NSW DPI conducted engagement in varied formats throughout the course of the project. Table 6 lists specific outreach activities and Table 7 lists specific engagement with industry for the development of the case studies. Note, additional informal interaction (e.g. phone calls, emails) were ongoing throughout the project with the relevant industry workers and groups for the iterative development of the case studies.

Further engagement and extension of the results of this project can be facilitated through work associated with recently funded project, ‘Forewarned is forearmed: equipping farmers and agricultural value chains to proactively manage the impacts of extreme climate events’.

Table 6: Key communication activities. *CoP is the seasonal climate forecasting Community of Practice.

<table>
<thead>
<tr>
<th>DATE</th>
<th>ACTIVITY</th>
<th>DETAILS</th>
<th>PROJECT STAFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 APR 2016</td>
<td>CoP*</td>
<td>First meeting. Three presentations on: project overview, literature review, case study development. Held in Sydney.</td>
<td>Rebecca Darbyshire, Jason Crean, Kevin Parton</td>
</tr>
<tr>
<td>2-4 AUG 2016</td>
<td>Conference presentation</td>
<td>‘Forecasting profit: valuing seasonal climate forecasts’ Australian Cotton Conference. Held on the Gold Coast.</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td>APRIL-MAY 2017</td>
<td>Industry article</td>
<td>'What value are seasonal climate forecasts for dryland cotton?', Australian Cotton Grower Magazine.</td>
<td>Rebecca Darbyshire, Anwar Muhuddin</td>
</tr>
<tr>
<td>1 MAY 2017</td>
<td>Stakeholder forum</td>
<td>Presented ‘Valuing the Forecast: Case Studies – Project 1a’ in Canberra.</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td>21 JUN 2017</td>
<td>Presentation to the BoM Agriculture group.</td>
<td>‘Valuing the Forecast: Case Studies – Project 1a’.</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td>1 AUG 2017</td>
<td>CoP*</td>
<td>‘Dryland Cotton Case Study: Update’.</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td>11-13 SEP 2017</td>
<td>Industry presentation at Goondiwindi, Rowena and Bellata with CottonInfo</td>
<td>‘What’s the value of rain forecasts for Dryland cotton?’</td>
<td>Rebecca Darbyshire</td>
</tr>
</tbody>
</table>
### Improved Use of Seasonal Forecasting to Improve Farmer Profitability

**Conference presentation**

24-28 SEP 2017


- Michael Cashen
- Rebecca Darbyshire

**Newspaper article**

28 SEP 2017


**CoP**

17 OCT 2017

- 'Determining critical farm management decision points to improve agrometeorological research and extension'

- Michael Cashen
- Rebecca Darbyshire

**Presentation to the BoM Agriculture group.**

7 DEC 2017

- 'Case Studies Update'

- Rebecca Darbyshire

**Presentation to the BoM Agriculture group.**

3 APR 2018

- 'Northern Beef Case Study'

- Rebecca Darbyshire

**Landcare presentation**

14 APR 2018

- 'Climate variability and change in livestock'

- Rebecca Darbyshire

**Industry Presentation at Warren, Trangie and Spring Ridge with CottonInfo**

2-3 MAY 2018

- 'Valuing the forecast: Dryland cotton planting decisions and managing extreme heat.'

- Rebecca Darbyshire

**Stakeholder forum**

16 MAY 2018

- 'Key findings from Industry Case Study Development'

- Rebecca Darbyshire

### Table 7: Engagement specific for the development of the case studies. Note engagement for northern beef and sugar was led by USQ.

<table>
<thead>
<tr>
<th>INDUSTRY</th>
<th>DATE</th>
<th>PERSON / ORGANISATION</th>
<th>ACTIVITY</th>
<th>PROJECT STAFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>COTTON</td>
<td>15-Apr-16</td>
<td>Jon Welsh (a key industry representative) / CottonInfo</td>
<td>Workshop held in Orange.</td>
<td>Rebecca Darbyshire, Michael Cashen, Jason Crean</td>
</tr>
<tr>
<td></td>
<td>8-Jun-16</td>
<td>Tony Taylor (grower and consultant; and Jon Welsh) / Taylor Ag consultancy</td>
<td>Visited farm, discussed use of forecasts</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td></td>
<td>3-Aug-16</td>
<td>Tony Taylor / Taylor Ag consultancy</td>
<td>Follow up discussions on results.</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td></td>
<td>8-Jun-16</td>
<td>Rob Holmes (and Jon Welsh) / HMag</td>
<td>Discussed use of forecast.</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td></td>
<td>2-Aug-16</td>
<td>Rob Holmes</td>
<td>Follow up discussions on results.</td>
<td>Rebecca Darbyshire</td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td>Participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31-Oct-16</td>
<td>Jon Welsh &amp; Janelle Montgomery / CottonInfo Feedback on key decision points and initial modelling results.</td>
<td>Rebecca Darbyshire and Anwar Muhuddin</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Mike Bange / CSIRO</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13-Apr-16</td>
<td>Tom Davidson &amp; Irene Sobotta / MLA Phone conference. Suggested to work via the SAMRC. Noted industry want to include sheep case study. Discussed approach to engage industry.</td>
<td>Rebecca Darbyshire, Michael Cashen, David Cobon and Roger Stone (USQ)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29-Jul-16</td>
<td>Angus Hobson / Sth SAMRC; Michael Campbell / CSU; Steve Exton / NSW DPI; Phil Graham / NSW DPI Workshop in Wagga Wagga</td>
<td>Rebecca Darbyshire and Michael Cashen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-Sep-16</td>
<td>Sth SAMRC / Several Presentation of approach and discussion of findings to date. Invited guest from chair (Angus Hobson)</td>
<td>Rebecca Darbyshire</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23-May-16</td>
<td>John de Majnick / RIRDC Discussed approach to engage industry. Recommended further engagement with Andrew Bomm, RGA.</td>
<td>Michael Cashen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-Jul-16</td>
<td>Ian Mason / Rice Research Committee; Anthony Vagg / RRAPL; Bruce Simpson (Murray Irrigation/ farmer); Troy Mauger / RGA; John Fowler / MLLS Workshop held in Deniliquin</td>
<td>Rebecca Darbyshire and Michael Cashen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19-Oct-16</td>
<td>John Fowler / NSW DPI; Troy Mauger / RGA Meeting in Deniliquin to further discuss decision points that could incorporate forecast information.</td>
<td>Rebecca Darbyshire and Michael Cashen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Feb-17</td>
<td>Chris Quirk / SunRice; Peter Snell / NSW DPI; Gae Plunkett / RGA; Brian Dunn / NSW DPI Meeting to discuss rice drainage and whole grain percentage</td>
<td>Rebecca Darbyshire and Michael Cashen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10-Aug-17</td>
<td>Troy Mauger / RGA Meeting to update on rice case study</td>
<td>Rebecca Darbyshire and Michael Cashen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-May-16</td>
<td>Ross Kingwell / AEGIC Discussed WA grains industry.</td>
<td>Rebecca Darbyshire and Meredith Guthrie (DAFWA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21/22-Jul-16</td>
<td>MADFIG (Merredin And Districts Farm Meeting, presentation and discussion of farm systems at a pre-</td>
<td>Rebecca Darbyshire and Meredith</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Improved Use of Seasonal Forecasting to Improve Farmer Profitability

#### Improvement Group: Doug McGinnis (Tambellup Grower) / MADFIG; Tony Murfit / Farm manager; Nigel and Garry Sheridan / Growers established meeting held at DAFWA
Meredith presented to the group, organised by Tanya Kilminster (DAFWA). Greg Shea (DAFWA) also present. Recommend advice from John-Paul Collins (DAFWA). Mixed grains-sheep operation.

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#### 13-Aug-2016
Ross Kingwell / AEGIC; Roderick Grieve / Farm Management Consultant, Arbitrage, Albany
Discussed options regarding use of forecasts in forward selling decisions. Provided details of some consultants to contact. Information about forward selling.

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#### 24-Aug-2016
Market Ag; Greg Shea / DAFWA Merredin
Forward Selling in Merredin. Forward selling, very uncomplimentary about seasonal forecasting, believes it has no value to growers when sowing and making decisions on market. Doesn’t know much about seasonal forecasting. The case study in Merredin would be forward selling based on a corporate farm and not a family run business.

---

#### Sep-2016
Pru Cook / BCG
Call to discuss utilising BCG networks to investigate southern grains case study. Suggested BCG help coordinate a Birchip workshop.

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#### Sep-2016
Peter Hayman / SARDI
Discussed Birchip workshop and linkages to Sth Australia circumstances. Recommended to continue with Birchip workshop planning.

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#### 18-Oct-16
Tim McClelland (Farmer); De-Anne Ferrier (Farmer); Hugh Keam (Farmer); Harm van Rees (Consultant); Ian McClelland (Farmer)
Workshop held in Birchip. NSW DPI run, with assistance from BCP.

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**Graeme Anderson (Ag Vic)**
9.3 BCG

CoP activities have led to increased adoption of project outcomes by primary producers due to increased industry collaboration, which provides high level, producer focussed technical information and professional development opportunities. This has led to better informed and targeted extension and communications products, continuous improvement of existing SCF products and services and the repurposing of products and services to expand sectors and/or regions of influence.

All elements of this project have applicability beyond this project. Further adoption will be achieved through the following:

- Continuation of the CoP;
- Continuation of the monthly BoM outlook webinar;
- Realistic evaluation metrics for future SCF extension efforts using results of the ADOPT analysis;
- Targeted and appropriate extension and communications using the framework provided in the Geoff Kaine report;
- Enduring availability of infographics and other project outputs available online;
- Improved relationship with BoM and CoP members for continued industry engagement;
- Engagement with the MCV Communications Coordinator, who can use project outputs and expertise for ongoing MCV communications.

A summary of extension activities is outlined in Table 8.
<table>
<thead>
<tr>
<th>DATE</th>
<th>ACTIVITY</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>MLA 'Feedback' article</td>
<td>Contributed to article (written by Rebecca Jennings at Coretext)</td>
</tr>
<tr>
<td>2015</td>
<td>BCG eNews article</td>
<td>'Improving the usefulness of seasonal climate forecasts'</td>
</tr>
<tr>
<td>20-FEB-2015</td>
<td>BCG Trials Review Day</td>
<td>'Get equipped: 2015 weather outlook and forecast', presentation by Dale Grey (Agriculture Victoria);</td>
</tr>
<tr>
<td>09-SEP-2015</td>
<td>BCG Main Field Day</td>
<td>'The value of seasonal climate risk and adding value to farm decisions', presentation by Eun-Pa Lim (BoM) and Dale Grey (Agriculture Victoria);</td>
</tr>
<tr>
<td>14-DEC-2015</td>
<td>Seasonal climate forecast, risk and decision-making workshop</td>
<td>Birchip; 25 attendees</td>
</tr>
<tr>
<td>15-DEC-2015</td>
<td>Seasonal climate forecast, risk and decision-making workshop</td>
<td>Manangatang; 10 attendees</td>
</tr>
<tr>
<td>29-JAN-2016</td>
<td>Seasonal climate forecast, risk and decision-making workshop</td>
<td>Swan Hill; 15 attendees (all Agrivision agronomic consultants)</td>
</tr>
<tr>
<td>FEB-2016</td>
<td>BCG Season Research Results</td>
<td>'Project: Improved use of seasonal forecasting to increase farmer profitability' article.</td>
</tr>
<tr>
<td>16-MAR-2016</td>
<td>Seasonal climate forecast, risk and decision-making workshop</td>
<td>Woomelang; 10 attendees</td>
</tr>
<tr>
<td>17-MAR-2016</td>
<td>Seasonal climate forecast, risk and decision-making workshop</td>
<td>Nhill; 12 attendees</td>
</tr>
<tr>
<td>23-MAR-2016</td>
<td>Seasonal climate forecast, risk and decision-making workshop</td>
<td>Southern Mallee Women Farmers; 10 attendees</td>
</tr>
<tr>
<td>14-APR-2016</td>
<td>NCCCMA Future Farmers Workshop</td>
<td>Two presentations on seasonal climate forecast and risk management with 80 farmers total</td>
</tr>
<tr>
<td>15-APR-2016</td>
<td>Bureau seasonal outlook workshop; Birchip</td>
<td>15 farmers</td>
</tr>
<tr>
<td>28-APR-2016</td>
<td>CCRISPI Conference</td>
<td>Presentation on seasonal climate forecasts risk and decision support tools</td>
</tr>
<tr>
<td>MAY-2016</td>
<td>CoP meeting</td>
<td>o &quot;Introduction to the &quot;Extension Hub Platform&quot; – Jamie Allnut, RIRDC.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>o &quot;Community of practice update – activity ideas, terms of reference, trial platform/s and future online meeting format&quot; – Pru Cook, BCG.</td>
</tr>
<tr>
<td>JUN-2016</td>
<td>CoP meeting</td>
<td>o &quot;WA update&quot; – Meredith Guthrie, DAFWA.</td>
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<td>o &quot;Seasonal climate forecasting and the VET sector&quot; – Felicity Harrop, Bendigo TAFE.</td>
</tr>
</tbody>
</table>
### Improved Use of Seasonal Forecasting to Improve Farmer Profitability

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL-2016</td>
<td>CoP meeting</td>
<td>‘Project 1 update’ – Rebecca Darbyshire, NSW DPI and David Cobon, USQ.</td>
</tr>
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<td></td>
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<td>‘Yield Prophet Lite’ – Tim McClelland, Model Agronomics.</td>
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<td>‘NSW online manual and workshops for farmers’ – Agata Imielska, BoM.</td>
</tr>
<tr>
<td>28-JUL-2016</td>
<td>Bureau of Meteorology catch-up</td>
<td>Presentation by Chris Sounness on seasonal climate risk</td>
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<td>‘Seasonal climate forecasting needs for the cotton industry’ – Jon Walsh, CottonInfo.</td>
</tr>
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<td>‘Agricultural community of practice’ – Johanna Couchman, DEDJTR</td>
</tr>
<tr>
<td>26-AUG-2016</td>
<td>Bureau of Meteorology catch-up</td>
<td>‘Spring seasonal outlook aka ‘the home straight’’, presentation by Dale Grey (Agriculture Victoria);</td>
</tr>
<tr>
<td>14-SEP-2016</td>
<td>BCG Main Field Day</td>
<td>‘BoM online learning module review’ – Andrew Watkins, BoM.</td>
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<td>‘Barriers and wins when communicating seasonal climate information to NSW farmers’ – Ian McGowan, NSW DPI.</td>
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<td>‘User experience; designing digital products for agricultural communities’ – Vicki Lane, SquareV.</td>
</tr>
<tr>
<td>29-SEP-2016</td>
<td>Bureau of Meteorology catch-up</td>
<td>‘Cotton growers survey results’ – Ingrid Roth, CRDC.</td>
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<td>‘Migrating SILO data to the cloud’ – Neil Cliffe, DAFF QLD.</td>
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<td>‘The Break’ survey results’ – Graeme Anderson, Agriculture Victoria</td>
</tr>
<tr>
<td>27-OCT-2016</td>
<td>Bureau of Meteorology catch-up</td>
<td>‘Seasonal climate outlook use by cotton growers’ – Ingrid Roth, Roth Rural.</td>
</tr>
<tr>
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<td>‘Results from recent survey of ‘The Break’ readership’ – Graeme Anderson, Agriculture Victoria.</td>
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<td>‘The drought and climate adaptation program’ – Neil Cliffe, DAF QLD.</td>
</tr>
<tr>
<td>24-NOV-2016</td>
<td>Bureau of Meteorology catch-up</td>
<td>‘Seasonal forecasts, do they make money?’ – Meredith Guthrie, DAFWA.</td>
</tr>
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<td></td>
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<td>‘Seasonal forecasts, can they be used with confidence for management decisions?’ – Dale Grey, Agriculture Victoria.</td>
</tr>
<tr>
<td>15-DEC-2016</td>
<td>Bureau of Meteorology catch-up</td>
<td>The ‘virtual’ Very Fast Break seasonal climate update’, presentation by Dale Grey (Agriculture Victoria)</td>
</tr>
<tr>
<td>25-JAN-2017</td>
<td>Bureau of Meteorology catch-up</td>
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<tr>
<td>FEB-2017</td>
<td>CoP meeting</td>
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<tr>
<td>17-FEB-2017</td>
<td>BCG Trials Review Day</td>
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<tr>
<td>23-FEB-2017</td>
<td>Bureau of Meteorology catch-up</td>
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<td>Date</td>
<td>Event</td>
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</tbody>
</table>
| MAR-2017   | CoP meeting                                                          | o ‘What is the appetite for seasonal climate forecasts? ADOPT tool’ – Rick Llewellyn, CSIRO.  
                                        o ‘Evaluation framework on skill testing, project 1b’ – Torben Marcussen, USQ.                                                          |
| 25-MAR-2017| Harrow Women on Farms Gathering,                                       | Seasonal Climate Forecasting                                                                                                                          |
| 30-MAR-2017| Bureau of Meteorology catch-up                                         | ‘Pacific Ocean temperatures and its effect on Australian climate’                                                                                   |
| 07-APR-2017| BCG eNews                                                             | ‘Pacific Ocean temperatures and its effect on Australian climate’                                                                                   |
| APR-2017   | CoP meeting                                                          | o ‘Decision support tools for livestock production’ – Jaci Brown, CSIRO.  
                                        o ‘GrassGrow and its use in the livestock industry’ – Matt Lieschke, LLS NSW DPI.                                                          |
| 27-APR-2017| Bureau of Meteorology catch-up                                         | ‘Pacific Ocean temperatures and its effect on Australian climate’                                                                                   |
| 28-APR-2017| Landcare in Focus and BCG eNews                                       | ‘Seasonal climate forecasting and its use in farm decision making’ article; Landcare in Focus is a 12 page insert that is published quarterly in; The Land (NSW), Stock and Land (VIC), Queensland Country Life (QLD), North Queensland Register (QLD), Farm Weekly (WA) and Stock Journal (SA). |
| 03-MAY-2017| Stock and Land and BCG eNews                                          | ‘Learning from the past, looking to the future’ article; Stock and Land has a readership of 21 347, with 47% reach to farmers (Source: QARS 2016 (Quantitative Agricultural Readership Survey) – average readers per issue). Please refer to previous milestone reports for extension activities complete outside of this reporting period. |
                                        o ‘The interesting information gleaned from Rainman’ – Dale Grey, Agriculture Victoria.                                                |
| 25-MAY-2017| Bureau of Meteorology catch-up                                         | ‘Pacific Ocean temperatures and its effect on Australian climate’                                                                                   |
| JUN-2017   | CoP meeting                                                          | o ‘Weather you like it or not. Modoki El Nino and Southern Annular Mode’ – Catherine Ganter, BoM.  
                                        o ‘The adoption of seasonal climate forecasting in agriculture’ – Geoff Kaine.                                                               |
| JUL-2017   | BCG Future Farmers Expo 2017                                          | ‘Weather you like it or not’, presentation by Catherine Ganter and Tom Fejes (BoM); In July 2017, the BCG Future Farmers Expo included two presentations from the BoM. Catherine Ganter provided a seasonal climate forecast and insight into the Southern Annular Mode (SAM) and its role in rainfall in south-eastern Australia. Attendance approached 160 farmers, advisors, research organisations and agricultural industry representations. |
| 27-JUL-2017| Bureau of Meteorology catch-up                                         | ‘Pacific Ocean temperatures and its effect on Australian climate’                                                                                   |
| JUL-2017   | CoP meeting                                                          | o ‘Square pegs and round holes: POAMA & APSIM’ – Jaci Brown, CSIRO.                                                                               |
| AUG-2017   | CoP meeting                                                          | o ‘A tour of ‘Ask Bill’ the Sheep CRC management tool’ – Lewis Kahn and Lucinda Hogan, UNE.  
                                        o Feedback on BoM’s new intra-month seasonal outlook  
                                        o ‘Climate dog-o-meter, envisioned’ – Danielle Park, BCG.                                                                                   |
<p>| 31-AUG-2017| Bureau of Meteorology catch-up                                         | ‘Pacific Ocean temperatures and its effect on Australian climate’                                                                                   |
| 13-SEP-2017| BCG Main Field Day                                                    | ‘Spring weather outlook’, presentation by Dale Grey (Agriculture Victoria)- In September 2017, the BCG Main Field Day included an update |</p>
<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEP-2017</td>
<td>CoP meeting</td>
<td>Improved Use of Seasonal Forecasting to Improve Farmer Profitability on seasonal climate from Dale Grey from Agriculture Victoria (a project partner). Attendance at the BCG Main Field Day was over 300 farmers and advisors, agribusiness and financial industry representatives.</td>
</tr>
<tr>
<td>OCT-2017</td>
<td>CoP meeting</td>
<td>‘Using critical farm decision points to guide seasonal climate communication’ – Michael Cashen and Rebecca Darbyshire, NSW DPI. ‘Agriculture and the BoM’ – Peter Stone, Bureau of Meteorology.</td>
</tr>
<tr>
<td>26-OCT-2017</td>
<td>Bureau of Meteorology catch-up</td>
<td>BCG GAPP (Growth Adoption Productivity Profitability) newsletter ‘How to read SST anomaly map: El Nino and La Nina, Indian Ocean Dipole’ article, 17 November 2017, in; The seven GAPP groups were BCG’s young farmer groups that ran from north of Manangatang to south of Horsham.</td>
</tr>
<tr>
<td>30-NOV-2017</td>
<td>Bureau of Meteorology catch-up</td>
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<tr>
<td>21-DEC-2017</td>
<td>Bureau of Meteorology catch-up</td>
<td></td>
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<tr>
<td>25-JAN-2018</td>
<td>Bureau of Meteorology catch-up</td>
<td></td>
</tr>
<tr>
<td>16-FEB-2018</td>
<td>BCG Trials Review Day</td>
<td>‘The virtual’ Very Fast Break seasonal climate outlook’, presentation by Dale Grey (Agriculture Victoria); 130 BCG members attended the annual BCG Trials Review Day on 16 February 2018, where Agriculture Victoria seasonal risk agronomist Dale Grey presented the 2018 season outlook. This presentation is something that BCG members look forward to hearing and enjoy being able to communicate with Dale.</td>
</tr>
<tr>
<td>28-FEB-2018</td>
<td>Bureau of Meteorology catch-up</td>
<td></td>
</tr>
<tr>
<td>07-MAR-2018</td>
<td>Stock and Land &amp; BCG eNews</td>
<td>‘2017/18 summer second hottest on record’ article Stock and Land has a readership of 21 347, with 47% reach to farmers (Source: QARS 2016 (Quantitative Agricultural Readership Survey) – average readers per issue).</td>
</tr>
<tr>
<td>29-MAR-2018</td>
<td>Bureau of Meteorology catch-up</td>
<td></td>
</tr>
<tr>
<td>14-MAR-2018</td>
<td>BCG eNews</td>
<td>‘December 2017 mega storm observed outcomes’ article; Circulated to 1114 members of the BCG eNews emailing list, this article gives an overview of the predicted and then observed outcomes of the extreme storm.</td>
</tr>
</tbody>
</table>
9.4 DEDJTR

For this project, sixty-two presentations on using seasonal forecast information was presented to a total of 3,923 participants (farmers and advisors) by DEDJTR’s Graeme Anderson and Dale Grey (Table 9).

A key focus for DEDJTR contribution to this project was the delivery of extension and capability development to advisors and farmers around understanding key drivers of seasonal variability, the role of seasonal forecasting and how it can be used in decision making.

The following pages lists the 62 presentations (3923 attendees) delivered by Graeme Anderson and Dale Grey attributed to this project.

Some useful insights given the 2015 El Nino story plus the record warm Indian Ocean. These events were all activities outside Victoria where DEDJTR Dale Grey & Graeme Anderson tested our approach in other regions of SA, NSW, WA and Tas. Some valuable interactions with farmers and industry stakeholders as the dry 2015-16 and El Nino story shifted into the strong negative Indian Ocean Dipole event which brought one of the wettest winter/springs for many years. These events were all activities outside Victoria where DEDJTR Dale Grey & Graeme Anderson tested some of our approach in other regions of SA, NSW, WA and Tasmania. Events covered grains, livestock, dairy, potato, viticulture and agri-banking industry stakeholders.
Graeme Anderson & Dale Grey were also regular attendees at the project team on-line CoP meetings for both project updates and climate forecast briefings. This also included attending a 2 day project workshop at Birchip BCG along with other project partners.

Graeme Anderson & Dale Grey also travelled to Wagga Wagga for 2 day meeting with project partners. As part of this workshop, Dale Grey developed a pilot product which showed Australia wide rainfall forecast outlook products from a number of global climate models – to add further context to BoM poama model outlooks. This was well received, and BCG will investigate how this style of product can be created on the project webs pages when established.

Note Dale Grey also presented at the GRDC Research Update at Bendigo in Feb 2017, as well as delivered a seasonal outlook webinar which had 400 views, however these activities were not attributed to this project.

Table 9: “Making sense of seasonal forecasting” presentations & some product testing attributed to this project.

<table>
<thead>
<tr>
<th>DATE</th>
<th>ACTIVITY</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>JUL-2015</td>
<td>Sessions with agronomist (Bill Long)/Warrikiirri corporate farm mgmt team</td>
<td>Three sessions on spring seasonal planning sessions for WA (Warrikiirri) and Victoria/Riverina &amp; north NSW (Dalby) - slideshow via telephone (Grey &amp; Anderson) - 30 attendees</td>
</tr>
<tr>
<td>Date</td>
<td>Event</td>
<td>Details</td>
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<tr>
<td>OCT-2015</td>
<td>NSW Murray Dairy Climate workshop (Grey)</td>
<td>Pre-recorded webinar 15 farmers, 4 advisors (<a href="http://www.murraydairy.com.au/setting-up-your-season-workshops">http://www.murraydairy.com.au/setting-up-your-season-workshops</a>)</td>
</tr>
<tr>
<td>FEB-2016</td>
<td>Hobart Agronomy Conf (Grey)</td>
<td>Evaluation of a climate model consensus forecast for Victorian farmers, seven years on (50 attendees)</td>
</tr>
<tr>
<td>FEB-2016</td>
<td>GRDC Wagga Advisors Update SA &amp; Vic Independent Consultants ADELAIDE Workshop</td>
<td>Grey (survey feedback - Satisfaction score averaged 8.6/10) 74 attendees.</td>
</tr>
<tr>
<td>MAR-2016</td>
<td>Regional Landcare Facilitators National Workshop Canberra</td>
<td>Forecasting &amp; carbon farming. Review 2015 seasonal predictions and key learnings/lessons from advisors. (Anderson) 36 advisors</td>
</tr>
<tr>
<td>MAY-2016</td>
<td>Seasonal Forecasting Video</td>
<td>For Bordertown SA for Rural Solutions farmer (70) event May 12th</td>
</tr>
<tr>
<td>08-JUN-2016</td>
<td>Cropping Agronomy Forum; South Australia – Maitland York Peninsula</td>
<td>Customised video presentation by G Anderson to 40 attendees Video presentation <a href="https://www.youtube.com/watch?v=62ogFyD_m0">https://www.youtube.com/watch?v=62ogFyD_m0</a></td>
</tr>
<tr>
<td>23-JUN-2016</td>
<td>Dalby Farm Manager Workshop; Northern NSW</td>
<td>Customised recorded video presentation for Warrakiri to 10 farm managers by G Anderson Covered seasonal forecasting overview, and pilot version of Fast Break Model comparison for northern NSW Video <a href="https://www.youtube.com/watch?v=1Agw2HeMX0">https://www.youtube.com/watch?v=1Agw2HeMX0</a> Photo <a href="https://twitter.com/AdrianGooran/status/746109379397640192">https://twitter.com/AdrianGooran/status/746109379397640192</a></td>
</tr>
<tr>
<td>28-JUN-2016</td>
<td>Farm Manager Workshop; Western Australia – Esperance/Merredin</td>
<td>Customised recorded video presentation for Warrakiri to 12 farm managers by G Anderson; Covered seasonal forecasting overview, and pilot version of Fast Break Model comparison for WA Video <a href="https://www.youtube.com/watch?v=tQ74fo5VfPI">https://www.youtube.com/watch?v=tQ74fo5VfPI</a></td>
</tr>
<tr>
<td>20-JUL-2016</td>
<td>Farm Manager Workshop; Riverina NSW – Lockhart/Arletham</td>
<td>Customised recorded video presentation for Warrakiri to 10 farm managers by D Grey Covered seasonal forecasting overview, and pilot version of Fast Break Model comparison for Riverina district NSW</td>
</tr>
<tr>
<td>03-AUG-2016</td>
<td>Setting up your season series; Murray Dairy – NSW Tocumwal</td>
<td>Presentation by D Grey to 18 dairy attendees on seasonal forecasting and outlooks</td>
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<tr>
<td>Date</td>
<td>Event Details</td>
<td>Location</td>
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<tr>
<td>11-AUG-2016</td>
<td>Presentation and flyer by D Grey to 65 attendees on seasonal forecasting and climate model outlook tables</td>
<td>Riverine Plains Cropping Mid-Season Update; NSW Mulwala</td>
</tr>
<tr>
<td>10-NOV-2016</td>
<td>Video Presentation on extension tips used in seasonal forecast virtual presentations by G Anderson &amp; D Grey</td>
<td>WA NRM Southwest Conference</td>
</tr>
<tr>
<td>17-NOV-2016</td>
<td>Presentation on 2016 The Break survey by G Anderson &amp; D Grey; Insights from 600 responses for seasonal forecasting program; Recording of presentation available to CoP project participants on CoP platform</td>
<td>MCV RD4P Community of Practice</td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td>Details</td>
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<tr>
<td>MAR/APR 2017</td>
<td>Customised youtube presentations on seasonal forecasting and climate risk provided for Agri-Link agronomists who then showed these at four farmer events – Lameroo, Tarlee, Farrells Flat, Kudina (40 attendees). Examples of recorded customised seasonal forecast pilot video talks can be viewed here: <a href="https://www.youtube.com/channel/UCFdymrT7s5aBsO2eH-M6zzq">https://www.youtube.com/channel/UCFdymrT7s5aBsO2eH-M6zzq</a></td>
<td></td>
</tr>
<tr>
<td>APR-2017</td>
<td>Adelaide Seasonal Forecasting 101 - South Australia AgEx-Alliance 40 attendees</td>
<td>Dale Grey presented</td>
</tr>
<tr>
<td>11-APR-2017</td>
<td>Seasonal forecasting update presentation; Maitland SA 60 attendees</td>
<td>Graeme Anderson produced a and created a youtube link for SA York Peninsula grains farming/agronomy discussion at Maitland April 11th, 2017. This was requested following an initial similar youtube presentation from June 2016. <a href="https://www.youtube.com/edit?o=U&amp;video_id=MQ9NRXZU7nl">https://www.youtube.com/edit?o=U&amp;video_id=MQ9NRXZU7nl</a></td>
</tr>
<tr>
<td>16-MAY-2017</td>
<td>Webinar 80 participants</td>
<td>Dale Grey presented on “Using Rainman” via webinar to eight CCoP participants from the RnD4P project.</td>
</tr>
<tr>
<td>13-JUN-2017</td>
<td>Dept Ag WA meeting 130 attendees</td>
<td>Dale Grey and Graeme Anderson spoke to Dept Ag WA about how to construct tables of model outcomes and sharing the approach used by the Fast Break</td>
</tr>
<tr>
<td>02-AUG-2017</td>
<td>Seasonal Outlook via webinar 7 attendees</td>
<td>Dale Grey presented a Seasonal Outlook via pre-recorded webinar to seven attendees at the Warakirri farm managers meeting at Lockhart NSW.</td>
</tr>
<tr>
<td>23-AUG-2017</td>
<td>Seasonal Outlook via webinar 10 attendees</td>
<td>Graeme Anderson presented a Seasonal Outlook via pre-recorded webinar to ten attendees at the Warakirri farm managers meeting (Nth NSW and SE Qld).</td>
</tr>
</tbody>
</table>
Rural R&D for Profit Program Final Report
Improved Use of Seasonal Forecasting to Improve Farmer Profitability

13-SEP-2017
Seasonal Outlook via webinar
Dale Grey presented a Seasonal Outlook via pre-recorded webinar to six attendees at the Waralirri farm managers meeting at Esperance WA.

SEP-2017
Fertiliser Australia’s National Conference
Feature Videos of Presentations:
- September 2017 Graeme Anderson & Dale Grey presented and facilitated a workshop on “Making Sense of Seasonal Forecasts” - with Andrew Watkins from BoM. Video recordings of the session are available at:
  - Graeme Anderson – Making Sense of Seasonal Forecasting https://youtu.be/sjo3C2zi36Y
  - Dale Grey – Insights into forecast Models https://youtu.be/7E1dQC7T70
  - Andrew Watkins – BoM seasonal Forecast Products - https://youtu.be/7TnqMzB70k 94 participants took part in the session and gave a rating of 8.7/10 for satisfaction and 100% said they would recommend the session to a colleague.

01-FEB-2018
Yarram dairy risk management workshop

02-FEB-2018
Maffra dairy risk management workshop

13-FEB-2018
GRDC research update in Wagga Wagga

21-FEB-2018
GRDC research update at Adelaide

22-FEB-2018
Crop Science Society of South Australia
Dale Grey presented a seasonal forecasting and climate driver overview to the. 22 participants farmers and advisors.

9.5 DPIRD

Table 10 outlines the extension activities outlined by DPIRD.

Table 10: Extension activities outlined by DPIRD.

<table>
<thead>
<tr>
<th>DATE</th>
<th>ACTIVITY</th>
<th>DETAILS</th>
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</thead>
<tbody>
<tr>
<td>02-MAR-2016</td>
<td>Liebe Group Crop Updates 2015</td>
<td>Year in review: who got the forecast right?</td>
</tr>
<tr>
<td>APR-DEC 2016</td>
<td>DPIRD’s Growing Season Outlook newsletters</td>
<td>Updates</td>
</tr>
<tr>
<td>Date</td>
<td>Event details</td>
<td>Description</td>
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<tr>
<td>APR-2016</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>Rainfall triggers an early start to seeding newspaper article</td>
</tr>
<tr>
<td>11-JUL-2016</td>
<td>Dowerin Field Day</td>
<td>DAFWA predicting drier months ahead article</td>
</tr>
<tr>
<td>21-JUL-2016</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>DAFWA predicting drier months ahead article</td>
</tr>
<tr>
<td>25/26-AUG-2016</td>
<td>Dowerin Field Day</td>
<td>Article DAFWA’s internal newsletter</td>
</tr>
<tr>
<td>08-SEP-2016</td>
<td>Murdoch University Lectures</td>
<td>Article DAFWA’s digital farming a feature at Dowerin Field Days</td>
</tr>
<tr>
<td>14-SEP-2016</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>Statistical Seasonal Forecast and Doppler Radar</td>
</tr>
<tr>
<td>15-SEP-2016</td>
<td>Dowerin Field Day</td>
<td>DAFWA eConnected Grainbelt Weather Station “Weather dictates probability-using weather forecasting technology to guide early decisions”</td>
</tr>
<tr>
<td>24/27-SEP-2016</td>
<td>Perth Royal Show</td>
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<tr>
<td>2016</td>
<td>DPIRD webpage</td>
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<tr>
<td>2017</td>
<td>DPIRD Growing Season Outlook</td>
<td></td>
</tr>
<tr>
<td>27/28-FEB-2017</td>
<td>GRDC Research Updates</td>
<td>Attended meetings</td>
</tr>
<tr>
<td>23-MAR-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Forecasts boosts WA optimism’ newspaper article</td>
</tr>
<tr>
<td>03-APR-2017</td>
<td>Facey Group technology workshop</td>
<td></td>
</tr>
<tr>
<td>27-APR-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Modelling shows below average rainfall’ newspaper article</td>
</tr>
<tr>
<td>04-MAY-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Below average winter rainfall forecast’</td>
</tr>
<tr>
<td>06-JUN-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
</tr>
<tr>
<td>08-JUN-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
</tr>
<tr>
<td>JUN-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
</tr>
<tr>
<td>AUG-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
</tr>
<tr>
<td>31-AUG-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
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<tr>
<td>22-SEP-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
</tr>
<tr>
<td>28-SEP-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
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<tr>
<td>SEPT-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
</tr>
<tr>
<td>APR-SEPT-2017</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
<td>‘Cold weather a frost concern’</td>
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</table>
2017 Tweets

<table>
<thead>
<tr>
<th>DATE</th>
<th>ACTIVITY</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>08-FEB-2018</td>
<td>CoP meeting</td>
<td>presentation of Research Updates</td>
</tr>
<tr>
<td>28-FEB-2018</td>
<td>Media release</td>
<td>GRDC Seasonal prediction tool explained</td>
</tr>
<tr>
<td>FEB-2018</td>
<td>GRDC Research Updates</td>
<td>Guthrie and Evans 2018 ‘Can seasonal forecasting improve grower profitability?’</td>
</tr>
<tr>
<td>01-MAR-2018</td>
<td>Farm Weekly</td>
<td>‘Tool provides seasonal updates’ newspaper article</td>
</tr>
<tr>
<td>08-MAR-2018</td>
<td>The West Australian Countryman</td>
<td>‘Model helps with forecast’ article</td>
</tr>
<tr>
<td>MAR-2018</td>
<td>DPIRD Seasonal Climate Outlook 4</td>
<td></td>
</tr>
<tr>
<td>28-MAR-2018</td>
<td>Northam agri-networking breakfast</td>
<td>Seasonal Outlook given</td>
</tr>
<tr>
<td>26-APR-2018</td>
<td>Farm Weekly</td>
<td>newspaper article ‘Research is the key to start of seeding’</td>
</tr>
<tr>
<td>APR-2018</td>
<td>Web page and Media release</td>
<td>‘Stored moisture and early sowing opportunities for wheat vary with location’</td>
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</tbody>
</table>

## 9.6 SARDI

Table 11 outlines the extension activities outlined by SARDI.

**Table 11: Extension activities outlined by SARDI.**

<table>
<thead>
<tr>
<th>DATE</th>
<th>ACTIVITY</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>02-MAR-2016</td>
<td>Liebe Group Crop Updates 2015</td>
<td>Year in review: who got the forecast right?</td>
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<tr>
<td>APR-DEC 2016</td>
<td>DPIRD’s Growing Season Outlook newsletters</td>
<td>Updates</td>
</tr>
<tr>
<td>APR-2016</td>
<td>Farm Weekly</td>
<td>Rainfall triggers an early start to seeding newspaper article</td>
</tr>
<tr>
<td>11-JUL-2016</td>
<td>Merredin and Districts Farm Improvement Group Seasonal Outlook</td>
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<tr>
<td>21-JUL-2016</td>
<td>Farm Weekly</td>
<td>DAFWA predicting drier months ahead article</td>
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<tr>
<td>25/26-AUG-2016</td>
<td>Dowerin Field Day</td>
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<tr>
<td>08-SEP-2016</td>
<td>DAFWA’s internal newsletter</td>
<td>Article DAFWA’s digital farming a feature at Dowerin Field Days</td>
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<tr>
<td>08-SEP-2016</td>
<td>Murdoch University Lectures</td>
<td></td>
</tr>
<tr>
<td>Date</td>
<td>Event Description</td>
<td>Details</td>
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<tr>
<td>----------</td>
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</tr>
<tr>
<td>FEB-2016</td>
<td>GRDC adviser update Adelaide Convention Centre</td>
<td>‘Can forecasts improve the profit and reduce the environmental risk of nitrogen fertiliser?’ Invited keynote presentation (300 present)</td>
</tr>
<tr>
<td>MAR-2016</td>
<td>GRDC adviser update Bendigo</td>
<td>‘Using climate information for improved decision making.’ P. (200 present)</td>
</tr>
<tr>
<td>MAR-2016</td>
<td>GRDC farmer update Clare</td>
<td>‘Climate information and N decisions’ presentation (100 present)</td>
</tr>
<tr>
<td>JUL-2016</td>
<td>Hart field day group winter walk</td>
<td>‘N topdressing and climate outlook’ presentation (40 present).</td>
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</tbody>
</table>

2016

<table>
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<tr>
<th>Date</th>
<th>Event Description</th>
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<tr>
<td></td>
<td>Journal article</td>
<td>Sadras, V.O., Hayman, P.T., Rodriguez, D., Monjardino, M., Bielich, M., Unkovich, M., Mudge, B. and Wang, E., 2016. Interactions between water and nitrogen in Australian cropping systems: physiological, agronomic, economic, breeding and modelling perspectives. Crop and Pasture Science, 67(10), pp.1019-1053. Peter Hayman’s contribution to this paper was on the climate section and economic discussion.</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>FEB-2017</td>
<td>CoP meeting</td>
<td>‘Intersection of climate system, agricultural system and decision system.’ Presentation; Wagga Wagga (15 present)</td>
</tr>
<tr>
<td>APR-2017</td>
<td>Barossa Improved Grazing Group, Nuriootpa, Barossa</td>
<td>‘El Nino and rainfall in Barossa region’ presentation. (15 present)</td>
</tr>
<tr>
<td>JUL-2017</td>
<td>Barossa Improved Grazing Group workshop; Keyneton, Barossa</td>
<td>‘Climate information and grazing decisions.’ Presentation (40 present)</td>
</tr>
<tr>
<td>JUL-2017</td>
<td>Hart field day group winter walk</td>
<td>‘N topdressing and climate outlook.’ (50 present)</td>
</tr>
</tbody>
</table>

2018

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<tr>
<th>Date</th>
<th>Event Description</th>
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2018

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<th>Date</th>
<th>Event Description</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Journal article</td>
<td>Parton K.A. Crean J.S. and Hayman P.T. Review of valuation studies of SCF in Australian Agriculture. (in preparation) Peter Hayman’s contribution to this paper was in agronomic interpretation of some studies and writing an introduction to the need for economic analysis of forecasts</td>
</tr>
</tbody>
</table>
10 Lessons learnt

10.1 NSW DPI

Several lessons were learnt throughout the project.

- Targeted consultation to determine key decision points that are sensitive to seasonal climate forecasts delivered an integrated view of farm systems. The approach to workshops as ‘information seekers’, rather than ‘information providers,’ was important to this success, as was small group numbers and physical presence of project members in growing regions.

- The mid-point project meeting (held in Wagga Wagga on 8th February 2017) provided a fantastic opportunity to garner feedback of preliminary results from an extension perspective regarding project partners. Through this active participatory workshop, the potential of NSW DPI results were highlighted as greater than original expectations. This illustrates the benefit of the project incorporating researchers through to extension specialists and the importance of constructive project meetings.

- The active and ongoing feedback processes with industry proved to be key in ensuring case study design aligned with industry experience, which was highlighted in two main examples. First, reconvening the southern beef workshop participants allowed early exploration of the results and provided new prisms to view and analyse the data, which will resonate better with producers (e.g. present results as $/ha as opposed to $/cow). Second, taking the opportunity to travel to northern NSW/southern QLD for the cotton industry climate update allowed further and wider interaction with growers regarding the dryland cotton case study. Further refinement of the case study was undertaken (e.g. allow later planting dates rather only investigating skip row spacing) after these interactions.

- The benefit of collaborating for improved project outputs was highlighted in two other examples. First, the northern beef case study was complicated through the use of biophysical modelling not specifically designed for this application. Through open and frank collaboration with USQ, a method to overcome this difficulty was designed and implemented and robust analyses ensued. Second, the northern grains case study utilised APSIM modelling skills in both NSW DPI and USQ. Due to the need to compare results, nuanced differences in scientist application of the model were highlighted and illustrate the need for accurate documentation of assumptions. More importantly, varying results between different software versions were identified. This is an important lesson in model version control and the need to stay up to date with incremental improvements.

10.2 Birchip Cropping Group

Three key pieces of work were conducted in project 2 (led by BCG and supported by project personnel from other agencies), which have improved understandings of barriers and opportunities for industry adoption of seasonal climate forecasts (SCFs) (refer to Appendix 17). These are:
Key lessons learnt from the project and ongoing challenges for adoption included:

- **Adoption of SCFs will take a long time, and only a small percentage of the target audience will adopt their use in decision making.**
  The application of the CSIRO ADOPT tool, which evaluates and predicts the likely level of adoption and diffusion of specific agricultural technologies and practices with a target population in mind, suggests that even if a ‘perfect’ forecast exists, the peak level of adoption (for the southern grains case study) would be 97 per cent and would take eight years to achieve.

  Applying the ADOPT tool to case studies with existing forecasts yielded results ranging from 12-6% peak levels of adoption, taking between 15 to 19 years to achieve. While these results suggest that widespread adoption is impossible within the lifespan of this project, and even improbable within the next decade, these results give preliminary indications of the audience likely to use SCF’s and sets realistic adoption targets, which will assist with future project evaluation efforts.

  Additionally, these results provide a strong baseline to extension practitioners and advisors regarding key decision points and times of year at which to most effectively communicate SCF messages.

- **The accuracy and presentation of forecasts, plus farmer understanding of climate drivers, need continuous investment if adoption is to improve.**

  In a survey (conducted by BCG in conjunction with Peter Hayman) assessing CoP member experiences with opportunities and barriers to the use of SCFs, the accuracy and guidance from the forecast was generally seen as limiting. In many cases, this was due to the decision being made at a low skill period or inadequate spatial precision.

  Other areas of the Rural R&D for Profit project (Project 1b and 3) are continually seeking to address these issues and improve the forecast.

  Additionally, results suggest that, although it is likely that there would be universal awareness of weather forecasts, the SCFs are an innovation that has emerged within the working life of many farmers and so the application has differed across regions and industries. The consensus was that while growers may know the names of the climate drivers, understanding how each of them effect their given region was still low.

  Continued surveying of the Break readership, conducted by Agriculture Victoria, demonstrates that ongoing extension efforts to raise awareness of and increase understanding of climate drivers has been effective, but the length of time that this takes should be considered in the context of the ADOPT work. It is recommended that the industry continue to sustain existing SCF extension products and support them with access to appropriate technical expertise (as demonstrated by the CoP), without adding to the volume of currently available information. Awareness and understanding of climate drivers is influenced by recent experience, so these opportunities should be
harnessed for most effective extension.

SCFs are commonly expressed as shifts in probabilities. There is ample psychology literature and anecdotal evidence to suggest that communication and use of probabilities in decision making is challenging. Dryland farmers are familiar with deciles, which seem to be interpreted as frequencies, that is to say, a decile three year is understood as a year in which seven out of 10 years are wetter. This appears to be better understood by farmers as opposed to saying, “a 30% chance of getting at least X amount of rainfall”, which is often how the information is presented. Formats that are more likely to lead to a correct assessment should be adopted to ensure that SCFs are presented in a way that leads to favourable use of the system.

**Communicating SCFs should be conducted at a time and decision point when they can provide the most value. For some decisions, a SCF will not be relevant and should not be communicated to avoid confusion.**

The activity, conducted in conjunction with extension specialist Geoff Kaine, which leverages off the southern beef case study conducted in project 1a, explores a framework to predict which management decisions will be influenced by SCFs, and managers’ preferences regarding the characteristics of those forecasts.

This work outlines an approach to identify user groups most likely to adopt SCFs among primary producers using a general systems theory. The use of SCFs in management decisions depends on whether or not the decision changes outputs or inputs, and whether the decision regulates farm performance by error control or anticipation.

From this, the following criteria can be followed by extension practitioners and communicators when engaging with farmers on the application of SCFs:

- Decisions that involve regulation by aggregation (variations in the state of the environmental input cannot be forecast such as times of low skill) do not require forecast and should not be extended;
- Decisions that involve exercising output flexibility (altering composition of outputs to obtain a mix that uses more/less of the input such as selling livestock) require more reliable forecasts than decisions that involve exercising input flexibility (altering timing of input use, reducing use of input or switching between inputs such as supplementary feeding). Output flexibility will be less sensitive than input flexibility to the same SCF;
- Decisions involving the exercise of anticipatory regulation (where enough is known about the causes, timing and extent of variability in the environmental input to predict changes in the state of it) require more precise forecasts of specific climatic variables than decisions involving the exercise of error control (where enough is known about the causes, timing and extent of variability in the environmental input to infer that a small change in the state of the input signals the possibility of greater change in the future). Error control regulation will be less sensitive than anticipation regulation to the same SCF.

Practitioners in each sector, through the CoP, have been made aware of this framework and have been encouraged to apply it to different types of producer decisions for inclusion (or exclusion) in their products and services.
An additional administrative challenge was experienced regarding access to digital platforms. Initially, the eXtensionAUS platform was pursued as the preferred option as it linked with another Rural R&D for Profit funded project, however, due to substantial increases in timeline to delivery, this approach was disbanded. The project sought an alternate platform, building on the existing Climate Kelpie website. This minimises the risk of duplication of resources and builds on an established product with an existing producer audience who are already familiar with the medium. Agencies responsible for approvals of similar products should be cognisant of project timelines and accommodate swift approvals wherever possible.

10.3 DEDJTR

The DEDJTR component of this project was largely focussed on translating seasonal forecast information for farmers and their advisors. The greatest value from the project collaboration came from the regular Community of Practice online meetings, which enabled sharing of project learnings and provided the opportunity to engage in the latest seasonal forecast information and expertise of the Bureau of Meteorology scientists.

The shift from the 2015 El Nino drought to the 2016 wetter (nIOD) event provided valuable insights and demand from stakeholders who struggled to translate seasonal forecasts for their region, as most had experienced extremes of variability between the spring of 2015 and 2016. Some key learnings by DEDJTR staff, Dale Grey & Graeme Anderson, were:

- Historical rainfall can be used to help show the effects of ENSO & IOD on winter/spring rainfall at the district level in previous years. The use of tercile pie charts worked very effectively, as did showing monthly rainfall in previous ENSO events (eg. previous El Nino or nIOD years for a specific location). These charts show the variability of the seasons, and how odds changed from drier through to wetter.
- ENSO & IOD climate drivers and the probability of Sea Surface Temperatures being a key driver behind wetter or drier seasons in southeast Australia should be explained to farmers and their advisors.
- Climate literacy can be improved by explaining concepts such as SOI, IOD, ENSO, SAM and STR climate drivers, and how they can each be measured and tracked by forecasters.
- The Fast Break table compares 10 different global forecast models (1-3mth and 4-6mth). This table and approach was well received in previous Australian states, as it showed the range of model outlooks and the time at which more of the models were suggesting drier or wetter for their region.
- The online Community of Practice gatherings were terrific, with valuable information shared between experts without the need for travel. The sharing of latest science and insights behind the BoM monthly outlooks was highly valued by development and extension agents as it helped to clarify and improve the commentary provided to farmers via the e-newsletters, such as The Break.
- A draft product by Dale Grey was shared at the Wagga Wagga team meeting and outlined the ability for a comparison of rainfall outlook maps from a number of global forecast models, and how this can provide additional context for the BoM POAMA rainfall outlooks. There is perceived value in this approach, especially as it shows when the majority of models might forecast a particular region to have a drier/wetter signal. By showing maps, it can be quickly looked at by farmers from any region to compare. The current AgVic Fast Break produces comparisons for 3mth and 6mth outlooks for 10
global models, but in a table format and only for Victoria, but there is value in this having this product modelled for other regions of Australia.

- Key lessons were learnt from designing and running the pilot workshop session, 'Making Sense of Seasonal Forecasts', for 90 participants at the National Fertiliser Australia 2017 Conference. The session gave an overview on how to use seasonal forecast model outputs, and then had a participatory workshop where attendees looked at a range of model forecast products, assessed the winter forecast for their region and then compared it to what actually happened. Attendees then looked at the 3mth outlooks and discussed what the various forecast maps were suggesting for their region. This approach was well received (8.7/10) and could be replicated elsewhere.

Future Opportunities identified by DEDJTR could include:

- The option to set up a new page on the Managing Climate Variability (MCV) website that signposts the new Video presentations of Graeme Anderson, Dale Grey & Andrew Watkins (BoM) speaking on 'Making Sense of Seasonal Forecasting', from the National Fertiliser Australia Conference.
- Follow the process to replicate the workshop style that was piloted at the Fertiliser Australia Conference 2017 session. These discussions were valued in explaining various elements of what forecast products can and can't do.
- Establish an MCV web page that shares maps of publicly available global forecast models that starts with BoM but allows comparison with other global expert models. This approach can assist in sharing more than a single forecast and can also show how multiple forecast products can be an effective way to show the wider "probabilistic nature" of seasonal forecasts, as well as how some seasons there can be higher confidence in forecast scenarios when a major climate driver or ocean phase is underway.
- The continuation of the successful and regular Community of Practice web-conferences (monthly) that connect key BoM forecast scientists with the key seasonal forecast extension participants across Australia.
- The development of new activities, such as webinar series that allows project participants from each state and industry to explain what they are doing in seasonal forecasting, how they go about it, what's working well and what improvements could be made in the future. Such tools can be efficient in sharing valued information and expertise, while avoiding expensive travel.
- The development a simple tool to allow farmers to see their local district's monthly rainfall during previous phases of El Nino/Southern Oscillation and Indian Ocean Dipole events in southeast Australia. Such a tool was shown to be highly valued by advisors in mapping out crop agronomy scenarios during the 2016 El Nino and 2016 IOD events.
- To look at using the ENSO/IOD tercile "chocky wheels" used by Dale Grey to be more broadly applied or built into other tools such as CliMate app, so that farmers can look at local ENSO/IOD impacts on their winter/spring rainfall in southern Australia.
- To expand or train others in replicating DEDJTR Dale Grey's 'Fast Break' climate model outlook table, which shows 11 rain forecast model outputs on a single page to see a wider list of 1-3 and 4-6mth forecasts. Such an approach was well received in testing with farmers and advisors across southeast Australia during this project.
- To explore widening the audience of the BoM seasonal outlook webinars to provide more details than just the current official webpage and 3minute video summaries. This would be useful for a range of agricultural stakeholders who are seeking more detailed
seasonal forecast information, which they can then use in scenario planning and communication to their client base.

10.4 DPIRD

Under the guidance of BCG, the Community of Practice was a highlight of this project. Another highlight is the monthly webinars from BoM, who generously give their time and effort to run these.

Initially the project was to run for 3 years, but due to a delay in contracting, the project was cut back to 2 years. Therefore, not all tool outputs could be delivered.

Seasonal forecasting is still not skilful enough for Western Australian growers to be confident enough to use it. However, this project provided opportunity for open communication between government departments and growers and provided more information about climate variability.
11 Appendix

Each appendix has been supplied in a separate document to the main report. These can be downloaded from agrifutures.com.au/seasonal-forecasting

APPENDIX 1  Literature review and NSW DPI Case studies

APPENDIX 2  Outline of the S2S (sub-seasonal to seasonal) prediction project

APPENDIX 3  Examples and calculations of the statistics of ‘actual forecast skill’ using the selection of previously tested systems for Australia

APPENDIX 4  Updated findings on the skill and timeliness of forecasts for the sugar industry cluster as an example of the analysis

APPENDIX 5  Hit score of POAMA2.4 forecasts

APPENDIX 6  An overview of the forecast assessment ('hit rates' and LEPS scores)

APPENDIX 7  Matrix of key issues raised during user workshops

APPENDIX 8  Case study events and periods of concern to provide details of appropriate forecast systems now tested and available to users

APPENDIX 9  Summary of further detailed discussion and workshops with northern Australian industry groups

APPENDIX 10 Listing of skill maps by season and forecast source

APPENDIX 11 NSW DPI KPI progress in the current reporting period

APPENDIX 12 Australian seasonal forecasting Community of Practice; implementation strategy

APPENDIX 13 The opportunities and barriers to the use of seasonal climate forecasts

APPENDIX 14 ADOPT summary report

APPENDIX 15 Tools and services presented to the Seasonal Climate Forecasting Community of Practice

APPENDIX 16 Managing Climate Variability (MCV) Program V; A research and development operational plan for 2016-17 to 2021-22

APPENDIX 17 BCG KPI progress in the current reporting period

APPENDIX 18 The workshop on climate and production systems; Plan, Prepare and Prosper

APPENDIX 19 Detailed responses regarding barriers and enablers, as suggested by respondents

APPENDIX 20 Suggested decisions and comments on decision context and forecast information
Rural R&D for Profit program Final Report
Improved use of seasonal forecasting to increase farmer profitability

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AgriFutures Australia

Building 007
Tooma Way
Charles Sturt University
Locked Bag 588
Wagga Wagga NSW 2650

02 6923 6900
info@agrifutures.com.au

@AgriFuturesAU
agrifutures.com.au

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