Final report

SARDI Climate Applications component of Forewarned is Forearmed

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Prepared by: Peter Hayman
SARDI

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Meat & Livestock Australia Limited
PO Box 1961
NORTH SYDNEY NSW 2059

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Abstract

The Forewarned is Forearmed project provided information to Australian farmers on the likelihood of climate extremes at a seasonal and muti-week time period. The SARDI Climate Applications component of the project was to ensure two-way communication between the Bureau of Meteorology researchers designing and developing extreme climate forecast products and the wine grape and grains industry. This was achieved by preparing industry engagement plans, convening industry reference groups and providing feedback to the Bureau researchers on the interpretation of five operational products.

We worked with the grains and wine grape industry to identify their main weather and climate risks. These lists provided a useful check for the final five operational products. The term 'risk' implies a range of possible futures and probabilistic forecasts provide a revised range (the plume is the forecast). At the multi week and seasonal timescale the plume is usually wide and one of the unintended beneficial outcomes of forecasting extremes is providing the full distribution of model runs relative to climatology. SARDI Climate Applications was also responsible for the design of the risk management packages. We have made progress on how to communicate and use forecasts that are better than guessing, but far from perfect.

Executive summary

Background

Compared to most OECD countries, Australian farmers are faced with a higher degree of year-to-year climate variability with low levels of subsidies and assistance. Seasonal climate forecasts have been one of the tools that farmers can use to manage the variable climate. Prior to the FWFA project, forecasts from the Bureau of Meteorology were expressed as a percent chance of exceeding the median. While this information is useful, farmers and advisers are quick to point out that it is the very wet or dry and very hot or cold seasons that present the greatest challenges. The FWFA project was the first time Australian farmers had access to information on climate extremes.

SARDI Climate Applications was responsible for the two-way flow of information between BoM climate scientists and the grains and wine grape industry. The main target audience were growers and advisers. Important next users were the Agricultural Services section of the Bureau of Meteorology and the RDCs. The five operational products are available on the BoM operational website and have been used by a wide range of users including emergency services.

The applied research of FWFA will be delivered in the five operational products. The range of experimental products may be used in future BoM work. SARDI Climate Applications also addressed the challenging task of how to communicate and use probabilistic seasonal climate forecasts in decision making.

Objectives

SARDI Climate Applications was responsible for four objectives. As discussed in section 2, all objectives were achieved.

- Objective 1. To work with GRDC and Wine Australia to design industry engagement plans for climate extreme information.
- Objective 2. To convene industry reference groups and provide structured feedback on prototype climate extreme information to Bureau of Meteorology researchers.
- Objective 3. To identify decisions and model response scenarios.
- Objective 4. To develop extreme climate risk management guidelines (generic, grains and wine grape).

SARDI and the University of Adelaide received additional funding which came with the following objective.

- To develop and test an interactive climate extremes risk management package.

Methodology

The main tasks for SARDI Climate Applications were as follows.

1) To ensure industry engagement and encourage the two-way flow of information between the Bureau of Meteorology and the wine grape and grains industries. This included developing the wine and grains industry engagement plans (objective 1), forming and running Industry Reference Groups and providing feedback on forecast products to BoM (Objective 2) and identifying key climate risky decisions (objective 3).
2) A second and related role was to develop risk management packages (objective 4). SARDI was responsible for industry risk management packages for the wine grape and grains industries and led the generic risk management package

Results/key findings

The results that SARDI Climate Applications was responsible for included 1) ensuring a high level of industry engagement through the grains and wine grape industry reference group, 2) coordinating and providing feedback from industry to BoM on the design and interpretation of forecast products along with priority weather and climate risks in the wine grape and grains industry 3) communication of climate science to the grains and wine grape industries and 4) risk management packages that explored frameworks to have dialogue between growers faced with climate risky decisions and climate scientists with information.

Benefits to industry

The FWFA project is the first time that Australian farmers have had access to forecasts of climate extremes at a multiweek and seasonal time scale. The main legacy of the project is the suite of five operational forecast products on the BoM website. We worked with the grains and wine grape Industry Reference Groups to prioritise the weather and climate risks and ensured that these risks are addressed by the forecast products.

SARDI Climate Applications addressed the challenging task of how forecast information can be applied to farm level decision making.

Future research and recommendations

The FWFA project has provided more complete access to the information in BoM Forecasts. Forecasts will improve, but there are good theoretical reasons to expect a wide range of outcomes at multiweek and seasonal timescales. If the ‘plume is the forecast’ we need to continue to work on ways to communicate information that there is a signal towards drier, wetter, hotter, drier but even with a wet signal, there are quite dry model runs. Thinking clearly about climate risky decisions without the forecast is a useful first step.

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1. Background

Industry problem or knowledge gap addressed
The SARDI component of Work Package (WP) 3 addressed the management of climate extremes in the grains and wine grape industries. Early conversations with both industries indicated average years are relatively straightforward to manage compared to the very wet or very dry and very hot or very cool conditions. Both industries also stressed the importance of industry involvement and the need to link research to practice. As discussed in the methods section, the FWFA project used industry reference groups as the main means of two-way communication with grain and wine grape growers.

In a review of seasonal forecasts Abazmi et al. 2018 identify three challenges to the use of seasonal forecasts

1) Climate information tends to be supply driven, not demand driven. Information is generally driven by those who produce it, not by those who use it. The importance of engaging stakeholders who use information for decision making and planning is recognised, but it is hard to achieve. *The FWFA project made a genuine attempt to have two- way flow of information from users and producers of climate information.*
2) Uncertainty is seen as a problem to avoid – part of the complexity of climate science is that the information has varied levels of accuracy and certainty. Uncertain information on future climate is taken as a barrier to using the information, even though it is more useful for planning than no information at all. *In FWFA we worked hard to communicate the uncertainty. Indeed, we argue that although the emphasis was on climate extremes, an unintended consequence of products such as decile bars and probability of exceedance was to communicate the uncertainty. We have progressed the idea of using Decision Analysis as a means of working with uncertain information.*
3) Planning for the unknown is challenging – visualising the short- or long-term impacts of predicted climate variability and change on daily life is difficult. *The name Forewarned is Forearmed acknowledges that we have aimed to contribute to the task of planning for uncertainty. The use of verbal decision analysis whereby we acknowledge that in an uncertain world, regret is unavoidable. Regret of caution will occur from lower than optimum rates of fertiliser and stocking rates or higher than optimum levels of investment in crop protection. Regret of optimism comes from higher than ideal inputs of fertiliser or animals per hectare and lower than ideal rates of crop and animal protection. Farmers, like the rest of us are always faced with these trade-offs of caution and optimism. Information can help, but it is also helpful to acknowledge that good decision making can be unlucky.*

Target audience
The target audience for SARDI Climate Applications was growers and advisers in the grains and wine grape industry. The project title included extreme events on value chains and there was discussion at the Project Leaders Group to broaden the notion of risk management to expand the coverage of risk for all risks that industry faced. Following discussion with GRDC and Wine Australia and other members of the PLG, we focussed the resources of the project on the value of multiweek and seasonal forecasts for tactical decision making at the farm level.

2. Objectives

SARDI Climate Applications had four objectives

- Objective 1. To work with GRDC and Wine Australia to design industry engagement plans for climate extreme information.

Achieved. Draft Industry engagement plans submitted to GRDC and Wine Australia with copies to MLA as Milestone 1.3 and final plans delivered as Milestone 2.1 in May 2018.

The process of developing these industry engagement plans started an effective partnership with clear communication between SARDI Climate Applications, the FWFA project and the RDCs (Wine and Grain). They provided a useful background document to the Industry Reference Groups. We benefited from sharing the approach to the Wine and Grains industry engagement plans with Dairy and Southern red meat that were developed by Ann-Marree Graham and Richard Eckard from U Melbourne.

- Objective 2. To convene industry reference groups and provide structured feedback on prototype climate extreme information to Bureau of Meteorology researchers.

Achieved. Foundational to the FWFA project were workshops which provided day long, two-way flow of information between the science of forecasting climate extremes and the practice of managing climate extremes in the vineyard or paddock. The grains IRG first met at Canberra BoM on 17th August 2018, Melbourne BoM on the 3 and 4 March 2020 and GRDC office in Canberra 2021 (some participants online). The wine grape IRG met at Adelaide BoM office on 13th October 2018 and then in a series of video conferences. The Wine Industry Reference Group was selected and chaired by Sharon Harvey (Wine Australia) and the Grains Industry Reference Group was chaired by Liam Ryan (GRDC). The process of forming and running these groups strengthened relationships between SARDI and the Bureau of Meteorology and between the project team and Grains RDC and Wine Australia. This was met through milestone 1.2 (forming IRGs), 2.2 (training IRGs).

SARDI Climate Applications provided regular feedback to BoM. Specific milestones for reports to BoM on feedback were milestone 4.1 (March 2019), milestone 6.1 (March 2020) and milestone 7.1 (September 2020).

- Objective 3. To identify decisions and model response scenarios.

Achieved. As reported in Milestone 3.1 in September 2018, we used the categories of operational (days to a fortnight) tactical (months to seasons but < year) and strategic (> 1 year) to organise the climate risks and decisions in the wine grape (Attachment 7) and grains industry (Attachment 6) (Milestone 3.1). These lists were effective as a check against the final five forecast products.

SARDI Climate Applications prepared a discussion paper outlining methods to analyse the risk and return of climatically sensitive decisions (Milestone 3.2, September 2018). In September 2019 we delivered response scenarios for two decisions in grains (N on wheat and allocating harvest resources) and two decisions in wine grapes (crop protection spraying for Botrytis in warm inland regions and the purchase or selling of extra irrigation water). In March 2021 we reported on a third decision in grains (crop protection in pulse crops) and wine grapes (buying or selling irrigation water).

- Objective 4. To develop extreme climate risk management guidelines (generic, grains and wine grape).

Achieved. The grains industry and wine industry risk management packages were developed and delivered to Wine Australia and GRDC as part of Milestone 8.1 in March 2020. A draft Generic Risk Management package was submitted as Milestone 8.2 and a later draft has been circulated to University of Melbourne and Uni Southern Queensland in October 2022 and submitted as part of this final report (Attachment 2).

- Objective from additional RD&E proposal SARDI and University of Adelaide. To develop and test an interactive climate extremes risk management package.

Achieved. Attachment 2 extends the generic risk management packages to explain an EXCEL version of Verbal Decision Analysis where a user defines the climate risk (eg dry spring for N) by stating the lucky outcome (wet to above average spring) and the unlucky outcome (dry spring). This can generate a reaction as to whether it is appropriate to refer to luck in terms of these outcomes. However, a principle of decision making under uncertainty in general and Decision Analysis in particular is to distinguish between a good decision (made with all the information at the time) and what turned out to be a lucky or unlucky decision. The user is then prompted to identify the cautious and optimistic choice and finally to rate the outcomes of choice and climate state.

We set ourselves the challenge of being able to derive a set of minimum clarifying questions on risky decisions. The achievement here is not the software design or interface. The achievement is codifying the process of risky climate decision making into three simple questions (what it the risk, what are the choices and how do you rank the outcomes). The process of codifying strips the context away to the essence of a risky decision for simple analysis which can then be pulled back together to consider the regret/reward of caution and regret/reward of optimism.

3. Methodology

The overriding FWFA project consisted of four work program (WP) areas in FWFA. WP 1 identifying user needs was led by the Agricultural Services section of the Bureau of Meteorology, WP 2 the development and delivery of forecast information was the largest component and led by the climate research and seasonal outlook section of BoM, WP 3 interfacing to industry decisions was managed by the University of Melbourne (Dairy and Sthn red meat), University of Southern Queensland (Nthn red meat and sugar) and SARDI (Grains and Wine grapes). WP4, extension and training was led by AgVic and U Melbourne with BCG. The main focus of SARDI Climate Applications was Work program 3. However we contributed to WP1 by collating and structuring feedback on extreme climate information and WP4 Community of Practice and Extension activities to share wider understanding of challenges and opportunities for the use of extreme event climate information.

The methods section is organised around the two main tasks for SARDI Climate Applications.

3) To ensure industry engagement and encourage the two-way flow of information between the Bureau of Meteorology and the wine grape and grains industries. This included developing the wine and grains industry engagement plans (objective 1), forming and

running Industry Reference Groups and providing feedback on forecast products to BoM (Objective 2) and identifying key climate risky decisions (objective 3).

4) A second and related role was to develop risk management packages (objective 4).

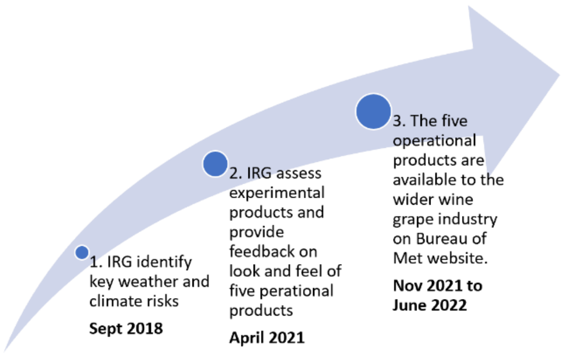
Methods to achieve industry engagement and BoM feedback

Industry engagement was incorporated into the design of the Rural R&D for Profit program which encourages effective partnerships between RDCs such as Wine Australia and GRDC with research providers such as BoM, SARDI, U Melbourne and USQ. The partnership started prior to the project. Peter Hayman, SARDI Climate Applications and Dr Tom Davison MLA visited GRDC and Wine Australia to invite/encourage them to join the consortia for the Rural R&D for Profit proposal. This entailed listening to what they wanted from the project and then designing a project with an Investor Advisory group separate to the Program Leaders Group.

An early task for Peter Hayman was to work with Tom Davison MLA and colleagues from University of Melbourne to clarify what RDCs would receive from the project with differing levels of contribution. This primarily revolved around industry reference groups and the level of detail in the risk management packages.

The first project step towards industry engagement was preparing the industry engagement plans (see Attachments 4 and 5). A second step was the involvement of Wine Australia and GRDC in selecting and chairing the Industry Reference Groups. The Industry Reference Groups became the primary vehicle for industry engagement and feedback to BoM. SARDI Climate Applications organised the meetings, paid for flights, meals and accommodation and prepared pre reading material, material for the meeting and follow up. SARDI also prepared draft emails for Wine Australia and GRDC to send out.

As a project we agreed that the best approach was for BoM to set up a password protected website with the experimental products. An underlying principle was to avoid advocacy research and to be clear that the reference groups are co-researchers rather than product champions. The reference groups were provided with training in access to information and appropriate caveats. SARDI Climate Applications was responsible for making the password available to the Industry Reference Groups and others in the wine grape and grains industry. The password was changed periodically. Our idea was that members of the IRG and others would access this website in their operations and report back on the usefulness or otherwise. Except for grain growers Barry Mudge and Arthur Gearon, we received very limited feedback. The low level of direct feedback was similar for dairy and southern meat (U Melb) and northern meat and sugar (USQ). One reason for the limited feedback was the multi-week outlook being a week out of date. Likewise, the 30 day meteograms generated a lot of initial interest, but couldn’t be used in real time (the 30 day meteograms were not put forward as a potential final product). In hindsight it was naïve for us to expect feedback. The critical times of harvest for grains industry (November and December) and the latter part of the wine grape growing season (January to March) are when the information is of most value but also when IRG members are extremely busy. Providing feedback might be recognised as important, but it was not urgent.



Key dates for the Wine Grape Industry Reference Group

One of the main purposes of the IRG meetings was to explain the underlying climate science and train members in accessing the products. These meetings became very effective as group activities to discuss climate risk and the role of climate information. Feedback from Industry reference groups and for the wine grape and grains industry groups to contribute to product design and vote on the final products. This information was collated and communicated to BoM directly or added to the dedicated on-line Google Sheets spreadsheet.

Our depth of engagement with the grains industry benefited from working closely with a grain farmer and consultant Barry Mudge and in a linked Landcare funded project with a group of leading farmers and agronomists on the Eyre Peninsula and a GRDC project with AgVic that ran workshops with 20 agronomists from across Victoria, Tasmania and South Australia. The wine industry engagement focussed on interaction with Nicky Robbins Barossa Grape and Wine, Lian Jensch from Langhorne Creek and Richard Hamilton who consults widely on disease and crop watch. We also interacted with a Wine Australia project led by University of Tasmania that conducted key informant interviews in the Cole Valley near Hobart, Devonport, Hunter Valley, SA Riverland, Barossa and Margaret River.

Methods to develop risk management packages

An important role for the Industry Reference Groups was to identify the main weather and climate risks faced by the wine grape and grains industries. We used crop climate calendars that linked the time of the weather or climate event to the key stages of crop development. The risks were prioritised and distinctions made between risks that were rare events but high consequence (eg frost) vs risks that were common but less catastrophic (eg dry spell). Working with the IRGS to move from risks to management decisions was beneficial to the overall FWFA project shifting from interest in climate forecasts to value from decision making. We distinguished between weather forecasts for short term operational decisions (1-7 days), multiweek and seasonal forecasts for tactical decisions (2 weeks to 6 months) and long term climate information for long term (> 1 year) strategic decisions. The emphasis of FWFA was on the tactical decisions and considering how probabilistic forecasts could be included in these decisions.

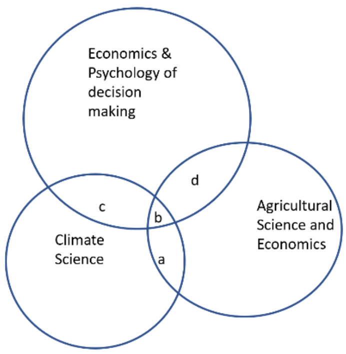


Figure 3.1 Conceptual framework for disciplines used in the risk management package

FWFA continued the substantial effort in Australia and internationally to link climate science to agricultural science (area a in Figure 3.1). A contribution from SARDI Climate Applications was to draw more heavily from the economics and psychology of decision making (area b in Figure 3.1). We considered decision making in climate sensitive disciplines other than agriculture such as disaster risk reduction, health, water management, energy and ecology (c). We also considered ways that agricultural science and agricultural economics dealt with non-climate risks such as price risk and disease outbreaks (d). We discussed our approach with leading agricultural economists including Professor Bill Malcolm (University of Melbourne) and Professor Kevin Parton (Charles Sturt University) and Dr Rick Llewellyn (CSIRO).

In developing the risk management packages we were guided by the following principles

1. To be as concise as possible or at least have a framework that could fit on a single page with background information. Not only are advisers and farmers busy, like most adult learners they want a quick overview to glean components rather than a text- book approach of introductory and background chapters. Requests for brevity came from GRDC, Wine Australia, the grains IRG and discussion with the PLG. Consistent with the notion of being concise or succinct is to be modular so that a user can take some parts of the framework and ignore others. The quest for a clear concise message often excludes references to probability. A challenge is to find simple ways to use forecasts that are skilful (better than guessing) yet uncertain.

2. To pose questions and start conversations about climate risk that begin with the decision maker as the user of information rather than climate science as the supplier of information. The questions start with “What are your important weather and climate risks” followed by “Do you have the climate information to address these risks” and then “Do you want to take a closer look at matching climate information to some specific decisions?” These questions follow the broad structure of “You, Me, Us”, inviting a farmer or adviser to talk about their risks (You) before introducing the climate information (Me) and then offering frameworks to link the decision context and the climate information (Us).
3. To be aware of ‘next users’ including the Bureau of Meteorology Agricultural Services, advisers, RDCs such as GRDC and students such as 3rd year Agricultural Science students at the University of Adelaide. Experience in parallel projects on climate risk with the Australian Centre for International Agricultural Research (ACIAR) and a GRDC project working with 20 advisers alerted us to the fact that while there is interest in risk management and decision analysis, it is hard work to maintain this interest. The request from most advisers and growers is for better forecasts or more information on climate drivers.

We used the applied economic discipline of Decision Analysis. Although there are many ways to analyse decisions, this is an established way to examine decisions under uncertainty. Decision Analysis requires clarity identifying the decision maker and the time of the decision, the options available and the information needs. Decision analysis also provides a method of estimating the value of information. By comparing situations with and without forecast information, the value of this information is revealed. We didn’t intend Decision Analysis as a decision support tool that prescribes advice for routine use in decision making. The aim was to improve the conversations with experts about the choices they face and how these choices interact with the weather or climate in the coming season. We used this information to explore how forecasts might (or might not) influence the decision making.

4. Results

4.1 Project Outcomes

The project level achievements for SARDI Climate Applications are covered under four sections. 1) industry engagement, 2) feedback from industry to BoM 3) communication of climate science to industry and 4) risk management.

1) **Project level achievements of industry engagement**

Industry engagement can be measured by breadth and depth. SARDI Climate Applications contributed to extension activities through climate kelpie articles, GRDC updates, farmer meetings, two workshops at the Australian Wine Industry Tech Conference and a series of webinars. We also prepared three Climate Kelpie articles, led two community of practice webinars and participated in many others.

Work Plan 3 encouraged deeper engagement with a relatively small number of wine grape and grain industry representatives. This included RDC program managers and the reference groups. Deep engagement requires a shared understanding of the very different knowledge domains of climate science and agricultural decision making. Evidence of this engagement comes from crop climate calendars and the lists of decisions. Both the wine grape and grains IRG were able to breakdown their weather and climate risk management into specific operational (1-10 days weather) and tactical (weeks and months ahead) and strategic (> 1 year) decisions. We have a list of decisions included in the industry risk management package for grains (attachment 6) and wine grapes (attachment 7). These risks are matched with climate information from FWFA. These documents are a succinct summary of the main decisions. While there will be additions, there has been a general level of agreement that these are an appropriately comprehensive set of risks. Furthermore, the IRGs agreed that the more interesting and valuable use of our time is to discuss how these risks are currently being managed and the ways that forecasts might assist.

2) **Project level achievements of feedback to BoM**

A major use of SARDI Climate Applications time and resources in the project was providing feedback to BoM on the look and feel of the products. An achievement of the project was the genuine two-way flow of information.

How would you explain this to a neighbour ?
How would you use the information ?



We provided opportunity for IRGs to give their opinions on forecasts, but found it most productive to provide a forecast product and ask one member to explain it to other members while BoM staff listened. Ample time was made available for deep discussion on how the information was being interpreted and the risks of misinterpretation. Examples of the engagement include an early request to link quintile bars to forecast maps (attachment 8), and discussion with the wine industry and grains industry on voting for products (attachment 9).

By working closely with a group of farmers and agronomists on the Eyre Peninsula we were able to experience some of the frustrations of using outlooks in 2020, 2021 and 2022. In each year the forecast was for a wet winter and spring, but for much of the southern grains region July, August and September were quite dry and the rain came late in October. This late rain was beneficial to later crops but too late for low rainfall regions. A similar pattern occurred in 2021 where much of the Mallee had a wet July followed by dry conditions until November. The very positive outlook in 2022 was followed by an extremely dry July followed by very wet conditions in August to November and early December. There seemed to be a general pattern of the outlook promising wetter than average conditions the months ahead and then often reverting to a more average outlook closer to the date.

Most wine regions in the world are in Mediterranean climates (cool wet winters and hot dry summers). Wet summers pose disease and operational challenges. The project coincided with the very hot dry summer of 2019/20 where the main problem was smoke taint followed by a triple La Nina. The summer of 2020/21 was not especially wet in most wine growing regions, 2021/22 was wet in NSW and Victoria and 2022/23 has been very wet with widespread disease and in some regions, flooding. There has been increased interest in the summer of 2022/23 due to the challenge of oversupply and low grape prices.

3) Communication from climate science to grains and wine grape industry

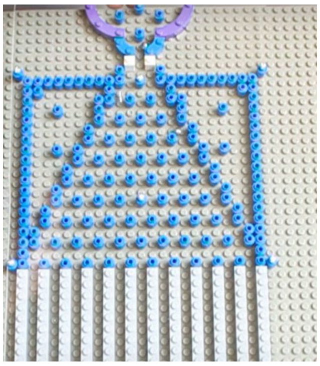
A strength of the project was the password protected site of forecast products with clear descriptions. As products were moved from the research site to the operational site, further improvements were made to the design and explanation. The main role for SARDI Climate Applications was to arrange opportunities for the Scientists from BoM to present to IRGs. Resources from the project were used for BoM team members to present to 20 agronomists, co-author GRDC updates and prepare wine grape industry workshops.

Working with the IRGs it became apparent that some members were confusing short-term weather with seasonal forecasts and were unsure about multiweek forecasts. Clarifying the difference between weather, multiweek and seasonal time scales was important due to the different basis of the forecast. Weather forecasts are initiated from the current state of the atmosphere and used to predict future states including the timing and amount of rainfall along with maximum and minimum temperatures for up to 10 days ahead. Seasonal climate forecasts are based on patterns of the sea surface temperature (SST) or associated atmospheric characteristics. Multi week (2-6 weeks) or sub-seasonal forecasts bridge the gap between weather and climate forecasts and start to blur the distinctions. In some ways, multiweek forecasts are more usefully seen as bringing the forecast period of climate forecasts earlier than extending weather forecasts.

We were able to match the time scales of weather and climate to decisions on a grain farm or vineyard. It was useful to identify strategic decisions with a planning horizon longer than a year and to point out that these decisions such as choosing a variety or buying capital equipment were important ways of managing climate extremes but would not be influenced by seasonal climate forecasts. One way to distinguish between tactical and strategic decisions is that tactical decisions respond to the state of the system such as stored soil water, time of season break, and potentially a seasonal climate forecast.

Another point of misunderstanding between climate science and agriculture is that climate scientists present forecasts with probabilities. Many studies have found that farmers, like the rest of the population, have difficulties interpreting probabilities. We continued to work on ways to communicate probabilities. We were guided by Gigerenzer 2013 who concluded that the rather than probability *per se.* the source of confusion was the event to which the probability refers. We reasoned farmers are comfortable talking about 70% of the farm being cropped, but less comfortable interpreting 70% chance of wetter than median rainfall. Proportion of land is easier to understand than proportion of future states of the climate because we all know that there will only be one future state of the climate. The Eyre Peninsula project highlighted that some farmers and adviser think that this number is derived as a consensus from a meeting of experts in Melbourne in the same way as Treasury forecasts the growth rate. In this way the percentage is taken as a measure of confidence “The Bureau is 70% sure”. I am finding that it can be easier to understand if we say “70% of the model runs were wetter than the median and 30% were drier”.

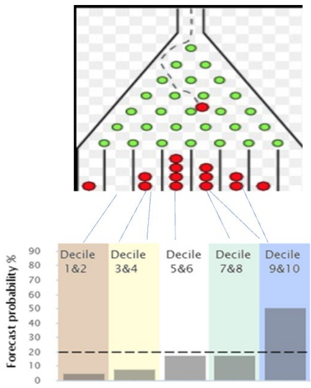
The quintile bars are an effective way of thinking through the distribution of model runs. An approach that seemed to be effective was to use the concept of a Galton Board as a way of conveying the spread and the uncertainty.



Thought experiment….

If I replace some round bricks with square bricks, the angle of the brick becomes important.

The negative IOD and La Nina changes the angle on some square bricks



4) Project level achievements for risk management

We have further developed a framework based on the principles of Decision Analysis to examine risky climate related decisions. This is not a decision support tool that prescribes advice for routine use in decision making. The aim is to improve the conversations with experts about the choices they face and how these choices interact with the weather or climate in the coming season. We use this information to explore how forecasts might (or might not) influence the decision making.

SARDI Climate Applications led the Generic Risk Management package and the industry specific risk management package for the wine and grains industry. The industry and the generic packages have three steps. Step 1: identify and prioritise climate risks using crop climate calendars and risk matrices. Step 2: link risks to climate information from BoM and management information from industry and Step 3: take a closer look at specific decisions.

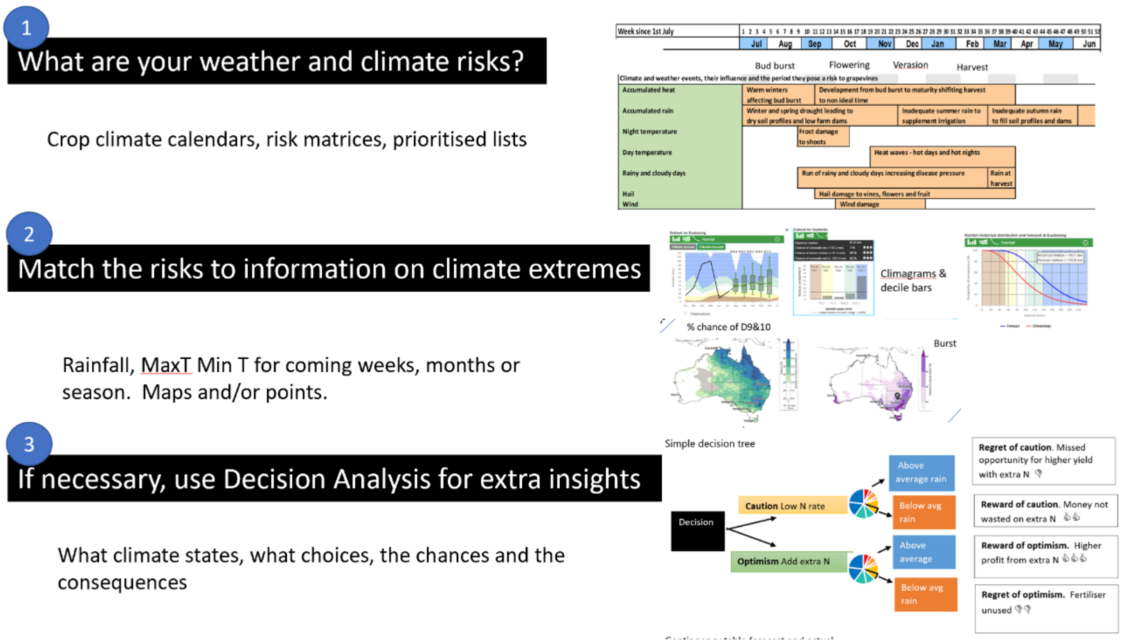
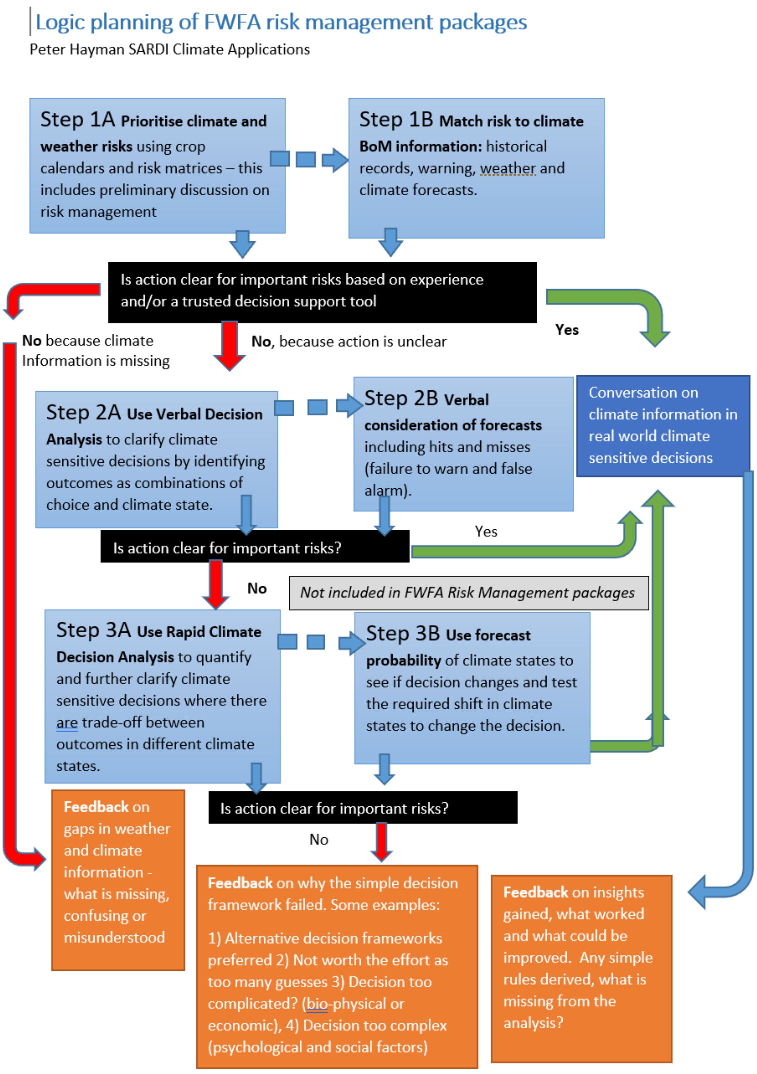
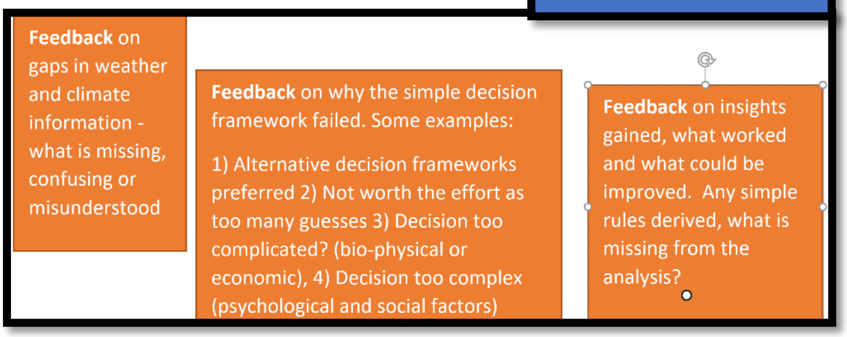


Figure 4.1 The three main steps of the Generic Risk Management Package

We prepared discussion papers on risk management (attachment 10) and invited feedback from the project team, especially WP3.



The purpose of engaging with end-users is to generate discussion on real world climate sensitive decisions (dark blue box on right hand side). By climate sensitive decisions we are referring to alternative actions where the 1) outcome matters to the decision maker and 2) the best choice is only known in hindsight as it differs depending on the state of the climate.



The endpoint of the flow diagram is feedback (orange boxes). The aim is a conversation rather than advice. We are interested to know whether information is unavailable (left hand box), the simple framework failed (middle box) and what worked including what could be improved (right hand box).

Step 1A Prioritise climate and weather risks using crop calendars and risk matrices – this includes preliminary discussion on how the risks are managed.	**Step 1B Match risk to BoM information:** historical records, warning, weather and climate forecasts.
Step 2A Use Verbal Decision Analysis to clarify climate sensitive decisions by identifying outcomes as combinations of choice and climate state.	**Step 2B Verbal consideration of forecasts** including hits and misses (failure to warn and false
Step 3A Use Rapid Climate Decision Analysis to quantify and further clarify climate sensitive decisions where there are trade-off between outcomes in different climate states.	**Step 3B Use forecast probability** of climate states to see if decision changes and test the required shift in climate states to change the decision.

The three main steps are to prioritise weather and climate risks (step 1) and if necessary, clarify the decision using verbal decision analysis (step 2) and where appropriate, to quantify the decision with Rapid Climate Decision Analysis (step 3). In discussion with WP3, we decided to restrict the generic risk management package to verbal decision analysis, not the numeric approach in Rapid Climate Decision Analysis. SARDI Climate Applications pursued Rapid Climate Decision Analysis funded by GRDC, Wine Australia and ACIAR as well as the Forewarned is Forearmed project.

Steps 1A, 2A and 3A come from structuring the decision with the decision maker's information. Steps (1B, 2B and 3B) involve information from BoM. Although the focus on this project is how to use weather and climate information from BoM, it is useful to separate the process of structuring of the decision from the process of providing additional information from BoM. It is our contention that information will be more useful after the decision context has been examined.

Grains industry response scenarios

1) Multi week and seasonal rainfall forecasts to manage N decisions in the grains industry.

This decision is made in late winter and depend on the outcome in spring. This is a time of the year when there is the highest skill in forecasts due to onset of ENSO and/or IOD. The high cost of nitrogen is matched by high grain prices, but this has increased the risk as well as the potential return.

Climate risky decisions such as applying nitrogen fertiliser to a wheat crop can be broken down into four components.
a) The decision: the rate of nitrogen topdressing which includes the 'do-nothing' option of not proceeding with topdressing. The decision is sometimes worded as selecting which decile should be aimed for.
b) The climatic conditions that create the upside and downside for the decision: primarily driven by spring rainfall, but frost and heat events are relevant along with untimely rain at harvest. Spring rainfall remains the dominant factor, hence the question "what decile to aim for?". This also drives the interest in the seasonal climate outlook for spring rainfall and the disappointment when an outlook for a wet spring doesn't eventuate. At the time of topdressing, there is often a range from below 1 to 2 t/ha in a dry spring and over 4 to 5 t/ha in a wet spring.
c) The more optimistic and more cautious choice: The optimistic choice might be to aim for decile 7, which is deciding to over-fertilise in 7 years out of 10 and under-fertilise 3 years out of 10. A cautious approach is to aim for decile 3, which is to over-fertilise 3 years out of 10 and under-fertilise 7 years out of 10.

d) The rewards and regrets of optimism and caution. By definition, a risky decision is one where future reward or regret is unavoidable. An optimistic choice has the substantial upside reward of fertilising for a wetter-than-average spring and the regret of a dry spring resulting in scarce funds spent on an unnecessary cost of nitrogen which was not needed in that year. The important work showing that a substantial amount of N that is unused in one year is available for the next season will reduce, but not eliminate, the regret of aiming for a decile 7 spring. The reward of caution is that scarce funds have been saved in a dry year. The regret of caution is missing out on the large upside economic opportunity of fertilising a nitrogen deficient wheat crop.

2) Multi week forecasts for harvest decisions in the grains industry

Harvesting equipment is expensive and most of it is only used at one time of the year for a single purpose. Losses of grain quality and tonnage at harvest can be very costly. Multiweek and seasonal forecasts have the potential to warn of a wet harvest and enable grain farmers to allocate extra resources, including labour. One of the findings was that many grain farms are slightly over-capitalised with harvesting equipment and tend to use the short-term forecasts to schedule their operations. It is possible that the multiweek and seasonal information will be useful to grain handling authorities.

Wine grape industry response scenarios included

1) Spraying a fungicide for botrytis at flowering of grapevines in hot dry inland regions. Exploring the potential for multi week rainfall forecasts to reduce the uncertainty of rainfall and humidity between verasion and harvest. The main finding from this analysis was that in higher rainfall regions, the cost of spraying ($200) was easily covered by the potential loss (say 8t/ha @ $1000/t). In the dry inland regions the chance of disease is low, but the damage is still high (20t/ha @ $300/t).

2) Deciding on the purchase of extra water in December in the Riverland. Exploring the potential for multiweek and seasonal forecasts of temperature and rainfall for the rest of summer. We found that decisions about water were complex and depended on the risk appetite of the grower. There is an interesting component whereby the price of water is sensitive to the market's perception of the future and this perception includes seasonal forecasts. A critique of the water market is that there is an asymmetry between traders and growers when it comes to the use of information on current and future supply of water.

We have included as attachments the grains industry risk management package (attachment 6), the wine grape industry risk management package (attachment 7) and the generic risk management package (attachment 2). We have also included an overview of the work with Dr Beth Loveys, University of Adelaide (attachment 3).

4.1.1 Contribution to program objectives

Meeting Program Objectives of Wine Australia.

Wine Australia invests in research and development (R&D), marketing, disseminating knowledge, encouraging adoption and protecting the reputation of Australian wine.

In the Wine Australia Strategic Plan 2015 to 2020 under the priority of increased competitiveness (p21) states *We will provide the sector with the information that it needs to manage the challenges of short-term climate cycles and long-term climate change. We will focus on gathering evidence to support strategies to manage long-term warming and prolonged seasonal heat events*

Climate is specifically mentioned as an area of investment with other RDCs (p15) *We invest with other research and development corporations (RDCs) in cross-sectoral collaborative research to deliver RD&E benefits to the broader community.*

The FWFA project's focus on multiweek and seasonal time scales complemented a larger project funded by Wine Australia on an atlas of future climate for Australian wine regions led by University of Tasmania. Like all agricultural industries, there is a long term planning horizon and a shorter term management of weather and climate extremes in the coming vintage.

Meeting Program Objectives of GRDC.

The purpose of GRDC is to *invest in Research, Development & Extension to create enduring profitability for Australian grain growers.* The SWOT analysis in the GRDC 2018–23 RD&E plan lists a range of weaknesses of the Australian grains industry. One of these is high environmental production risk. A threat to the industry is that changes to weather/climate significantly increases variability and production risk. A key outcome from the RD&E plan is the research priority of *'Improving the management of production and business risk*' (p15) with the outcome of managing risk to maximise profit and minimise losses. The GRDC 2018–23 RD&E plan emphasised both profit and risk *"Risk is an important part of the profit equation. Risk management that is too conservative can limit profit in above average production years while approaches that are too aggressive can expose the grower to equity issues that adversely impact profit and future operations."*

The main program level requirement from the grains and wine grape industries was for better information on climate extremes to help manage the direct impact of climate variability. Most of the investment of the FWFA project went to WP2 from BoM who addressed this requirement. In WP 3, SARDI Climate Applications ensured that the main climate risks for the wine grape and grains industries were addressed (drought, dry spell, too wet, heat events and spring frost).

The risk management component addresses the indirect cost of climate variability created by the uncertainty. As a predominantly dryland crop, the grains industry is aware of the challenge of balancing risks of being too optimistic or too cautious in decisions such as top-dressing nitrogen or the amount of riskier crop to plant. The notion of enduring profitability encompasses the idea of sustainability, but it can also include the balance between profit and risk, between caution and optimism. As a high value irrigated industry, the wine grape growers tend to install frost fans and irrigate prior to heat events. However, with low grape prices and prospects of a wet year, there has been increased interest in the risky question of how much should be spent spraying to protect a crop of unknown future value.

4.2 Collaboration

The project has strengthened collaboration between SARDI Climate Applications, Bureau of Meteorology, the University of Melbourne, USQ and Ag Vic. All of these groups had worked together on previous projects, and it is likely that they will do so again. Resources from the project contributed to developing closer collaboration with the University of Adelaide, the South Australian Drought Hub, the GRDC National Risk Management Initiative, the Australian Wine Research Institute and farmers and advisers on the Eyre Peninsula through the Landcare funded Resilient EP project.

The interaction with module 3, especially University of Melbourne has been very beneficial. Peter Hayman made two visits to University of Melbourne team and had useful discussion with USQ. It was also helpful to have the interaction with BoM through planning and running the workshop as part of the Wine Tech Conference in July in Adelaide. The interaction with module 4 has continued through the Community of Practice webinars which have been an opportunity to learn from others and contribute ideas.

4.3 Extension and adoption activities

The extension for the project has been collated by Ann-Maree Graham University of Melbourne. SARDI Climate Applications has been very involved in grains and wine grape industry meetings and incorporated the FWFA information in Drought Hub Workshops.

4.4 Lessons learnt

Please see attachment 1. Lessons learned

5 Conclusion

5.1 Key findings

As outlined in the project results (section 2), SARDI Climate Applications was responsible for 1) industry engagement, 2) feedback from industry to BoM 3) communication of climate science to industry and 4) risk management

Some key findings from industry engagement
The design of the Rural R&D for Profit which included the RDCs as partners was a unique and beneficial aspect of the program. The Industry Reference Groups were an effective way to engage with industry. Although industry acknowledge that application is paramount, the challenge of using probabilistic forecasts in risk management remains hard work.

Some key findings on feedback from industry to BoM
It was easier to attract attention of industry to new climate science than to maintain regular feedback. This might be due to COVID, but we had identified problems prior to COVID. Group meetings with industry and BoM were very effective. We had observed, and taken part in, a previous project, run by communication experts, which asked end users to rank forecast products with sticky labels. We tried a different approach of asking participants to explain a forecast to their neighbour. This provided rich information on preferences, but also misinterpretations. This activity was guided by work in communicating probability in medicine where the most popular graphics were often misinterpreted.

Some key findings on communication of climate science to industry
As outlined in (attachment 1, lessons learned), the project has been aided by an increasing interest in the science of extreme climate following the positive IOD in 2019 and the triple La Nina

in 2020,21 and 22. A large part of the target audience know that there are climate drivers and these are utilised by BoM to forecast the coming season. One of the conclusions of a survey of end users conducted as part of the project was as follows *" There is an opportunity to help producers maximise the value they get from forecasts. As most (82%) are already engaging with a seasonal climate forecast, the job to be done is not increasing awareness and driving 'traffic', but rather ensuring producers get value from the interactions they are having."*

An unintended consequence of products such as decile bars and probability of exceedance was the communication of uncertainty. If the plume is the forecast, then showing a more complete picture of the forecast is potentially beneficial, however there is the ongoing challenge of communicating probabilities.

Over this project we challenged the common orthodoxy that farmers don't understand probability. This is different to saying that farmers, like most of us would prefer experts to be clear and forthright and avoid couching statements with probabilities. Following Gigernezer (2013) argument that when a user hears 70% chance of exceeding spring rainfall, the problem isn't so much the user not understanding the maths of probability, rather the lack of clarity on what the probability applies to. We have found that farmers and advisers understand the notion that 70% of the model runs were wetter than median and 30% drier. This is communicated by the decile bars and it would be useful for BoM climate scientists to investigate and explain why some ensemble runs are quite dry in a climate driver favouring wet.

Some key findings on risk management

We found numerous references to climate risk management but much of the discussion is quite vague and amount to little more than warnings that bad outcomes are possible, and hence it is wise to take this into account when making plans. It has been rewarding to have the time allocated to read, write and think about risk management and what this means for linking FWFA to agricultural industries in general and particularly the wine and grain industries.

We relied heavily on Decision Analysis. Decision Analysis is not new, Parton et al 2019[1] reviewed 80 Australian studies on the economic value of seasonal forecasts for agricultural decisions from 1979 to 2017. Most of these studies use a variation of Decision Analysis and Bayesian revision to determine the value of information by comparing outcomes *with* and *without* the forecast. In the previous project R&D for Profit project NSW DPI used a form of Bayesian revision to allocate a value to forecasts. The important difference in the approach that we have used in FWFA is that rather than provide the *results* of Decision Analysis, we are working to make the *methods* of Decision Analysis available to farmers and advisers. The results of Decision Analysis might be presented in a newsletter article informing farmers that the value of the forecast is $X/ha. Here we are trying to empower advisers and farmers to conduct their own sensitivity analysis and think through how probabilistic climate forecasts can be applied to their risky decisions. We acknowledge that farmers (like the rest of us) are likely to rely on intuition for most decisions. We are suggesting that for decisions worth tens of thousands of dollars where a major part of the uncertainty is due to climate, it is worth slowing down and applying some analysis to complement the intuition. It has been a privilege to work with Barry Mudge. The following transcript is from a webinar organised by University of Melbourne as part of FWFA. It is notable for clarity on the benefits of risk planning to the business and the mental health of farmers.

[1] Parton K, Crean J and Hayman, P.T. 2019 Value of SCF for Australian Agriculture. Agricultural Systems.

Graeme Anderson – when do you use these tools?
Barry Mudge every so often you come across a time when you say to yourself "if I knew what the season was going to do, I would know what decision to make?" if you are saying that then you can sit down and do some of this work.
I don't think that I am a mug farmer, but I continue to throw up different context of the decision situation when I slow down and consider across five future climate states, which is just really hard to do in your head without having some sort of structure.
When you go through this process and it still goes pear shaped, you can go back and look at the process and say 'at least we had a fair crack at it, we were wrong or unlucky, so be it.' That was certainly the case for the lentil vetch decision, we thought we did the right thing but it didn't turn out. But we can have a look and from a mental health thing that can help you feel a little bit better

5.2 Benefits to industry

The end point of the Rural R&D for profit is more profitable agricultural industries. In a paper discussing the value of seasonal forecasts, Hansen (2002) noted that climate variability has both a direct and indirect cost. The direct costs of extreme events on agriculture are obvious. During the life of the project members of the grains and wine grape industry reference groups have experienced drought, flood, wet harvests, extreme heat and frosts. The indirect costs of extreme events is the uncertainty that they create in the mind of the decision maker. This leads to what Hansen (2002) called the moving target effect where allocative decisions on inputs such as what crop to plant, how much fertiliser to add and the appropriate level of crop protection are decisions that have to be made prior to the season eventuating.

Figure 5.1 was developed by SARDI Climate Applications as part of the previous R&D for Profit Project "Improved Use of Seasonal Forecasting to Increase Farmer Profitability" December 2015 to May 2018.

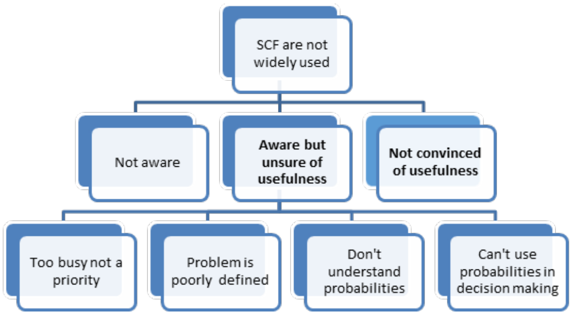


Figure 5.1 A simple root cause analysis of why SCF are not widely used

The FWFA project addressed the farmers and advisers who were aware of SCF but not convinced of their usefulness (middle of second row). The SARDI Climate Applications component addressed the lower row. We addressed the time poor farmer and adviser with a simple framework. It seemed surprisingly beneficial to just clarify the climate risky decision. We have made some progress on the ongoing task of explaining probabilities. We have worked on new ways such as the Galton board to show that probabilities represent the spread of the forecast (plume is the forecast). We have used Decision Analysis to show established ways that this information can be incorporated into decision making.

The immediate outcome from the project for grain growers and wine grape growers is access to five forecast products and some guidance on the use of forecasts in decision making. There is an important task to explain these new products to the grains and wine grape industry. Due to the timing of the five products, the extension effort for most of the FWFA products will be in the future.

The Medium- term outcomes includes better use of seasonal forecasts in Australian agriculture as the FWFA products are incorporated into decision making. Another outcome is improved conversations between forecast users and forecast developers. A decision framework helps identify where climate forecasts, at their current level of skill, are likely to be beneficial and where they are best ignored. If our experience is correct, the number of cases where forecasts are valuable is not as common as might be initially thought. 1) decisions are often quite constrained or following rules 2) strategic decisions and not tactical decisions.

Work from FWFA will be incorporated into the GRDC National Risk Management Initiative which has the overall goal that *"Within five years, 80% of growers can articulate their production management decisions couched in terms of probability of upside returns offset against the associated downside risks."*

The long-term outcome is improved profitability and reduced climate risks through better use of seasonal climate forecasts and clearer thinking about climate risky decisions. We are arguing that there is much to be gained by clearer thinking on climate risk. The work with the University of Adelaide will increase the understanding for future students.

6 Future research and recommendations

Recommendations

- Build on the growing interest and understanding of climate science concepts in the broader community (eg. widespread interest in the triple La Nina).
- Ensemble modelling conveys that the plume is the forecast. The uncertainties captured in the spread of the plume need to be clearly communicated. Although disappointing that the climagram shows the spread of the box plot returns to climatology beyond a fortnight, this is important information.
- Following from above, although the FWFA products visually show the level of skill/accuracy, the project work has not included improving the accuracy of the forecast. This remains an issue for end users.
- This project has worked on ways to convey probabilities, continued extension and communication in this area will strengthen this broader understanding.
- Future research projects producing journal articles may benefit from having a parallel delivery on their subject published in popular publications (e.g. The Conversation) to extend circulation of information and results.

7 References

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