Final report

Insights into Barriers and Bridges to the producer adoption of seasonal climate forecasts

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Abstract

Seasonal Climate Forecasts (SCFs) have the potential to be beneficial to many in the agricultural industries, but they have had variable uptake. This qualitative study examined why the barriers to the use of SCFs exist and propose bridges to increase their use. Key informants and stakeholders with experience with SCFs from the winegrapes, dairy, sugar, red meat, and grains industries were interviewed. The interviews were transcribed and analysed to identify patterns and themes with growers' use of SCFs. We found that it was not a simple matter of overcoming one or two barriers, but rather the barriers to the use of SCFs happen in combinations and they are mostly related to how SCFs are communicated by their developers and understood by their users. This knowledge will assist those involved in developing, promoting, and using SCFs to better understand what could be changed to increase their appropriate use, which will over time lead to improved profitability for agriculture.

Executive summary

Background

The rationale for this project is that identifying and understanding the characteristics of the barriers to the increased use of SCFs will make it possible to consider the types of bridges that need to be built to overcome the identified barriers. The target audience for this are the people developing, promoting, and using SCFs in agricultural industries. The findings from this study can be a useful guide for those wanting to improve the use of seasonal climate forecasts among growers.

Objectives

The main research aims were to:

1. Identify the barriers to the use of seasonal climate forecasts for tactical climate-sensitive decisions.

2. Propose bridges to build farmers' more informed use of seasonal climate forecasts for tactical climate-sensitive decisions.

This project intended to review, categorise, and prioritise the barriers to the adoption of seasonal climate forecasts (SCF) drawing from the existing literature as well as being informed by interviews with stakeholders from the dairy, grain, red meat, winegrapes, and sugar industries.

Interviewees from the five different agricultural industries were asked for feedback on 25 statements about barriers to the use of SCFs found in the literature. The interviews were conducted from 2-24 December 2021.

Methodology

1. A brief review of previous projects and existing literature to identify barriers to adoption, develop a conceptual framework of barriers to adoption, and design bridges to adoption.
2. Formative interviews to guide the research process and inform the main interviews.
3. Main interviews to explore any additional issues emerging from the formative interviews, identifying gaps in the proposed barriers and next steps.

Results/key findings

This work confirms the findings of Taylor et al (2021) that a large proportion of growers are aware of SCFs, but many have made little use of them beyond their initial engagement.

There are three factors that are influential in encouraging growers' more informed use of SCFs. Two are related to the design and communication of the SCF itself, and one is related to growers' understanding of SCFs and their potential benefits.

1. Usable design: SCFs are designed for growers as a result of testing and multiple engagements with agricultural end-users.

2. Appropriate communication: SCFs are communicated in such a way that users and intermediaries can more easily understand their underpinning concepts. Concepts of probabilities, forecast skill level, and that low skill level may mean that at times they should not be used are central to the communication, not footnotes.

3. From awareness to value: Growers are provided with tools to assist with the application of SCF outputs to climate risky decisions so that they can assess the potential benefits in their own situation.

Benefits to industry

Encouraging the use of SCFs when they have something to offer agricultural industries could result in substantial financial gains through increased profitability and reduced risk. Helping growers develop an awareness of when not to use SCFs will increase their confidence in them so that they are more likely to use them successfully when they have something to offer.

Future research and recommendations

A useful social science research project could focus on translating what probabilities mean into a language that farmers can grasp. Previous attempts at assisting growers to develop an improved understanding of probabilities (and even deciles) have been successful for some, but not all growers. What needs to be explored is the terminology around the communication of risk, with an emphasis on seasonal climate risk, so that information can be presented in a way that growers can easily comprehend. The practical application of the results from this project is that they can be used to inform the materials and programs around SCFs and similar tools so that they are more likely to be used by growers when they can deliver a benefit to them.

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1. Background

1.1.1 Why this research is needed

The use of Seasonal Climate Forecasts (SCFs) can provide benefits to farmers, which can be increased profits in good years or reduced losses in poor years. Even though they possess these potential advantages their adoption in Australia has fallen short of expectations (Parton, Crean et al. 2019). If the test of the value of SCFs is whether producers are using them in a way that improves the productivity of their farms then it appears that producers are not recognising the value of SCFs (Parton, Crean et al. 2019). A large proportion (82%) of growers engage with SCFs but less than half (44%) of growers rely on them in some way. This means that almost all growers are likely to be aware of the existence of SCFs but only about half of those that engage with them in some way have chosen to make greater use of them beyond their initial engagement (Taylor 2021). It is likely that the 44% who "rely on them" would use them in a wide variety of ways, from little through to much use.

The uncertainties around the use of SCFs suggest that further research is needed to identify how producers are using them, and the value that they gain from their use (Parton, Crean et al. 2019). SCFs are likely to have increasing importance as an adaptation to droughts that are expected to become longer and more frequent in the current climate (Crimp 2018).

Even though the barriers to the use of SCFs appear to have a great deal of consistency across industries there is also room for further research that could investigate how SCFs could be tailoured and delivered for particular agricultural industries (Taylor 2021). While much research has focused on the decision of whether or not to apply extra N to a growing grain crop, there is a need for more research that explores the use of SCFs for other decisions and other agricultural industries (Parton, Crean et al. 2019).

The mid-term review of FWFA recommended further investigations using social research methods to evaluate how the different agricultural industries use climate information to identify the lessons that can be learnt to better engage industry (Clarke and Alford 2020). The authors also suggested that research was required to understand the amount of climate literacy amongst farmers and their supply chain so that the best form of SCF was identified for use by farmers (Clarke and Alford 2020).

1.1.2 Research aims

The main research aims of this project were to:

a. Identify the barriers to the use of seasonal climate forecasts for tactical climate-sensitive decisions.

b. Propose bridges to build farmers' more informed use of seasonal climate forecasts for tactical climate-sensitive decisions.

The rationale for this project is that identifying and understanding the characteristics of the barriers to adoption will make it possible to consider the type of bridges that need to be built to overcome

the identified barriers to the adoption of seasonal climate forecasts. This would result in greater levels of adoption which occur sooner, with the benefits from their use being experienced by more people earlier; and the consequent pay-off to the grower's investment in the use of SCFs being larger and occurring quicker. The findings from this study can be used as a guide that is useful for those making investments in encouraging the adoption of seasonal climate forecasts.

The focus of the "Forewarned is Forearmed" (FWFA) project (Clarke and Alford 2020) has been on the development of improved weather and climate products with the commonly held assumption that the adoption of the associated tools such as multi-week and seasonal climate forecasts would follow as awareness of them developed (Kuehne, Llewellyn et al. 2017). This assumption was realistic to some extent, but it still may have meant that the speed and extent of adoption were less than they could have been. There are surmountable barriers to the adoption of multi-week and seasonal forecasts that can be overcome, and some of these have been identified in the FWFA mid-term review (see Hayman, Pearl et al. 2018). Some still need to be identified, categorised, discussed, and prioritised so that they can be responded to, which this study does.

2. Objectives

The hypothesis investigated by this research was that:

> ***Surmountable barriers exist preventing farmers' greater use of seasonal climate forecasts for climate-sensitive decisions.***

The intention of this project was to review, categorise, and prioritise the barriers to the adoption of SCFs drawing from the existing literature as well as being informed by interviews with stakeholders from the dairy, grain, red meat, winegrapes, and sugar industries.

In a two-step process of formative interviews and main interviews with stakeholders and key informants from the five different agricultural industries were asked for feedback on 25 statements about barriers to the use of SCFs found in the literature. The interviews were conducted from 2-24 December 2021. The purpose of understanding the barriers is to be able to build better bridges between developers and users of SCF.

3. Methodology

3.1.1 Review of previous projects and existing literature

A review of the existing literature was undertaken to:

a. Identify barriers to the adoption of SCFs. This used previous project findings (e.g., Rural R&D For Profit program) and existing literature to develop a concise, categorised list of barriers to the use of SCFs.

b. Develop a conceptual framework of barriers to adoption informed by (but not limited by) the ADOPT conceptual framework (Kuehne et al. 2017), for example:

I. Relative advantage for the population.

II. Learnability characteristics of the innovation.

III. Population-specific influences on the ability to learn about the innovation.

IV. Relative advantage of the innovation.

c. Design bridges to adoption. This was done to show how barriers to the use of Seasonal Climate Forecasts can potentially be overcome.

3.1.2 Formative interviews

Formative phone interviews were conducted with members of the FWFA project team. One key informant was chosen to provide comments on the previously identified and categorised barriers and potential bridges to the use of SCFs for each of the dairy, grain, red meat, winegrape, and sugar industries. The results from these interviews guided the research process and informed the main interviews.

The interview discussion aimed to:

a) Identify the relevance, and the priority, of each of the proposed barriers to the adoption of multi-week and seasonal forecasts for each industry.

b) Uncover how respondents think that bridges can be built, and barriers can be overcome so that users are more likely to adopt SCFs.

3.1.3 Main interviews

Semi-structured one-on-one interviews were conducted by phone with 18 stakeholders from the dairy, grain, red meat, winegrape, and sugar industries allowing them to explain their perspectives on the barriers and bridges to the use of SCFs. Stakeholders were nominated by members of the FWFA project team. These interviews aimed to gather rich descriptive data that was used for exploring issues emerging from the formative interviews, identifying gaps in the proposed barriers and bridges, as well as asking interviewees what they see as the next steps. The results from the previous formative interviews were synthesised into the broader observations made from these interviews.

3.1.4 Analysis

The interviews were digitally recorded, transcribed by a professional transcriber, and then coded to themes. The analysis of the interview transcripts was done using a thematic approach that identifies re-occurring themes. These themes were summarised using the addition of quotations from the interviewee's transcript as supporting evidence. Some of the quotes presented in this report have been edited for readability without changing the interviewee's intended meaning.

4. Results

4.1.1 Proposed barriers and bridges conceptual framework

The examples in the literature that illustrated the benefits to growers from the use of SCFs are mostly presenting an ideal version of what could happen if the grower was able to use the information from the SCF with no extra demand on cognitive, financial, or temporal resources.

The interview section of this study aimed to have users sift through the potential barriers to the use of SCFs that have been identified in the literature (See the Appendix – Literature review) and identify those that they found important from their practical experience.

Table 1: Barriers to the use of SCFs from the literature (1. Characteristics of SCFs).

Accuracy	1. SCF have limited skill (accuracy)(Brown, Hochman et al. 2018, cited in Pearl, Hayman et al. 2018, Parton, Crean et al. 2019). SCF skill level is less than what would encourage adoption as a result of ongoing trialling (Ash, McIntosh et al. 2007, Brown, Hochman et al. 2018).
	2. SCF skill is not uniform through the year (and poor when needed most) (cited in Dilling and Lemos 2010, Soares and Dessai 2015, Pearl, Hayman et al. 2018).
	3. SCFs that fail in the first few times they are used will delay or block adoption (Ziervogel, Bithell et al. 2005).
Relevance	4. SCFs do not take into account growers' own history and experience of the climate (Brown, Hochman et al. 2018).
	5. Spatial precision of SCFs is too broad so that it has limited relevance to the grower's own location (Dilling and Lemos 2010).
	6. SCFs are only relevant to a limited range of growers' decisions (Crane, Roncoli et al. 2010, Dilling and Lemos 2010, Marshall, Gordon et al. 2011, Soares and Dessai 2015, Taylor 2021).
	7. The lead time of SCFs does not match lead times for some agricultural activities (Crane, Roncoli et al. 2010, Dilling and Lemos 2010, Klemm and McPherson 2017).
Communication	8. SCFs provide vague, indefinite forecasts when growers are wanting definite, consequential forecasts (cited in Pearl, Hayman et al. 2018).
	9. A focus on climate drivers has captured growers' attention at the expense of their better understanding of probabilistic forecasts (cited in Pearl, Hayman et al. 2018).
	10. SCFs are not communicated in such a way that growers can effectively understand their value (Hayman, Crean et al. 2007, Dilling and Lemos 2010, Soares and Dessai 2015, Davis, Lowe et al. 2016).
	11. The language used in SCFs to communicate uncertainty may not match the language used by growers (Crane, Roncoli et al. 2010, Soares and Dessai 2015, Klemm and McPherson 2017, Terrado, Lledó et al. 2019).
	12. SCFs are not flexible enough to provide for the different needs and preferences of growers from different industries (Carr, Montz et al. 2018).
	13. SCF outputs have not been translated into agricultural information very effectively (Peck, Derner et al. 2019).
	14. The connection of SCFs to weather forecasts is not seamless (cited in Pearl, Hayman et al. 2018).
	15. The benefits from the use of SCFs are not experienced consistently year after year which means that evaluation by growers for trialling purposes is difficult (Hayman, Crean et al. 2007, Marshall, Gordon et al. 2011, Terrado, Lledó et al. 2019).

Table 2: Barriers to the use of SCFs from the literature (1. Characteristics of SCF users).

Knowledge	16. Growers have low awareness of the benefits from the use of SCFs and how they could use them in farm management decisions (Hayman, Crean et al. 2007, Parton, Crean et al. 2019).
	17. Growers have a limited number of people (including their own trusted advisers) who can explain the use of SCFs. (Agri-Futures Australia 2019).
	18. Growers do not understand the concepts underpinning SCFs such as deciles, probabilities, and what shifts in probabilities mean (cited in Pearl, Hayman et al. 2018).
	19. Growers perceive SCF to be inaccurate (because they are probabilistic and they have a limited understanding of probabilistic forecasts) (cited in Pearl, Hayman et al. 2018).
	20. Growers who want to use probabilistic climate information may be uncertain about what the next step is after gaining information about SCFs (Agri-Futures Australia 2019).
Attitude	21. SCFs are probabilistic forecasts when growers are likely to be more comfortable with deterministic forecasts (Agri-Futures Australia 2019).
	22. The psychological cost for growers of making a wrong decision based on using SCF outputs may be more than the forgone profit from not using them (Kahneman and Tversky 2013).
	23. Growers remember when SCFs get it wrong more than when they get it right (Taylor 2021).
	24. Decisions about climate are only one among many that growers need to make (Agri-Futures Australia 2019, Taylor 2021).
	25. Growers (and their advisors) may not have the resources to invest time in developing an understanding of SCFs (Soares and Dessai 2015, cited in Pearl, Hayman et al. 2018, Agri-Futures Australia 2019, Parton, Crean et al. 2019).

4.1.2 Interview results

Proposition 1: SCFs have limited skill (accuracy)

Growers may be aware of SCFs and use them to some extent, but not be advocates for them because of their perceived inaccuracy:

> *They're bloody hard to believe, they're not very reliable. I really love long-range forecasts, but I don't look at them a lot. I haven't seen them to be too right in the last few years. If I could have more confidence in them, I would use them more.* (G4)[1]

It seems that growers are prepared to criticise the SCFs for being "inaccurate" rather than seek to understand them:

> *If you go back to 2015 or 2014, if you went off the long-range forecast, we were going to have a pretty ordinary year. But we picked up some April rains and we had a really good start to the year, and it ended up a pretty handy year, but if you had taken notice of what the seasonal forecast was, we wouldn't have been able to capture most of that year.* (G4)

Obtaining the information from SCFs is using them even though the information may not be acted on. This means that people may be using SCFs to some limited extent without being completely aware that they are using them:

[1] The prefixes G, D, W, M, S, refer respectively to the grains, dairy, wheat, red meat, and the sugar industries.

> *When I say we don't use them, we always read them, put it in our heads, but then we don't use them, and haven't found them very accurate.* (G7)

Growers may expect a level of skill from SCFs beyond that which is realistic:

> *Would a farmer actually change their practice if the skill went from 60% to 70%, probably not. I would think that it has to go up to 95% before we actually rely on it. That was always going to be a barrier for this project, that BoM could improve the accuracy by 10% or 20% and it really has to go up to 90. That became the issue, the mismatch between the level of realistic skill versus the skill level a farmer would need to really make a big change.* (D1)

Other growers are happy with the existing skill levels:

> *I don't think people want to understand. It has limitations and it's your management, it's your farm, you've got to make the decision, so you've got to understand this. We're talking probabilities and when you think about it it's pretty amazing that the forecast is as accurate as it is.* (D3)

Even when the accuracy is questioned growers will still use SCFs:

> *I sort of have a look at the BoM three-month outlook. I have been looking at it more for interest rather than planning anything, because I've never really plotted the predictions versus actually what happens to prove the accuracy of it.* (W2)

Providing a skill level helps users to know whether they should even use the forecast:

> *We're too often given a forecast and not given enough reference to the skill component of it. If the forecaster itself agrees that there is no skill, then don't give us the forecast. It's of no value.* (M5)

SCFs should probably be routinely provided with conspicuous skill levels:

> *But it should be made clear about when the information's being provided to you has a large degree of uncertainty associated with it. It should not be promoted as being accurate. It's an accurate model, the results from the output of the forecast are correct, but there's a lot of variability.* (S4)

The information about forecast skill needs to be available and accessible to be useful:

> *There are skill maps on the website, on the BOM website, so if you can navigate your way through the BOM website and find them, you're pretty good, you're a better person than most. Because it's pretty complicated.* (M1)

Forecast skill is complicated, and varies according to several factors:

> *At different times and different locations, [a forecast will] have different accuracy or skill attached to it and it all depends on basically what time of the year you're looking at it and what time of the year you're looking for and what your location is.* (M6)

Finding: Growers may be aware of SCFs and use them, but they may also question their accuracy (their skill). They use them in different ways so even just hearing what the seasonal climate forecast is from others is still using them to some extent. They may not be accessing them from the BoM website. Skill level is something that growers may not be aware of. On the other hand, even if they are accessing them from the BoM website they may not know where to find the skill level, and in

any event, they may be expecting higher levels of skill than the forecasts can deliver. There are times when SCFs do not have skill and should not be used, and growers should be made aware of those times. These are also the times when growers lose trust in the forecasts because they do not turn out in the way they had hoped for. The use of SCFs would be improved if growers knew more about SCF forecast skill but forecast skill for SCFs is difficult to characterise.

Proposition 2: SCF skill is not uniform through the year (and poor when needed most)

The Autumn predictability barrier is a good example of SCF skill not being uniform:

> *Can't help people looking for information at the time when they're most desperate to have some. Everyone would love to have a better feel for the coming season at planting time when the skill is worst. But arguably they never will so probably they should just stop looking.* (G1)

In some instances when SCF skill becomes acceptable some of the most important decisions of crop growers have already been made:

> *We know when we're in an El Nino year we're accurate, but we're already three months into the season of a six-month crop in terms of our grain production.* (G5)

Growers from different industries will find that SCF skill is useful or not at different times of the year:

> *I find that the skill is not uniform throughout the year, but I don't necessarily agree with it being poor when needed most. I think it is reasonable to good when needed most.* (S4)

Growers from different locations will find that SCF skill is useful, or not, at different times of the year:

> *I really notice that the southern people are more aware of seasonal variation [in skill], whereas up in our northern area I haven't even had anyone mention it.* (D3)

It seems that growers from northern parts of the country are more comfortable with SCF skill levels:

> *For Northern Australia it's actually fine, it's accurate when they need it most. They want to know in August-September and into October what's coming for the next wet season. We have the IOD and SOI to help us there. It isn't uniform throughout the year, but I don't think that that bothers them once they understand it.* (M2)

Judging forecast outcomes based on isolated model outputs can be misleading:

> *The last two years have not been that great, but the two previous years the models gave early signals, which turned out to be correct and people thought the models were getting better, it was sheer luck, sheer chance, then we've had two years where models, in autumn have not been that great.* (G1)

An awareness of the significance of forecast skill and the influences on it may not exist:

> *You've got to know when they've got good skill and you've got to know when they've got poor skill. If you know that, you can use them at the right time. That changes between season, time of the year and also your location. We've really got to have an extension program that points this out to people, the forecast may not be useful at your location for that time of the year.* (M1)

Finding – SCFs are not uniform throughout the year, with the autumn predictability barrier providing a good example of how it is not skilful at certain parts of the year, and especially at times when farmers want the information to help with some of their more important decisions. This skill level will vary for growers from different locations and different industries. Judging forecast skill level based on isolated events can be misleading. Growers need help to understand that the forecast skill level varies through the year.

Proposition 3: SCFs that fail in the first few times they are used will delay or block adoption

Forecasts that do not turn out as predicted can destroy farmers' trust in them, especially if they are interpreted as categorical forecast

> *In October they told us we'd get 50-100 mls*[2] *by the end of October and we didn't get a drop. Then we've just had the wettest November in history, and nobody predicted that. The forecasters said it could be average or above average and now we just had the wettest November in history. So, I can't place any faith in those forecasts.* (S2)

The issue with a probabilistic forecast is that users can perceive less likely (and usually undesirable) forecast outcomes as a failure, even though they were always a possibility:

> *I've been really struck by how the trust has eroded by the BoM being wrong once or twice and then they've shifted their allegiance*. *If the BoM get it wrong once, they are dead in the water. There's very little forgiveness. And that goes to I think the lack of understanding of probabilities.* (D1)

The forecasts can perform well and still be seen by users as failing:

> *There's probably been a few people burnt. South Australia is having a particularly shocking one with what models are saying and what it's coming out with. If they really burn you badly, you remember those. If it was two in a row, then you'd just be thinking, this is rubbish*. *They're biased by their most recent experiences of them.* (G1)

Definitive forecasts that do not turn out as hoped for, can have a substantial impact:

> *It will absolutely shut them off I'd say for the next 3-5 years. It was a massive issue last year with that La Nina. The forecasts were for very wet conditions, and it ended up being drier than most El Ninos, so that was really, really bad.* (M2)

More understated forecasts that do not turn out as hoped for, can have a less substantial impact:

> *The BoM seasonal forecast in March 2017 was a 50/50 probability so a neutral forecast. We took on more livestock, we didn't see any rain until February 2020. In January 2020 they were forecasting the rainfall component to be a bit more favourable, but we didn't believe it. But then in mid-February we started to get rain. And ever since then, the forecast has been to the wetter deciles, which is great, but we still interpret them with a bit of disbelief.* (M3)

Finding – Probabilistic forecasts such as SCFs provide a range of possible outcomes. When the outcome is not what the farmer wants, the forecast is seen as being a failure even though the outcome was always possible but just less likely. This means that SCFs can perform well but still be seen by users as failing. When this happens, it destroys growers' trust in the forecast. This would

[2] The convention of growers when contracting millimetres is to express it as mls. They are not referring to volume.

have a greater impact if the decision associated with the forecast is significant and it will have a lesser impact if the decision is less consequential. The use of SCFs would be improved if growers were more aware that when SCFs appear to have failed it is just where the less likely outcome has occurred.

Proposition 4: SCFs do not take into account growers' history and experience of the climate

Interviewees did not see that it was important for SCFs to consider the grower's history and experience of the climate. One grower explained:

> *SCFs don't need to, because they are describing the climate in relation to the science. So, in a sense... the SCFs are what they are, and growers bring their own history and experience of climate to interpretation of the forecast.* (S1)

Similarly, another interviewee expanded on the role of grower's history and experience of the climate:

> *That's a part of the decision-making puzzle. You use your own history and experience of the climate to interpret them. I think people do that a lot, the model's saying this, but I think it feels like this. People use their gut for climate decisions just as much as they're using models. Whether their gut's right as much of the time as the models are, that's a good question, but some people are better than others.* (G1)

Finding – Interviewees didn't see that taking farmers' history and experience into account was important they suggested that farmers do this anyway when they're using seasonal climate forecasts. The use of SCFs is not likely to be improved by adding in growers' history and experience of the climate.

Proposition 5: Spatial precision of SCFs is too broad so that it has limited relevance to the grower's location

Growers understand the constraints of their geography on SCFs:

> *We sit on a range of hills, and it can be sunny three kilometres away. We understand that there's those localised geographical features that are going to impact.* (D2)

Spatial precision is more or less useful depending on the type of weather that is being forecast:

> *With Southern Australian systems, spatial precision is pretty good. In Longreach you can have storm predictions for the day, but they miss you by 20 km and you don't get anything for three storms in a row. That's where spatial precision becomes far more important whereas in Southern Australia you know the cold front's going to hit. If you're relying on rain in February in Longreach in big storms, they could all go 100 km north of you and miss you completely and you get nothing.* (D1)

The act of providing what appears to be spatial precision could be misleading:

> *If you go onto the BoM website, on the seasonal climate forecast, you can type in your exact coordinates, and it will pop up with a box for those exact coordinates and give you a forecast. It's giving unrealistic expectations based on actually providing too much spatial precision.* (M2)

The relevance of spatial precision also differs between locations:

> *The Bureau's been forecasting La Nina, but you've got to do interpretations as to what La Nina means across Australia. La Nina means that the Eastern Seaboard in particular, is going to be fairly wet. Parts of Western Australia may be wet and cold but for the rest of it, it's a line ball. The problem we've got is that people haven't gone into that level of interpretation and they're saying the forecast is just hopeless, because it says La Nina, but it's been dry.* (W3)

Finding – For some growers, spatial precision means just being able to identify where they are on a map; for others, it is focused on a much smaller scale. The ability to enter the specific location information into the seasonal climate forecasts suggests a level of skill that does not exist. It is suggesting misleading precision. The use of SCFs could be improved if spatial precision was increased but at the moment those improvements are mostly illusory, and it seems that growers accept spatial variability.

Proposition 6: SCFs are only relevant to a limited range of growers' decisions

The first thing to acknowledge is that SCFs are one of several climate tools:

> *Our red meat guys use a number of different weather and climate tools/products, to make decisions. They might start out with a seasonal forecast and then as the decision time gets closer, they might look at a monthly thing and then as it gets closer still, a weekly forecast and then you know, it's closer even still, they look at the weather forecast. Seasonal forecasts aren't the be all and end all, most of our people would use a number of different forecasts to make a decision, it's just about the timing and when you use it.* (M1)

SCFs may not provide detailed enough information for them to be useful for growers' decisions:

> *For our summer spraying, if we knew we were going to have a wet summer, we would probably hold off and only do one dose. if we knew we were going to get 25 ml now and then the weeds come up and you knew you were going to get another 25 ml rain in two weeks, you'd wait. But it's not that detailed, you don't know the timing of the event.* (G7)

The decisions that SCFs are relevant to vary between locations:

> *You can use them for a variety of things, like heat load and heat stress in livestock. You know, in vitro or embryo transplant or AI work in your cattle, or whatever you're doing. If producers know that they can get something out of it, then they might be more likely to look at it. If you show them that this tool can give you a vibe of what the season is, it can help them planning this, this, and this. It's not just about rain, but also the temperature side of it if you're serious about your breeding programs.* (M6)

The time when SCFs have skill determines the decisions that they will be useful for:

> *When you ask, "what are the decisions in grains that a seasonal climate forecast can be used for?", you only come up with about 3-4 and none of them are at planting, because there's no skill at the time. They're all once the crop is in the ground and it's things like putting out nitrogen, putting out fungicide, choosing to go to hay or grain; even then the climate forecast is only one factor in that decision-making process.* (G1)

A careful analysis of a decision, even though it is a climate-sensitive decision, may not require input from an SCF.

> *Quite often they're decisions that we just don't know which way to go, and the forecast may or may not be a really important part of that decision. There may be a best way forward in most cases anyhow, even though the result is going to be heavily dependent on what the season does. A lot of the times you think that, if the season's going to be good, I should do this or, I should do that and when you sit down and analyse it out, quite often you find that it's actually still a no brainer.* (M5)

Not all decisions require the input of SCFs, but some can benefit from them:

> *It's probably important to your important decisions, like are you going to grow a crop of corn this year? And is it worth the extra money to irrigate it because the forecast is wet? it's definitely important decisions. I reckon it's really relevant.* (D3)

Finding – Seasonal climate forecasts are one weather and climate tool among others that are routinely used. Growers make many different decisions and some of them can benefit from the use of seasonal climate forecasts but many of them cannot benefit from them. Some climate-related decision should just be made anyway regardless of the SCF outputs. The use of SCFs might be improved if growers were aware of decisions that could benefit from their use. This will vary between locations and industries.

Proposition 7: The lead time of SCFs do not match lead times for some agricultural activities

For growers, longer lead times are seen as being desirable, but they are also aware that there is a trade-off between increasing lead time and forecast skill:

> *I think that's critical. Most of our forecasts are zero lead time, so you have forecast issued on the 1st of December for example for January/February. To be more useful you might need one month, two months, three months, four months, five months lead. The problem is that as you increase the lead time, the skill of the forecast reduces.* (M1)

Some industries do not see the value of making trade-offs between lead times and forecast skills:

> *Some of the feedback we've had from dairy farmers is that the forecast going a bit further out isn't giving them much more confidence. Existing products are probably giving them most of what they need right now, and the uncertainty beyond two weeks is of limited use in planning.* (D1)

How relevant the lead time of SCFs is, depends on the industry:

> *Seasonal forecasts by definition are for the next three months[3], so usually they're okay in the red meat industry, but if you're in different industries, say horticulture, the whole crop is raised in 12 weeks. Seasonal forecasts aren't that useful for lettuce or cabbage or a lot of those things. They need shorter term forecasts, whereas for grazing, gestation length of a cow is 9 months, so in many ways, they don't project out long enough.* (M1)

Finding – Growers would like longer lead times but that would come at the expense of poorer forecast skill. The importance of lead times varies between industries.

[3]Recently the BoM has moved to providing more information at fortnightly, monthly and 3 monthly scales, with weekly updates.

Proposition 8: SCFs provide vague, indefinite forecasts when growers are wanting definite, consequential forecasts

Growers understand that the forecast is variable:

> *The biggest barrier we have as producers is that we're in the riskiest business in the world and we have to understand that there's no guarantees. You can't guarantee your cow's going to calve and that's exactly how your seasonal outlook and forecasts are. You can't give a definite consequential forecast, it's like everything else we do in agriculture, there's so many variables that can dictate the outcome.* (M6)

Like everyone, growers would prefer not to be dealing with uncertainty:

> *The average person just wants certainty in life and they're never going to get it. Because who wouldn't want an accurate seasonal climate forecast at the start of every year, farming would be very easy then, wouldn't it?* (G1)

Growers may need to adjust their understanding of SCFs:

> *We have to limit expectations. Most producers don't make the connection if you look at a seasonal forecast and it's indicating wet conditions. Those conditions might not eventuate, but you can make changes to your plans that will let you take advantage of the situation if it does rain.* (M2)

SCFs are best seen as tools that can help support a decision:

> *The nature of rainfall is that a forecast can't provide absolute accuracy. They are by definition vague in a sense, but they provide a guide based on what the model's suggesting, to help producers make decisions in relation to rainfall and temperature.* (S1)

Finding – Growers understand that SCFs are modelling uncertainty. It may also be that they are used to the more certain outputs of crop trials and similar research activities. The use of SCFs would be improved if growers could adjust their understanding of seasonal climate forecasts, recognising that even though they are uncertain, they still have something to offer when they are used as a guide to decisions.

Proposition 9: A focus on climate drivers has captured growers' attention at the expense of their better understanding of probabilistic forecasts

One grower suggested that focusing on the predictions of an SCF can be a starting point followed by an examination of climate drivers to provide more detail:

> *Seasonal forecasts give an overall indication of what the season might be and then you can go and look at just how strong your climate drivers are that actually affect your area. It's a good starting point, the seasonal outlook, you generally start there and then you can delve a little deeper.* (M6)

Climate drivers provide evidence for SCFs:

> *If I'm just giving a longer talk, I actually talk about the climate drivers because I've found that if producers can understand the reason behind the probabilistic forecast, they're much more likely to trust it.* (M2)

Climate drivers contribute to added understanding:

> *Having people focussing on climate drivers is not a bad thing. We've now got a much better idea of climate literacy across the southern regions, and one would hope that that's given people a more holistic vision of what the different climate drivers mean. El Nino doesn't equal drought and La Nina doesn't equal flood and it never has, it just simply changes the odds, it's not giving anyone certainty in life.* (G1)

Climate drivers are included in the model so understanding more about them doesn't change the actions that would be taken as a result of the model's output, but a better understanding of probabilities may:

> *The current ACCESS model incorporates all of those drivers. An overemphasis on discussing drivers, I think dilutes to some extent the focus on the output of the model, which takes into account all those drivers. You could perhaps shift to more discussion of understanding of probabilities.* (S1)

For some growers, especially those in northern parts of Australia, a better understanding of the climate drivers may be of more use:

> *All our seasonal stuff is about where the SOI is, the IOD also. That will tell us where the cyclones are going to be and the MJO, it's bloody important. That's what affects our climate up here.* (S3)

For some growers an examination of climate drivers can help them to develop trust and confidence in the usefulness of SCFs:

> *We don't believe that you can get people to change their practices without providing some sort of background and understanding about the forecast and what drives them. Making sure they have a really good understanding, provides confidence. Once you've got confidence, trust and understanding and you can show how to use the forecasting decisions, that's when you tend to get practice change.* (M1)

Finding – Growers may not understand that probabilities underpin seasonal climate forecasts, whereas they are probably aware that climate drivers do. Growers are more likely to build trust and confidence in the use of seasonal climate forecasts if their initial use of them is supported by an examination of climate drivers which will help them in developing an understanding of how SCFs work.

Proposition 10: SCFs are not communicated in such a way that growers can effectively understand their value

The value of the SCF forecast is tied to the decisions that growers could make as a result of the forecast:

> *…describing it in a way that gives an indication of the effect to the end-user or the benefit of that rain. There's got to be some ability for it to feed into the decision-making process.* (S4)

SCFs are probabilistic forecasts which can mean that some growers may benefit from a better understanding of probabilities:

> *That is a big issue, and the issue is the insistence that they have to understand probabilities. I don't think they need to understand probabilities. It doesn't mean you give up on the probabilistics for those that want it, the majority of your dairy farmers are just not going to be interested.* (D1)

Having growers who can communicate the values of SCFs to other growers may be one of the best ways for them to learn:

> *This is critical and that's why we have regional people to help us out, because most of them are producers and they use climate forecasts on their own property, and they communicate it really well to other people in the area. But if you just have somebody coming in, and just telling people about a forecast, just telling them how to use it, it would be fairly worthless for 99% of people.* (M2)

It is likely that communication will not just be about the language, but that it will also be enhanced by coming from the same culture:

> *I've got a bit of an advantage because I can sit there and I can say, I've got a cattle station, this is what I do. I can give them real life examples of seasonal climate forecasts being applied, you can see them start thinking" yeah, I can do that". That's the thing about having people who are delivering the messages that are already embedded within the industry. I think that's quite powerful.* (M4)

Good communication about SCFs starts with reducing barriers:

> *Had a real chat to them and just sort of got them engaged that way. I think you have to do it in person, at least to start with, to build that relationship, so that people know that you understand them and you're not there to lecture to them you're here to say, look, here's the information.* (M5)

Informal and easily digestible information about SCFs is suited to the learning styles of growers:

> *You can't expect people who have been out of any sort of formal schooling for decades to be able to sit in a room and absorb information like a sponge and stay focussed. I feel the way to extension is beer and sausages and some general conversation or short 3-minute videos at home. It's all about making it bite-sized.* (M2)

Finding – Communicating with growers about SCFs is a combination of knowing what important aspects of SCFs need to be communicated to them and knowing how best to carry out the communication. For some the communication of SCFs could be improved by making greater use of members of the same cultural group who share the same experiences and understandings. This would mean that a common easily understandable language is used, and information is presented in informal and easily digestible ways.

Proposition 11: The language used in SCFs to communicate uncertainty may not match the language used by growers

Unnecessary complexity is the enemy of good communication with growers:

> *The key thing is to try and put things in a simple form, I mean it's a complex issue, but keep it simple so that the information can be taken in readily, because if it's too hard, people don't do it.* (G2)

The group with the largest number of users of SCFs is likely to have the greatest sway over the choice of language used for SCFs:

> *Language is one of our biggest barriers and we do understand it's a big thing and what we tell producers is that the BoM has to try and cater for everybody, not just us producers, so*

> *they have to use language and terminology that will cover the broader population and unfortunately, we're only a smaller population in the whole scheme of things.* (M6)

Communication of probabilities with growers remains difficult:

> *Language and the ability to communicate probabilities are getting at the same issue. The insistence that farmers need to learn probabilities is barking up the wrong tree. We need some good social scientists or someone to inform the BoM. If you're going to make traction in the agricultural community, you need to think of a different way of communicating that.* (D1)

Issues continue to exist where the language of scientists and growers do not match:

> *There's an ongoing issue around matching the language of science to the language of producers and it's something we've got to continue to work on and I think the projects like FWFA where producers are providing feedback to the Bureau on how these new forecast products can be modified to communicate more effectively to them are working quite well. It doesn't mean there's not a way to go yet.* (S1)

Scientists are recognised as providing credible scientific information, but not always for their ability to communicate it:

> *The only way you can keep up with this sort of stuff is listen to the scientists. But when some scientists come, they bring their university degree with them and you haven't got a clue what they're talking about, because they're using words that we don't understand. These are farmers, they're not out of universities, you've got to bring it down to their skills and their language.* (S3)

Finding – Growers are a subgroup of Australian society. They mostly realise that SCFs will not be tailored to their needs. The language may be different from what they would like. The nature of the forecast may also be different. The SCFs are likely to be presented in a way that satisfies the largest group of potential users in Australia. The problems with communicating the uncertainty that is seen in SCF outputs are not helped by the language and complexity of scientific communication. The use of SCFs could be improved if intermediaries took the information presented by SCFs and then presented it in the language that growers understand.

Proposition 12: SCFs are not flexible enough to provide for the different needs and preferences of growers from different industries

Some see that there is a benefit from having SCFs individualised so that they are much more specific to certain industries and places:

> *We need to have SCFs customised for different industries and different purposes and obviously by different regions. How small a region you can go to depends on the granularity of the forecast.* (S4)

However, another interviewee suggested that it would be too problematic to have SCFs suited to all industries:

> *It's just a Pandora's Box trying to match everyone. If you know what you're looking for it's there. Being motivated and prepared to do it is another thing.* (D3)

Not having SCFs designed for particular industries may not stop growers using them, but industry-specific design could make it easier for them:

> *Producers definitely do want a forecast that's either laid out differently or easier to read but I don't see that as being a huge barrier.* (M2)

Having industry-specific information may be needed more by some industries, but most can work with the information that is currently available:

> *There might be specific industries like horticulture that might need a specific forecast around chill index, which could be developed specifically for them. But in terms of rainfall and temperature information there's a lot of information now available on multi-week to seasonal forecasts which are relevant to a lot of industry decisions.* (S1)

Finding – SCFs are currently not flexible enough to provide for all of the different needs and preferences of growers from different industries. However, that doesn't stop growers from using SCFs, industry-specific design would just make it easier for growers to use them. While it may be desirable the use of SCFs may not change substantially if they were more specific to the needs and preferences of growers.

Proposition 13: SCF outputs have not been translated into agricultural information very effectively

Growers want to know what the SCF outputs mean to them and their businesses:

> *What does it actually mean for me on my place and how do I integrate that into particular decisions? What does more rainfall mean in our context for pasture growth and what does that mean for live weight gain and so on. Given that I've got this forecast, what decisions does it apply to, and how do I actually adjust my decision-making to what the forecast is saying?* (M1)

Practical examples of how SCFs can be used are useful for growers:

> *We've had a few meetings where you get blank looks and not a lot of engagement until you put a practical example through it. Maybe that point is about being able to work with the farmer to show that forecast would make a difference to them. Leading farmers are always going to be able to interpret it, but for most of the farmers, it's really more the consultants that would be able to translate that information. It's not the BoM that can translate that into agricultural information, but consultants.* (D1)

One grower reinforced the limitations of other growers in their industry:

> *The highly educated growers you can count on your hand. Fellows that go to grade 10, that's what makes a farmer, a good hard worker and not a lot of brain. It's not communicated in such a way that those growers can understand it.* (S3)

The result from not communicating the limitations of SCFs effectively is that a large problem exists with SCFs being provided to some growers at times when they shouldn’t be used:

> *They make decisions at the wrong time of the year when the models have poor skill, they don't understand that the model's saying something, but it's at the time of the year when it's only ever been a flip of the coin. They get it wrong just as many times as right.* (G1)

Finding – The communication of SCF outputs is the communication of a climate prediction, it doesn't tell growers what to do. For some this communication is unsatisfactory; it is communicating concepts that they do not understand. The use of SCFs could be improved if information about the forecast skill was communicated well enough for growers to understand the constraints that they face when they use SCFs.

Proposition 14: The connection of SCFs to weather forecasts is not seamless

One interviewee suggested that making SCFs seamless with weather forecasts would be beneficial:

> *I don't think they separate the two... this is a short-term climate forecast versus this is the weather forecast. I think it's in our own interest to make them seamless.* (D1)

One interviewee pointed out that they are very different tools:

> *You're talking two completely different models. And the weather is not the climate, and the climate model is pathetic at modelling weather. Sometimes you get years where there's a disconnection between the climate forecasts, the climate forecast is saying it should be raining or at least it should be raining normally, and the weather is dry, and the forecast says it's going to be dry. They're looking at different things, at different resolutions.* (G1)

Even though there are two different forecasting models there are attempts to make them seamless:

> *Historically the only seasonal climate forecasts you could get was for three months. Now FWFA and the Bureau are trying to make a seamless forecast for the next day, two days, next week, the week after, the fortnight after that... the month... month one, month two, month three... the next three months and then another outlook for three months beyond those three months. There's lots of scope for use of this range of different multi-week to month seasonal forecasts that give people capacity to make decisions in a longer time frame. But you've got to match those SCFs with their skill.* (S1)

Finding – Growers mostly would understand that SCFs are different from weather forecasts and that they are different tools. The BoM is attempting to make them seamless, although for growers it doesn't appear that there is a substantial issue with the two tools being independent of each other. It is unlikely that the use of SCFs by growers would be substantially improved if they were seamless.

Proposition 15: The benefits from the use of SCFs are not experienced consistently year after year which means that evaluation by growers for trialling purposes is difficult

It is only in some years that the SCFs can provide information that can be acted on to provide benefits to users:

> *You might only expect an El Nino and a La Nina every 4-5 years, there is a climate driver that's been active in the majority of years, it's way more than probably 7/10 or 8/10. There's been very few years where there's nothing going on. But if you're only looking at El Nino and La Nina, you'd say there was lots of years where there's nothing going on. The reality is that they're sitting on the fence a lot, well you just don't look at them.* (G1)

Added to the variation from climate drivers is the variation from different models:

> *How confident they are in the forecast goes a long way to helping people understand how they should approach it. It seems like it doesn't matter what weather models you look at;*

> *sometimes different models are more accurate. Just understanding that that does happen, that's just weather events or periods of weather that some models align more closely to than others.* (D3)

An interviewee reminded that:

> *That's just part of the probabilistic nature of the forecasts, it's important to understand that.* (M1)

The consistency of SCF outputs can only be judged in hindsight:

> *If things were consistently wrong or consistently right or consistently sat on the fence, then you would have some consistency, but when the problem is some years they're absolutely right and you just don't know whether this year's the one. And it's only in hindsight you can say that model was right, and I chose to ignore it this year.* (G1)

It may be that some users have unrealistic expectations of SCFs:

> *I think that that's more of a communication issue and that they're not understanding what benefit they did derive when they used it. Or perhaps they were looking for benefits that were never going to exist.* (S4)

Finding – The information that SCFs provide does not need to be acted on each year. (Australia has strong climate drivers in only about half the years). The years when the information provided by SCFs can be acted on occur irregularly which means that growers' opportunities for evaluating the use of SCFs are also irregular. Growers' use of SCFs might be improved if they understood that SCFs are best evaluated in the years that they provide information that can be acted on.

Proposition 16: Growers have low awareness of the benefits from the use of SCFs and how they could use them in farm management decisions

Growers' low awareness of benefits may simply be because there are low levels of benefits to be obtained:

> *I think they are well aware that if these models were any good, and were telling them something good, they would use them. I think they would know how to use them. The problem is they're perhaps using them where they shouldn't be and they're using them more than they should.* (G1)

The potentially low awareness among growers that SCFs exist may be due to the amount of extension effort:

> *You can have the best toolbox in the world, but if you don't know where to find it, you're stuffed. BoM are often very limited in what they can do in extension, and they rely on the Department of Ag and consultants and stuff to alert people to the fact that these things exist. It could be overcome with some communication and short videos and capacity building for advisors on how to use and interpret the seasonal forecast tools.* (D2)

Finding – Rather than thinking that all growers have a low awareness of the benefits from the use of SCFs it might be more correct to think that some have a perception that SCFs do not offer substantial benefits for them. In the cases where SCFs can offer substantial benefits their use could be improved by making growers more aware of their benefits.

Proposition 17: Growers have a limited number of people (including their own trusted advisers) who can explain the use of SCFs.

Some industries have had more experience with SCFs and provide better advice to new users:

> *I'd say in the grains industry we're probably doing better than a lot of others. We've had people banging on this stuff for 20 or 30 years. There are trusted advisors who understand this stuff perhaps better than some other industries.* (G1)

Consultants can have a role to play in explaining the use of SCFs:

> *This is where the upgrade of knowledge should be in the dairy industry. Most dairy farmers have a consultant, so would we do better explaining probabilities to consultants than to dairy farmers? Just go to the consultants and you'd get them.* (D1)

But consultants may need to be upskilled so that they are able to provide satisfactory advice about SCFs:

> *Many people, even advisors share growers' scepticism [about SCFs] and they don't understand probabilities either. There's a problem there*. (S1)

Even though the BoM's role is not extension, they have provided useful information about SCFs:

> *I have seen some better communication from BoM as well in that place. It's just a matter of them being connected to that message. Some of the videos and stuff that BoM has done on Twitter and social media are very interesting.* (G5)

Some industries are less likely than others to rely on outside advice:

> *Cane farmers have never trusted advisors, and they'll make their decisions on their own, generally. We barely use them; all we use them for is variety of cane and weed ID and how to kill it. That's the main thing your advisors will do. They don't do it on weather, they don't do it on soil moisture, nothing like that.* (S3)

Finding – Whether growers have access to people and trusted advisors that can help them with SCFs may depend on the industry that they come from. Advisors who are knowledgeable about SCFs, are likely to play a large role in helping growers understand and use SCFs. The use of SCF's may be improved if advisors from industries and regions that could benefit from the use of SCFs were able to advise their clients about their use. (GRDC are funding 'train the trainer' projects to work with agronomists to achieve these aims).

Proposition 18: Growers do not understand the concepts underpinning SCFs such as deciles, probabilities, and what shifts in probabilities mean[4]

The concepts underpinning SCFs are not familiar to all growers. They are not things that they regularly use:

> *When you go out to the average farmer and you talk deciles, quintiles, probabilities, they glaze over very quickly. I think you'll find a correlation between those advisors, consultants, and researchers that have been more in-depth with this type of work, that think that*

[4] For some growers with infrequent use of SCFs there is likely to be a lag in their awareness of improvements made by the FWFA project. Growers' understanding of the probability of forecasts is expected to improve as probability ranges are now shown rather than just a measure that is above and below the median.

> *terminology is okay and the less they've been engaged, the more they think it's completely confusing to farmers.* (D1)

The concepts underpinning SCFs are often not understood by growers in a way that helps them to use SCFs:

> *One of the biggest barriers is definitely understanding deciles, probabilities and what it all means. That's something that took me a while to get my head around it. It just takes a bit to shift your brain around in looking at it. I'm just a producer, I don't have a degree in anything. Sometimes I think there's a simpler approach to take it back to the basics that they need to know and what is helpful information and what's not helpful information.* (M6)

The problem with not understanding the concepts underpinning SCFs is that it affects how users evaluate the value of SCFs:

> *…leads to misinterpretation and thinking that the forecast is wrong, when actually it was right. Then they don't want to use it because they thought it was wrong. With a bit of education, it's easy to overcome, but we just need that educational component.* (M2)

The answer to the poor understanding of the concepts underpinning SCFs could be to normalise their use:

> Deciles is a good example. People throw their hands up in the air and go what does that *mean? It's one of those things, the more people are using it, the more it becomes part of the way you think, and the more people are exposed to it. It just becomes what everyone is used to.* (D3)

Perhaps they could just be explained differently:

> *Just giving a percentile, as a percentage of chance is really helpful, because it then says it's not fixed. We know that if there's a 75% chance of a wetter period for the next three months, then there's 25% chance that it's not going to be wetter. Once we really understood how percentages worked, it was very easy to understand.* (G2)

However, explaining the concepts may not be sufficient to improve growers' understanding:

> *It's not easy. Once they've been explained some producers have a better understanding of probabilities, while others are still in the dark as they were before you started to introduce the concept. It is possible that producers exist on a continuum, some of them are more engaged and have a capacity to take that in more than others.* (S1)

It may take much more effort focused on growers' ways of learning for them to become familiar with the concepts:

> *There seems to be a prevailing view that we just need to teach farmers what deciles are and get them on board. I wonder if we need to actually insert someone in the middle there that can do a translation of what probabilities mean into language that farmers can just grasp. We've had 20 years of trying to upskill farmers on probabilities and deciles and we still haven't got anywhere. Do we get some social scientists to tell us what the translation should be? What is going to get traction in the terminology that farmers appreciate and I'm not sure it's deciles and probabilities.* (D1)

Finding – Growers may not understand probabilities as well as other concepts such as deciles. Their understanding will vary depending on the industry that they are from. For example, the grains

industry, especially in the south routinely use deciles. Growers need to have an understanding of probabilistic forecasts, the shifting of probabilities and the importance of forecast skill before they can understand how seasonal climate forecasts work. Without this it is difficult for them to evaluate their value. To improve the use of SCFs, these concepts may be able to be explained differently, taking into account the way that growers learn. As more growers use SCFs they will likely become more familiar with the concepts so that they can help each other to learn.

Proposition 19: Growers perceive SCF to be inaccurate (because they are probabilistic, and they have a limited understanding of probabilistic forecasts)

Much of the problem that growers have with SCFs is that they do not understand probabilities:

> *The problem is that's a communication issue because probabilistic forecasts are never wrong. I think for a lot of people, that is confronting information. They perceive them to be inaccurate, even when there's no such thing as an inaccurate probabilistic model. The chances of what occurred were low, it didn't mean they couldn't happen.* (G1)

Incomplete information can also lead growers to think that SCFs are inaccurate:

> *I would like to see, if we know the season's going to be a La Nina, how that shifts the probabilities. I don't think we communicate probabilities well once we know there's an underlying trend. So, once we know we've got a La Nina, is this a strong La Nina? is this a weak La Nina? I think there's opportunity there to better understand probabilities within the seasonal forecast.* (G5)

Probabilistic forecasts use concepts that growers do not use routinely which therefore makes it difficult for them to easily understand them:

> *They don't understand probabilities, they don't understand that the BoM did say there's a 20% chance you're not going to get that rain. And when that happens, they perceive the BoM to be inaccurate. Their tolerance, because of the lack of understanding probabilities is a problem*. (D1)

But some growers do understand probabilistic forecasts:

> *The ones who understand how to interpret probabilities are much more comfortable using them, because they understand, well if it's 70%, if I'm falling into the 70% bracket then I'm more comfortable with that and I understand 30% of the time I get a different result. I'll get that and move on.* (S1)

Finding – Growers' generally poor understanding of the concepts that underpin SCFs such as probabilities makes it difficult for them to easily understand SCFs. When outcomes come from the less likely part of the range of all possible outcomes, growers see them as being inaccurate even though they were always a possible outcome. Growers' use of SCFs may be improved if they were to understand more about probabilities so that they did not mistake a less likely outcome for an inaccurate outcome.

Proposition 20: Growers who want to use probabilistic climate information may be uncertain about what the next step is after gaining information about SCFs

Knowing what the next steps to be taken after getting a seasonal climate forecast could rely on…

> *… having somebody around who can tell them how to apply it and if there isn't that person then that would definitely be a barrier, because it's not intuitive.* (M2)

Advisors can be critical to a grower for identifying the actions that can be taken after an SCF forecast:

> *In the dairy industry, that is a conversation they would be having with their consultant. That's pretty critical, because you can get the forecast, but what do you do with that knowledge? Often, they don't see the opportunity, because they haven't had a conversation about what that forecast would mean.* (D1)

The information provided by an SCF may need to be interpreted so that the impact on the growers' farm is understood:

> *When you get told that there's a doubling of the odds that it might be wetter this year, the next question is, what does that really mean? How much wetter? Significantly wetter? I think that's where the FWFA project is trying to put information out so if we're actually talking about a 50% chance it will be 9/10, rather than just a 60% chance of it being higher than the median, which probably hasn't been greatly useful information over time.* (G1)

An interviewee provided an example of the problem that growers could face from an SCF:

> *I went to the seasonal climate forecast, and it said there was a 4/10 chance that it might be wetter, but there's a 2/10 chance it could be drier and a 4/10 chance that it might be normal, and I don't know what to do with that.* (G1)

Finding - The information that comes from an SCF is one part of the process. For it to be useful, it needs to be understood in relation to the grower's farm. How this happens may need the services of an advisor.

Proposition 21: SCFs are probabilistic forecasts when growers are likely to be more comfortable with deterministic forecasts

Probabilities are not explicitly used by growers:

> *When people are making decisions, they're not saying what's the chance that the price of hay is going to go up in the next two months. At least the seasonal climate forecasts actually give you the odds. You may not choose to look at them, you may not understand what they're saying, but they exist. People don't talk about probabilities for their decisions. They're looking for more deterministic things about yes, no. Will it be wetter, will it be drier, do this, do that?* (G1)

Some interviewees would give up on the idea of using probabilistic forecasts with growers:

> *Deterministic forecasts are far more palatable to the audience we're trying to get through to. Probabilistic forecasts will sit behind the scenes so that if the consultant wants probability information they can get it, but the farmer's not going to be that keen on that.* (D1)

Presenting probabilistic and deterministic forecasts together has advantages and disadvantages:

> *When you're given more information not everyone makes a better decision. I want to see both, because they both tell you different things, the deterministic and the probabilistic*

> *forecast, but I know that everyone would rather a deterministic forecast, that it's easier to digest. Even if it might not be as useful.* (G1)

Finding - Probabilistic forecasts are difficult for growers (and sometimes their advisors) to understand. This is because they are unlikely to use them in their day-to-day activities. A deterministic forecast that gives the grower perceived certainty (even though it doesn't exist) could be more suitable for many. The use of SCFs may be improved if they were presented as deterministic forecasts, but this might just result in a different set of problems.

Proposition 22: The psychological cost for growers of making a wrong decision based on using SCF outputs may be more than the forgone profit from not using them

This proposition assumes that growers make a decision solely based on the SCF information, but if SCFs are used as one tool among a number they are not likely to be blamed for decisions that turn out unfavourably:

> *It feeds into the whole knowing how to understand that it is a guidance tool, all you're doing is slanting your decisions over time in your favour as opposed to making the right decision all the time, every time.* (D3)

The psychological effects of a wrong decision made using SCF outputs vary according to the implications of the decisions:

> *It would depend on the decision and the magnitude of the decision, but if they really stuff something up, they would not use them again.* (M2)

It is unlikely that the use of SCFs is restrained by growers' avoidance of the psychological cost from poor decisions because:

> *They wouldn't run totally off the forecast. It's just one of the many tools they would use, including the next-door neighbour.* (S3)

Finding - The psychological cost of making a wrong decision following the use of an SCF may not occur because SCFs are not likely to be used solely by themselves to inform a climate-sensitive decision. This is likely to mean that any potential regret from a wrong decision will not be easily apportioned to any tool in particular. It is unlikely to be a barrier to the use of SCFs.

Proposition 23: Growers remember when SCFs get it wrong more than when they get it right

The problem with growers tending to remember when SCFs are wrong rather than when they are right is that it becomes a part of their learning. If they act as a result of the SCF output which turns out "wrong" it will be seen as a mistake, and the learning from the perceived mistake is to not do it again:

> *The growers I speak to about BoM predictions can tell you when they got it wrong. But they won't acknowledge all the times they got it right, because that just fitted with their mental model anyway. They don't credit the BoM with getting it right, because they think they should have got it right. They're kind of damned if they do damned if they don't.* (D1)

A grower's mindset may have a lot to do with whether they apportion praise or blame:

> *If they're a skeptic to start with they'll always look at the negative side first, if they are more of an optimist, they'll always see value out of it and understand the risks around it.* (S4)

Some of the grower's perceptions of SCFs getting it "wrong" may be based on different less skilful models:

> *In under four years we've had POAMA, ACCESS 1 and now ACCESS 2. We're now looking at a model that's got twice the skill for predicting for Victoria than the old one did. But we're just lumping it in with our experience for the last 15 years of it being useless and wrong most of the time.* (G1)

Finding - Probability forecasts such as SCFs by their nature are never wrong but they are more skilful at various times of the year. A grower may act on a forecast at one of these times of the year and get a poor result. This is likely to add to the reputation of SCFs. The use of SCFs may be able to be improved if growers understood probabilistic forecasts better and the challenges involve in providing them.

Proposition 24: Decisions about climate are only one among many that growers need to make

For some growers in the sugar industry using an SCF to inform their decision-making may be a low priority, compared to the other decisions that they need to make

> *We get hung up about all the climate stuff and that you must use your climate forecast, but producers are dealing with a multifaceted business operation, dealing with labour issues, bankers, the productivity of their business, profitability, climate's just one element amongst that mix and depending on how much debt they've got, it will impact on their attitude to risk and all the other stuff, it's just one aspect.* (S1)

… from the red meat industry:

> *We have so many things that we have to know about. Our day-to-day life is so busy with having to know how to do stuff, that there's not a lot of space to pick up outside knowledge, particularly if it doesn't have an immediately applicable way of being used. Something that's nice to know, falls off the list because you're so busy with everything you have to do. Just the energy that you need to expend to gain that knowledge, it's hard. There's so much that you have to know just to get by on a day to day.* (M4)

… from dairy:

> *All the things dairy farmers have got to think about, breeding values, fertiliser, soil tests, mastitis testing... you go through all the decisions they make in a day, and you think, that is a pretty impressive skillset on its own, do you now put rainfall probabilities into that as well? When you come in with one point of interest, which is the short-term climate forecast, that's only one of 10 considerations they're making in any one instance.* (D1)

… from grains:

> *Climate is often a very small piece of the puzzle when they believe it to be a bigger piece than it actually is.* (G1)

In any event, climate-sensitive decisions are not, "*separate, independent decisions, they need to be incorporated or integrated".* (S4) The decisions are:

> *Never about just one thing, it's not just about the climate, it's about how much feed you've got, what's the condition of the stock, are the markets good? Are you going to get a good*

> *price for those sorts of things, whether they've got a repayment on their loan? All those things are really important.* (M1)

For some, SCFs will only provide a small amount of decision support if at all:

> *We've explored them and really thought through how we might use them. I don't know if there's a decision on the farm that would hang on any of these tools, but it's more the bigger-picture strategic planning of things like will we resow in the spring or will we resow in the autumn.* (D2)

Sometimes, the decisions that SCFs can contribute to need to be made anyway despite any potential SCF contribution:

> *Most of the time I'm struggling to find decisions that are actually going to have [a need for a seasonal climate forecast] there are a few, but most of the time the decisions are strategic and are just done, because we have to do them, regardless of the seasonal forecast.* (M5)

Finding - Growers are often working in complicated farming systems where many interrelated decisions are being made. SCFs will not have a lot to offer for many of these decisions. The use of SCFs may be able to be improved if growers were provided with examples relevant to their own circumstances demonstrating how SCFs can be used effectively.

Proposition 25: Growers (and their advisors) may not have the resources to invest time in developing an understanding of SCFs

SCFs need an investment in time before users can become familiar with them:

> *The climate stuff is not intuitive and not easy to really understand it. You can't just look at it once and be like, "yep, got it". It takes time and most people don't have the time.* (M2)

The difficulty with SCFs is not only that time is needed to understand them, but it is also about knowing what to do once the information is gained:

> *They don't have the time to invest and do the interpretation and then the integration. They've got to decipher all of that information, well what does it mean for me? And then it's how do I factor it into my decision-making. Then it becomes too hard and an increasingly difficult decision.* (S4)

Understandably growers rely on advisors for recommendations:

> *A lot of growers perhaps go, 'this is too hard', and they hope that their advisor has the resources. And it's like a lot of things, whether it be for chemical usage or rotations or variety choice, a lot of farmers go, 'it's all too hard, I trust my advisor to keep on top of this'.* (G1)

Advisors are likely to have built up their knowledge of SCFs if they have recognised a demand for them:

> *A lot of advisors I think have wanted to get on top of seasonal climate forecasts, because it's always a topic of discussion and I think they believe they owe it to themselves and their clients to be providing the best information available. I think in grains our advisors have probably decided to do that. They've realised its importance.* (G1)

Advisors are also likely to be situating their advice about SCFs in with the other decisions that might need to be made on the farm:

> *I'm not sure dairy farmers have the resources and time to invest in improving their understanding of probabilities. I wouldn't be surprised if the dairy farm consultants weren't in some way across probabilistic forecasts. They would be looking at soil moisture coupled with pasture growth conditions and short-term forecasts would all be factored in.* (D1)

Finding – SCFs are difficult for growers to grasp, it takes them time to become familiar with them, and it may be better that their advisors provide the needed support instead. The advantage of this is that advisors can see how the SCFs can fit in with everything else that is happening in their business. The use of SCFs may be improved if advisors take a greater in helping growers to understand how they might fit with the decisions that they need to make in their business.

The BoM and its website

The BoM and its website were not initially identified as a potential barrier to the use of SCFs. However, there was enough discussion in the interviews that it needed to be included in this report.

> *You'll always get farmers whinging about the accuracy of the BoM, I think they do a bloody amazing job in terms of accuracy with the science they've got available to them. There will always be people that will criticise, it's a day-to-day conversation with certain people.* (D2)

There is an interesting tension between growers supporting and criticising the BoM:

> *I'm a big fan of BoM I think they're great. It's just the way that some of this information is presented. Once people think they've got the forecast wrong they don't have much faith in it. Their website's a nightmare, trying to find anything on it.* (M4)

Not being able to easily access climate information is a barrier to its use:

> *To access this information on the Bureau website, it's still problematic, it's not necessarily intuitive. I'm quite familiar with this stuff and even I get lost, I go down the wrong rabbit hole when I'm trying to get to the climate extremes page website. If it's not easy to find, it's not mobile accessible and friendly, then people won't go there and won't access it.* (S1)

Similarly, the critics of the BoM are also using the information supplied by them:

> *It's almost an Australian sport, bagging the weather bureau. The same people are pretty quick to check what the weather bureau is saying. There's a conflict there I reckon, they say they don't believe it, but they still know what the forecasts are, and they hear when the La Nina is declared.* (D3)

The way that BoM communicates probabilities leads to a lack of understanding among growers:

> *BoM can be their own worst enemy, some of their tools are not well explained. If people look at MetEye and they see the forecast says 80% chance of rain and the rainfalls between 10-20 mls, it's natural and instinctive that it's an 80% chance to get between 10-20 ml. But that's not the case, it's only an 80% chance you're going to get anything, 50% chance of 10 mls and a 25% chance of 20 mls, which is a very different scenario, so if you're only going to get 3 mls, then the bloody BoM got it wrong again.* (M4)

Some see that farmers need to take responsibility for their use of SCFs:

> *Farmers need to understand that it's their farm and they've got to take ownership of the management. The bureau and the forecaster are providing information that you can use, and*

> *they've got to make a decision how you use it, instead of taking the lazy route and saying oh they didn't say this exactly.* (D3)

Finding - Some growers have a fraught relationship with the BoM. They recognise the skill of the people involved but they are critical of how the organisation communicates with growers, especially when that communication is about probabilities. Some suggest that advisors may need to take a greater role to remedy some of the communication problems, but they may also be caught up with issues of communication as well. It seems that some of the strongest supporters of the BoM are also quite vocal critics of its communication approach. The use of SCFs may be improved if growers were helped to understand how to navigate the BoM website and some of the quirks with how the BoM communicates.

5. Discussion

This study examined how stakeholders and key informants from the five agricultural industries, red meat, grains, dairy, sugar, and winegrapes perceive the barriers to the use of SCFs identified in the literature and found in the reports from the FWFA project.

Some of the barriers identified from the literature (see Table 1) have been addressed[5], and continue to be addressed by improvements made by FWFA and the Bureau of Meteorology.

This study has shown that although SCF acceptance and use varies somewhat among the stakeholders of the different regions and industries most of the issues about SCFs are similar between the regions and industries.

A critical way to evaluate the accuracy of SCFs is by using the forecast skill level, which growers may not always be aware of. This is relevant because, depending on the grower's location and industry, there are times of the year when the forecasts are of low skill, and they should not be used.

This study has found that growers mostly do not understand the nature of probabilistic forecasts. They may not understand that the forecasts have a range of possible outcomes, and when the less likely of the potential SCF outlooks occur, the forecast is not inaccurate. If growers understood the probabilistic nature of SCFs better, they would be likely to have more confidence in the SCF outlooks. However, it is not surprising that they often don't understand probabilistic forecasts because even though they are making decisions about risk all the time, the tools that they use to assist with these decisions are different to SCFs. This is important because some of the problems that growers have with understanding SCF outputs is that it relies on knowledge that is not routinely used in their activities. Growers often have some understanding of how climate drivers influence the forecast, but they do not understand so well the probabilistic nature of the forecast. Their knowledge about SCFs varies across regions and industries. For example, those in the grains industry are mostly very familiar with deciles, while others are less so.

SCFs may not be useful for all growers because, even though growers make many decisions, it may be that few of the decisions that they make will benefit from the input of SCFs. Growers are critical of how SCFs are communicated in a technical way that does not fit with the language that they are familiar with. It can also be that they have the forecast output and know what it means, but they do not know what to do with it and whether there is any benefit from taking any action. In these cases, growers could benefit from the support of advisors who could situate the forecasts in the growers' context so they know when, and how they could use them to the best advantage.

This study was designed to identify individual barriers to growers' use of SCF and then propose bridges to overcome the barrier and encourage more informed use of SCFs (see Tables 3 and 4). The bridges span the gap between the grower's perceptions of what SCFs are, what they can be used for and when they can be used, and the characteristics of SCFs which determine what they can be used for and when they can be used.

[5] In some case the interviewees may have been unaware of recent changes that had been made to SCFs, so were being critical of problems that had already been solved.

Table 3:Responses to propositions and potential actions (1. Characteristics of SCFs).

	Proposition (Perceived barrier)	Perceived importance[6]	Bridge
Accuracy	1. SCF have limited skill (accuracy).	Important	Explain forecast skill in a way that growers and others can easily understand.
	2. SCF skill is not uniform through the year (and poor when needed most).	Important	Explain forecast skill in a way that growers and others can easily understand.
	3. SCFs that fail in the first few times they are used will delay or block adoption.	Important	Explain that probabilistic forecasts that are perceived to have failed are just because of the less likely outcome occurring.
Relevance	4. SCFs do not take into account growers' history and experience of the climate	Negligible importance	-
	5. Spatial precision of SCFs is too broad so that it has limited relevance to the grower's location.	Negligible importance	-
	6. SCFs are only relevant to a limited range of growers' decisions.	Important	Provide basic information on the relevance and usefulness of SCFs for growers' climate-sensitive decisions.
	7. The lead time of SCFs do not match lead times for some agricultural activities.	Important	Growers need to recognise that there is a trade-off between lead time and forecast skill.
Communication	8. SCFs provide vague, indefinite forecasts when growers are wanting definite, consequential forecasts.	Moderately important	Explain that probabilistic forecasts such as SCFs are best used as a guide.
	9. A focus on climate drivers has captured grower's attention at the expense of their better understanding of probabilistic forecasts.	Negligible importance	-
	10. SCFs are not communicated in such a way that growers can effectively understand their value.	Important	Develop communication suited to growers with their assistance.
	11. The language used in SCFs to communicate uncertainty may not match the language used by growers.	Important	Develop communication suited to growers with their assistance.
	12. SCFs are not flexible enough to provide for the different needs and preferences of growers from different industries.	Negligible importance	-
	13. SCF outputs have not been translated into agricultural information very effectively.	Important	Provide information on the relevance and usefulness of SCFs for growers' climate-sensitive decisions.
Co nsi	14. The connection of SCFs to weather forecasts is not seamless.	Negligible importance	-

[6] This is not a quantitative ranking but rather a judgement of the importance of the proposition for influencing the use of SCFs derived from the analysis of the interviews.

	15. The benefits from the use of SCFs are not experienced consistently year after year which means that evaluation by growers for trialling purposes is difficult .	Important	Increase awareness among growers and others, that due to climate drivers not providing strong signals in some years the forecast will be no better than referring to averages.

Barriers to the use of SCFs are likely to be unique to the industry, the individual producer, and the climate-sensitive decision that is being considered, which means that the bridges (or package of bridges) encouraging the informed use of SCFs are also likely to be similarly unique.

Some of the barriers to the use of SCFs are cumulative in their effect, so they may only add another small reason for not using SCFs, while others are more definitive.

Table 4: Responses to propositions and potential actions (2. Characteristics of SCF users).

	Proposition (Perceived barrier)	Perceived importance	Bridge
Knowledge	16. Growers have low awareness of the benefits and how they could use them in farm management decisions.	Variable importance	Provide examples to growers and others of when SCFs can have benefits to their decisions.
	17. Limited number of people (including their own trusted advisers) who can explain the use of SCFs.	Variable importance	Encourage advisors to upskill with information about SCFs that is useful to growers.
	18. Growers do not understand the concepts underpinning SCFs such as deciles, probabilities, and what shifts in probabilities mean.	Important	Explain to growers SCF what deciles, probabilities, and what shifts in probabilities mean in language and settings that suit their learning styles.
	19. Growers perceive SCF to be inaccurate (because they are probabilistic, and they have a limited understanding of probabilistic forecasts).	Important	Explain to growers the probabilistic nature of SCFs in ways that they can relate to their own experience.
	20. Growers who want to use probabilistic climate information may be uncertain about what the next step is after gaining information about SCFs.	Important	Encourage advisors to upskill so that they can incorporate SCF information into farmers' decisions.
Attitude	21. SCFs are probabilistic forecasts when growers are likely to be more comfortable with deterministic forecasts.	Important	Explain to growers the probabilistic nature of SCFs in ways that they can become more familiar with the concept.
	22. The psychological cost for growers of making a wrong decision based on using SCF outputs may be more than the forgone profit from not using them.	Negligible importance	-

	23. Growers remember when SCFs get it wrong more than when they get it right.	Important	Explain to growers that probabilistic forecasts are always correct and that the less likely outcomes will occur at times.
Capacity	24. Decisions about climate are only one among many that growers need to make.	Important	This is not just a perception. Growers need to make many different decisions and decisions that can benefit from being informed by SCFs may not be very common or important. This does not require a response.
	25. Growers (and their advisors) may not have the resources to invest time in developing an understanding of SCFs	Important	If it is easy for advisors to upskill so that they incorporate SCFs into their services, and there is a demand for that knowledge, they will.

If the aim was to have SCFs used to the greatest extent, the communication used for presenting the results would be designed with users' involvement so that SCFs more closely represent what users want from them and how they prefer to access them. One of the likely reasons that this does not occur is that the worlds of the weather forecaster and the farmer are different. They have different goals, one being the provision of the SCF and the other being the use of the SCF. It may be that the onus is on growers to adjust rather than the forecasters. This is because what might appear to the grower as a simple input-output model for the transfer of knowledge is likely to be much more complicated with the forecasters having many more people involved, and more strong ideas of what the best practice in communication of SCFs is from their knowledge and experience (Dawson 1997). The farmer is only one of several consumers of SCFs and may not be the most important.

Australia’s large size and varied climate mean that different regions and their unique mix of agricultural industries will have different climate-sensitive decisions that farmers need to make and that they may not always occur at the time when the SCFs have the best skill. In some areas, there are not many decisions that can benefit from the use of an SCF because the forecasts are just not good enough when they are needed the most.

The next part of this discussion focuses on the steps to the adoption of SCFs and the barriers to their use (see Table 5) that interviewees identified as important (see Table 3 and 4). The barriers are grouped according to where they occur in the steps to use of SCFs.

The process of the grower deciding to use SCFs can be seen as having five steps. It starts with (1) outputs of climate models as basic ensemble forecasts and then moves through to (2) design of the forecasts, then (3) communication of the forecast, (4) growers’ comprehension following the communication, and finally (5) growers’ evaluation of whether they should use them.

Each of these steps includes barriers that impact the likelihood of the use of SCFs. The first step which is the outputs of the climate models as an ensemble forecast has the fixed characteristics of probability and skill. The factors that impact users’ choice of whether to use them or not, are that they are perceived as having limited skill, the skill is not uniform, the benefits from using the forecasts are not consistent, and longer lead times reduce forecast skill.

The second step in the pathway to use is the design of the forecast products. This is where there are more choices, and these include how the forecasts will be presented to potential users.

Table 5: Steps to use of SCFs and barriers to use

Steps to adoption	1. Outputs of climate models as ensemble forecast	2. Design of forecast products	3. Communication	4. Comprehension	5. Evaluation	Use of SCFs
Key issues of each step	Mostly fixed SCF characteristics (probabilities & skill)	Design of changeable characteristics of SCFs	Communication of probabilities & skill	Growers' comprehension of probabilities & skill	Influence of probabilities & skill on growers' evaluation of SCFs	
Barriers to SCF adoption	• Limited skill • Skill not uniform • Inconsistent benefits • Unsuitable lead times		• Not in growers' 'language'	• Growers not aware of SCF benefits • Probability & skill not understood • Perceptions of SCF inaccuracy • SCFs are probabilistic not deterministic	• SCFs relevance limited • One among many decisions • Growers remember SCF failures not wins • Unsure what to do with SCF information • Don't have time to learn about SCFs	

The third step is the communication of the SCFs. This is mostly about the communication of probabilities and skill, and how effective that communication is. A barrier to that communication can be that it is not in the growers' language. When growers suggest this, a part of what they are referring to may be that it doesn't fit with their communication style. This means that it is different to the way they communicate with other farmers, their agronomists, and others. The other part of this barrier is that SCFs are communicated in language that is different to the language of the other websites that growers visit. This is what Jakob Nielsen alludes to with his "Jakob's Law of Internet User Experience" which states, "Users spend most of their time on other sites. This means that users prefer your site to work the same way as all the other sites they already know. Design for patterns to which users are accustomed". The rule is, of course, related to website usability but the concept also has a lot to offer for general communication around unfamiliar topics.

The fourth step in the pathway leading to use is comprehension and the key issue for this step is whether growers have sufficient understanding of the probabilities and skill of SCFs. There is a range of specific barriers. These are that growers may be aware of the existence of SCFs but not aware of the benefits gained from the use of SCFs. Also, the probabilistic nature and skill of SCFs may not be understood. In addition, growers may have perceptions of SCFs inaccuracy which likely results from their lack of understanding of probabilities and skill. The last barrier is that SCFs are probabilistic while growers would prefer deterministic forecasts.

The last step before the decision to use SCFs is evaluation. Among other things, this is where the influence of probabilities and skill can affect growers' evaluation of SCFs. The barriers that they experience are that SCFs may have limited relevance, the information that SCFs provide feeds into decisions that are one among many that growers need to consider, and they may not be the most important decision. Another barrier is that growers remember when SCFs fail but they don't remember when they have succeeded. The understanding of failure or success is more about the forecast not turning out the way they had hoped for. Growers may be unsure about what to do with SCF information which is why intermediaries such as their agronomists have a large role to play in this space. Importantly growers may not have the time to commit to learning about SCFs and this may also apply to their advisors.

This next section is about the bridges to the use of SCFs and the stakeholders that are influential in each of the steps on the path to SCF use (see Table 6). The first step is the outputs of climate models as ensemble forecasts have some influence from BoM. Because the barriers to adoption are relatively fixed characteristics the thing that might be the most easily changed is growers' understanding of these characteristics which is often low.

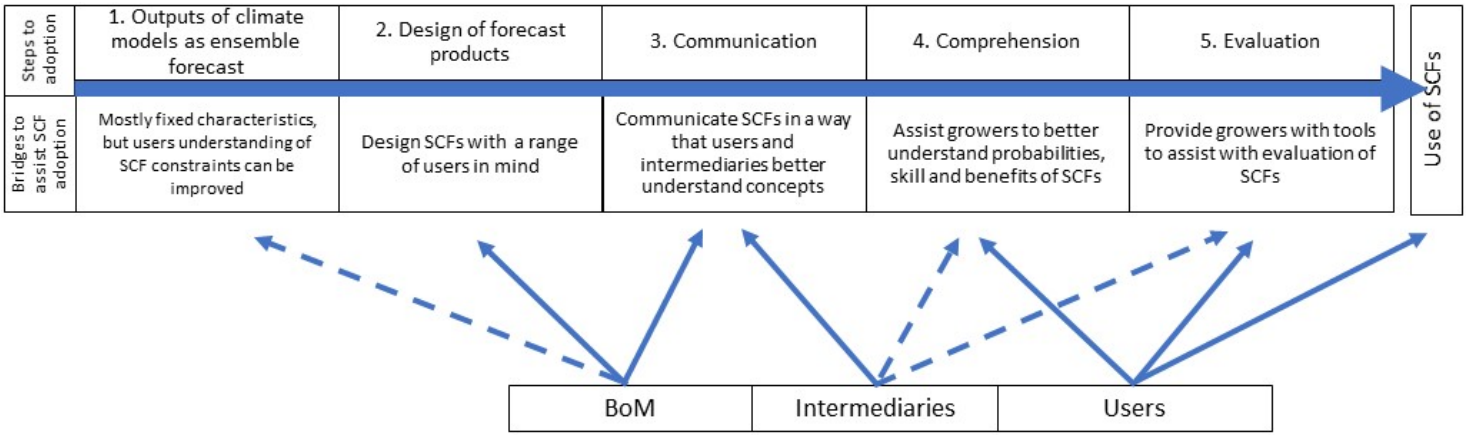
The next step is the design of the forecast products, and this is where BoM has a large role to play. SCFs could be improved if they were designed with a range of users in mind.

The enabling bridge of the third step is that SCFs need to be communicated in a way that assists growers and intermediaries in better understanding the concepts, which are that they are probabilistic and that they have the added overlay of skill. This bridge can be built through the efforts of the BoM as well as growers' intermediaries.

The fourth step is about comprehension and the bridge that is needed here is assistance for growers to better understand probabilities, skill, and the awareness of the benefits that they can obtain from using SCFs. This is where growers need to understand what benefits SCFs are offering, and they may need their intermediaries to help them to achieve this.

The last step is the evaluation of the SCFs. Some growers may be able to do this themselves, but others may need help from their intermediaries, and this is likely to be the provision of tools and the calculations needed to determine whether any of their practices should change. At this point, the grower is likely to have developed a better understanding of SCFs and an awareness of whether they offer sufficient benefits to them. They have the information that will allow them to decide whether to use the SCFs or not.

Table 6:Bridges to increased use of SCFs and stakeholders' areas of influence



6. Conclusion

The probabilistic characteristics of SCFs and their use of forecast skill mean that they are not easily understood by most growers, and they need to be communicated to them in a way that assists them in developing a better understanding of them. How and when SCFs can be useful to a grower also needs to be better explained to them, and this may be best done face-to-face and with examples that are relevant to their situation. Intermediaries can play an important part in connecting SCFs and growers in a way that growers understand the value that they can gain from the forecast. Some intermediaries may not have the necessary knowledge to do this at the moment.

To improve the acceptance and use of SCFs, communication should happen in easily understandable language that is grower relevant. Unless SCFs change to be more intuitive, this grower relevant communication may need to be provided by intermediaries. Growers learn about SCFs best by having examples provided, especially when it is face-to-face. Trust and confidence in the person conveying the information will often need to be built before learning begins.

Providing examples of the use of SCFs that are relevant to the grower's situation will give them more confidence in their use. Knowing how to navigate the BoM website so that they can easily find the SCF, and its associated features will also make it easier for growers to use SCFs.

SCFs might be more useful and used appropriately (this could mean more or less use), if growers had greater knowledge about forecast skill, and that there are times of poor forecast skill when SCFs should not be used. If growers knew more about probabilistic forecasts; how they are always accurate, and how the less likely outcome is always possible, they may be less critical of them.

Knowing about probabilities is important but knowing about climate drivers is also important for the confidence that it provides to growers in the models that underpin the SCFs. Growers might use SCFs more if they were aware of the type of decisions that they could use them on, and that often no action may be needed, but in some cases, acting based on an SCF outlook may be very beneficial. It is in these instances that the value of SCFs should be evaluated. Growers need to consider that SCFs are a guide, they are not providing certainty.

6.1 Key findings

This work confirms the findings of Taylor et al (2021) that a large proportion of growers are aware of SCFs, but many have made little use of them beyond their initial engagement.

There are three factors that are influential in encouraging growers more informed use of SCFs. Two are related to the design and communication of the SCF itself, and one is related to growers' understanding of SCFs and their potential benefits.

1. Usable design: SCFs are designed for growers as a result of testing and multiple engagements with agricultural end users.

2. Appropriate communication: SCFs are communicated in such a way that users and intermediaries can more easily understand their underpinning concepts. Concepts of

probabilities, forecast skill level, and that low skill level may mean that at times they should not be used are central to the communication, not footnotes.

3. From awareness to value: Growers are provided with tools to assist with the application of SCF outputs to climate risky decisions so that they can assess the potential benefits in their own situation.

6.2 Benefits to industry

Encouraging the use of SCFs when they have something to offer growers in the various agricultural industries could result in substantial financial gains through increased profitability and reduced risk.

Helping growers to become aware of when not to use SCFs will increase growers' confidence in the SCF results so that they are more likely to use them successfully at times when they have sufficient skill level.

7. Future research and recommendations

The finding that growers' understanding of skill level, deciles, and probabilities is variable, and often low, shows that there is a need for social science research focused on translating what probabilities mean into a language that farmers can grasp. Previous attempts at educating growers about probabilities (and even deciles) have been successful for some, but not all, growers. What needs to be explored is the terminology around the communication of risk, with an emphasis on seasonal climate risk, in a way that growers can understand and appreciate.

The practical application of the results from this project is that they can be used to inform the materials and programs around SCFs and similar tools so that they are more likely to be used by growers.

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4. Appendix – Literature review

4.1.1 The users of SCFs

Growers and SCFs

If growers are to adopt the use of SCFs they need to perceive that the SCFs provide them with a relative advantage over not using them. In other words, they need to gain a net benefit of some sort from their use (Rogers 2003). The main influences on relative advantage, and how that impacts the adoption of agricultural innovations, in general, are described in the ADOPT tool (Kuehne, Llewellyn et al. 2017). Many of those influences fit with what has been identified in the literature review that follows.

Perhaps one of the first things to consider about SCFs is why would growers even use them? For most growers, the main focus of SCFs is on rainfall, and their use of them relies on having clear information provided with a straightforward interpretation so that it can be understood without substantial effort (Taylor 2021). However, not all growers find that SCFs provide the information that is helpful for the decisions that they need to make (Marshall, Gordon et al. 2011). This is because the variables that seasonal climate forecasts focus on may not be the variables that are important to them (Soares and Dessai 2015), and the forecast may not perform for the variables that they are interested in (Dilling and Lemos 2010).

Growers appear to be conservative when making decisions based on seasonal climate forecasts, but this is not always the case because they are focused on managing and making decisions concerning their current situation which they can do more easily, and where they are more sure of affecting profits (Taylor 2021). It is also important for growers that they can take action as a result of using the SCF (Dilling and Lemos 2010, Raftery 2016) and that the forecasts are consequential so that the effort that they need to make in obtaining, understanding, and responding to them can be justified (Rebbeck and Duffield 2008). But this also may be some disincentive to the adoption of SCFs because predictions that can be acted on, may also require that changes that are seen as onerous are made to how things are done in the grower's business (Soares and Dessai 2015).

The potential users of seasonal climate forecasts may not have the skills and knowledge that allow them to take full advantage of the forecasts (Soares and Dessai 2015) and if the forecasts have an added cost to the grower in terms of the effort that they need to put in to using them, or learning about using them, they need to provide sufficient benefits to the grower to justify their continued use. This is an important point because probabilistic forecasts will take time to learn about (Parton, Crean et al. 2019).

One problem is that growers do not perceive seasonal climate forecasts as being reliable (Taylor 2021). This means that they are understanding the probabilistic nature of SCFs as being evidence of inconsistency. This becomes a problem especially when first-time users encounter what they perceive as a less than accurate forecast because they will then be less likely to persist with their use of the forecast (Marshall, Gordon et al. 2011).

What growers need from SCFs

There has been a long history of farmers wanting to know more about the coming season with a number of long-range weather forecasters including Lennox Walker and before him Inigo Jones providing long-range forecasts to farmers. Even though they were unsuccessful as forecasters their popularity demonstrated that Australian farmers saw that there was potentially a lot to be gained from long-range forecasts (Wiesner 1965). Reinforcing the value of long-range forecasts the CSIRO scientist, Priestley (in p.2, Wiesner 1965) suggested that " there are many fields of activity, notably in primary industries where advance decisions have to be made in the light of expectations for the coming season; 'black or white' predictions based on even a small advantage of probability, or shade of odds in betting parlance, must be better than no information at all provided the odds are stated.

Often the research that has been conducted with forecasts and their uncertainty has focused on what shouldn't be done when communicating uncertainty and not so much on what should be done, or how it should be done to match users' needs (National Research Council 2006). This is important because the successful uptake of SCFs will depend at least in some part on the developers of the forecasts recognising users' needs and designing the forecasts with those needs in mind. The participation of growers is essential because the information that scientists think is useful for farmers is unlikely to fully match up with what farmers think is useful (Dilling and Lemos 2010). Understanding users' needs should ideally be incorporated into the process of developing the forecasts (National Research Council 2006). This is now being done as forecast developers are beginning to better understand farmers' decision-making requirements and provide more tailored forecasts that improve the value of SCFs for particular decisions (Klemm and McPherson 2017).

One way that growers are likely to be using SCFs is as an added support for decisions that they were already planning to make. This way of using SCFs is more common than using SCFs for direct decisions (Taylor 2021).

4.1.2 Difficulties with SCFs

Difficult to demonstrate SCF benefits

Part of the difficulty with evaluating SCFs is that making a judgement on a prediction made for one year is not a realistic or a fair way to measure the SCF's performance. This is because the benefits that users gain from the forecast are not experienced consistently year after year, and may not occur in some years at all (Hayman, Crean et al. 2007, Taylor 2021). Due to the variation in benefits that users receive from SCFs, they can only be assessed over the longer term (Terrado, Lledó et al. 2019).

Demonstrating profit from SCFs is challenging

SCFs have the potential to positively impact growers' level of profit, and ability to manage risk; but it is difficult to demonstrate to growers the benefits of using probabilistic weather forecasts because it is challenging to show how they can use them to make a greater profit (Hayman, Crean et al. 2007, Taylor 2021). Some of the challenges come from the broad range of profit outcomes from the use of SCFs in various Australian studies, which leave farmers dealing with a set of confusing and inconclusive messages about how the use of SCFs can impact profitability (Parton, Crean et al. 2019).

SCF skill level is low

If the current level of forecast skill for seasonal climate forecasts was to improve it would be easier to show farmers how they can achieve a benefit from incorporating them into their decision making (Hayman, Crean et al. 2007, Brown, Hochman et al. 2018).

There are spatial and temporal considerations affecting the use of SCFs. For example, SCFs have better levels of skill when they are looking at a wider area than if they are looking at smaller areas, but farmers want the information for the smaller areas (Dilling and Lemos 2010). Also, they have different levels of skill at different times of the year, which means that their usefulness varies through the year (Dilling and Lemos 2010). The result of this is that at some times they shouldn't be used, but at other times when the SCF forecast skill is high and the forecast is more usable a "window of opportunity" can occur where the forecast is much more beneficial (Soares and Dessai 2015).

Forecasts involve uncertainty

Uncertainty in forecasting restricts growers understanding of forecast products (Carr, Montz et al. 2018) but this uncertainty is an integral part of all forecasts and knowing more about it gives growers extra information to reinforce their decision-making related to the forecast (NOAA 2021). However, communicating uncertainty information is not easy to achieve because growers have a limited amount of things they can devote their attention to, and uncertainty information can be a large topic to grasp (Raftery 2016).

An important reason for communicating forecast uncertainty is that it corrects the false impression of certainty that forecasts can give (Carr, Montz et al. 2018). One reason that uncertainty is not more prominent is that by making it, and lack of skill explicit, the developers of forecasts feel that users will lose trust in the forecast (Fischhoff 2012). On the other hand, it may be that probabilistic predictions are trusted more if they also include an estimate of their past accuracy which then becomes a measure of what can be expected of their future performance (Terrado et al. 2019).

4.1.3 Communicating the SCF

General communication problems with SCFs

The problem with the communication of SCFs is that many of the barriers to their use are not directly related to the forecasts themselves but are related to social factors such as ineffective or non-existent communication between the developers and the users of the forecasts which is likely to contribute to a poor understanding of the decision contexts where the SCF outputs are used (Soares and Dessai 2015). Further developments to SCFs should be reviewed by users who ideally should be involved as co-creators (Taylor 2021).

Effective communication is one of the important factors determining how SCFs will be adopted (Davis, Lowe et al. 2016). The information provided by SCFs needs to be presented in an accessible fashion so that the grower can easily obtain the information and understand it (Dilling and Lemos 2010). Growers' judgements about the usefulness of weather forecasts are based on how the characteristics of the forecasts match up with their needs, and how effectively the communication of the information that is needed to evaluate that match-up takes place (Crane, Roncoli et al. 2010). The way that growers prefer to receive their communications about weather forecasts is no different to how they prefer to receive the other information that they use for their business

decision-making. This means that using plain understandable language for communicating the forecast will result in growers making better use of them (Taylor 2021).

While having a high-quality SCF and a good understanding of it is necessary, having the information that matters to them provided in terms that are relevant to the decisions that the grower needs to make on their farm is also important and would assist in their use (Peck, Derner et al. 2019).

Previous research has found that users do not always understand SCFs in the way intended by their developers, but it hasn't found a conclusive way of doing it better (Joslyn and Nichols 2009, Tak, Toet et al. 2015). One of the problems is that the providers of SCFs find it difficult to communicate uncertainty in a way that can be understood by users who may have varying capabilities (Carr, Montz et al. 2018). A way to reduce the cognitive load for users is to summarise and simplify[7], but also allow the forecast user to access more information when they need it (Fundel, Fleischhut et al. 2019). It is also understandable that the people providing the weather forecasts may see their role principally as providing the knowledge, (Dilling and Lemos 2010) and that communicating that knowledge is not an important part of that role.

The problem with communicating probabilistic forecasts

The growth in recognition of the usefulness of probabilistic forecasts for decision-making also brings with it a growing awareness of the difficulty of communicating probabilistic-based information (Carr, Montz et al. 2018). The difficulty in clearly communicating the probabilistic information from an SCF influences how growers can use the information in their decision-making (Hayman, Pearl et al. 2018). One of the core issues appears to be that the developers and promoters of SCFs are familiar and comfortable with the use of probabilities but this is not the case for many growers who may find them difficult to understand (Gill 2008). While growers are familiar with making decisions under uncertainty, these intuitive and familiar farm management decisions are different to the conceptual stretch that they experience when they use probabilistic forecasts (Hayman, Crean et al. 2007).

There is also the problem of the probabilistic forecast predictions being different from deterministic forecast predictions which people are more familiar with. This means that farmers and advisers may choose to ignore chance, and the idea that there is a range of possible forecast outcomes and convert probabilistic forecasts into deterministic forecasts. A more defined prediction rather than a range of predictions fits better with their decision-making. Importantly this also means that they can interpret a result that is within the range of the predicted probabilities as being inaccurate when it is a valid result (Hayman, Crean et al. 2007, Terrado, Lledó et al. 2019).

Explaining SCFs better

Developing one SCF that meets the needs of everyone is difficult because users' needs and situations vary so much (Carr, Montz et al. 2018). Explaining the probabilistic nature of seasonal climate predictions is difficult (Soares and Dessai 2015) and there is no one best way to do it. It depends on the audience, their experience with, and attitudes towards similar forecasts, and the decisions that they are using the forecasts to inform (Fundel, Fleischhut et al. 2019).

An ideal way to work toward the better communication of probabilistic weather forecasts is to:

- Build from what the potential user already knows (Fundel, Fleischhut et al. 2019).

[7]This is the approach that BoM have chosen for their weather forecast app (see: http://www.bom.gov.au/app/).

- Identify the “reference class” which is the class of events that the probability refers to (Gigerenzer, Hertwig et al. 2005).
- Include additional statements that put the prediction in a context by describing how it compares to an average year. Rather than just giving a per cent chance above the median or chance of being in a particular decile also include a statement such as, “this is more than twice the normal chance for this time of the year” (Gill 2008).
- Develop SCFs with a good understanding of the forecast users’ needs and their decision contexts (Soares and Dessai 2015, Carr, Montz et al. 2018).

The language of the forecast

At its core, the problem with an SCF prediction is that the user of it needs to understand it in the same way that the generator of the forecast does (Gill 2008). One important barrier to this happening is when the language that is used in the seasonal climate forecast does not match the language used by farmers (Terrado, Lledó et al. 2019). Forecasters’ attempts to communicate a forecast may be constrained by the inability of our language to unambiguously describe the prediction (Gill 2008). Because there is limited space in an SCF (in the way that they are commonly presented) it means that it is important to get every word right so that they can be understood as intended by users (Gill 2008).

For SCFs to be routinely used by growers the forecasts need to be composed in a way that allows growers to interact with them in the way that they wish (Crane, Roncoli et al. 2010) which could be achieved through a greater engagement and collaboration between scientists, developers, and end-users (Fundel, Fleischhut et al. 2019).

Information sources and advisors

While it is easy to access weather and climate information, it is not so easy to gain a useful interpretation of it. One way is through the use of participatory approaches that encourage learning and build skills (Cliffe, Stone et al. 2016). Growers have different demands on their time, but developing an understanding of SCFs to the point where they feel confident in using them as part of their decision-making may not be the best use of their time (Taylor 2021). The emphasis on growers needing to directly access and understand SCFs may not be so important because SCF information can also be obtained through interactions with other growers, or their advisors, through rural media (Taylor 2021), offline and online social networks, as well as other parts of the grower’s information network. Although this information may not be detailed, in some cases it may be all that the grower wants. The chain from the developer to the user of the climate forecast can be complicated, because of the different relationships between the links in the chain and the different points in the chain where the value that is useful for decision-making is added (Soares and Dessai 2015).

The connection between the developers of SCFs and their users may not occur directly but may instead be through the use of intermediaries who can build bridges between the different paradigms and ways of communicating between both worlds (Klemm and McPherson 2017). An example of this is where local advisors with expertise in climate science and its applications have substantially increased the use of SCFs in decision-making in Australian pastoral areas (Cobon, Jarvis et al. 2021).

Climate drivers and SCFs

Skilful regional climate predictions require that models can represent the connection between climate drivers and regional climate (Hudson, Alves et al. 2017) but explaining how the models work that the seasonal climate forecasts are based on is difficult (Soares and Dessai 2015). Nevertheless, a better understanding of climate drivers has underpinned the increased application of climate science in agricultural decision-making using seasonal climate forecasts (Cobon, Jarvis et al. 2021). A combination of increasing knowledge of climate drivers and the learning gained from a workshop process is suggested as a way to improve growers' abilities in understanding and identifying climate information and how it could be used in farm management decisions (Cliffe, Stone et al. 2016). Others suggest that for the grower, knowing what the SCF means, is more important than having an understanding of the complicated nature of SCFs (Taylor 2021).

The relevance of SCFs

SCFs provide one piece of useful information that is considered along with other pieces of information of varying relevance when growers are making climate-sensitive decisions (Ash, McIntosh et al. 2007, Hayman, Crean et al. 2007). Combined with their other sources of information SCFs give the grower more confidence in making the decision. It is possible that too great an emphasis has been placed on their standalone use, and that the focus may need to shift to seeing them as one component in a package (Taylor 2021). For example, Peck, Derner et al. (2019) suggest that making a climate-informed decision in a grazing context could involve separate forecasts using different combinations of precipitation and temperature, each with different prediction times, and lead times. One forecast would be aimed at predicting the demand for feed, and the other the supply of feed. They suggest that the two forecasts would then be used with current and expected cattle prices, together with stored and paddock feed to arrive at a decision. Mitchell and Brown (2019) suggest that soil water status could be added to SCF information to inform decisions about crop planning, fertiliser management, and forward selling of the crop. Cobon et al. (2019) added consideration of cattle prices and pasture availability to the SCF and found that growers had much to gain from using SCFs at times of low feed availability.

Added complexity also arises because different crops are planted and harvested at different times of the year and have different requirements. This means that different decisions will need to be made at different times of the year which may also mean that SCFs should be crop-specific (Klemm & McPherson 2109).