

**SRDC Research Project
Final Report
CSE009 Appendices**

APPENDIX 2: BACKGROUND ON IRRIGATION COMPONENT2
APPENDIX 3: BACKGROUND ON NITROGEN MANAGEMENT COMPONENT5

APPENDIX 2: BACKGROUND ON IRRIGATION COMPONENT

Geoff Inman-Bamber and Steve Attard

The irrigation component of the project led by Steve Attard and Geoff Inman-Bamber dealt with two case study groups, one at Bundaberg which had some previous exposure to the irrigation research and the other at Sarina with very little knowledge of previous work done by the research team.

Initial expectations before the project

Expectations at the start of the project were different for the two case study groups. For the Bundaberg group there were no expectations initially because we knew very little about the issues with water in that region. After workshopping these issues with growers, other scientists and growers it was clear that the most critical factor regarding limited irrigation was the timing of its use. When should farmers best use the small amounts of irrigation available to them and how should they allocate this water to different types of cane crops? Project funds were sought, with the help and support of the extension officers (EO's) in Bundaberg and Childers, to answer these large questions and a number of less important ones. The field work was carried out on private farm land together with the EO's and farmers who decided what information was required while we performed the technical role of designing experiments and building models to provide answers that they wanted. The growers involved understood the background very well when it came to developing a tool that farmers could use over the internet (called Caneoptimser) and we therefore expected that they would use it.

For the Plane Creek group we had to explain the science behind Caneoptimser from scratch and Steve Attard spent about six months in various grower meetings explaining the model and the probabilistic nature of results. We expected that uptake would be slow.

How were expectations realized?

In the lead up to the project we were disappointed that our field research and modelling could not help the Bundaberg growers to increase yield benefits from their limited water applications. This was discovered in a competition played out in field experiments where the researchers and growers did their best to achieve the highest possible yield with a given amount of water but in reality there was little difference in the way our model performed compared to grower performance with respect to both the timing of water use and the yields obtained. However the growers rather than being disappointed were impressed by what a group of scientists and programmers could do from their lab 1000 km from the experimental site. One grower said that he managed irrigation with 30 years experience on the farm but could not explain how he achieved good results and it was our job to find the explanation and in his opinion we did.

Was the project satisfactory in the end?

Looking back it is very satisfying to realise that we have understood at least part of the grower decision making and information processing framework and that we have developed something useful that fits within this framework. We had little idea how long was the path to understanding how these growers operated and what they needed for improved water use but we now understand their 'technical frames' and they understand ours and this mutual understanding is essential for the process of developing and delivering computationally

intensive technology like WaterSense. It is very satisfying to see how growers and EO's are learning about their production system through WaterSense even if they do not use it regularly and it is satisfying to see how some have embraced this technology for their everyday use.

How could interactions with the case study groups have been improved?

The importance of a local champion cannot be over emphasised and in Plane Creek we didn't really have that. We had people coordinating meetings at times but the turnover of staff was too rapid for any continuity whereas in Bundaberg we had one person (Maurie Haines) arranging meetings and that made a big difference. The success of the Bundaberg case study was partly due to Maurie's enthusiasm which took some time to develop but eventually he realised that the technology we were developing with his growers would make his life a lot easier and give him more reliable information to share with the group and with the growing community in general.

Another issue that could have been better was the response time for making improvements to WaterSense as requested by the case study groups. When this was rapid they expressed their appreciation but some more difficult requests took far longer than anticipated.

How did the project change the way you now conduct research?

The project had a large effect on our irrigation research and current interaction with the CRC for Irrigation Futures indicate that few have had the experience we were fortunate to gain in the project. Few understand the importance of intense engagement with end users throughout the R&D process and most are still guessing what end users may want. Some guessing is required initially so that you can develop something to put on the table for growers to consider but from then on your research needs to be guided almost entirely by the issues raised by the end users. Emma has coined the term 'boundary object' to describe the process of defining the issues and the technology to address them and the boundary object changes as researchers and growers iterate around it to find a match between what science can deliver and what the growers can implement.

The project also affected the way we as researchers interact with EO's who are generally much closer to growers in regard to technical frames than to the science community. However it may be hard to convince EO's that your technology is more reliable and more representative than what they have been using for many years in some cases. These people particularly the older ones often have well entrenched and very useful concepts and you can't just charge in with your better idea, your concepts, and imply that their ideas are wrong. They want you to demonstrate that your technology is better for them and for their growers because they carry the risk if it is not or if your technology fails to deliver for whatever reason. This may take a lot of time and patience and a willingness to understand their technical background and thinking.

Has the researchers view on irrigation scheduling changed as a result of the project?

Researchers are probably expecting to see large changes from their efforts but mostly you can only make small incremental changes which are nevertheless very important to people for whom water is extremely important. We need to realise that small contributions to the

understanding of the biophysics of water use can be highly valued by people who think about rainfall and water supply for their livelihood a lot more than we do.

How has the internet helped with irrigation scheduling?

The first scheduling tool we put together was accessible over the internet but it was slow and complicated and was hardly used. We realised that people wanted the access to be simple and fast and we have tried to comply with these requirements. However you have to demonstrate that the information is reliable and this cannot be done remotely. Once users understand at least superficially how the web system works and it provides information that matches their expectations a position of trust is reached and mostly they will take the information at face value. We have provided the capability for users to go back and dig in to the background data if they really want to and sometimes they do.

How should WaterSense be used and what for?

WaterSense needs to be used regularly in order to take into account the most recent weather information in deciding when to irrigate. For the farmers who irrigate regularly it would need to be updated every two or three days but for limited water users it would be necessary to update only weekly or even monthly depending on the amount of water available and the climate. WaterSense was developed primarily for irrigation scheduling but growers have pointed out its use as a record of their use of water and an estimate of runoff and drainage and the effectiveness of rainfall. These kinds of records are being required increasingly for regulation of water use and off site impacts.

APPENDIX 3: BACKGROUND ON NITROGEN MANAGEMENT COMPONENT

Peter Thorburn and Tony Webster

This appendix details the participatory activities conducted with the Tully case study group seeking more sustainable management of nitrogen (N) fertiliser, and the potential for seasonal climate forecasting to guide sustainable N fertiliser management.

Introduction

There has been much discussion about the impacts of agriculture on water quality in the wet tropics, including the Tully region. Thus there is interest in developing more sustainable crop management practices in this region.

In initial discussions about the potential applications of seasonal climate forecasting in the region, the Tully case study group had identified that seasonal climate forecasting could have potential for helping in the sustainable management of N fertiliser. For example, the group held the belief that losses of N to the environment were very high in wetter than average summers, resulting in reduced yields from limited availability of N. If these conditions could be forecast, additional N fertiliser could be applied to avoid N stress and low yields in the crop. Conversely, forecasting dry summers possibly could allow N applications to be reduced.

This report summarises the activities undertaken with the case study group to examine these issues.

Participative approach

All interactions, subsequent to introductory discussions, were driven by the interests of the case study members. The project team did not seek to influence the issues raised by the team or the way in which these issues would be examined. Given the group's overall unfamiliarity with modelling and cropping systems simulation, the project team often proposed different ways in which an issue could be analysed, providing the groups with options from which to choose.

The participative interactions addressed the following issues:

- Describing and gaining trust in the technology available to predict sugarcane production in Tully.
- Detailing soils and management systems to be used in investigations.
- Identifying the management practices that might provide improved outcomes in terms of productivity, profitability and environmental impact (N losses).
- Analysing the potential outcomes of these management practices.
- Identifying future actions for region and/or project team.

Initial scoping of issues and technologies

The interactions with the group commenced at a meeting in November 2004 with an exploration of the group's aims for this part of the project, and then consideration of the

possible management options open to local farmers for changing N fertiliser management. The results of these discussions were:

- Reasons the group would like to improve the management of N fertiliser.
 - Water quality, cost, productivity, profitability, reduced time, environment.
- Options available to growers to manage N fertiliser.
 - Rates, method, splits, product, organic forms, placement.
- Comments on interactions with climate that influence N responses in sugarcane crops.
 - Knowledge gaps in what these interactions are.
 - Possible ways to predict these interactions of the upcoming climate and therefore change N management.

At this stage, and in response to the final comment, the project team presented the technology that could be used to examine these issues with the group – the APSIM-Sugarcane cropping system model¹. The project team presented information on:

- The model – capability, operation, assumptions.
- Relevant illustration of its accuracy.
 - Predicting N responses in a long-term N fertiliser rates experiment at Bundaberg.
 - Predicting yields in different treatments at the “trash trial” at the BSES Tully Research Station.
- Initial long-term simulations of cane production in Tully to illustrate the model’s capabilities.
 - Long-term N response curves.
 - Yield as affected by annual rainfall.
 - Environmental N losses as affected by annual rainfall.

At the conclusion of this session the group agreed that there would be value in participatively analysing, with APSIM-Sugarcane, how sugarcane yields and environmental losses of N were affected by the different options for managing N fertiliser. These analyses were conducted during four subsequent meetings from March 2005 to March 2006.

This initial meeting concluded with discussion on (1) choosing a range of soils and management systems to be specified in, and subsequently investigated with the model, (2) basic economic data for use in profitability analyses, and (3) the management practices to be examined. Three soil types, Coom, Tully and Thorpe, were chosen to represent a range of textures (fine to very coarse) that occurred within the Tully region. It was decided to firstly examine the management practices of varying N fertiliser rate (what is the optimum N rate and how does it vary between years) and applying N fertiliser in split applications (e.g. half the amount applied at two times). “Splitting” involves extra effort and cost compared to single application, and so is not generally seen as convenient or profitable. However, the group maintained that splitting was a viable management option and would be adopted if it provided triple-bottom-line benefits.

¹ Thorburn P.J., Meier E.A. and Probert M.E. (2005). Modelling nitrogen dynamics in sugarcane systems: Recent advances and applications. *Field Crops Research*, 92: 337-352.

Second meeting

In the second meeting, the results of simulations were presented to, and discussed with the group. The simulations were divided into two groups, tactical and strategic simulations, which are described separately below.

Tactical simulations

The tactical simulations were a detailed presentation of sugarcane yields and environmental N losses in each of the years 1998 to 2004. These specific years were chosen as the group remembered climatic conditions of each, which varied across those years (including much wetter than average and much drier than average seasons), and resulted in contrasting crop production. Simulations focussed the response of yields and N losses to increasing N fertiliser application rates for the three soil types. The effect of splitting N applications was also considered.

The tactical simulations were also used by the group to gain further trust in the model's capabilities. In the first meeting, two issues were identified where simulations did not reflect the local sugarcane yield responses to different N fertiliser rates and climate in the region. The project team had agreed to re-parameterised the model to better reflect this local experience².

When presenting the results of tactical simulations the following questions were asked:

- Does the model capture the yearly variation in yields (at recommended N rates) in recent years?
- Have the N response curves been “flattened” adequately, to be sufficiently like those in local experiments?
- What are environmental losses at different rates of N fertiliser?
- Does splitting increase productivity and/or reduce N losses?

There was general agreement that the model was capturing the yield variations that the group expected and discussions around the amount of N lost to the environment. It was noted that crop yield responses to N fertiliser (applied at rates above those recommended) were not greater in wet years, contrary to the group's initial expectations³. The effect of splitting N applications was variable, giving benefits in wetter years, especially in the coarse textured Thorpe soil.

² Initial simulations showed yields increasing with increasing rainfall whereas they decrease in the region. Simulating this response to rainfall was achieved by incorporating the processes of crop lodging and water logging into the model, processes not included in simulations for the initial presentation on the model. The group also felt simulated yields increased too greatly with increasing N fertiliser applications, and thus the N response curve needed to be “flattened”. This is a common experience when comparing “local experience” with simulations. Fields used for N fertiliser experiments have a history of particular N fertiliser management (e.g. application at recommended rates). There are time lags between imposing a change in N management and responses in the crop due to processes such as storage of N in the soil profile. Long-term (e.g. over decades) N response curves are often simulated results, as there are no experimental data of this type available on the long-term outcome of different N management practices. N response curves were “flattened” by running simulations for 40 years with a constant N rate (the recommended rate) then changing N rates and examining the annual response following the change (more accurately reflecting data produced in local experiments). Also, effort was put into obtaining accurate parameters for the soils.

³ This result occurs because lower radiation in wet years reduces the crop's yield and hence demand for N, balancing the greater loss of N to the environment.

Strategic simulations

The strategic simulations presented longer-term predictions, over 40 years from the early 1960's. This time period was specified by the group as being relevant to their experience and covered a range of decadal climatic cycles. The strategic simulations concentrated on:

- Predicting the long-term outcome of a management strategy in terms of;
 - Yield and profitability,
 - Environmental losses.
- How do these outputs varied in response to;
 - N fertiliser rate (through graphing N response curves),
 - Annual climate (through examining the variability in yield at each N fertiliser rate).

Outcome of the meeting

Based on the outputs of the tactical simulations, the group asked that splitting be analysed in greater detail and included into the strategic simulations. In particular, they wanted to see if there was benefit in developing a conditional rule linking splitting with climate forecasts. It was possible that splitting could be used as a risk management strategy: The first half of the N application may be adequate in wet years (when yields are constrained by radiation). But there is also an opportunity to apply the second split if the season turned out to be drier than forecast and crops yields potentially higher. They also suggested that simulations be confined to the recommended N rate (150 kg N/ha of ratoon crops).

Third meeting

At this meeting strategic simulations were presented for six N management rules based on either constant management each year, or conditional management based on SOI climate forecast, as follows:

- Constant management:
 1. 75 kg N – single
 2. 150 kg N – single (currently recommended management)
 3. 150 kg N – split
- SOI-based rules: If SOI Phase = 2 (forecasting high chance of above median rainfall), then
 4. 75 kg N – single
 5. 150 kg N – split
 6. 150 kg N – conditional split (apply first split, then the second split if not 'wet')

In the final rule, 'wet' was defined as receiving more than 300 mm rain between mid-October (the time of the application of the first split of N) and mid-December (the latest time for convenient fertiliser application).

The three conditional management systems resulted in yields and profitability similar to that in the recommended practice, but environmental N losses less than those in the recommended practice. The third rule (150 kg N, split every year) resulted in the highest average yield, similar profitability and lower environmental N losses compared with any of the conditional rules. Thus it was the most sustainable management system.

This analysis examined a single cropping system; all crops harvested mid-season and N applied (all or first split) 6 weeks after harvest. For the next meeting, the group requested that different harvest times (early- and late-, as well as mid-season) be examined. As well, the group wanted different delays between harvesting and fertiliser application to be included. The group wondered if the benefits of splitting would apply to crops harvested at different times in the season. They also wondered if earlier applications of N fertiliser (e.g. straight after harvest) might give better outcomes.

Fourth meeting

At this meeting different harvesting and fertilising dates were presented for the six management systems presented at the third meeting.

The general results of the different harvesting timings confirmed the conclusions of the mid-season harvest. In addition, there seemed to be some benefits in later (i.e. 6 weeks after harvest) application of N fertiliser, especially in the Thorpe soil. This delay better synchronised the fertiliser availability with crop growth in the coarse textured soils which do not have sufficient organic matter to immobilise the N fertiliser when it's applied close to harvest.

The overall conclusion from these investigations seemed to be a general rule of:

- Always splitting N fertiliser applications, and
- Not applying N fertiliser too soon after harvest on coarse textured soils.

Final review

A final meeting was held to review the progress made in the case study and determine whether there were any further practical actions (e.g. on-farm trials, changes to local recommendations) that should be taken regarding the N fertiliser management strategies examined during the study. The group's general feeling was that, even though they accepted that splitting N fertiliser every year was the most sustainable system, the inconvenience involved in splitting was not worth the benefits identified in the simulations. Their original interest in examining splitting was, essentially, based on a hope/expectation that it would provide dramatic improvements in sustainability. There was some general interest in considering splitting in years where the SOI Phase was 2 during the harvest season: The less frequent inconvenience might be acceptable for the possible benefits.

**SRDC Research Project
Final Report
CSE009 Appendices**

APPENDIX 4: APPLICATION OF THE THEORETICAL FRAMEWORK	2
APPENDIX 5: EVALUATION OF CASE STUDY GROUP EXPERIENCES	35

APPENDIX 4: APPLICATION OF THE THEORETICAL FRAMEWORK

Emma Jakku and Peter Thorburn

This appendix details how the theoretical framework developed in this project can be used to help understand the participatory technology development process and outcomes that occurred in the seasonal climate forecasting, irrigation management and nitrogen management case study groups.

Seasonal climate forecasting in Tully, Plane Creek and NSW

With the help of our local coordinators, case study groups were established in Tully, Plane Creek and NSW, to explore in a participatory manner the opportunities and benefits associated with seasonal climate forecasting. This section demonstrates how our theoretical framework helps us understand the context, process and outcomes of our interaction with the seasonal climate forecasting case study groups. It concludes by reflecting on participant's overall satisfaction with the process and some of the key learnings about the participatory technology development process.

Participatory technology development context and approach

Interpretative flexibility and technological frames in seasonal climate forecasting case study groups

In each region, the same overall technology development approach was used in the seasonal climate forecasting case study groups. The initial meetings with each case study group focused on developing participants' understanding of climate forecasting terminology, to build understanding within the group of the strengths and limitations of seasonal climate forecasting. These early meetings focused on clarifying the difference between weather forecasting and seasonal climate forecasting, which illustrates the **interpretative flexibility** that shaped participants' reactions to seasonal climate forecasting. The following quotes illustrate the range of perceptions that were held about this issue of the difference between weather and seasonal climate forecasting:

When they say climate forecasting, the first perception was weather forecasting. I went there with the total wrong idea; soon modified. ...I learnt the difference between weather and climate. When I thought there was no difference at all. ...We went there with the perception to understand three days to seven days, weather forecast. Not 12 months, two years or six months ahead, none of that. Then I soon realised that seven days is only just good for five minutes. (Tully, Grower)

Yeah, from when we first started we were trying to learn about what the climate meant to us. And it wasn't weather, it wasn't weather forecasting. (Tully, Grower)

I've learnt that there are differences between climate forecasting and weather forecasting. And neither of them are exact sciences. (Tully, Mill)

...you might've noticed that even within the group...there was a confusion between weather and climate. (Tully, Extension)

Interpreting the probabilistic information that comes with seasonal climate forecasting provided another area of interpretative flexibility within the case study groups.

Seasonal climate forecasting requires integration of probabilistic information with decision making activities. People have different perspectives on what probabilities mean, based in part on different attitudes towards risk. The project team member responsible for leading the seasonal climate forecasting case study groups noted that: “It’s always the hardest bit about making sure they’re interpreting probability the correct way.” Several case study group participants also highlighted the challenges associated with the probabilistic nature of seasonal climate forecasting:

Because I think one of the problems with it all [seasonal climate forecasting], we’re not all statisticians, and so if you start talking probabilities, some people, if they follow the races you can use probabilities. But they’re not so good on probabilities. It takes a little while sometimes to get that probability message across. And so I think they’ve got to realise what the probability system means, and that’s why I think I tend to spend a bit more of the initial stage on to ‘likelihood’ rather than ‘probability’. (Tully, Extension)

It's mainly on probabilities. You're not talking about it's going to do this or it's going to do that. There's a probability that it will be this or maybe that. ...For people that don't understand it...they say it's a 50% chance of it being wetter and yet it will never happen, what's going on, you know. I think it's the understanding of probabilities that comes back to that, the education of that. (Plane Creek, Grower)

Generally, it’s a fairly murky science. It’s a probability game. There’s a lot of factors in there that are not understood yet. ...I suppose you could say one was hoping for a bit more precise information, but in reality it doesn’t exist. (NSW, Grower)

In NSW, the case study group paid particular attention to the issue of what level of probability was high enough to influence decision-making, as the following participant explains:

Whether you’re prepared to make a decision based on a 65 per cent chance of above average rainfall. I’m just using that as an example. Or whether you’re more conservative and you’d want to – a 75 or 80 per cent chance of it being above average rainfall before you’d use that as a weighting in terms of making a decision. I’m probably conservative and 65 per cent is okay but I’d probably prefer a higher probability if I was gonna make a major decision in terms of say season length, when to start the harvesting season. ...it all comes down to what your personal view of risk or probability. Answer to that is yes, if you came up with a projection that you had a probability of 75 per cent or greater, yeah, you’d definitely use it as a guide. I’m not saying you base your decision on it but you’d use it as a weighting in making a decision as to some sort of – whether you’re looking at season length or some sort of management option on the farm. (NSW, Extension)

Another significant phase of the early case study group meetings involved identifying how and when seasonal climate forecasting might be able to assist industry decision-making. An important step in these early meetings involved identifying key industry decisions and testing the skilfulness of seasonal climate forecasting for assisting with these decisions:

...initially we had a workshop session where we listed out all the things where we might use climate forecasting, that was very useful. It probably surprised me a little bit as to how many things in how many areas we could use the information if...you had a...high probability rating on the prediction, in how many areas you could use it. (NSW, Extension)

This stage explored the different **technological frames** held by those involved in the case study groups, since some of the participants initially had different perceptions about how and

when seasonal climate forecasting information might be useful. For example, different users required very specific or targeted forecasts for different times of the year, supplied with varying lead-times.

Many participants described the initial scepticism that shaped their perceptions of the seasonal climate forecasting:

I think like a number of other growers I was fairly sceptical that it was really going to add too much value to our decision-making process. (NSW, Grower)

I didn't have any expectations [about the use of seasonal climate forecasting] as I didn't think it was possible. (NSW, Grower)

Yes, my first initial thought was that there's no hope in hell as where we are the climate comes from three ends of the country. I've seen some results from Tamworth and they have had it down pat. Down there they have 70%, 70+ accuracy. With the drought it doesn't help. I went into this thinking it would be very hard, a bit skeptical. Now I think it has potential but accuracy needs to be improved. The current forecast... I'm likely to agree with." (NSW, Grower)

If you didn't know anything about it well...you'd just think it was a lot of hooey. When it's been explained to you and taught to you, you can sit back and say 'yeah that's right'. (Plane Creek, Grower)

I really couldn't see it was going to make a heck of a lot of difference as far as the routine day to day management things of when you plant it, when you harvest it. (Tully, Extension)

Other participants noted that their initial perceptions of seasonal climate forecasting focused more on their hopes for how it could be used to influence their decision-making.

I was trying to be able to...predict the weather so I could basically build up an A and a B scenario for my farming operations. A, being for La Niña and B, being for El Niño... (Tully, Grower)

A better understanding of how we may forecast what is ahead. (Plane Creek, Grower)

I guess what we were looking for was another suite of tools that we could use in terms of decision-making both at the mill area level and at the farm level. I guess I had been watching what had happened across other industries because probably when we first started in the sugar industry the grains industry was probably more developed and more mature in terms of looking at climate forecasting. (NSW, Grower)

I thought it would give us some handle on what to expect for the forthcoming season, particularly during some of the critical periods during the season that are affected by weather. (NSW, Extension)

Well, I thought it could have the potential for being very helpful with things, like, season length and a whole range of management issues on the farm in terms of weed control and things like that. (NSW, Extension)

I guess we're interested in seeing whether or not you could get any better indication of long term climate trends that might influence decisions that farmers and what we would make at the sugar mill. That was basically the nuts and bolts of it. (NSW, Mill)

These comments illustrate the range of technological frames initially held by participants about seasonal climate forecasting. However, after a series of discussions, the different case study groups reached a general level of consensus about the potential for seasonal climate forecasting to assist decisions relating to fertiliser regimes, harvesting, planting and herbicide applications, all from a routine three monthly forecast updated monthly.

Many participants highlighted the influence of the participatory process within the case study group on their learning about how seasonal climate forecasting could be applied. This illustrates how a participatory process can facilitate the development of **congruent technological frames**.

It's always interesting to see someone else thinking in their line of work which is totally different, and you can learn from that. You just can't look through your own window the whole time. It's good to hear what other people do. It just broadens your mind so then, I suppose, with the varying aspects of what could possibly happen, you can sort of adapt, by someone else's knowledge. (Tully, Grower)

One good thing also was, with the other farmers...they're all in different areas, except for one. He was my next door neighbour. But because we were all in different areas, they were doing things different to what we were doing. I said to myself, "Can I adapt that? Should I adapt that?" ...We started to learn off one another. (Tully, Grower)

And just as importantly is listening to my fellow growers. Their comments back. And how they're relating this information to their own places as well as me trying to relate it to my own. (Plane Creek, Grower)

The project team member responsible for the seasonal climate forecasting work discussed the importance of this move towards congruent technological frames:

...the most important thing that has become clear to me is it's important to have everybody thinking on the same page, until you have that, you're not going to go anywhere. I've just discovered how I can do that basically. (Seasonal climate forecasting project team member)

The next phase of the technology development approach was to develop a tool to assist with the delivery of seasonal climate forecasting information and try to implement a delivery mechanism to distribute information about seasonal climate forecasting information in the case study regions. The climate forecasting program called RainForecaster was developed for this purpose. However, whilst the RainForecaster program was designed primarily as part of the adoption strategy to extend the use of seasonal climate forecasting systems beyond the case study group, it was also useful in facilitating discussions with the group about how seasonal climate forecasting could be applied. For instance, it assisted in the transition to routine three monthly forecasts by demonstrating that outlooks did not change greatly for different rainfall periods post autumn. This illustrates how RainForecaster acted as a **boundary object**, since it helped facilitate negotiation and cooperation between the project team and case study group participants over the application of seasonal climate forecasting. The next section shows how this phase of the participatory technology development approach evolved within each case study region.

Participatory technology development process and outcomes in seasonal climate forecasting groups

Tully

In Tully, discussions with the industry participants were facilitated by the RainForecaster program. This program was designed to be used by the case study group coordinator and local extension staff to produce climate updates and forecasts that were tailored to the Tully region. Outputs from RainForecaster were placed on the local grower website and were displayed as a graph familiar to the case study group participants. As the local co-ordinator explained, the strength of RainForecaster is that:

...it gives you the probability. So it comes out with a probability which is pretty easy and I suppose it gives you an indicator of what the median rainfall is. So it just reminds you about where you are. (Tully, Extension)

RainForecaster was designed in consultation with the case study group, so that the outputs were relevant to, and interpretable by, the industry participants. This process of tailoring RainForecaster to local needs promoted co-learning within the group. The co-learning that emerged from this group interaction was commented on by many participants:

We had a contrast of farmers here. Each one was supporting their little different views from where their locations are. We were learning off them too. (Tully, Grower)

I think I would describe my role as the same as everyone else's. Their life experiences are different to everyone else's, and you learn from that. You learn from other people's experiences. ...it's not possible for one person to come up with all the right questions. Whereas, if you're thinking on a certain track, someone else thinking probably somewhere else, and wants to ask questions down there. It just shortens the time period you need to be there. Because someone's covering another angle, another base which you didn't think about. Yeah, group participation is really great. It's important. I hope other people learn from what, some of the questions I raised. (Tully, Grower)

...I think if you've got a productive group, or an enthusiastic group, you're going to get more out of it than trying to do something by yourself. And there's people can throw in things that you haven't even thought of at times, or add additional information. So I think that's the real benefits of working in a group situation, provided the group's got the right vibes. (Tully, Extension)

In this way, RainForecaster acted as a boundary object by helping to facilitate negotiation and cooperation between the project team and case study group participants over the application of seasonal climate forecasting for the Tully region. Two of the case study group participants explained the effectiveness of RainForecaster and its outputs for facilitating discussions within the case study group:

Graphs are quick. You can visually look at something and you get the idea of what it means. Even if you've got a graph, and there's a line in the middle, which is more or less neutral, and you're over it or above it, you just get the idea straight away. You know what someone's talking about. You can follow people when they're explaining something. (Tully, Grower)

Like I think it's a valuable way of explaining how to use things and in identifying what are the types of things you may change. (Tully, Extension)

Attention within the Tully case study group turned to identifying other ways in which the outputs of RainForecaster might reach a larger audience in the Tully sugar industry. In a brainstorming session on this issue, the idea of packaging RainForecaster outputs onto a refrigerator magnet was suggested. The prototype magnet acted as a boundary object, since its development facilitated further discussion between the case study group participants and project team about how seasonal climate forecasting information could be applied to the Tully region.

The development of the magnet also illustrates a move towards Outcome 2 in the framework, since iterations between the project team and case study participants resulted in the simplification of the problem, which in turn allows for the identification of a ‘rule of thumb’ that can act as a *knowledge embedded management recommendation* with ongoing relevance.

For example, the magnet revealed two different types of years – those when the risk of rain was higher, and those when the risk of rain was lower. Industry members could use this rule of thumb to ‘finetune’ their planning to suit these different year types. In particular, case study group participants identified the rule that if the SOI is positive during harvest, then there is a higher chance of rainfall. This ‘rule of thumb’ could then be distributed through appropriate extension processes, such as shed meetings, industry newsletters and other industry meetings and forums.

Many participants described the way in which they saw seasonal climate forecasting as a useful management tool, especially in relation to managing climate risk:

It is something that we’re going to do gradually, employing it as a minimum risk management tool or implement. (Tully, Grower)

I’m always interested in La Niña and that. I think the MJO part would be more interesting now that I’ve evolved my farming operations as all sort of defaulted to the La Niña situation. (Tully, Grower)

In some years it [seasonal climate forecasts] meant that you change your practice differently, not just fertiliser, but your activities, your cultivation. It affected cultivation, harvesting and the time of both, not just the way you did it. Planting, your fertilising, and even your plough-out situation. It affected the timing of that, and how you actually did it, whether you went intensive in some circumstances, or in some years that you couldn’t afford to go intensive because the risk was too high. You did it some minimum tillage type of work. So therefore, you could use it all the time. Once you pick up on the year, what it’s doing, then you just adopt it, adopt different practices for the year. And the next year might be different. And the other thing, I suppose, is you have to be flexible. As your knowledge in the year strengthens, on what’s happening, you have to be flexible and be able to change, accommodate any sort of recommendations for how to treat that year. You have to be flexible the whole way through. You can’t have a plan...out in May for the whole year. Even in July you still have to have a flexible plan. (Tully, Grower)

It’s a tool, and I would see you’d still continue to use it. I certainly wouldn’t throw it out the window. But when you look at the reliability, if you like, in predicting our conditions here, it’s not as good, as I said earlier, or doesn’t appear to be as good as, say, in a dry environment. But I think it seems to have a reasonable chance of success at predicting those wetter years. That’s where you’ll continue to use it, to hope like hell you can make use with that. (Tully, Extension)

If, for instance, the thing was saying that we were above chance of having terrible rainfall during the season, I would probably say that I would somehow advertise that fact. (Tully, Mill)

However, although there was a degree of consensus within the case study group about the usefulness of seasonal climate forecasting as a management tool (i.e. some evidence of congruent technological frames), there were still differences of opinion within the group (i.e. incongruent technological frames) regarding the application of seasonal climate forecasting. For instance, one of the growers noted that he felt that seasonal climate forecasts were not applicable to the Tully region:

No, because you just go on the average of the history of the past, more or less. As I said, you can't – you can get information but that information, that's not – it does not apply to this area more or less, you know. The other areas might be accurate. I don't know what the others, whether they agree with me on it, but it's very hard to – that long weather forecast for this area, other than you could apply to here, all the figures. ...To me I just do what I have to do. I don't think – as I said, I can't look too far ahead. I've been caught before more or less and you haven't got that trust in it. (Tully, Grower)

Furthermore, the Autumn Predictability Barrier raised concerns regarding the compatibility of seasonal climate forecasting with current farming systems:

That autumn unpredictability. ...Yeah, it would be good to get over that. That is just as valuable as understanding what the SOI is. With the ability to go through your grey period, you then have the ability to plan out further, which is good. ...At the moment, a group of farmers can have a talk, say in April next month, and using the SOI and the climate factors, we could sit there talking for half a day, talking about what are we going to do for the next two months, and we all have different ideas. We're a bit confused, and no-one can really guide you, I suppose, no-one can really help you. No-one's going to provide the answer for you to help you. It's strange how we have this grey period, yeah, but I understand it's a change of the climate year, you could say that, that's how I understand it. (Tully, Grower)

The autumn predictability barrier and that most of the decision making that you can change actually your decisions are made in April, May, June and whatever you do there carries through. So if you haven't got a good predictor then you're basically playing catch up anyway." (Tully, Extension)

Many participants also pointed to the perceived low accuracy or skill of seasonal climate forecasting as factor that constrained its usefulness as a management tool.

I enjoy it when they say okay, 70 per cent it's going to be fine. Seventy per cent it's going to be dry. Or 70 per cent it's going to be wet. Thirty per cent it's going to be fine or dry or wet. When it goes into the 50/50, hmm. That's a bit of a drawback. (Tully, Grower)

I think the limitations of climate forecasting is that in the middle of the rainy season, where you don't know what the thing's doing...it really doesn't seem to offer you any better than a calibrated gut feeling, in this climate here. So I suppose that's probably the major limitations. (Tully, Extension)

There were also contrasting views on how seasonal climate forecasting information could be distributed outside of the case study group. For instance, in the final Tully group evaluation session, one participant suggested that people could be provided with documentation and a copy of the RainForecaster program (Outcome 1 in the framework), while another participant

suggested that most growers do not need this level of information and updates on the current SOI and probability of above median rainfall are sufficient (Outcome 2 in the framework).

These contrasting views on how to distribute seasonal climate forecasting information outside of the case study group were also reflected in the interviews with case study participants. One of the extension officers involved in the group discussed the challenges of adoption beyond the case study group:

Have you got the group in promoting it, the life after? And at the moment, there has been no life after. And I think probably that'd be unfortunate. If we had the magnets, or if we have something then it goes on, that we ensure that it's a subject that gets discussed openly at group meetings and things like that, then it may continue. ...unless you have a central body, such as the Canegrowers for example, producing some charts that are regularly updated...it could fall by the wayside. (Tully, Extension/Service)

Some of the growers highlighted the range of opportunities for wider communication of seasonal climate forecasting information:

...I see emails and things like that. Even newsletters. Newsletters are simple. A point about a newsletter, you deliver the information using existing newsletters. And at a point, if more information is required, they can come into those places, BSCS, Prod Services, Canegrowers, to be given more information, which would be off the net. You then download something, and you can give it to them in hard copy. And then if you've created an interest, you've got to be able to deal with the interest you've created. (Tully, Grower)

The climate forecasting one can be related to a certain year, so therefore the delivery at a meeting has to be when there's a strong indication of what the year's unfolding to. And then you could talk about that particular year to growers. (Tully, Grower)

...I think people are starting to become aware of the climate variability, especially with all this talk about the climate change and things like that. It has got people's attention. ...I would probably like to have a workshop say at the rec hall here and to have a summing up by Yvette and Peter and Tony and probably one or two growers involved having a say on how it affected them. (Tully, Grower)

Despite discussions in the case study group and interviews about the opportunities to raise awareness about seasonal climate forecasting outside of the case study group, at the final case study group meeting there were still no plans for this to happen. One participant summed up the groups' apparent hesitance by noting that: "seasonal climate forecasting is a tool not an answer therefore it can not be put in a newsletter."

Therefore, although there is some indication that the Tully seasonal climate forecasting case study group was moving towards Outcome 2 in the theoretical framework, it is unclear whether there is enough interest or commitment within the region to see further distribution of seasonal climate forecasting information through local extension processes (e.g. newsletter articles, shed meetings and other industry forums or activities).

Plane Creek

In Plane Creek, discussions with the industry participants were also facilitated by the RainForecaster program. As with the Tully case study group, the RainForecaster program was designed to be used by the case study group coordinator and local extension staff to

produce climate updates and forecasts that were tailored to the needs of the Plane Creek region. The local co-ordinator noted that the localised information that RainForecaster provides is its key strength:

...it's in our individual areas and our own records. That's where it comes home and says so many millimetres are going to fall, probability of so many millimetres on Camilla or Plane Creek. It's individual. It puts it back to our area. It's very interesting to see how the different areas vary too. (Plane Creek, Grower)

Participants also highlighted the value of learning from the group interaction.

...listening to the fellow growers and their questions and what they were thinking and how they saw everything. And it was all quite fascinating really. Very informative. (Plane Creek, Grower)

At the beginning of the project, extension officers were actively involved in raising awareness about seasonal climate forecasting. For instance, seasonal climate forecasting was discussed at numerous cell group (grower) meetings in the project's first year. However, this momentum was lost as key extension staff left the region. Opportunities for further awareness raising activities were constrained by the high turnover of extension staff in this region that existed during the remainder of this project. This illustrates the impact that external factors can have on participatory technology development and adoption processes.

Nevertheless, the Plane Creek case study group were very keen to see the seasonal climate forecasting work continue in the region. A member of the case study group was asked to provide regular climate updates to an email distribution list. These updates included outputs from RainForecaster. Initially the email distribution list consisted only of the case study group participants (eight locals). Since then, some extra locals have joined the email list. There are currently 15 locals on this email list, which is approximately 10% of growers in the region. There seems to be an agreement within the group that these email updates have been useful for increasing understanding and awareness of seasonal climate forecasting in the Plane Creek area:

It's giving us information that we're not getting off our local weather forecasting nightly. (Plane Creek, Grower)

The group gets a detailed summary about every month I suppose. ...I find...the comparison of years' records, past history is enlightening. ...the years that have been similar to the present—whatever the present pattern may be. I can relate to those years and once again, it is following it through to see what the correlation is but I can think back to those years and say, oh yeah, such and such was an effect of the weather and the climate then was such and such and you know, can relate to it. (Plane Creek, Grower)

It is always very useful information that, while he's happy to go to the trouble to do it, I'm happy to take notice of it. (Plane Creek, Grower)

There was agreement among participants about the usefulness of seasonal climate forecasting, which suggested that there was some evidence of congruent technological frames in the Plane Creek group:

I think as long as I'm farming, I'll be looking at it. I'm sure of that, yeah. (Plane Creek, Grower)

...while I am actively practising cane farming and even afterwards, it is still a thing that affects our lives. If you are planning into the future, yes. (Plane Creek, Grower)

As long as I'm a farmer. As long as I'm breathing air. (Plane Creek, Grower)

As with the Tully case study group, many of the Plane Creek participants described seasonal climate forecasting as a useful management tool. This illustrates a move towards Outcome 2 in the framework, whereby interactions in the case study group resulted in the identification of management recommendations:

You know if...it looks like an El Niño year you can make sure your dams are full before the season starts. That's one way of using it. Also if it's going to be an El Niño or wet year, you're scheduling your harvesting so that the wetter paddocks aren't left to last. You've got a fair possibility of being able to get them off when it's dry. That's another way of using it. (Plane Creek, Grower)

I brought an extra irrigator a few years ago now on the strength of the information we had on an El Niño event being forthcoming. I put in an order for one much sooner than what I would have. (Plane Creek, Grower)

...we're in a big harvesting cooperative. We're going into our third year of that and when you're starting off there are a lot of things that haven't been done and we probably haven't got as good a wet weather gear as we could have. In the last couple of years, one was neutral and last year was supposedly an El Niño year. Last example, for example, we said, oh well, it's an El Niño year. We won't spend any money on tipper bins. ...You know, it can sort of push you one way or the other. (Plane Creek, Grower)

Being a bit more positive in decision-making I think. Well my decisions are not entirely in the lap of the Gods you might say. There is some basis to them. (Plane Creek, Grower)

Nevertheless, there was evidence of incongruent technological frames in the group, with some participants still unsure about seasonal climate forecasting. For instance, one of the growers noted that he missed the first couple of meetings and struggled to catch up.

The climate forecasting I'll have to admit I missed the first two due to being a bit crook at the start and I struggled I'll have to be honest with you. ...It was good what I understood, but I got nowhere near as much as I should have. You know it is you miss them first couple of important meetings they had so I struggled. My neighbour helped me out...but nothing like what I would have gained by being at the meetings.

Another grower remained doubtful of the relevance of seasonal climate forecasting.

Yes, well if we were doing some outstanding things based on weather information, they might get excited about it but basically we've just got the same routine every year. ...we plant every year, we always get a crop every year and it varies a bit besides. We never really have any big failures. (Plane Creek, Grower)

One grower told of how he made some decisions based on the expectation that January was going to be drier than normal:

I brought an extra irrigator a few years ago now on the strength of the information we had on an El Niño event being forthcoming. I put in an order for one much sooner than what I would

have. This last year has worked the other way. I was working on information received and I expected to have a dryish summer period, a dry January, much lower than normal January/February period and I pumped a lot of underground water into a dam but I needn't have because it didn't turn out that way. The dam has overflowed early in what has become a more traditional wet season. (Plane Creek, Grower)

He went on to note that this highlighted the challenge of interpreting the seasonal climate forecasting outlooks.

Just the fact that you can be wrong I suppose. As I just said a moment ago, I pumped a whole lot more water than I needed to pump sort of thing. (Plane Creek, Grower)

Overall, there is some indication that the Plane Creek seasonal climate forecasting case study group was moving towards Outcome 2 in the theoretical framework. The email updates are continuing, although as with the Tully group, it is unclear whether there is enough support within the region to see any further distribution of seasonal climate forecasting information.

NSW

The RainForecaster program was also used as a boundary object in NSW to facilitate initial discussions with case study group participants about when and how seasonal climate forecasting could be applied to the NSW region. Many participants highlighted the co-learning that was involved in this process:

We were picking up points that she was making and she was picking up points that we were making. Basically we were educating each other. (NSW, Grower)

I suppose we had the opportunity to be involved and help guide it along in the right direction. (NSW, Grower)

I think it also allows for researchers to not be operating in a vacuum and it allows them to throw some ideas around with other people. (NSW, Grower)

I guess you've got a range of people, you have a range of ideas and that sort of thing. So rather than just having a group from one particular area, you have farmers and other people in the group and that's always beneficial and think your people from CSIRO probably got as much out of that as what everyone else did too, I think. (NSW, Mill)

In NSW, the extension sector has been actively involved in raising awareness about seasonal climate forecasting. Indeed, NSW has received the most awareness raising activities. This is primarily because three extension officers from three different districts within NSW made a commitment to 'testing' if climate forecasts are useful for their respective areas. One of the extension officers in NSW uses the RainForecaster program to provide regular seasonal climate forecasting updates, which are tailored to the local region. Therefore, the delivery mechanism for NSW occurs via these updates in the local newsletter, *Sunshine News*, which is mailed out to more than 500 growers in NSW. This emphasises the importance of support within the local extension sector.

Similar to the Tully and Plane Creek seasonal climate forecasting case study groups, the NSW group reached Outcome 2 in the theoretical framework, whereby they agreed on a rule of thumb that provided a management recommendation. However, in NSW, the focus of this rule of thumb was on when seasonal climate forecasting was not useful. In the final group

evaluation session within NSW, it was agreed that the rule of thumb in this region is that if the chance of above median rainfall is between 40-60%, then seasonal climate forecasting information does not provide a strong enough signal to influence planning and decision making.

The interviews illustrated the level of congruency in the technological frames within the NSW case study group in relation to this point, with most participants reaching the conclusion that the skill of seasonal climate forecasts for their area has not been high enough:

...the numbers that come out [of seasonal climate forecasts] are in that 60 per cent, so 60/40, which is not an adequate or large enough number to change. ...Basically there's not much precision there. (NSW, Grower)

Well I think if it has done anything, it has given the industry in New South Wales a better appreciation and understanding of the tools that are available. We have tested them under the current seasonal climate that we have experienced over the last few years and unfortunately it is sort of in that 50 per cent probability range which is probably not adding a lot of value to our decision-making. (NSW, Grower)

It's just not accurate enough to be able to use it in our decision making. (NSW, Grower)

You can't use it because...it just doesn't give you enough accuracy to be able to get enough confidence to be able to go ahead and use it. (NSW, Grower)

Maybe it's just 'cause we've had a bad run but a lot of the time it's very close to 50/50 or 55/45. If you get a run like that, a run of a number of months where your probability is round about 50 per cent, you tend to sort of...lose a bit of interest or lose a bit of confidence. We'll say, "Okay, it's really no better than flipping a coin." And maybe that's bad because maybe you should really stick at it until you get one where there's a much higher probability of 65 per cent or greater. But you tend to – I guess tend to lose a little bit of confidence. And that's what's happened over the last 12 months or so. (NSW, Extension)

This issue of the probabilistic nature of seasonal climate forecasts concerned many of the participants. One grower noted that a forecast with 80% probability would still concern him:

I think the biggest limitation for us has been that 50 per cent probability issue and applying it to our local area. Even an 80 per cent prediction still means there is a 20 per cent chance of the opposite happening. I mean farming is all about reducing risk. You need to get it right most of the time these days given the economic pressure you are under to perform. (NSW, Grower)

Nevertheless, this grower went on to add that overall he felt that seasonal climate forecasting was a still useful tool:

I think it is a useful tool that you use in your decision-making process; another one. I'll use any tools that are available to me. (NSW, Grower)

Similarly, other participants noted that despite the overall perception that seasonal climate forecasting had not been particularly useful so far, they still thought that seasonal climate forecasting might be useful in the long-term:

It was interesting, we agreed last time [the case study group meet] that we would like to see it continue, but we also sort of agreed that we weren't getting that much out of it. (NSW, Grower)

If it keeps coming and improves, that's going to be the main thing. If it shows some sort of accuracy I will continue to use it, won't ignore it. (NSW, Grower)

I think now that I've had a taste to it and been introduced to what it is all about, we'll continue to use it. Both at the mill area level...but also at the farm level as well. (NSW, Grower)

With improved accuracy it will have a lot of potential. (NSW, Grower)

I see it as a fairly immature technology; an emerging technology and if you look at what has happened with the five to six day weather forecasting over the last few years. I mean it was hopeless when they started but now it is pretty bloody good. ...I reckon the same thing is going to happen with the climate forecasting. In time, it is going to become more mature and we're going to get better, maybe even simpler, models to come to grips with the real factors that are affecting it. (NSW, Grower)

The project team member leading the seasonal climate forecasting noted that the rule of thumb that the NSW case study group arrived at demonstrated that they had a good understanding of the risks and limitations of seasonal climate forecasting:

...the [for NSW] group have demonstrated to me that they understand the risks of climate forecasting, they understand the limitations, there's still an interest in climate forecasting, even though the forecasts for the last three years have been 50/50, they're still coming along to meetings, they're still asking really good questions, but they haven't been able to use them to make too many decisions over the last two years because we haven't been in a dominant El Niño and La Niña pattern. That's really incredible. We've had a lot of awareness raising activities that have been taken on board by the extension staff there. They've really ran with that... (Seasonal climate forecasting project team)

The NSW case study highlights both the importance of support from the local extension sector and the affect that weak climate signals can have on perceptions of the use of seasonal climate forecasting information. When combined, these points reinforce the impact that external factors can have on the technology development and adoption process.

Irrigation scheduling in Bundaberg and Plane Creek

As with the seasonal climate forecasting groups, local coordinators helped established case study groups in Plane Creek and Bundaberg, to explore in a participatory manner the opportunities and benefits associated with improving irrigation scheduling. This section demonstrates how our theoretical framework helps us understand the context, process and outcomes of our interaction with the irrigation scheduling case study groups.

Participatory technology development context and approach

Interpretative flexibility and technological frames in irrigation scheduling case study groups

A decision support system called WaterSense, developed initially as part of the Rural Water Use Efficiency Initiative, was designed to enable sugarcane growers to assess when to use their limited water. The project team members developing the tool worked closely with two groups of growers and extension officers, one in Bundaberg and one in Plane Creek. The

range of expectations that case study groups participants initially had about involvement in the project illustrates the **interpretative flexibility** that shaped their initial reactions to the irrigation scheduling technology:

I wanted to maximise our cane production here and also to get some networking going between myself and other farmers and researchers and our local rural water guy... (Bundaberg, Grower)

I think I probably, in the beginning, had higher expectations than most because I had been involved a lot with modelling processes in other aspects of sugar. I really did think that this had the potential to be a good product, right from the word go. But I also was aware that we were going to have to make it farmer friendly and we were going to have to iron out some bugs and fill that gap between science and the people, that often occurs. (Bundaberg, Extension)

We just wanted some information on the best use of limited water during the season so some sort of guide on when, for example, we could use two megalitres of water to maximise yield. So the situation we were in we had the crop needs between six to eight megalitres per hectare and we only had two. We wanted to know when during the year should we be applying it to maximise our yield. (Bundaberg, Extension)

I didn't really know what to expect when I first started. ...But as we got into it, to me it pointed out some inefficiencies on my part. (Plane Creek, Grower)

It was mainly...just to get a better idea of when to irrigate really. (Plane Creek, Grower)

I didn't have too high an expectation...because we've got limited water here and then you know it can be wet and then only a couple of weeks and it dries out. And then we can start watering and then it is not too long and we are just behind. There's not much we can do about it because we've got limited ability to cover ground. But I was interested in it because even though you do get behind, if you start irrigating at the right time you make the most of the bit of water that you've got. (Plane Creek, Grower)

The interactions through the industry group allowed the project team members, growers and extension officers to explore their different perspectives on irrigation (i.e. their technological frames) and provided an opportunity to gain insights into others' perspectives:

The right ingredients to have in these sort of projects is respect from the different parties involved so the researcher has a respect that the issues at the grower level or extension level can feed back into the research project and also there's got to be a respect from the grower and the extension officer to say that the research findings are relevant to them as well. ...when you respect those parts you have a successful collaborative-type project and I think that project had those ingredients. (Bundaberg, Extension)

Well, I suppose it's probably interacting with other farmers as well too. ...I mean, everyone had put forward, you know, he's put forward an idea and either someone would like it or they wouldn't like it and they have an idea so yes, you sort of work around all that. (Plane Creek, Grower)

...it's just they [the growers] don't think numerically, they don't think in terms of models. But when they grasp something and you get a guy jumping up with, oh I see what you're doing, and then he explains it back to you and adds a whole load of ideas that you never thought of, that is really quite thrilling. (Irrigation project team)

...at every step of the way you're learning specific things about how they wanted to view information... And also, with it there was a lot of things like soil type...there's so many different names for different soils. ...We would put one soil type down and it'd be the same soil but they would say, no that's called a cracking clay or something... you know, they always had specific requirements on the correct terminology to use. Also on what variables they actually wanted to see. (Irrigation project team)

The project team members note that their collaboration with the growers and extension officers in the case study groups was essential for the development of WaterSense:

Particularly in Bundaberg, I think they felt it was their idea, which is all Steve's doing really... They're kind of coming up with the ideas; it's quite amazing the way he does that. I remember one bloke in Bundaberg getting up on the whiteboard and he said, look, I understand what you've done, that's not what we want. If you do it like this – and he drew a picture on the board. If you do it like that, we will use it. And we did it like that. So I think that gives them the feeling that it was basically their idea. (Irrigation project team)

The best thing about working with the collaborators [was] direct feedback or direct questions. ...It basically allowed the grower to be involved in every step of the way and for them to actually be part of the design of it as well as, not just at the end, being shown the package and asking them to take it and leave it. (Irrigation project team)

Through its development, WaterSense acted as a boundary object, as the project team members, growers and extension officers explored the assumptions of the tool, allowing all participants to gain a better understanding of irrigation and the consequences of different irrigation strategies. The next section shows how this phase of the participatory technology development approach evolved within the Bundaberg and Plane Creek case study regions.

Technology development process and outcomes

Bundaberg

By acting as a boundary object, WaterSense helped facilitate negotiation and cooperation between the project team and case study group participants over the development of irrigation scheduling technology, as two of the extension officers involved in the project explained:

...it was bridging that gap between what was seen to be pretty good science, but making sure that it was paddock useable. [WaterSense]...could've been developed in an office in Townsville and it could've been spat out on a disk, and I don't think anybody would've used it. ...the process of developing it and taking the science to the people and the people to the science and bringing the two together so as at the end of the day, something was useful to the grower at his level rather than the scientist at his level, has been the real deal. (Bundaberg, Extension)

I think the best thing was it was addressing a specific need and we had the flexibility that we could change things slightly as we were going along as we were starting to learn more and more about what the research was telling us but also more about what the issues were for the growers as well and trying to finetune them what we were doing at the research level. (Bundaberg, Extension)

The participatory development of WaterSense facilitated a common learning experience, which was important for making the technological frames more congruent. This point was highlighted by one of the project team:

...in the end I realised there was a long way to go for us to understand how these people operate and what they need and I'm very happy that we've done that. We've understood where they're coming from and they've understood what we can offer. (Irrigation project team)

This collaboration within the case study groups created a strong ownership of WaterSense among the group members:

...they were committed, they took ownership, and they felt that we valued their input. And I believe also that for me, that these people were all...really contributing, and helping to progress the technology. (Irrigation project team)

...the difference was that the growers were being asked to tell the scientists what they didn't know, and that brought growers onboard. What...the growers thought the scientists didn't know, I suppose is a better way of putting it. They were having their point of view listened to. (Bundaberg, Extension)

One of the Bundaberg growers discussed the importance of grower's involvement in the development of WaterSense for gaining growers' confidence in the technology:

I feel like we were listened to. And I guess if something is going to be accepted, there's got to be some grower input into something like that, because otherwise people are just going to say, 'Here we go again, another hair-brained idea'. ...it comes back to the confidence side of things; there was growers involved with it [WaterSense]. Whereas...sometimes, some ideas are put up and growers may not have had much input into what they wanted, what they expected out of it. I feel we got a fair bit of input into what we expected of it, and yeah, I like it, it's good. (Bundaberg, Grower)

This comment regarding confidence in WaterSense underlines the importance of building trust among the project team, growers and extension officers. Several other participants also discussed the issue of trust:

In the past, there's been a lot of guesswork in the irrigation side of things. You just think 'This block looks like it might need a drink now', whereas I'm probably taking a bit more time and attention now into how much water the crop is using. So yeah, I am starting to trust it [WaterSense] more. I suppose that was the biggest thing, just learning to trust it." (Bundaberg, Grower)

They [the case study group participants] were quite standoffish in the beginning, I felt, and then warmed to and begun to trust. So that's my personal observation." (Bundaberg, Extension)

With the increase in trust and confidence in WaterSense, attention turned to delivering WaterSense over the internet. This suggests that WaterSense could reach Outcome 1 of the framework, whereby the complexity of the irrigation scheduling problem that WaterSense addresses means that it may be routinely used by some growers. In doing so, WaterSense may influence growers' irrigation management decisions by calculating optimum scheduling of irrigation in the context of limited water supply and uncertain rainfall.

The majority of the participants in the Bundaberg case study group noted that they wanted to continue using WaterSense to help guide their irrigation scheduling decisions, including the potential for it to be applied to other crops or for monitoring purposes:

...[normally] you have to drive around every block at a certain time of day, morning and afternoon, and say mid morning and mid afternoon, to observe those crops and see what they're doing, whereas WaterSense you just pull a screen up. (Bundaberg, Grower)

I'm keen to get onto Steve now and work it [WaterSense] in with my lucerne too. It...takes a lot of the guesswork out of it. I like to get on and see what you're evaporation rate is, and you know how much water your crop's using. That's what I like about it. Whereas in the past, you've always just thought, Gee, it was hot today, the crop must be using a bit of water. (Bundaberg, Grower)

We're working very hard to make sure it [WaterSense] exists beyond and beyond. ...I say repeatedly that I believe Water Sense will revolutionise irrigation scheduling in the Australian sugar industry. ...I'm getting the impression that the government could be pushing for everybody to have some form of monitoring on their farm. ...Well, I see Water Sense is the best option for that monitoring. ...Water Sense monitors, irrigation, rain, climatic impacts, deep drainage. Water Sense monitors everything. (Bundaberg, Extension)

...I think in the future it [WaterSense] is going to become a lot more important...as government legislation comes in where people are expected to monitor the water on their farm. It's going to happen sooner or later, that they're going to start passing more regulations on farmers to monitor their water... (Irrigation project team)

The participants from the milling sector also noted that they used WaterSense to help prioritise their activities:

I put information in on Mondays about irrigation that we had in the week before. I put it into [WaterSense on] the web. ... I run the program and print and give [the report] to the leaders which farm they have to irrigate. It's so easy. (Bundaberg, Mill)

We generally get a weekly report, or generate a weekly report from which we organise our activities for the week ahead. (Bundaberg, Mill)

Nevertheless, there were a number of factors that participants pointed to, which could influence the ongoing use of WaterSense. One of the Bundaberg growers noted that his long-term use of WaterSense might depend on cost once it is commercialised:

I'll keep using it long term. After 2009, I guess it will be commercialised...so then it's purely a matter of dollars, what they would want to run that program for a year. (Bundaberg, Grower)

The issue of access to water was another factor that could influence growers' ongoing use of WaterSense:

If we don't get good rainfall, we won't have any water in our storages to use it anyhow, and you do need water here to make the program work. If you haven't got any water, it doesn't matter. The dams are empty and no allocation, then there's no point messing with the program to tell you how dry it is, because at the end when it gets real dry, the cane is dead. You don't need the program to tell you that it's crook. You can see that. (Bundaberg, Grower)

The need for support from the extension sector and industry leaders was also raised as an issue that could influence the ongoing use of WaterSense:

I guess the problem with all of things is that unless you have someone driving them, this is from an extension point of view, unless you have someone driving them they will undoubtedly progressively fall behind as a tool for people to use. So unless extension staff and people are actively pushing these things then they will stagnate I believe. (Bundaberg, Mill)

I think as we develop more interest, more knowledge of it [WaterSense], I think there'll be more than one driver, there'll be the industry itself, which has been a bit sceptical; the industry leaders, they were a bit sceptical. I think we've got them pretty well onboard now. I think it's like most of these things, it'll evolve, the wheels will turn the wheels. There'll be many, many things that'll drive it, but it'll keep getting driven as long as it's available. (Bundaberg, Extension)

Industry endorsement, and then support. Support for initial training and then ongoing support for once the training sessions have stopped. And then there's also for the upkeep of the product itself, either the weather stations we're talking about, or the housing of the model, where is it going to reside? (Irrigation project team)

Therefore, there is evidence that WaterSense might reach Outcome 1 of the framework, since it has the potential to be used in an ongoing way to help guide irrigation management decisions. However, there are a range of contextual factors that will influence its application.

Plane Creek

The Plane Creek case study group evolved more slowly than its Bundaberg equivalent. This was largely because there was less exposure to irrigation scheduling in this region compared to Bundaberg. The loss of key extension staff the region also meant that the case study group did not have a local co-ordinator to help drive the project. These factors influenced the way in which the Plane Creek case study group developed:

...we had to go in and explain to them from scratch what we'd been doing in Bundaberg. ...It might have...been six months... (Irrigation project team)

The Bundaberg group was much more advanced when we started in their understanding of irrigation and the significance of irrigation or irrigation management, than was the Plane Creek group. That was probably due to the on-ground support that we had from Maurie Haines, who has been here in the region working with irrigation-based projects for a long period of time. And so he was familiar with the farmers, he was familiar with the issue of water management, or irrigation management, and the farmers' level of understanding, basically of understanding, was much higher than the Plane Creek farmers. And the Plane Creek farmers didn't have any continuous on-ground local support. ...So for the whole duration of the project, the project in Plane Creek suffered because we didn't have a single person who we could liaise with and who we knew had been doing consistent work with farmers on an irrigation issue. ... I had to then act as that local support. (Irrigation project team)

Some of the growers described the steep learning curve that the case study group was on with regard to irrigation scheduling:

I didn't get frustrated, but like asked a lot of questions and some of it was hard to understand, I mean some of it that's a lot to take in and they didn't mind us pulling them up and asking them to explain things a little bit closer. (Plane Creek, Grower)

...we always had a big issue on where we needed to irrigate first and what our priorities were on our farm. ...I don't hold back with irrigation, if it needed water then we just started to irrigate and we went from one end of the farm to the other. We tried to put as much on as quick as we could and that's how we irrigated. No one had any clue of what water we were using; we knew we had an allocation, but we just started at one end of the farm and just across it that's how we irrigated. And I was hoping to get out of it, the actual scheduling the message out of that work, schedule the irrigation. (Plane Creek, Grower)

Despite the challenges that the Plane Creek case study group faced, participants still commented on the way in which they felt involved in the development of WaterSense:

...it [WaterSense] is of no use unless it aides the man on the land. And they're working with the man on the land to make sure it fits in with him so yes, they're going hand in hand. So one's no good without the other. (Plane Creek, Grower)

It's not like someone standing up there lecturing us and telling us what we had to do and you do this or do that. They were consulting with us ourselves and I think it's just our involvement with the whole project. ...I think you could say – I'm talking for the whole group. I'm pretty sure that they'd all say that they've learned and...they've gained from the whole experience. (Plane Creek, Grower)

I like the idea that they took our data on board too; they didn't use it as like an area. They didn't pick irrigation and cane itself they picked irrigation like in Plane Creek Mill, do you know what I mean? Scientists tend to want to look at irrigation on a wide scale thing and like they looked at it as us in Plane Creek and they took all our research and I think that's why they've got it fairly accurate; they didn't use it on like a broad thing. (Plane Creek, Grower)

As with the Bundaberg group, participants in the Plane Creek group commented on how the collaborative approach used in project helped develop trust and confidence in WaterSense:

When we started out I was little bit sceptical of them. ...The relationship has just grown through the whole project and we've got respect for each other, that's for sure. (Plane Creek, Grower)

Generally I was using it [WaterSense] as a guide and just comparing it with what I would do normally but as I come to learn the scheduling and understand it better, I think 'oops it's right, I'm wrong'. ...Yeah I trust it more that I'm able to use it the last 12 months or so, yeah. Sometimes I told Steve that he was mad. ...Yeah and then you look back and he wasn't mad. (Plane Creek, Grower)

In terms of the outcome of the technology development process in Plane Creek, the Plane Creek group gained access to the web-based version of WaterSense much later than the Bundaberg group. This was largely a result of the lack of local extension support in the Plane Creek region:

...for them [the case study group participants] to understand how the model worked, and how the tool could be useful, I had to go back and start the process of talking about irrigation management, what are the fundamentals of it, so basically do a lot of the groundwork that someone like [the Bundaberg extension officer] had been doing for the last ten years, to get them up to a level where the use of the tool made more sense to them, they understood about what was driving irrigation management. ...And that's why...the Bundaberg group, were exposed and given access to the web-based technology very early. So we were able to give it to them and say, 'Yeah, you're now at a stage where we believe you're okay to have access to

this'. The Plane Creek group, it's only just now that I've given them access to it. So they've actually seen the front end for the first time just now. Because it was pointless giving it to them and not being able then to provide them with the support that they really did need to have. And I was very reluctant to just throw it at them, and say you've now got access to this tool, and know that we couldn't give them a level of support that they really needed. That would've been, I think, really a misguided approach to say away you go, when they don't have the skills and understanding of crop water use, or some fundamentals about in-putting information into the model, and understanding how the model was driven, to then make some interpretation of the results that come from that. (Irrigation project team)

Certainly with Plane Creek, having a local facilitator who was working in the irrigation field with these farmers, would've meant that the project would've moved faster with that group of farmers. (Irrigation project team)

One of the Plane Creek participants described the groups' early experiences with the web-based version of WaterSense, highlighting how far they had come:

To me, I would say my thinking has advanced a hell of a lot in a short time. ...Like, at the last meeting that we did the, on the computers with the new program, everyone in the room...the broad questions that come out, they're really thought about. They're not questions from blokes that aren't interested. (Plane Creek, Grower)

There is some evidence to suggest that WaterSense could reach Outcome 1 of the framework in Plane Creek, whereby it may be routinely used by some growers. Some of the participants in the Plane Creek case study group noted that they wanted to continue using WaterSense to help with their irrigation management decisions:

...one of the big advantages for me was that I didn't, couldn't see that until we started the program was the different soil types and their water holding capacity and on our own properties you could relate to what areas have to get to start...Some start feed irrigating two weeks after, others [are] different... And I've only just got into it, like I'm not really into it...I haven't got the whole farm under it. We've had one block then we're going to do another block this year. (Plane Creek, Grower)

I'd use that [WaterSense] all the time I'm farming. (Plane Creek, Grower)

...I'd have a look at what it [WaterSense] was saying and then sort of go and have a look at the paddock and try and get a better idea of what the moisture was actually really like and I'd go from there, sort of thing. So sometimes you'd water when it said and other times you might have thought, well, there's still a bit of moisture there, I might leave it for another week, sort of thing. (Plane Creek, Grower)

Nevertheless, as with the Bundaberg group, Plane Creek participants noted that factors such as irrigation infrastructure and access to irrigation water constrained the application of WaterSense:

...its lack of infrastructure I would say. ...we can't actually irrigate it to the scheduling because we just can't get around the property. (Plane Creek, Grower)

...we've got limited water here and then you know it can be wet and then only a couple of weeks and it dries out. And then we can start watering and then it is not too long and we are just behind. There's not much we can do about it because we've got limited ability to cover ground. But I was interested in it because even though you do get behind, if you start

irrigating at the right time you make the most of the bit of water that you've got. (Plane Creek, Grower)

Ah well it [use of WaterSense] would depend greatly on how much water they can access. Because there isn't a lot of irrigation through the area. (Plane Creek, Grower)

There was also evidence of Outcome 3 in the Plane Creek group, whereby the participants felt that there is no reason to change current practice. This outcome occurs when the participants feel that they have a better understanding of the problem, but that there is no need or opportunity for changes to the current management practice:

Strangely enough it [WaterSense] pretty well coincided with what I intended to do anyway. There was a remarkable correlation there. But it served to reinforce my ideas sort of thing and it is getting another opinion. Well it is talking to an expert on it. (Plane Creek, Grower)

One grower noted that he had learnt about irrigation management through being involved in the group, even though he has not actually used WaterSense:

Even though I didn't know how to use it physically, the information and education I got from it is something that will stand me in good stead whether I use them or not. The experience and the information gained is something that will stop with me all the time. (Plane Creek, Grower)

As the following comments suggest, Outcome 3 also occurs if the parties involved believe that the technology will not provide a sufficient advantage necessary to justify its use:

I guess if you've got a lot of water, it [WaterSense] is worth it in that regard. But with only a small amount of water, the good that it actually does, is not worth a lot to me in real dollar terms. I'm inclined to not worry too much about it. I just do the best I can and that's that. The irrigation model; I think it is pretty close to what I do anyway. To go to a lot of extra trouble to feed figures into computers and go and look at the computers for that sort of thing. I've really got better things to do I think. But it's useful that it's there. Like some people use it and if that information is generally available to people it is good. (Plane Creek, Grower)

The theoretical framework can help understand the different stages that the irrigation case study groups have reached. The Bundaberg group had previously had more exposure to irrigation scheduling than the Plane Creek group. The framework illustrates the way in which the Plane Creek case study group required a longer phase for the process of iterative cycles of negotiation and co-learning around a boundary object, namely the irrigation schedules, in order to develop congruent technological frames. In contrast, the Bundaberg case study group advanced further and the technology team members felt as though they have reached a higher level of shared understanding with the case study group members about irrigation scheduling, which illustrates the theme of developing congruent technological frames. The irrigation scheduling team members also explained that the history of collaboration through a previous project in Bundaberg, which helped develop trust and rapport, means that the different contexts in which the two case study groups have evolved are crucial for understanding the differences between these case study groups.

Despite these differences between the two case study groups, the project team described the participatory technology development process as a positive experience:

But all the farmers in both groups saw value in what we were doing, believed that it would have some impact on themselves, and could see a value for their industry. And therefore,

they were prepared to continue for the whole duration of the project. So in both groups, people continued to participate even though they were at very different levels and progressing at different rates. (Irrigation project team)

...in the end I'm very happy with the way a few growers have understood what we've been doing and appreciated it. (Irrigation project team)

Nitrogen management in Tully

In addition to focusing on seasonal climate forecasting, the Tully case study group wanted to explore the opportunities and benefits associated with improving nitrogen management. This section demonstrates how our theoretical framework helps us understand the context, process and outcomes of our interaction with the Tully case study group around the issue of nitrogen management.

Participatory technology development context and approach

Interpretative flexibility and technological frames in the nitrogen case study group

The Tully case study group wanted to improve the way they manage nitrogen fertilizer, particularly to see if they could reduce the environmental losses whilst maintaining productivity and profitability. The range of expectations that case study groups participants initially had about involvement in the project illustrates the **interpretative flexibility** that shaped their initial reactions to the nitrogen management component of the project:

...I thought that there would be something in it but I think farmers today are very responsible in what they do and I don't think anybody wants to waste our nitrogen and input for our crops. It's very costly and if you don't have control and manage your business well, you will not survive. ...I think I have been responsible [re: N mgt] all along, even before the project. I always tried to manage as best as possible and as far as nitrogen, I think all my life I've tried to use as least as possible and tried to be productive. (Tully, Grower)

...I was curious to see how you could use the nitrogen application part of, with it, which I understand we probably all have our own ideas through experience, about putting on nitrogen in different wet years and dry years, and things like that. (Tully, Grower)

...I thought we might be able to get much better, from an environmental point of view, and an economic point of view, better utilisation of nitrogen. (Tully, Extension)

...I suppose it [his expectation for the project] was to learn about climate forecasting and how it might be used and the various tools that are available and for nitrogen management. (Tully, Extension)

There are few data on environmental losses of nitrogen in the sugar industry, especially at different rates of nitrogen fertilizer. However, the environmental losses can be simulated and so a crop model was used to explore the outcomes of different nitrogen fertilizer management practices with the group. The interactions in the case study group allowed the project team members, growers and extension officers to explore their different perspectives on nitrogen management (i.e. their technological frames).

The participatory approach to this simulation exercise provided an opportunity to gain insights into others' perspectives and was design to help facilitate a common learning experience, which was important for making the technological frames more congruent. This point was highlighted by both of the project team members:

...The idea that you want to move to congruency is something that is important to be able to do. ...It's difficult to put your finger on it. I think it's about understanding...where the other person is coming from... (Nitrogen management project team member)

...I think we got some credibility that outsiders could walk in and we could teach those guys who had lived them all their lives, that we had insights into the place that they lived that were valuable and perhaps a bit different to what they had... I suppose I had the more detailed knowledge of the biophysical system and that was on the left side of me, and on the right side are the farmers saying what they wanted to achieve, and so I could say, well, do you think this would work, whatever, and yes, well let's test that and come back, so it was almost as a facilitator between the biophysical science, and this case was embodied in the simulation model, and also my own experience, and the specifics of their environment and the ideas that they had for management. Perhaps I purposely tried to be a bit of a facilitator and not inject too much of my own ideas into it, because otherwise it wouldn't be grower driven. Everything we did, I could have sat back and done in my office in a much shorter term, and then impose that upon them. (Nitrogen management project team)

One of the participants described the co-learning that emerged from the group interaction:

That was good, the interaction, to hear George talk about what he does up there. And what George does, I can't do. And probably what I do, George can't do. But it's interesting, you learn from that. (Tully, Grower)

In these participatory simulation exercises, APSIM acted as a boundary object, as the project team members, growers and extension officers explored the assumptions about nitrogen management, allowing all participants to gain a better understanding of the nitrogen cycle and the consequences of different nitrogen management scenarios.

The next section shows how the participatory modelling exercise evolved within the Tully case study group.

Participatory technology development process and outcomes

By acting as a boundary object, the APSIM modelling helped facilitate negotiation and cooperation between the project team and case study group participants over the exploration of nitrogen management scenarios. As with the seasonal climate forecasting and irrigation case study groups, it was necessary to build trust in the APSIM modelling. This was achieved by illustrating the capabilities of the model to simulate crop yield responses to different nitrogen fertilizer inputs over recent years for a range of soils and management timings (e.g., planting, harvesting and fertilizing dates) nominated by the case study group. Many of the participants were seeing APSIM modelling for the first time and most were impressed:

You know the APSIM modelling was very impressive. It sort of introduced me to that and to me I think that is a very powerful tool. (Tully, Grower)

[The Nitrogen project team] had to deliver a lot of information, and it was a lot of data, but that's another angle, that's hard. That's hard, to put the thing forward. And he did a pretty job too. He displayed things pretty well, and he explained how good they were and how strong they were, and things like that. Because of all the data involved, the scientific data too, that's over the top of our heads there. He's got to be careful there. But I'd say he kept it simple. (Tully, Grower)

It [the nitrogen modelling] was very informative. That really appealed to me and sent a big message home. (Tully, Grower)

Once the group had agreed that the simulations captured the main features of the crop responses in their environment, they suggested different nitrogen management scenarios to be simulated. The scenarios centered on the timing and splitting of nitrogen fertilizer, both as a routine practice (every year) and in relation to specific seasonal climate forecasts. Specific questions were: “when to split?”; “how much nitrogen should be applied in wet years?”; “what is the difference between early and late fertilizer applications?” The results from the scenarios were presented to the case study group and the implications of the results discussed. Within the participatory paradigm, these interactions were conducted iteratively over a number of meetings. As the following comments show, participants found these simulation scenarios informative:

I was just fascinated with the different responses of the soil types. Sort of say, okay what about this scenario? Peter could put it into his thing and got one result and change a few parameters and you come out with totally opposite results. A bit of time has gone by and I can't say I remember the thing but I do remember if I did two or three splits during those wet years I would have been from 65 to 80 tonnes a hectare better off. ...I'm very enthusiastic about it, opened up a lot of possibilities, scenarios, something like that. (Tully, Grower)

I just told...my brother at that time, I said, “Look.” I said, “Do you know what? We're going to listen to these fellows. ...There's something that we're doing. There's something that they are telling us that we should really listen to.” (Tully, Grower)

The ‘sensitivity’ of the model outputs contributed to growers and extension agents in the group accepting the value of modelling for exploring nitrogen fertilizer management options.

Unlike the irrigation problem of “when to irrigate”, it was discovered that the answers to the nitrogen questions could be reduced to simple rules (i.e. Outcome 2 in the framework). For example, by interacting with the model it was discovered there was little difference between fertilising early or late in the season, and for wet summers it can be beneficial to reduce the amount of nitrogen applied, and in the case of coarse textured soils, split nitrogen applications if the summer is likely to be wetter than average. The following comments illustrate four participants' interpretations of these simple rules:

What got my attention first was that during the wet years...his modelling [was] indicating that if I had split my fertiliser I would have been up another...25 tonnes a hectare, from 65 up to about 80 tonnes. So that really got my attention. (Tully, Grower)

It [the simulation modelling] did help, yes, it did help, for those extreme years I'm talking about. ...Yeah...the examples that were given, it did show the response curve to nitrogen, and things like that, when this happens and that happens. So...we all pretty well knew that this was happening, but how much? (Tully, Grower)

...We were looking at a lower rate in those wetter conditions. That's one of the things we're planning. (Tully, Extension)

It was very clear to me that [for] nitrogen in thorp soils...the management is critical. (Tully, Extension)

However, not all of the participants accepted the simple rules that emerged from the modelling. This suggests that there is also evidence of Outcome 3 in the framework, whereby the participants felt that there is no reason to change current practice and possibly Outcome 4, where participants ultimately rejected the results of the simulation modelling.

In terms of Outcome 3 (i.e. no reason to change), some participants noted that the modelling results had not convinced them that there was much opportunity for improving nitrogen management:

I don't think I've learnt much more, but I've been doing it [nitrogen management], you know, pretty right till now. I don't think there's much further I can improve it. (Tully, Grower)

[Nitrogen management is the] one that I am concerned about and confused about still, in that it would seem from a water quality perspective, nitrates are the ones that are getting targeted and from this project I saw significant limitations in what growers can actually do about it. So even at best practice, I didn't get a strong feel that we were going to solve the problem. (Tully, Extension)

There was also some evidence of Outcome 4 (i.e. rejection of the modelling), with some participants being in the end quite sceptical of the simulation modelling results:

I think more research is needed, though, there's no doubt about that. You got to get stronger. Models are all well and good, but they need to be tested. (Tully, Grower)

As far as the APSIM model is concerned, I have reservations about that, and because it doesn't always agree with what we've actually found in real life, and I don't think people are actually validating the model enough to give it credibility. ... Let's say I'm open to some of the concepts that came out of the models, but I'm not 100 per cent convinced on the results of the models. (Tully, Extension)

Other participants described the challenges of interpreting and understanding the modelling results, which could explain some of the reservations within the group:

Once you deliver a lot of information, it gets confusing of what you're trying to show. We had some pretty big graphs. A lot of different ones, you know, not just one big one. But there might have been nine graphs, the little bar graphs happening, probably more in some instances. (Tully, Grower)

I guess their [simulation modelling] outputs tended to be a bit more confusing, a little bit harder to get your head around... I don't think that was well understood and...there wasn't necessarily agreement that the model output was there. ...But I think it was useful. So it's useful to understand the concepts, and where you take it from there, that's the question after that. (Tully, Extension)

...I still must say I don't know where a lot of the information came from. There must be hordes of information somewhere that they've had access to. I didn't understand how some of it was arrived at. (Tully, Mill)

One of the project team members summarised the outcomes of the nitrogen management modelling exercise, noting that:

I suppose at the end, I think we all had a very common understanding, the biophysical system but there [were] some different expectations of what the appropriate management was... In

the end, we came up with ways to tweak the system, which fulfilled their initial objectives and some of the management reactions, which they said they considered quite good, but they weren't looking for tweaking, they were looking for big pictures, silver bullet type change. (Nitrogen management project team)

The different outcomes specified in the framework help clarify the difficulty faced in reaching agreement on nitrogen management strategies. This highlights the challenge of achieving congruent technological frames between scientists and growers.

Reflections on the participatory technology development process

This section summarises participant's overall satisfaction with the process and some of the key learnings about the participatory technology development process. Appendix 5 provides a more detailed evaluation of experiences of those involved in the case study groups.

Satisfaction with involvement in the case study group

As Table 1 shows, when asked to rate how satisfied they were about their experience of involvement in the case study groups, the majority of participants (25 out of 32 interviewees) were either satisfied or very satisfied.

Table 1: Overall ratings of satisfaction with involvement in the case study groups.

Group (No. of participants)	Very unsatisfied	Unsatisfied	Neutral	Satisfied	Very satisfied
Tully (7)	0	0	1	3	3
Plane Creek (6)	0	0	1	1	4
Bundaberg (6)	0	1	2	1	2
Northern NSW (7)	0	0	1	5	1
Project team (6)	0	0	1	2	3
Totals (32)	<i>0</i>	<i>1</i>	<i>6</i>	<i>12</i>	<i>13</i>

These ratings were supported by many positives responses from participants about their involvement in the project, for example:

My person opinion is that the project was very successful. It was a lengthy project, so therefore we lost some participants. But then right at the end, we picked up a new participant who wished he was there the whole time, he said. He was ready to start on the project, whereas we were all winding down. ...The researchers were very good, I'd say, the people delivering the information were very good. (Tully, Grower)

I think the way it was run was good. The style of the meeting was good, the style of the workshops. ...I guess it's the adult learning type method rather than lecturing and the group participation. (Tully, Extension)

...with the climate forecasting when I went and what I understood was excellent... I don't say I know everything about it, far from it, but the irrigation [is] a five plus [i.e. very highly satisfied]. I mean honestly not because I know Steve, just now you can push a button on a computer and I can know how much water we've used on our farm for this quarter. Before I would ravage through notebooks and wouldn't have a clue, but now it's all documented. (Plane Creek, Grower)

Very high [satisfaction] and that was really because of the interaction that we had. The way we'd set the project up from the beginning, the research was to complement the extension activities and vice versa, I guess, because there were things that we didn't know so we were using the research project to answer that for us but then the extension program was a good way of getting the research-type stuff out so it sort of worked very well together. ...It was very interactive and it worked because of that. (Bundaberg, Extension)

In NSW, participants commented on their increased understanding of seasonal climate forecasting, even though it had not proved viable as a predictive tool:

Yeah, just being involved helped me understand the weather forecasts a bit better, like the southern isolating index and all that. It meant nothing to me before, but like it's helped me understand a bit about forecasting. (NSW, Grower)

Personal satisfaction from the point of view of the knowledge I've gained, but in terms of using it as a predictive tool, probably I'd rate the level of satisfaction below that. (NSW, Extension)

One participant who was neutral regarding with his involvement in the group noted:

The benefits being minor...there [was] not as much [benefit] as I expected because I think I have done more or less like we're aiming to do. (Tully, Grower)

Another participant was not satisfied with the frequency of the meetings:

The networking, [did] not really [meet expectations], because we had infrequent meetings... (Bundaberg, Grower)

For the seasonal climate forecasting groups, the project team member noted that it was very satisfying to see that the New South Wales case study group had demonstrated that they understand the risks of seasonal climate forecasting and are still interested in it:

...the [NSW] group have demonstrated to me that they understand the risks of climate forecasting, they understand the limitations, there's still an interest in climate forecasting, even though the forecasts for the last three years have been 50/50, they're still coming along to meetings, they're still asking really good questions, but they haven't been able to use them to make too many decisions over the last two years because we haven't been in a dominant El Niño and La Niña pattern. That's really incredible. (Seasonal climate forecasting project team member)

The level of awareness-raising in New South Wales was also positive:

We've had a lot of awareness raising activities that have been taken on board by the extension staff there. They've really ran with that, so that would put that at a five [i.e. highly satisfied]. (Seasonal climate forecasting project team member)

Although there was less awareness-raising in Plane Creek, the fact that there was a clear local champion was satisfying:

There hasn't been as much awareness raising done in the Plane Creek region, but within the consultative group, we've got somebody who is leading the way, it looks like they'll be happy

to do that for a long time, they'll be the champion I guess of providing the climate forecasting information after the project finishes. (Seasonal climate forecasting project team member)

There had also been reasonably good progress in Tully regarding awareness-raising and learning:

In Tully, whilst things have moved a little bit slower, I can see the learning cycle that the groups are going through. We thought that would be the tool, but it's not the tool, to go outside the case study group and then we inherently started to work on something else that might help them to go outside the consultative group. That sort of reflected on 'this isn't really a good idea', and so we're just going through a cycle that is perhaps progressing just a little bit slower than the other regions, but still on that cycle. ...We've done some awareness raising activities in Tully... In terms of going outside of the consultative group, widely and engaging, it's difficult really for me to say. I suspect what's happened in New South Wales, has probably reached more people than what's happened in Tully. (Seasonal climate forecasting project team member)

The irrigation project team members were satisfied that they had reached a richer level of understanding because of the participatory research approach:

...I felt that they [case study group participants]...became part of our project team, albeit contributing different insights, and contributing in different ways. So, as a result of that, I believe we got a much richer understanding about the issues and the scope of farmer knowledge and aspirations. So if we had had two identical groups in two regions, we would, I think, have had less insight than what we have. So, looking at the complexities that we've got in front of us then gives us a much better understanding about the limitations of technology like this, to have success out there. But all the farmers in both groups saw value in what we were doing, believed that it would have some impact on themselves, and could see a value for their industry. And therefore, they were prepared to continue for the whole duration of the project. So in both groups, people continued to participate even though they were at very different levels and progressing at different rates. (Irrigation project team)

Oh look, in the end I'm very happy with the way a few growers have understood what we've been doing and appreciated it. ...But yeah, in the end I realised there was a long way to go for us to understand how these people operate and what they need and I'm very happy that we've done that. We've understood where they're coming from and they've understood what we can offer. Even though it's a small number of growers. And I can see that could really, over time, convince a lot of growers. (Irrigation project team)

There were mixed views within the nitrogen management team. One of the members described working with the case study group as a satisfying experience:

I found it both enjoyable and also I felt as if it was giving the growers value as well, which is satisfying. (Nitrogen management project team member)

The other nitrogen management team member noted that it was hard to keep momentum because of the relatively infrequent meetings:

Essentially, we met with them twice a year and that was difficult. Things were going a bit cold in between, so that was a resource constraint. We could have done a better job if we had more resources, so we were resource limited at the end of the day. (Nitrogen management project team member)

This team member went on to note that he was a little disappointed with the result of nitrogen management work:

It became apparent at the end - the old thing, if we had have known some of the things that we found out they were thinking at the end, had we known that at the beginning, we might have done it a bit differently, and I suppose that specifically they were hoping for a miracle and that when we were asking for feedback on some of the scenarios we were running and proposing, you would say, 'okay, this is a hassle, would you really do this on the farm?', and they would say, 'yeah, yeah, no sweat, that's all right', and then we said, 'look, that looks like a good thing to do', and then all of a sudden, it was 'actually it is a hassle'. They were being a bit cavalier in the case study and maybe undervaluing our time and what we could do. We went in there idealistically thinking, if we get something, we can make a change. (Nitrogen management project team member)

Strengths and weaknesses of the participatory approach

Participant noted that one of the main strengths of the participatory approach is that it prevents scientists from becoming insular and ensures that users' needs are met, for instance:

I think it prevents the scientists from becoming insular, and believing they have the solution to everything. So it helps keep your feet on the ground and sort of understand what the needs are, and whether your research is actually addressing the needs of the recipients. So I suppose that's probably the main things. Scientists aren't always the fountain of all knowledge. But I think the industry or the groups like that can...contribute something. (Tully, Extension)

Well, simply that it's of no use unless it aides the man on the land. And they're working with the man on the land to make sure it fits in with him so yes they're going hand in hand. So one's no good without the other. (Plane Creek, Grower)

I like the idea that they took our data on board too; they didn't use it as like an area. They didn't pick irrigation and cane itself they picked irrigation like in Plane Creek Mill, do you know what I mean? Scientists tend to want to look at irrigation on a wide scale thing and like they looked at it as us in Plane Creek and they took all our research and I think that's why they've got it fairly accurate; they didn't use it on like a broad thing. Taking all our data down that we got here on our soil types, on our rainfall and on our equipment that we have got to irrigate with. (Plane Creek, Grower)

We've got to get the grower involved, and we have had some growers that have been very involved in this and contributed greatly. [The irrigation team] have taken on – not always exactly done what the grower thought, because sometimes the grower doesn't quite understand the science. But in the end, I think it achieved the outcomes that they were looking for, what the grower was looking for. It's got to be grower friendly, they've got to be able to work it and it's got to mean something. (Bundaberg, Extension)

They're developing a product that meets the expectation of the grower. It's relevant and meets expectations of growers. (Bundaberg, Extension)

Participant also emphasised the way in which they felt genuinely listened to:

They seemed to listen to what we were asking and they were a bit limited in time and things like this and funding and modelling time and things like that but we sort of thrashed out some standard scenarios. (Tully, Grower)

I feel like we were listened to. And I guess if something is going to accepted, there's got to be some grower input into something like that, because otherwise people are just going to say,

'Here we go again, another hair-brained idea'. I think I might've even made that comment right at the start, when they were talking about how to get growers involved and stuff. And I said, getting growers to trust what information that's there is—actually, the more I think about it now, that was discussed at one of the meetings, having grower confidence in what was being put out. ...You've got to have the confidence. And I think, yeah, I'm confident with it [WaterSense], so long as you put the right number into there to start with. (Bundaberg, Grower)

Some participants noted that they valued the opportunity to be involved in and learn from the research, even if they did not quite get the outcome they were hoping for:

I suppose we had the opportunity to be involved and help guide it along in the right direction. We would set some of the directions and she would then go off and hunt down for the next 12 months and report back next year. I mean, it's basically trying to find a role for it and we're slowly coming to the conclusion. It was interesting, we agreed last time that we would like to see it continue, but we also sort of agreed that we weren't getting that much out of it. But that's sometimes a problem with stuff which is a bit out there. It takes a while to get it right and work out where you're going, which is the whole purpose of research grants. (NSW, Grower)

Like I said before, just that it helped me to understand some of the terms they used and things, and it was pretty good to be involved, but it just didn't come up with the result we wanted. (NSW, Grower)

Another participant pointed out that the fact that people stayed engaged in the process was one of the strengths of the approach:

...I thought it worked well. The fact that not only people like Peter McGuire and myself, but the growers were willing to go back to subsequent meetings. As I said, not every time, but the same growers go back to each meeting, but in most cases they did. Usually in my experience...if it wasn't a good experience they wouldn't go to subsequent meetings, whereas in this case they have. (NSW, Extension)

When asked about the challenges associated with the participatory approach, many participants emphasised its time consuming nature:

They're very time-consuming. You can do the same thing, having to do the same thing over and over again, and because the people you're dealing with aren't used to that type of research, they don't necessarily have everything logically planned as to what they're looking for, things like that. So you can end up doing a lot more than you want. Or going down a lot of dry gullies to satisfy. I think then if you like, the key to the success is really the, if you can, the ability to steer people away from those dry gullies, if you can. (Tully, Extension)

If there's anything it's probably that there is a reasonable time in everybody fencing or being very nice to each other. So you tend to use one or two meetings being nice and not actually going anywhere versus saying let's just get down to business. (Tully, Extension)

Probably the amount of time that it actually took. (Plane Creek, Grower)

Another meeting to go to, but that's all right. (NSW, Grower)

It means more work for the researcher which they probably don't appreciate at times. But that's the only downside and I mean it's just a fact of life in R&D today that you are going to have to do this. (NSW, Grower)

Participants also highlighted how difficult it was to ensure that the science was “paddock savvy” and user-friendly:

...I know what the real challenge was, it was taking science and making it paddock savvy. That was the real challenge. Yeah, well...it was bridging that gap between what was seen to be pretty good science, but making sure that it was paddock useable. I think that's been the key for this. This thing could've been developed in an office in Townsville and it could've been spat out on a disk, and I don't think anybody would've used it. Because every time you would've used it, you would've said, there's a problem with this. The fact that we've gone the way we have, the process of developing it and taking the science to the people and the people to the science and bringing the two together so as at the end of the day, something was useful to the grower at his level rather than the scientist at his level, has been the real deal. (Bundaberg, Extension)

I guess the most important challenge was that because the industry really wanted this information, because they had low water allocation, it's sort of a bit like research by the seat of your pants. So these guys are after this sort of information and you're trying to feed it back to them at the same time as you're discovering it and that's the challenge. ...No, that's probably the main challenge because we were moving along at quite a quick pace. (Bundaberg, Extension)

...it needs to be very easy to understand for the growers, for managers to be able to have a relatively simple report that will give them data based on some fairly complex variables that occur on the back end of the model, or the program, WaterSense program. Being able to marry up water, soil, water relationships and crop growth models and that sort of thing. Obviously we need to be able to have something that is pretty easy for a farmer to understand at the front end. (Bundaberg, Mill)

Many participants could not identify anything negative about the process:

No, none that I could point out, no. I couldn't considering the short time that I've been in it and the gains that I can see in it straight away. So, no I couldn't be critical of it, no. (Plane Creek, Grower)

No I don't think there was. I didn't get frustrated, but like asked a lot of questions and some of it was hard to understand, I mean some of it that's a lot to take in and they didn't mind us pulling them up and asking them to explain things a little bit closer. (Plane Creek, Grower)

No, I can't really – I think if you did that every time I can't see any problem. I can't pinpoint anything negative actually. (Plane Creek, Grower)

No, I couldn't think of any other ways of doing things different, you know. (Plane Creek, Grower)

I wouldn't say there were any downsides, no. (Plane Creek, Grower)

Can't really say any problems with any of it. Can't condemn any of it. (NSW, Grower)

I can't think of any. (NSW, Extension)

I don't think there was any [problems with the approach]. As I said before, it's what we do anyway and I think if people don't do it that way, they're going up the wrong tree, I think.

You have to involve the farmers in these sorts of projects. The farmers are the people who are doing the work out in the paddock, so this is no different. (NSW, Mill)

The project team members were also interviewed about the strengths of the participatory approach that was used within the group. The interaction with the case study group members and the chance to get a better understanding of what the growers wanted from the project were common responses:

The best thing that I like the most, is the relationship, the interaction. I quite enjoy that personally. You get to know the people and you think you can help them. You don't get that by working in isolation from a group, so the group dynamics, I really enjoy. (Seasonal climate forecasting project team member)

Well...getting to understand the framework on which these people make decisions and how to deliver it to that understanding. (Irrigation project team member)

The fact that we do respond to their [i.e. case study group members'] suggestions. ...so it's a lot of interaction going on. So they're comfortable in doing that as well. And they have been willing to contribute. (Irrigation project team member)

I guess it was a good opportunity to actually do it [i.e. use a participatory approach]. It's nice to have a little bit of freedom. I think that was the best thing about it. It gives you a nice feeling that you are doing what the growers are asking and hope that it's what they're wanting. It's nice to be able to respond that way. (Nitrogen management project team member)

Project team members also commented that it was rewarding to see how growers' thinking developed and to help growers gain insights into their system:

The other thing I really like is you get to see how their thinking develops over time. That's really rewarding, to see that participatory approach. What's important about that approach is it gives people the opportunity to stop and make a critical reflection on what's happened in the past, and then to be able to help with finding a new direction or a future direction to take. That's what's really important I think with the participatory approach. (Seasonal climate forecasting project team member)

It's fairly intense, so I think the experience is probably really embedded in everybody who participated. Even if they don't change their actions, they've probably got different insights into their system. (Nitrogen management project team member)

One project team member highlighted the way in which he felt they had reached a level of shared understanding with growers:

I suppose at the end, I think we all had a very common understanding [of] the biophysical system but there was some different expectations of what the appropriate management was, that biophysical outcome. (Nitrogen management project team member)

The way in which the participatory research approach creates a better product, tailored to end-user requirements was highlighted by one of the irrigation project team:

I think the quality of the product at the end. I think, at the end, it generates a much better product, much more – just a matter of a better product. I mean, it pretty much gives the user exactly what they want and actually they quite often come up with better ideas than you

initially came up with. I guess more heads are better than one. (Irrigation project team member)

Nevertheless, project team members nominated defining aims and motivations and user requirements as key challenges of the participatory approach:

Changing user requirements from the growers... (Irrigation project team member)

I suppose the other challenge was getting them to engage really seriously, rather than giving quick shallow reactions to ideas. This thing about looking for the silver bullet - yes, we'll be in this, because if we can find the miracle benefit by not actually changing - I mean, at the end of the day, the guys weren't as committed to change as they made out in the beginning. They were committed to change provided there was an enormous benefit. They weren't looking to tweak the system. (Nitrogen management project team member)

Another challenge of participatory approaches related to resource and time issues:

We generally did what we could, unless there was a real big reason why we shouldn't do it. And one of that would've been time. (Irrigation project team member)

The challenge for the resources. How much time it required from us and commitment to that time required from them. (Nitrogen management project team member)

Key lessons

A number of key lessons about the participatory technology development process emerged from the interviews with case study group participants and project team members, including:

- The need to explicitly recognise and take stock of the different ways that people interpret technologies;
- The importance of working towards a shared understanding of the problem and the technology between the scientists and the industry members involved in the process;
- Recognition that both the scientists and the industry members change and learn through the participatory technology development process;
- The significance of being able to simplify a complex problem to a rule of thumb and the affect of different contexts and adoption strategies on this process; and
- The value of working in a participatory mode with industry members and the significant commitment that this requires from all parties.

The interviews with case study group and project team members suggest that there is strong support for participatory research and development approaches from industry members and researchers alike, despite its sometime challenging nature.

APPENDIX 5: EVALUATION OF CASE STUDY GROUP EXPERIENCES

Emma Jakku and Peter Thorburn

We conducted in-depth interviews with 26 case study group participants across each case study region and the six project team members who facilitated the groups, in order to evaluate any changes in knowledge, attitudes, skills and aspirations.

Participants and project team members were asked to reflect on the best things about their involvement in the groups, whether they had made any changes as a result of involvement in the groups and any lessons they felt that they had learnt through being part of the project. The interviews also covered attitudes toward the participatory research approach used in the project, personal satisfaction with involvement in the group and any suggestions for how the groups could have been improved. The following sections report on the results of these interviews.

Evaluation of the Tully case study group experience

Seven participants in the Tully seasonal climate forecasting and nitrogen management case study group were interviewed about their experience of involvement in the group.

Best things about involvement

When participants were asked what the best things about involvement in the case study group were, two participants pointed to the potential to improving farm management:

The real leading thing, financially, was the fertiliser nitrogen program. So much so, we had an implement that used to do side dressing... When we started doing this [project], I changed it. Even though it was new, three to a few years old, I changed it, sold it. I bought a stool spreader. We now incorporate that with the different types of studies that they were showing us at different rates at different times, depending whether the expectation of climate's going to be wet or dry. (Tully, Grower)

...I did see the zeal that some of the farmers had, where they thought that they may have been able to do some things different. I believe in this day and age that if a farmer can do something different and save a few bob, he's got to do it to stay afloat. I'm sure that there are a couple of those people that will do things a little bit differently on occasions because of what they find. (Tully, Mill)

Four participants described their increase in knowledge as a result of their involvement in the group:

Well, it sort of gives you a bit more knowledge of many things really and whether these have benefited but at least you can separate things differently. (Tully, Grower)

Yes, I understood a lot more about it [seasonal climate forecasting] and I came to grips with that unpredictability barrier. (Tully, Grower)

[My understanding of seasonal climate forecasting has] gone from a fairly low level to understanding that there are certain indicators that have fairly strong relevance in Tully. ...I guess the SOI mainly. But then sea surface temperature and some of those indicators. ...Oh it seems to me that the strongly positive SOIs are the times we're going to get above average wet weather. (Tully, Extension)

...I've got a feeling now for what might be going to happen down the track [regarding seasonal climate forecasting]. I wasn't even aware that any of these websites existed previously. (Tully, Mill)

Two participants appreciated the interaction within the group the most:

Yeah, the interaction was great. It's always interesting to see someone else thinking in their line of work which is totally different, and you can learn from that. You just can't look through your own window the whole time. It's good to hear what other people do. It just broadens your mind so then, I suppose, with the varying aspects of what could possibly happen, you can sort of adapt, by someone else's knowledge. (Tully, Grower)

I think if you've got a productive group, or an enthusiastic group, you're going to get more out of it than trying to do something by yourself. And there's people can throw in things that you haven't even thought of at times, or add additional information. So I think that's the real benefits of working in a group situation, provided the group's got the right vibes. (Tully, Extension)

One participant commented that he liked the way that the information was presented within the group:

I thought the way Yvette presented all the information was really good. Yvette, she's sensitive to the way someone learns; she is really, really good. The way that she puts things forward to you, she doesn't offend anyone, and she listens. She listens really well, which is important. I think no-one can come away complaining about any of the speakers there. Peter Thorburn had to deliver a lot of information, and it was a lot of data, but that's another angle, that's hard. That's hard, to put the thing forward. And he did a pretty job too. He displayed things pretty well, and he explained how good they were and how strong they were, and things like that. Because of all the data involved, the scientific data too, that's over the top of our heads there. He's got to be careful there. But I'd say he kept it simple. It was a good group...it really was. (Tully, Grower)

Another participant noted that he really appreciated having access to experts:

Having access to Yvette and Peter Thorburn basically. ...Just the way they walked us through all the program. Meeting all these scientists basically, yes. (Tully, Grower)

Evidence of changes

In trying to ascertain the impact of the project, we asked participants to nominate whether they had changed what they do as a result of the project. Three of the participants noted that they had made changes to their farming practices:

Like I said, we've changed our fertilising practice. We have changed the outlook of how we plan farming. I now realise a tractor and implement is not the only implement. The other one is also the computer, which is the internet. I mean, we're sourcing information out through the different channels that Yvette showed us. (Tully, Grower)

At the beginning of this project, I was starting to change my practices anyway, and I have, I still have continued that. I didn't go back to my old ways or anything like that. So I adapted that way. ...And I know, you just can't go drastically cutting down your nitrogen application by 50 per cent without hurting productivity. In certain spots around your farm, you probably can, but not just a broad acre approach to the whole of your farm. (Tully, Grower)

I was aware I was losing nitrogen from my water quality work but now I've sort of said, well what can I do to reduce it? And there were several different scenarios... (Tully, Grower)

Two of the participants noted that now felt more confidence in adapting their farming practices to different seasons:

I'm now confident, more confident for different changing seasons to adapt practices, most definitely. Whereas before this, we all related after the fact, always after the fact, of a chance that we should've done this and should've done that. (Tully, Grower)

I'm not too sure if it is because of the group by itself, but I've got the water quality work and I'm also associated with Alan Garside...and also this group. Between the three of them and different readings and things like that, well...this season is 11.03: eleventh year in the third month. I'm constantly reviewing it and trying to improve it and basically any scientific information I get, I try and work it into the farming system. I have two or three scenarios and I zero in on those. I amalgamate them or make one and then go ahead until I've got another bit of a challenge and then go again. (Tully, Grower)

One of the participants who did not feel as though he had changed his practices as a result of this project, noted that this was because he felt that he was already doing the best he could, particularly in terms of his nitrogen management practices:

I think I have been responsible all along, even before the project. I always tried to manage as best as possible and as far as nitrogen, I think all my life I've tried to use as least as possible and tried to be productive. ...I think overall, there's not too much that has changed me in the way I do things because I think we have reduced our costs as much as possible and I'd love to know if there's any other things that I could do to reduce it and be better at it. (Tully, Grower)

Two of the participants noted that they remained reluctant to give advice on seasonal climate forecasting.

I wouldn't give advice on climate forecasting. [I'd just stick to] here's the tool and explaining what the tool can do. (Tully, Extension)

I would find it very hard to advise somebody not to do something. (Tully, Mill)

Lessons learnt

Participants were asked to summarise what they saw as the key lessons that they had learnt through this project. Three participants noted that they had learnt the difference between climate and weather:

When they say climate forecasting, the first perception was weather forecasting. I went there with the total wrong idea; soon modified. ...I learnt the difference between weather and climate. When I thought there was no difference at all. ...We went there with the perception to understand three days to seven days, weather forecast. Not 12 months, two years or six months ahead, none of that. Then I soon realised that seven days is only just good for five minutes. (Tully, Grower)

Yeah, from when we first started we were trying to learn about what the climate meant to us. And it wasn't weather, it wasn't weather forecasting. (Tully, Grower)

...I've learnt that there are differences between climate forecasting and weather forecasting. And neither of them are exact sciences. (Tully, Mill)

Two of the participants highlighted what they learnt about nitrogen application and interactions with soil and weather:

One of the greatest things that I learnt was with application of nitrogen, fertilisers. ...It's a new notion brought to us and we're adapting it. I look at different types. We've got heavy soils, light soils. We've got high country, low country. So it's still a learning process. But it's opened up our eyes a little bit – not opened our eyes, just given us a new vision. (Tully, Grower)

I've learned how important nitrogen application is, even not enough of, I've learned that. ...So I've learned...that there's a right figure in there to put, every year [it] changes, that's all. We've just come through a cyclone year, for a lot of rainfall, and that. I've tried different things there. (Tully, Grower)

Two of the participants pointed to the increased understanding of the limitations of seasonal climate forecasting as their biggest learning:

...I've realised that the autumn predictability barrier, which I didn't know about... (Tully, Grower)

As far as climate forecasting is concerned, I gained a better understanding of it and its limitations, and that's how good it could work. (Tully, Extension)

One participant described the way that his involvement in the group had led him to the idea of 'weather-proofing' his farm:

...basically now, instead of having two farming systems, I've gone to the one, which is aimed at the La Niña. That is just splitting three applications and things like that. ...It is structured for the worst scenario. ...Mainly because of the autumn predictability [barrier]. ...I'm not too sure if I'm unique or something, but I've tried to weatherproof my farm. (Tully, Grower)

One of the participants noted that he learnt about working with groups through involvement in the project:

In terms of the project itself, obviously you picked up some skills there but I think just in dealing with groups and that I got a little bit out of that. ...Yeah, just the different way of getting responses or trying to explore things. (Tully, Extension)

Attitudes towards the participatory approach

We asked participants to identify what they liked best about the participatory approach that was used within the group. Three participants commented on the co-learning that emerged through the group interaction:

We had a contrast of farmers here. Each one was supporting their little different views from where their locations are. We were learning off them too. (Tully, Grower)

I think I would describe my role as the same as everyone else's. Their life experiences are different to everyone else's, and you learn from that. You learn from other people's experiences. ...it's not possible for one person to come up with all the right questions. Whereas, if you're thinking on a certain track, someone else thinking probably somewhere

else, and wants to ask questions down there. It just shortens the time period you need to be there. Because someone's covering another angle, another base which you didn't think about. Yeah, group participation is really great. It's important. I hope other people learn from what, some of the questions I raised. (Tully, Grower)

...I think if you've got a productive group, or an enthusiastic group, you're going to get more out of it than trying to do something by yourself. And there's people can throw in things that you haven't even thought of at times, or add additional information. So I think that's the real benefits of working in a group situation, provided the group's got the right vibes. (Tully, Extension)

Three participants noted that the approach used in the case study group promoted understanding and acceptance and encouraged growers to take ownership of the group outcomes:

If you were just told to go and do it, and it didn't matter what you thought about it, well, you know, you didn't like it. ...It's like an attack. It's just their approach. So the way it was conducted in here was really, really good. There was a bit of information given, and then it was, well, what do you think of that? Yeah, and then give an instance; let's talk about that. If you didn't understand it, let's cover that. Let's try to understand it. (Tully, Grower)

...farmers like it [the participatory approach] because they're actually being asked so they do take some ownership. (Tully, Extension)

I think it is about getting people involved. Making them feel like they are participating rather than being spoken to or just being told, this is how it happens. ...If you involve people, they are more than likely going to accept some of the outcomes. (Tully, Mill)

Similarly, one participant emphasised the way in which he felt genuinely listened to:

They seemed to listen to what we were asking and they were a bit limited in time and things like this and funding and modelling time and things like that but we sort of thrashed out some standard scenarios. (Tully, Grower)

Another participant noted that the strength of the participatory approach is that it prevents scientists from becoming insular and ensures that users' needs are met:

I think it prevents the scientists from becoming insular, and believing they have the solution to everything. So it helps keep your feet on the ground and sort of understand what the needs are, and whether your research is actually addressing the needs of the recipients. So I suppose that's probably the main things. Scientists aren't always the fountain of all knowledge. But I think the industry or the groups like that can...contribute something. (Tully, Extension)

When asked about the challenges associated with the participatory approach, two participants emphasised its time consuming nature:

They're very time-consuming. You can do the same thing, having to do the same thing over and over again, and because the people you're dealing with aren't used to that type of research, they don't necessarily have everything logically planned as to what they're looking for, things like that. So you can end up doing a lot more than you want. Or going down a lot of dry gullies to satisfy. I think then if you like, the key to the success is really the, if you can, the ability to steer people away from those dry gullies, if you can. (Tully, Extension)

If there's anything it's probably that there is a reasonable time in everybody fencing or being very nice to each other. So you tend to use one or two meetings being nice and not actually going anywhere versus saying let's just get down to business. (Tully, Extension)

One participant noted that it was a shame that the project came to an end:

I guess just coming to the end. Time, money, whatever, ran out. (Tully, Grower)

Personal satisfaction with group involvement

When asked about their overall satisfaction with involvement in the group, the majority of responses were positive:

My person opinion is that the project was very successful. It was a lengthy project, so therefore we lost some participants. But then right at the end, we picked up a new participant who wished he was there the whole time, he said. He was ready to start on the project, whereas we were all winding down. ...The researchers were very good, I'd say, the people delivering the information were very good. (Tully, Grower)

All these other options and things like that. ...I love it. ...I was just fascinated with the different responses of the soil types. (Tully, Grower)

...I think as far as the whole thing was concerned, I think it was handled quite well. The people involved, in the providers' side, if you like, related fairly well with the group and...they came down to our level of understanding, and worked through with us. And I think the group overall got on fairly well, and were interested in trying to make something out of climate forecasting. (Tully, Extension)

I think the way it was run was good. The style of the meeting was good, the style of the workshops. ...I guess it's the adult learning type method rather than lecturing and the group participation. (Tully, Extension)

Well I know at the end of the day I can at least read the [seasonal climate forecasting] charts now. That's something that I couldn't do before. (Tully, Mill)

One participant noted that although he was satisfied overall with his involvement in the group, he did find the seasonal climate forecasting component somewhat confusing:

I didn't fully grasp the...SOI. I still find it confusing. When I do go onto the computer, the language – it's a lot of words, a lot of sentences, a lot of paragraphs. When they could just say it in two words, El Nino, La Nina. Or be aware for the next three months. That type of thing. (Tully, Grower)

One participant was somewhat unsatisfied with his involvement in the group:

The benefits being minor...there [was] not as much [benefit] as I expected because I think I have done more or less like we're aiming to do. (Tully, Grower)

Suggestions for improvement

When asked how their experiences could have been improved, two of the participants suggested that there could have been more growers involved in the case study group:

Probably disappointing at times that there wasn't enough growers; but at certain times, people just got busy. (Tully, Grower)

I think possibly another couple of people in there [i.e. the group] might've helped. ... I don't know, just maybe a little bit different...types of growers that were involved... (Tully, Extension)

Two of the participants noted that they could not really see how the case study group could be improved:

...I couldn't see how it could have been improved. (Tully, Grower)

...I guess there could have been but I can't think of anything. (Tully, Grower)

One participant noted that the group members, himself included, could have come to the meetings a bit more prepared:

...probably some of the growers' preparation for these meetings probably wasn't good enough. I suppose, if...there was a let-down, I suppose it'd be myself. I didn't give enough preparation for the next meetings and things like that. (Tully, Grower)

Evaluation of the Plane Creek case study group experience

Six participants in the Plane Creek seasonal climate forecasting and irrigation management case study groups were interviewed about their experience of involvement in the group.

Best things about involvement

When asked what the best things about involvement in the case study groups were, two of the Plane Creek case study group participants emphasised the way in which they valued learning from the other growers that were in the case study group:

And just as importantly is listening to my fellow growers. Their comments back. And how they're relating this information to their own places as well as me trying to relate it to my own. (Plane Creek, Grower)

Well, I suppose it's probably interacting with other farmers as well too. ...I mean, everyone had put forward...an idea and either someone would like it or they wouldn't like it and they have an idea so yes, you sort of work around all that. (Plane Creek, Grower)

One participant highlighted the way in which he appreciated being able to contribute to the research:

Being able to contribute my thoughts. Just seeing where it was growing and coming together... (Plane Creek, Grower)

Three participants noted that they liked being able to have access to the latest information to improve their farming practices:

Using the latest information available and improving my chances as a grower to make the most of our natural environment... (Plane Creek, Grower)

Overall was just having a handle on all the water we used and where we used it and how much water we used on our block. Like before we had no idea, we had no idea. We knew we used X amount of water to water the farm...we knew where we watered, but we didn't know

what we put where and we can go back now on our records and say oh gee you know that block there didn't take a lot of water; that other block over there we over watered, next time we'll have to rearrange our water there we might have to speed our water up or something. (Plane Creek, Grower)

...you just sort of keep up to date on how the work out the SOI and talk about the MJO and you are just familiarising yourself with that but the fact is that in that regard, nothing much has changed. You sort of go along in case they've learnt something new. (Plane Creek, Grower)

Evidence of changes

Five participants described how the project had influenced them to change their farming practices:

Well probably the main thing is just the irrigation side. You know if...it looks like an El Niño year you can make sure your dams are full before the season starts. That's one way of using it. Also if it's going to be an El Niño or wet year, you're scheduling your harvesting so that the wetter paddocks aren't left to last. You've got a fair possibility of being able to get them off when it's dry. That's another way of using it. (Plane Creek, Grower)

I brought an extra irrigator a few years ago now on the strength of the information we had on an El Niño event being forthcoming. I put in an order for one much sooner than what I would have. This last year has worked the other way. I was working on information received and I expected to have a dryish summer period, a dry January—much lower than normal January/February period and I pumped a lot of underground water into a dam but I needn't have because it didn't turn out that way. The dam has overflowed early in what has become a more traditional wet season. But I'm not sorry about that. ...Yes well I'd have been on top if it had been dry wouldn't I? (Plane Creek, Grower)

Earlier on I did [use seasonal climate forecasting] when I was setting up irrigation. It showed it was going to be an El Niño year and so I said, righto it's going to be dry, I'll need to water some paddocks. The question was whether to spend some money to lay some underground which would extend my watering capabilities. So I went ahead. Whereas if it had been going to be wet, I may not have spent that money. (Plane Creek, Grower)

...one of the big advantages for me was that I didn't, couldn't see that until we started the program was the different soil types and their water holding capacity and on our own properties you could relate to what areas have to get to start...Some start feed irrigating two weeks after, others [are] different... And I've only just got into it, like I'm not really into it...I haven't go the whole farm under it. We've had one block then we're going to do another block this year. (Plane Creek, Grower)

...I'd have a look at what it [WaterSense] was saying and then sort of go and have a look at the paddock and try and get a better idea of what the moisture was actually really like and I'd go from there, sort of thing. So sometimes you'd water when it said and other times you might have thought, well, there's still a bit of moisture there, I might leave it for another week, sort of thing. (Plane Creek, Grower)

Lessons learnt

Three participants summarised what they saw as the key lessons that they had learnt through this project:

For the seasonal forecasting basically...if you're just going on from year to year without even looking ahead to see what the season is going to be ahead I think you're just going to do it,

aren't it? You've got to have some sort of forward looking. That's my opinion anyhow. For harvesting, planting, fertilizing, everything you know. (Plane Creek, Grower)

Yeah, my guess is as we get better at reading it [seasonal climate forecasting information]...when we're planning what particular varieties we're going to plant on the property...some are more tolerant to wet conditions and some are more tolerant to dry conditions. ...we can see like a trend over the next few seasons and look at the cycle. ...Well capability has to increase before I get that built up. (Plane Creek, Grower)

Even though I didn't know how to use it [WaterSense] physically, the information and education I got from it is something that will stand me in good stead whether I use them or not. The experience and the information gained is something that will stop with me all the time. (Plane Creek, Grower)

Attitudes towards the participatory approach

We asked participants to identify what they liked best about the participatory approach that was used within the group. Four participants described how they appreciated the way in which the project team were working with growers to meet the growers' needs and involving the growers in the research:

Well, simply that it's of no use unless it aides the man on the land. And they're working with the man on the land to make sure it fits in with him so yes they're going hand in hand. So one's no good without the other. (Plane Creek, Grower)

As long as there is some useful information in it that is going to be of ongoing value, it is a good thing. (Plane Creek, Grower)

I think well we involved in the whole project. ...It's not like someone standing up there lecturing us and telling us what we had to do and you do this or do that. They were consulting with us ourselves and I think it's just our involvement with the whole project. Just a group involvement and I think you could say – I'm talking for the whole group. I'm pretty sure that they'd all say that they've learned and...they've gained from the whole experience. (Plane Creek, Grower)

I like the idea that they took our data on board too; they didn't use it as like an area. They didn't pick irrigation and cane itself they picked irrigation like in Plane Creek Mill, do you know what I mean? Scientists tend to want to look at irrigation on a wide scale thing and like they looked at it as us in Plane Creek and they took all our research and I think that's why they've got it fairly accurate; they didn't use it on like a broad thing. Taking all our data down that we got here on our soil types, on our rainfall and on our equipment that we have got to irrigate with. (Plane Creek, Grower)

One of the participants noted that the approach used in the case study groups encouraged the growers to adopt a more scientific approach:

For growers to take a more scientific approach I suppose. To base their decisions on science and not what dad might have done, I think. I mean we mightn't necessarily agree all the time but it is certainly good to listen to and to weigh up what advantages we can see and where we might improve. (Plane Creek, Grower)

When asked about the challenges associated with the participatory approach, one participant noted that it was a time-consuming process:

Probably the amount of time that it actually took. (Plane Creek, Grower)

The other participants could not identify anything negative about the process:

No, none that I could point out, no. I couldn't considering the short time that I've been in it and the gains that I can see in it straight away. So, no I couldn't be critical of it, no. (Plane Creek, Grower)

No I don't think there was. I didn't get frustrated, but like asked a lot of questions and some of it was hard to understand, I mean some of it that's a lot to take in and they didn't mind us pulling them up and asking them to explain things a little bit closer. (Plane Creek, Grower)

No, I can't really – I think if you did that every time I can't see any problem. I can't pinpoint anything negative actually. (Plane Creek, Grower)

No, I couldn't think of any other ways of doing things different, you know. (Plane Creek, Grower)

I wouldn't say there were any downsides, no. (Plane Creek, Grower)

Personal satisfaction with group involvement

When asked about their overall satisfaction with involvement in the groups, the majority of participants were either satisfied or highly satisfied, for instance:

...it challenged me and it was very interesting. (Plane Creek, Grower)

...I've been very satisfied with the whole thing, yeah. ... I have had an interest in weather forecasting for years now and this just fell right into my lap. That's exactly what I love doing. (Plane Creek, Grower)

...with the climate forecasting when I went and what I understood was excellent... I don't say I know everything about it, far from it, but the irrigation [is] a five plus [i.e. very highly satisfied]. I mean honestly not because I know Steve, just now you can push a button on a computer and I can know how much water we've used on our farm for this quarter. Before I would ravage through notebooks and wouldn't have a clue, but now it's all documented. (Plane Creek, Grower)

One participant noted that he was more interested in seasonal climate forecasting than irrigation management:

I was more interested in the weather predicting one. I know that it goes hand in hand with the irrigation but I would give the weather one a four [i.e. satisfied] I suppose. ...And then the other one [i.e. the irrigation group], well it is pretty useful so probably a two. If you asked me if I'd want to go again to the irrigation one, well I'd probably give it a miss but I'd still go to the weather one. (Plane Creek, Grower)

Suggestions for improvement

When asked how their experiences could have been improved, two participants pointed to the practical constraints on implementing WaterSense:

I know the limitation was there with noticing that they couldn't keep up with what needed to be done to practice the irrigation scheduling. (Plane Creek, Grower)

I mean, I only probably – if we could've had water when we wanted it, sort of thing, I guess.
(Plane Creek, Grower)

One participant noted that he felt he could have participated in the groups a bit more:

I think just participating a bit more with them I would have learnt probably ten times as much as I did, but as far as the irrigation scheduling goes I would like to keep going with this.
(Plane Creek, Grower)

The rest of the participants did not offer any suggested improvements, for instance:

I just can't really put my finger on anything. It seemed to go pretty well, yeah. Pretty well explained all the way through. (Plane Creek, Grower)

No, I don't think so. I think it was well enough handled. (Plane Creek, Grower)

Evaluation of the Bundaberg case study group experience

Six participants in the Bundaberg irrigation management case study group were interviewed about their experience of involvement in the group.

Best things about involvement

When participants were asked what the best things about involvement in the case study group were, two nominated having input into the development of WaterSense:

Yeah, just having the say in what we wanted out of it... (Bundaberg, Grower)

Potential for input into an irrigation tool I suppose. (Bundaberg, Mill)

Two participants highlighted the interactions between the growers and the project team as the best thing about involvement in the group:

The interaction between the scientist and the grower, and the willingness of the scientist to talk through issues with the grower. (Bundaberg, Extension)

I think the best thing was it was addressing a specific need and we had the flexibility that we could change things slightly as we were going along as we were starting to learn more and more about what the research was telling us but also more about what the issues were for the growers as well and trying to finetune them what we were doing at the research level. ... It was a participatory process. It was fairly dynamic. It allowed us to move at the same time.
(Bundaberg, Extension)

One participant noted that his large increase in knowledge about irrigation was the best thing about involvement in the group for him:

Definitely increasing my knowledge of irrigation, a massive increase. ...this last three years involved with the group and the last year with WaterSense, my knowledge in water use and in particular in the cane industry, has improved massively. (Bundaberg, Grower)

One participant appreciated the way in which his involvement in the group had confirmed his beliefs about irrigation on his farm:

I like to get on the computer and watch the evaporation rate, and your daily water usage and things like that. That's good, and it's just for the water scheduling side of things, it's confirmed what I believe was happening on a few of my different blocks.(Bundaberg, Grower)

Another participant noted that the best thing about the group was that now there is a tool available that improves irrigation scheduling:

That now we have a tool really for irrigating that we didn't have before. (Bundaberg, Mill)

Evidence of changes

Participants were asked to nominate whether they had changed what they do as a result of the project. One participant referred to being better able to optimise his cane production through improved irrigation:

Changes in scheduling of irrigation and water use, to optimise the cane production. (Bundaberg, Grower)

This participant also discussed the way in which he had developed a water budget to complement WaterSense:

I had to develop a water budget. ...we did have a water Excel sheet for monitoring our water usage, but I had to modify it to put in factors. (Bundaberg, Grower)

One participant noted that he felt he had improved his irrigation practice:

Just probably...going a little bit tighter to the schedule perhaps. I think it's a matter of...just being confident that you're not going to lose in your production. ...it probably reaffirms some of the things that I thought, whereas traditionally in the past, on some of our blocks, I've always gone in and watered too soon. So I found the Water Sense good like that, you could sort of draw down. Because I can get on the computer now and say, yeah, well, today's evaporation rate was such-and-such, and you can sort of watch your water level slide. (Bundaberg, Grower)

This participant noted that he would like to be able to use WaterSense for other crops:

I'm actually trying to use the Water Sense—I've been talking to Steve about it—with my lucerne now, just to try and schedule it. So yeah, it's something we talked about, and he looked into that for me, as into crop factor and water usage. And he said, it's actually very close to cane, so I'm keen to give that a go now too. (Bundaberg, Grower)

Another participant noted that involvement in the group had reaffirmed his beliefs about participatory approaches:

I think my general philosophy with people has been the same, provide a...bigger resource to people that provide support and assistance. ...we're all out there in this participatory extension role. If we just stand and deliver and tell people that this is what's right and that's what they should do, I don't think you'd get anywhere. You've got to demonstrate. I rarely ever tell people that this is right and that's wrong. I provide them with information to make their own decisions... (Bundaberg, Extension)

The participants from the milling sector both pointed to the way in which WaterSense had improved their ability to prioritise the mill's irrigation:

Well I guess the most significant thing for us is being confident in the program to be able to allow it to tell us where we begin irrigating after a significant rainfall event. So in other words, that's where for us Water Sense I think, is of greatest value. That's where I see it fitting into our system as in prioritising those blocks that we need to irrigate and I think theoretically it does that quite well. There are issues, nuts and bolts type issues of inputting data and getting the correct data out of it but there have been issues over the time. Just recently we have used it quite effectively after this last rainfall event to help prioritise those blocks that we irrigate first and what order we basically go about our program. (Bundaberg, Mill)

The priorities of the irrigation. ...now I am checking the distribution and the efficiency of this irrigation. Now we can say properly how much water we're putting into irrigation because I have to have this data for the program. (Bundaberg, Mill)

Lessons learnt

Participants were asked to summarise what they saw as the key lessons that they had learnt through this project. Two participants described how they had learnt a lot about irrigation:

Soil characteristics, cane physiology, its usage, water application systems and their efficiencies, even just evaporation characteristics, delivery scheduling. ...So it was a really big learning curve in terms of irrigation and exposing me to - I call it my virtual envirosan, WaterSense. (Bundaberg, Grower)

A lot about irrigation. It's was really useful for me because I have to learn a lot of science...and it was good. ...The whole capacity of the science. To really know how much water is required. (Bundaberg, Mill)

One participant highlighted the lesson he had learnt in developed a water budget to complement WaterSense:

So WaterSense doesn't do a water budget and WaterSense won't work without a water budget. ...After talking to Maurie...I went and modified the Excel spreadsheet to do the water budget and then showed Maurie and we talked about when we thought it would rain and looked at all the other information we could get, when we thought it would rain. We thought it would rain in mid February and January was very dry, so I bought water to provide for January and there was a little bit of an insurance policy there as well, to buy a little bit more. Then if you're going to have to do a water budget, you have to know what's the maximum you can pay for water to get a return on investment. Then...you have to know what the cash supplies are. So WaterSense, water budget, cash flow. They won't work unless you do all those three. That's the biggest learning. (Bundaberg, Grower)

Another participant described how he had learned to trust WaterSense:

In the past, there's been a lot of guesswork in the irrigation side of things. You just think 'This block looks like it might need a drink now', whereas I'm probably taking a bit more time and attention now into how much water the crop is using. So yeah, I am starting to trust it more. I suppose that was the biggest thing, just learning to trust it. (Bundaberg, Grower)

When asked about his key learnings, one participant spoke of the way in which the project had reinforced his views about participatory approaches:

I've been involved in several participatory approach programs, and...I guess it's not a learning, it's a reinforcing. But that process does work, participation. (Bundaberg, Extension)

One participant noted that he had learnt the importance of using all allocated water in a season:

The answer to the research question was that the timing issue wasn't as significant as what we first thought. What was significant was that we needed to be in a position to use all of our water. The strategies that we needed to run was more around using the available water that we had whereas previously we thought if we had two megalitres the crop yield was going to be sensitive as to when we used that during the season but the crop actually had a bit of resilience. The main thing was not to get too conservative in your irrigation management in a way that you had water left over at the end of the season and that's when you did suffer you penalty so that was pretty much the answer to the research question... (Bundaberg, Extension)

One of the participants from the milling sector noted that involvement in the project had helped confirm suspected inefficiencies in the Mill's irrigation system that could be improved:

It has backed up information that we have already known. Soil, water data. I guess weaknesses in our own irrigation system, where we can improve there I guess. It has highlighted things that we need to do there. From management point of view, we knew our irrigation system for mechanical reasons or whatever, there were weaknesses in it so I guess it sort of highlights where we may be able to improve as far as maintenance and those sorts of things are concerned. There is a myriad of other issues associated with – well I mean from management point of view we have to get water to the irrigation system first, which can be a problem with open drains and things like that which any irrigation farmer will tell you requires fairly significant maintenance. We have got a huge irrigation infrastructure which...I am aware of its inefficiencies. (Bundaberg, Mill)

Attitudes towards the participatory approach

We asked participants to identify what they liked best about the participatory approach that was used within the group. Two participants highlighted the way that the interactions between the growers and the project team made WaterSense more grower-friendly:

We've got to get the grower involved, and we have had some growers that have been very involved in this and contributed greatly. [The irrigation team] have taken on – not always exactly done what the grower thought, because sometimes the grower doesn't quite understand the science. But in the end, I think it achieved the outcomes that they were looking for, what the grower was looking for. It's got to be grower friendly, they've got to be able to work it and it's got to mean something. (Bundaberg, Extension)

They're developing a product that meets the expectation of the grower. It's relevant and meets expectations of growers. (Bundaberg, Extension)

One participant nominated the opportunity to network with other growers as the best thing about the participatory approach:

I liked the meetings and networking with other growers. (Bundaberg, Grower)

Another participant noted that the approach meant that the participants really felt like they were listened to and their input was valued, which helped develop trust in WaterSense:

I feel like we were listened to. And I guess if something is going to be accepted, there's got to be some grower input into something like that, because otherwise people are just going to say, 'Here we go again, another hair-brained idea'. I think I might've even made that comment right at the start, when they were talking about how to get growers involved and stuff. And I said, getting growers to trust what information that's there is—actually, the more I think about it now, that was discussed at one of the meetings, having grower confidence in what was being put out. ...You've got to have the confidence. And I think, yeah, I'm confident with it [WaterSense], so long as you put the right number into there to start with. (Bundaberg, Grower)

One participant noted that the participatory approach allows people to keep up to date with recent research (1 comment)

I suppose personally it keeps you up to date with some of the relevant issues that are occurring in research programs. (Bundaberg, Mill)

When asked about the challenges associated with the participatory approach, three participants highlighted how difficult it was to ensure that the science was “paddock savvy” and user-friendly:

...I know what the real challenge was, it was taking science and making it paddock savvy. That was the real challenge. Yeah, well...it was bridging that gap between what was seen to be pretty good science, but making sure that it was paddock useable. I think that's been the key for this. This thing could've been developed in an office in Townsville and it could've been spat out on a disk, and I don't think anybody would've used it. Because every time you would've used it, you would've said, there's a problem with this. The fact that we've gone the way we have, the process of developing it and taking the science to the people and the people to the science and bringing the two together so as at the end of the day, something was useful to the grower at his level rather than the scientist at his level, has been the real deal. (Bundaberg, Extension)

I guess the most important challenge was that because the industry really wanted this information, because they had low water allocation, it's sort of a bit like research by the seat of your pants. So these guys are after this sort of information and you're trying to feed it back to them at the same time as you're discovering it and that's the challenge. ... No, that's probably the main challenge because we were moving along at quite a quick pace. (Bundaberg, Extension)

...it needs to be very easy to understand for the growers, for managers to be able to have a relatively simple report that will give them data based on some fairly complex variables that occur on the back end of the model, or the program, WaterSense program. Being able to marry up water, soil, water relationships and crop growth models and that sort of thing. Obviously we need to be able to have something that is pretty easy for a farmer to understand at the front end. (Bundaberg, Mill)

For the participant who developed the water budget, the most challenging part of the process was developing this economic component to complement WaterSense:

That was probably the biggest challenge there in the limited water situation, working out whether it was worth buying water, how we made it an economic tool instead of an irrigation

tool. It's really an economic tool. It says it's an irrigation tool, but it's an economic tool. It's about making money and it wraps up with environmental issue as well, about not over-watering, so you don't waste water...salinity risks and all that sort of stuff. (Bundaberg, Grower)

Personal satisfaction with group involvement

When asked about their overall satisfaction with involvement in the group, three participants were either satisfied or highly satisfied:

Yeah...it's good. (Bundaberg, Grower)

...Well, I was the one who pushed for the new...project to deliver web-based irrigation tools, namely Water Sense, to the Queensland industry. I take full credit for pushing hard for that to happen. So you'd have to say I'm quite satisfied. (Bundaberg, Extension)

Very high [satisfaction] and that was really because of the interaction that we had. The way we'd set the project up from the beginning, the research was to complement the extension activities and vice versa, I guess, because there were things that we didn't know so we were using the research project to answer that for us but then the extension program was a good way of getting the research-type stuff out so it sort of worked very well together. ...It was very interactive and it worked because of that. (Bundaberg, Extension)

One participant was not satisfied with the frequency of the meetings:

The networking, [did] not really [meet expectations], because we had infrequent meetings... (Bundaberg, Grower)

One participant noted that he did not feel that he had been involved enough to comment:

Probably, I haven't had a huge amount to do with it apart from sort of advice to various scientists over the period of time but my involvement has been very limited so I don't know whether I can answer that particularly well. (Bundaberg, Mill)

Another participant was somewhat ambivalent, noting that using WaterSense used to be a time-consuming process, but that it was good to see it was quicker to use now:

...because the time when I'm using this – it's a lot of time. ...It was a lot of time and a lot of correction over time and it took a lot of time. Now it's quick; now [WaterSense] is good. I think it will be better. (Bundaberg, Mill)

Suggestions for improvement

When asked how their experiences could have been improved, one participant noted that he would have liked to work more closely with other farmers using WaterSense and that the collective learning would have been greater if more farmers had been using WaterSense:

I would have liked and gone and seen other farmers. I would like more of them to be using it [WaterSense] and then we could have gone to their farms and seen their application times and patterns. ...If a broader range of farmers were using it to the level that I am and then we went and sat down in a meeting and say, 'well, I learnt this', they could put their learnings up and I could learn from them, because at the moment, I just learn from myself each year, so this year was limited water, last year wasn't. I did that last year, I did this, this year. (Bundaberg, Grower)

The rest of the participants could not identify any specific ways in which the project could have been improved.

The two participants from the extension sector commented that the project is a good example of how participatory projects should work:

I think it's a good example of how a project should work. The right ingredients to have in these sort of projects is respect from the different parties involved so the researcher has a respect that the issues at the grower level or extension level can feed back into the research project and also there's got to be a respect from the grower and the extension officer to say that the research findings are relevant to them as well. I guess, to summarise, everyone has a part to play and when you respect those parts you have a successful collaborative-type project and I think that project had those ingredients. (Bundaberg, Extension)

... I don't really have any problems with the approach we've taken here, I think it's been a good approach. I think it's one that CSIRO should use more often, be more involved. (Bundaberg, Extension)

Evaluation of the NSW case study group experience

Seven participants in the New South Wales seasonal climate forecasting case study group were interviewed about their experience of involvement in the group.

Best things about involvement

When participants were asked what the best things about involvement in the case study group were, the majority identified the way in which the group had increased their understanding of seasonal climate forecasting:

It gave me a much better appreciation of all the tools, especially the tools and the terms that are used. That is probably the most important. Before that, I mean you would read it, but nothing would sink in and you couldn't put the whole package together in your mind when you are looking at all the different terms that are used; El Niño, La Niña, ENSO and Southern Oscillation Index and all that. But I think it gave the growers that were on that group a really good background to it all and I actually remember what it all means now to some small degree. Whereas before you would read what it means when you were reading a particular article about climate forecasting, etc and then you would forget about it. So I'm more conversant with the terms that are being used I guess is what I'm saying. That is probably the biggest benefit for me. (NSW, Grower)

Probably...helping me to at least understand the forecasts. (NSW, Grower)

Just getting a deeper understanding to what's happening with climate research. (NSW, Grower)

...learning some basics about the SOI. (NSW, Grower)

Learning more about how El Nino, La Nina works, sea surface temperatures, a much better understanding of that. (NSW, Extension)

...from a personal point of view I've gained a lot of information out of it, gained a lot of knowledge out of it, learnt a lot. (NSW, Extension)

...I certainly know more about it now than what I did when I started. (NSW, Mill)

Two participants noted that the best thing about the group was being able to identify the opportunities for applying seasonal climate forecasting in their industry:

The group members, we've had some people who are pretty open minded and can see opportunities. Any new technology that comes along, they can see the opportunities for the industry and where things might be of benefit to the industry, so that's probably been the best thing... (NSW, Extension)

...we had a...workshop session where we listed out all the things where we might use climate forecasting, that was very useful. It probably surprised me a little bit as to how many things in how many areas we could use the information if...it had a high probability rating on the prediction, in how many areas you could use it. (NSW, Extension)

One of the participants nominated working with Yvette Everingham, the project team member responsible for leading the seasonal climate forecasting work, as one of the best things about being involved in the group:

...the other good thing is working with Yvette, who has been good to work with. (NSW, Extension)

Another participant highlighted the diversity within the case study group as one of its strengths, particularly the way in which this diversity increased learning for all involved, including the project team:

I guess you've got a range of people, you have a range of ideas and that sort of thing. So rather than just having a group from one particular area, you have farmers and other people in the group and that's always beneficial and think your people from CSIRO probably got as much out of that as what everyone else did too, I think. (NSW, Mill)

Evidence of changes

Participants were asked to nominate whether they had changed what they do as a result of the project. The majority of participants noted that they have not used seasonal climate forecasting to change their farming practices, because the majority of outlooks have been around 50/50:

...generally what's happening, a figure comes out of 60 per cent or something like that, but that's too small a number to change practices. You need something well over 80 per cent. (NSW, Grower)

It's just not accurate enough, you know, like if you want to know the weather, what it's going to be doing in a few months time for planting or something like that, the best they can sort of come up with is like a 55% chance of above average rainfall or, you know, or below average rainfall. Well that's not good enough for us to go ahead and plant on ... That's more or less a 50/50 chance that we're going to get above or below average rainfall. Well most people know that anyway. That's common knowledge. ...Well, we'd need like 75 or 80% chance, then you might be able to go ahead and plant because it's a good chance that you're going to get the rainfall. ...You can't go ahead and plant a crop on the assumption that it's got a 50/50 chance, more or less. (NSW, Grower)

I think the earliest foray into it didn't really provide us with too many tools because too many of the probabilities were in that 50 to 60 per cent range and weren't really going to affect your decision making. (NSW, Grower)

...during the course of the project a lot of the time the probability has been round about 50 per cent, so I guess I'd have to be honest and say from that point of view it hasn't been all that helpful. (NSW, Extension)

...I'm not 100 per cent sure that the models or the forecast give us enough accuracy that you would really want to hang your hat on. ...I think at the moment, it hasn't been as definitive as what it could have been. If you're looking at things of say, 50/50 or 60/40, well you probably can't make too much out of that. (NSW, Mill)

The participant from the milling sector also noted that the Mill was constrained in terms of its ability to change its practices, although he suggested that seasonal climate forecasting might be able to influence decisions in the future, if the current methods were to improve:

Once we start the crushing season here, there's a limited amount of things that we can change, and quite often a lot of our other decisions are made on commercial reasons and availability of sugar and the availability of the crushing rate and that sort of thing. In a lot of cases, the climate forecasting information wouldn't make a lot of difference, for example, when we start the season and that sort of thing. It will come. I think as time goes on, the current methods, it will improve over time. (NSW, Mill)

Lessons learnt

Participants were asked to summarise what they saw as the key lessons that they had learnt through this project. As noted above, many participants felt that they seasonal climate forecasting had so far been unable to help them make decisions. As one participant noted:

What I have come to learn - the output that...climate forecasts [are] generating is not providing a significant level of confidence to cause change in practices as a general rule. (NSW, Grower)

Another participant noted that he had learnt about the Florida State University model, a new tool for seasonal climate forecasting, which he felt had the potential to be very useful:

I think like a number of other growers I was fairly sceptical that it was really going to add too much value to our decision-making process. ...But I'm really excited about the new FSU model...because I think it seems as if it is going to give us some benefits in forecasting earlier in the year for what is going to happen in the September to December period. If it proves itself over the next few years I think that is going to be a really useful tool for us, both at the mill area level and at the growing level. (NSW, Grower)

One participant gave a very detailed described of what he'd learnt about how seasonal climate forecasting could be used:

If I'm looking at a dry year, obviously I take the priority in keeping all my drains in first class order. In terms of harvesting, we probably cut back on the amount of maintenance we do on the full track gear that we only use under wet harvesting conditions. I would probably look at minimising the amount of money I put into pump maintenance because we use a couple of large watering pumps on the farm. I would probably put off maintenance on those pumps. In terms of actual farming operations, I would be looking at if it is going to be wet, I would be focussing more on getting raised beds thrown up and using more direct drill which gives me a big advantage in terms of timeliness of the operations for the cane planting operation in spring and the soybeans in that wetter summer period. I would be looking at targeting how I'm putting my nitrogen on, whether I do it in one big dose while I've got an opportunity or

whether I'm fearful of perhaps losing that in an extreme rainfall event. I might split it into a couple of smaller applications to split the risk of losing it on the farm. I'm looking at whether I'm probably going to use more herbicides in terms of weed control strategies and conventional cultivation. Obviously in the wetter years I'm going to favour herbicides for weed control. If the forecast is for drier conditions, I'm going to take steps to conserve my soil moisture and keep out of the paddocks as far as the tillage—reduce the number of tillage operations. If moisture is not a consideration then I probably wouldn't worry about how many tillage operations I run.

In terms of reducing the risks, not so much on saving inputs but in terms of reducing the risks, I'd be looking at my harvest rotations and when I actually harvest my plough out field. Under a normal season my plough out, which traditionally go early in the season, is one or two rounds. In a wetter season I would be tending to leave those plough-out fields to last when we come into that wetter than usual summer period when you run the risk of storms, etc. I would leave the plough out cane until then so that if it does get bogged off it is not a big loss. Under a wetter prediction, I wouldn't be leaving heavy two year old crops for harvest late in the season. So I would be taking off my heavier two year old plant crops from in that August to October period where normally they would be left in the October to December period for harvesting. I would be trying to—besides leaving the plough-out cane until the last round, I'd be leaving one year old returns that have been well trafficked and have compacted inter-row so I'm not going to bog them off. One year old crops because they are always easier to harvest under wet conditions than two year old crops without destroying the paddock. They are always drier.

I think one of the other areas, of course, is frosts which we talked about earlier. If the forecast is for a drier than normal season, when I'm doing my crop estimates, I would normally put a hedge factor in there of more tonnage to cover me if we need to harvest crops that are effected by frosting. The way the forecast looks for this season, I think I am pretty safe in just estimating the crop that I want to cut and put that on the books for my rotation. But normally I would probably have a couple of thousand tonne in there as insurance so I had some room to move if I did get frosted. (NSW, Grower)

Attitudes towards the participatory approach

We asked participants to identify what they liked best about the participatory approach that was used within the group. Two participants noted that they valued the opportunity to be involved in and learn from the research, even if they did not quite get the outcome they were hoping for in terms of using seasonal climate forecasting:

I suppose we had the opportunity to be involved and help guide it along in the right direction. We would set some of the directions and she would then go off and hunt down for the next 12 months and report back next year. I mean, it's basically trying to find a role for it and we're slowly coming to the conclusion. It was interesting, we agreed last time that we would like to see it continue, but we also sort of agreed that we weren't getting that much out of it. But that's sometimes a problem with stuff which is a bit out there. It takes a while to get it right and work out where you're going, which is the whole purpose of research grants. (NSW, Grower)

Like I said before, just that it helped me to understand some of the terms they used and things, and it was pretty good to be involved, but it just didn't come up with the result we wanted. (NSW, Grower)

Three participants noted that they were strong advocates for participatory approaches, because of the focus on achieving results and involving industry:

...I'm a great advocate for that [participatory] approach, as far as research goes, it's the only way to go. I think what it means is that the research is very focussed on producing results at the end of the day. It is not just blue sky stuff [that] has got no relationship to industry needs at all. That is one of the biggest positives. I think it gives the researcher some heart that other people are benefiting from the work they are doing. It probably gives them some enthusiasm at times when they are under a bit of pressure in terms of funding and work commitments and so on. They can say, well this is going to make a difference to these people. I think it also allows for researchers to not be operating in a vacuum and it allows them to throw some ideas around with other people. ...I think that's pretty important to research. (NSW, Grower)

The best thing is that you're working with people and you're not trying to second guess what they get out of the project. You actually consult with them and get them to list down, with some facilitation, to get them to list out what they want out of the project and what they need that information for. So everyone is clear what they want to get out of the project. So, Yvette did a good job in drawing that out of the group and keeping that as a goal for the group that we worked with. (NSW, Extension)

One participant emphasised the way in which the participatory approach encouraged co-learning between the case study group and the project team:

We were picking up points that she was making and she was picking up points that we were making. Basically we were educating each other. (NSW, Extension)

Another participant pointed out that the fact that people stayed engaged in the process was one of the strengths of the approach:

...I thought it worked well. The fact that not only people like Peter McGuire and myself, but the growers were willing to go back to subsequent meetings. As I said, not every time, but the same growers go back to each meeting, but in most cases they did. Usually in my experience...if it wasn't a good experience they wouldn't go to subsequent meetings, whereas in this case they have. (NSW, Extension)

When asked about the challenges associated with the participatory approach, one participant noted that it was another meeting he had to get to:

Another meeting to go to, but that's all right. (NSW, Grower)

One participant commented that he was disappointed that they did not get any definitive results:

There's no real bad thing, I suppose, just that we didn't get any result. (NSW, Grower)

Another participant pointed out that the participatory approach means that there is more work for the researchers:

It means more work for the researcher which they probably don't appreciate at times. But that's the only downside and I mean it's just a fact of life in R&D today that you are going to have to do this. (NSW, Grower)

One participant noted that the case study group did not meet as frequently as most participatory projects, but he believed that this was appropriate for the project:

...ideally, you should be getting together four times a year or something, but with the climate forecasting, we're forecasting a wet or a dry harvest season, so there's no point getting

together three times. We've only got one principle event through the year that we're forecasting, so we get together at the beginning of the year to review last years and also to forecast next year. It's a bit unusual as far as participatory projects are concerned, in that we're not getting together more often, but it's the appropriate frequency for this particular project. (NSW, Extension)

The rest of the participants noted that they could not think of any problems with the participatory research approach:

Can't really say any problems with any of it. Can't condemn any of it. (NSW, Grower)

I can't think of any. (NSW, Extension)

I don't think there was any [problems with the approach]. As I said before, it's what we do anyway and I think if people don't do it that way, they're going up the wrong tree, I think. You have to involve the farmers in these sorts of projects. The farmers are the people who are doing the work out in the paddock, so this is no different. (NSW, Mill)

Personal satisfaction with group involvement

When asked about their overall satisfaction with involvement in the group, the majority of participants were either satisfied or highly satisfied. Two participants commented on their increased understanding of seasonal climate forecasting, even though it had not proved viable as a predictive tool:

Yeah, just being involved helped me understand the weather forecasts a bit better, like the southern isolating index and all that. It meant nothing to me before, but like it's helped me understand a bit about forecasting. (NSW, Grower)

Personal satisfaction from the point of view of the knowledge I've gained, but in terms of using it as a predictive tool, probably I'd rate the level of satisfaction below that. (NSW, Extension)

One participant highlighted the way that working with the case study group and with Yvette Everingham was a good experience:

It's been a good group to work with. We've got some people who are pretty good thinkers. Yvette has been excellent to work with because she always does what she says she's going to do and she always does it on time, so working with people like that is always good. (NSW, Extension)

Suggestions for improvement

When asked how their experiences could have been improved, most participants noted that they had hoped for more precise or accurate seasonal climate forecasts:

I suppose I could have said that more precise models, but that doesn't exist. (NSW, Grower)

They were pretty good at explaining things, it's just that yeah, it's not accurate enough for us. (NSW, Grower)

I think the first couple of years when we were playing around and looking at the application of the Southern Oscillation Index and ENSO, etc to the New South Wales industry. It would have been better if it had been more positive and there would have been 30 per cent probabilities and 70 and 80 per cent probabilities. But I guess the 50 per cent sort of reflects

the fairly stable conditions that we have been used to experiencing on the coast. (NSW, Grower)

I probably would be a lot more positive about it if we had had some instances where you had high probability and the predictions came out to be reasonably correct. (NSW, Extension)

One participant noted that the project could have been improved if longer rainfall records were available for some of the areas:

...rainfall for different areas we were looking at vary a lot. It would have been good to have some longer, 100 year records. (NSW, Grower)

Project teams' evaluation of their case study group experience

The six members of the project team responsible for facilitating interaction with the seasonal climate forecasting, irrigation management and nitrogen management case study groups were also interviewed about their experiences.

Best things about involvement

When project team members were asked what the best things about involvement in the case study group were, they all highlighted the positive experience they had working collaboratively with their case study groups and getting insights into the needs of the case study group members:

Then of course the enthusiasm of [the local co-ordinators] has been really good. ...I feel really pleased with what they've done in the regions. (Seasonal climate forecasting project team member)

I think when they grasped the concepts. When you see they're just really struggling to – it's not that they're stupid it's just they don't think numerically, they don't think in terms of models. But when they grasp something and you get a guy jumping up with, oh I see what you're doing, and then he explains it back to you and adds a whole load of ideas that you never thought of, that is really quite thrilling. (Irrigation project team member)

...it was the fact that they were committed; they took ownership; and they felt that we valued their input. And I believe also that for me, that these people were all contributing, really contributing, and helping to progress the technology. They're pretty nice people as well. ... They were really good. We have a laugh, and so it's good, it's fun. (Irrigation project team member)

Direct feedback or direct questions. Quite often you were able to, as you were developing software you were able to, if you had a question in your mind, you didn't have to wait. You could just pick up the phone, ring them up, ask them what they thought. You'd have options, lots of options to choose from with how you're going to do it. So instead of having to just pick one and then hope you picked the right one down the track, you could immediately pick up the phone and contact them and get an immediate response. So I guess it's immediacy of feedback rather than having to wait. (Irrigation project team member)

They were quite a good bunch of guys to work with. I enjoyed interacting with them. I also enjoyed the fact that we were doing work that was based on what they wanted us to do. They would ask us to do something - essentially from one meeting to the next, we knew we were

going to be doing something, but that something was decided by the growers, not by us. (Nitrogen management project team member)

It was really good finding out what they [the case study group members] were thinking, understanding what they were doing, the things that were possible or not possible on their farms. (Nitrogen management project team member)

The project team member responsible for the seasonal climate forecasting work noted that she felt like she made a difference in improving people's ability to use seasonal climate forecasting:

The best thing for me is if I walk away, I know that the people in the consultative group will be prepared for changes in climate in the future. (Seasonal climate forecasting project team member)

One of the nitrogen management team members was pleased to see that there was some acceptance of use of simulation within the Tully case study group:

It was good that we had some acceptance to the simulation approach and that it was useful in addressing their issues. ...I think we got some credibility that outsiders could walk in and we could teach those guys who had lived them all their lives, that we had insights into the place that they lived that were valuable and perhaps a bit different to what they had... (Nitrogen management project team member)

Evidence of changes

Project team members were asked to identify whether they had changed what they do as a result of the project. Two of the project team members described how they now paid more attention to ensuring that they have a better understanding of what collaborators want and what they understand:

Yeah, I've been trying to do nothing until – it sort of comes from them. You've got to go to them and say, what do you guys want? ...So my idea might be completely wrong or inappropriate for that, but eventually you get panel beaten into something that you and they understand. ...Yeah, whatever we do...I'm thinking all the time well, what does it really matter in the final analysis. For example, you could have a very sophisticated model that you've published papers on, but if it's harder to explain than a simple one or less accurate one... You've got to think of what's going to be acceptable, not only in terms of its accuracy but in terms of its understanding. So yeah, it makes a big difference, trying to figure out what people will understand and accept. (Irrigation project team member)

Yes, you really try to perhaps get a better understanding of what people want, and to be honest, the group themselves didn't understand. The things they said, 'yes, this is an easy change', but when we put them back and said, 'yes, that's a good change', they started backing off, that's because they thought more seriously about it. I suppose it's drilling a bit into what people are really looking for. (Nitrogen management project team member)

Lessons learnt

Project team members were asked to summarise what they saw as the key lessons that they had learnt through this project. One of the key lessons was the importance of appreciating that growers can see things differently than they do and the value of understanding growers' perspectives:

I've learned that...you've got to just spend time finding out what the working environment is, what the decision making process is. The farmers' is completely different to yours so you've just got to find out. You can't assume that he knows. You...can't second guess their questions, you've got to find out what they really need to know. How they want that information. (Irrigation project team member)

Our sugarcane industry people, the farmers there, we have to be acknowledging the huge range in—they're individuals in their starting knowledge base, and how important the differences are... Just being aware that there can be some enormous gulfs in knowledge. I've always suspected it, but this has just confirmed just how wide that gap can be... (Irrigation project team member)

...at every step of the way you're learning specific things about how they wanted to view information... And also, with it there was a lot of things like soil type...there's so many different names for different soils. ...We would put one soil type down and it'd be the same soil but they would say, no that's called a cracking clay or something... you know, they always had specific requirements on the correct terminology to use. Also on what variables they actually wanted to see. (Irrigation project team member)

...there's also [learnings about] growers responding different ways to what I respond. I guess that's got to do with aims or whatever. That was something that I understood...quite well, because I could see that happening in Tully. I would look at a presentation and think (a) and growers would look at the same presentation and think (b). All those things weren't dynamically opposed, they were different things. (Nitrogen management project team member)

I suppose that issue about next time I spend a bit more time and effort into really drilling down about how serious were they about changing their management? ...In the end, we came up with ways to tweak the system, which fulfilled their initial objectives and some of the management reactions, which they said they considered quite good, but they weren't looking for tweaking, they were looking for big pictures, silver bullet type change. (Nitrogen management project team member)

Two of the project team members highlighted the importance of developing a shared understanding within the case study groups (i.e. congruency of technological frames, in the framework):

In terms of learning, the most important thing that has become clear to me is it's important to have everybody thinking on the same page, until you have that, you're not going to go anywhere. I've just discovered how I can do that basically. (Seasonal climate forecasting project team member)

...The idea that you want to move to congruency is something that is important to be able to do. ...It's difficult to put your finger on it. I think it's about understanding...where the other person is coming from... (Nitrogen management project team member)

Two of the team members noted that they had learnt the importance of having ongoing, local co-ordination and support:

The key lesson I learnt, is you must have one person who can help coordinate things in that region. I needed that local coordinator, so that was a good thing. (Seasonal climate forecasting project team member)

...how important it is to have local support dedicated to continuing the development and use of knowledge-intensive technologies... (Irrigation project team member)

For the project team member responsible for seasonal climate forecasting, one of the key learnings related to understanding the process of helping people use seasonal climate forecasting:

Overall, I think I understand what happens when you try and get people to use climate forecasting. Basically, you go out and you get people to think on the same page, and then they want forecasts for specific targeted decisions which specifically ties a new test of skills for all of that, and then somehow, you go from these targeted decisions down to them being happy with rolling three monthly forecasts. Then they're on their way. (Seasonal climate forecasting project team member)

The idea of having boundary object that would help facilitation discussion, which was central to the theoretical framework developed in this project, was another key lesson:

I guess...that is to get the boundary object. It's really important to have something that we can facilitate discussion with, and it's really important and something that I probably have to reinforce from the framework, so I would continue doing that. (Seasonal climate forecasting project team member)

This project team member went on to note that the importance of having a boundary object had implications for the success of global circulation models:

Another key lesson...is at a much higher level, that is...general circulation models or global circulation models. ...There's been a lot of money invested in these and relatively little adoption compared to the climate forecasts. There's a push to get the global circulation models or GCMs used more readily by farmers. It's highlighted to me what the challenge is there, in that it's difficult to have a boundary object with the GCM. We've developed these little tools and we've been able to go away and answer the questions directly, but it's just going to be a challenge in the big picture for climate forecasting. ...I can see that we need to have that boundary object to interact so that we can eventually - it is coming down to these rules on climate forecasting, and it's going to be difficult for farmers to gain trust of these GCMs and to be able to see how they've performed over recent periods of time. I guess it's helped me to think outside of the project as well. (Seasonal climate forecasting project team member)

Another lesson from the seasonal climate forecasting case studies was that it would have been beneficial to incorporate economics into discussions about the forecasts:

At the last meeting, I would have liked to have brought in some of the economics thinking, into the project work. Getting them to think about the pluses and the minuses of particular actions. (Seasonal climate forecasting project team member)

The challenge regarding working with seasonal climate forecasting when the forecasts are 50/50 was another key lesson:

...it has been really hard for the last three years, because it's all been 50/50 mostly. We haven't had anything to really think about where there has been big decisions made on based on a climate forecast. (Seasonal climate forecasting project team member)

One of the nitrogen management project team highlighted the technical learnings about nitrogen management that the project had delivered:

We've learnt all of those things to do with modelling work, so there's the technical learnings on nitrogen and management... (Nitrogen management project team member)

The importance of frequent interactions in participatory research was another lesson from the nitrogen management case study group:

Ideally, you would like to have more frequent interactions, you would want to put more resources into it and you would want them to put in more resources, or else if those resources weren't available, going to a less interactive model, more a classical outside expert model. (Nitrogen management project team member)

Attitudes towards the participatory approach

The project team members discussed what they liked best about the participatory approach that was used within the group. The interaction with the case study group members and the chance to get a better understanding of what the growers wanted from the project were common responses:

The best thing that I like the most, is the relationship, the interaction. I quite enjoy that personally. You get to know the people and you think you can help them. You don't get that by working in isolation from a group, so the group dynamics, I really enjoy. (Seasonal climate forecasting project team member)

Well...getting to understand the framework on which these people make decisions and how to deliver it to that understanding. (Irrigation project team member)

The fact that we do respond to their [i.e. case study group members'] suggestions. ...so it's a lot of interaction going on. So they're comfortable in doing that as well. And they have been willing to contribute. (Irrigation project team member)

I guess it was a good opportunity to actually do it. It's nice to have a little bit of freedom. I think that was the best thing about it. It gives you a nice feeling that you are doing what the growers are asking and hope that it's what they're wanting. It's nice to be able to respond that way. (Nitrogen management project team member)

Two of the project team members commented that it was rewarding to see how growers' thinking developed and to help growers gain insights into their system:

The other thing I really like is you get to see how their thinking develops over time. That's really rewarding, to see that participatory approach. What's important about that approach is it gives people the opportunity to stop and make a critical reflection on what's happened in the past, and then to be able to help with finding a new direction or a future direction to take. That's what's really important I think with the participatory approach. (Seasonal climate forecasting project team member)

It's fairly intense, so I think the experience is probably really embedded in everybody who participated. Even if they don't change their actions, they've probably got different insights into their system. (Nitrogen management project team member)

One project team member highlighted the way in which he felt they had reached a level of shared understanding with growers:

I suppose at the end, I think we all had a very common understanding, the biophysical system but there was some different expectations of what the appropriate management was, that biophysical outcome. (Nitrogen management project team member)

The way in which the participatory research approach creates a better product, tailored to end-user requirements was highlighted by one of the irrigation project team:

I think the quality of the product at the end. I think, at the end, it generates a much better product, much more – just a matter of a better product. I mean, it pretty much gives the user exactly what they want and actually they quite often come up with better ideas than you initially came up with. I guess more heads are better than one. (Irrigation project team member)

When asked about the challenges associated with the participatory approach, the members of the irrigation management team described the uncertainty that comes with participatory software development, particularly in terms of developing the web-based version of WaterSense:

And the other was, we didn't know how long it would take to do the web development. I thought that would be done in, actually somebody said, it'll take me about a week. They really took about two years. I was really nervous about that because you don't see anything. The software engineer is working away. We can't see anything. That was pretty nerve wracking. (Irrigation project team member)

The challenges, I think, were really for [the software developer]. ...We were saying, 'This is what we want: we want to have a page where all the pages were listed, and it said, This bit's for information. That's what the farmers want; this is what we believe is important. Go and write the code to do that.' And then we'd get this, 'Oh, it's not quite that easy, because ...' and we don't have an appreciation for that. Or we would like a graph, and this graph would need to display these bits of information. And we change as we interact with farmers, and [he] makes these changes, and then says, 'There you go, it's up and running.' We go and show the farmers, and then we all go, 'Oh, it's not quite doing what we want'. (Irrigation project team member)

Quite often they'd tell me to make a change, I'd make the change, then they'd look at it and go, we don't like it actually – change it back. And then I'd have to change it all back again. So from my point of view, this participatory action research isn't very fun because...it means I've constantly got to be going over and redoing it and rebuilding the whole thing again and making changes. And sometimes changes will require, like they think something is a simple change but in fact, in order to make that change, you have to structurally change a lot of other things behind it in order to make that seemingly minor change for them. They use it and it seems all simple but in actuality – like some of the changes are simple but some of them are complicated. (Irrigation project team member)

Another difficulty related to resource and time issues:

We generally did what we could, unless there was a real big reason why we shouldn't do it. And one of that would've been time. (Irrigation project team member)

The challenge for the resources. How much time it required from us and commitment to that time required from them. (Nitrogen management project team member)

Two project team members nominated defining aims and motivations and user requirements as key challenges of the participatory approach:

Changing user requirements from the growers... (Irrigation project team member)

I suppose the other challenge was getting them to engage really seriously, rather than giving quick shallow reactions to ideas. This thing about looking for the silver bullet - yes, we'll be in this, because if we can find the miracle benefit by not actually changing - I mean, at the end of the day, the guys weren't as committed to change as they made out in the beginning. They were committed to change provided there was an enormous benefit. They weren't looking to tweak the system. (Nitrogen management project team member)

Given the experience in the nitrogen management case study group, one of the team members noted that he would think twice in the future about being involved in grower-driven work:

I think that I would probably think hard about going into that sort of stuff again, being truly grower driven. Time in life is too valuable to go down dry gullies, you want to be a little bit careful, a bit more of a technology push wouldn't be bad. We would improve the efficiency, and in this case, could we have arrived at that outcome a lot quicker? So a better appreciation perhaps of where to use it or some insight into different places on that scale that are appropriate for different issues and also different resource constraints. (Nitrogen management project team member)

For the seasonal climate forecasting work, one of the key issues is making sure that people understand the concept of probability:

It's always the hardest bit about making sure they're interpreting probability the correct way. (Seasonal climate forecasting project team member)

One of the irrigation project team members focused on getting the science right:

I suppose getting the science right...it would have been terrible had we failed there. It wouldn't have gone anywhere. So that was a bit of a challenge, getting the science right. (Irrigation project team member)

Personal satisfaction with group involvement

When asked about their overall satisfaction with involvement in the group, most of the team members noted that they were either satisfied or highly satisfied.

For the seasonal climate forecasting groups, the team member noted that it was very satisfying to see that the New South Wales case study group had demonstrated that they understand the risks of seasonal climate forecasting and are still interested in it:

...the [NSW] group have demonstrated to me that they understand the risks of climate forecasting, they understand the limitations, there's still an interest in climate forecasting, even though the forecasts for the last three years have been 50/50, they're still coming along to meetings, they're still asking really good questions, but they haven't been able to use them to make too many decisions over the last two years because we haven't been in a dominant El Niño and La Niña pattern. That's really incredible. (Seasonal climate forecasting project team member)

The level of awareness-raising in New South Wales was also positive:

We've had a lot of awareness raising activities that have been taken on board by the extension staff there. They've really ran with that, so that would put that at a five [i.e. highly satisfied]. (Seasonal climate forecasting project team member)

Although there was less awareness-raising in Plane Creek, the fact that there was a clear local champion was satisfying:

There hasn't been as much awareness raising done in the Plane Creek region, but within the consultative group, we've got somebody who is leading the way, it looks like they'll be happy to do that for a long time, they'll be the champion I guess of providing the climate forecasting information after the project finishes. (Seasonal climate forecasting project team member)

There had also been reasonably good progress in Tully regarding awareness-raising and learning:

In Tully, whilst things have moved a little bit slower, I can see the learning cycle that the groups are going through. We thought that would be the tool, but it's not the tool, to go outside the case study group and then we inherently started to work on something else that might help them to go outside the consultative group. That sort of reflected on 'this isn't really a good idea', and so we're just going through a cycle that is perhaps progressing just a little bit slower than the other regions, but still on that cycle. ...We've done some awareness raising activities in Tully... In terms of going outside of the consultative group, widely and engaging, it's difficult really for me to say. I suspect what's happened in New South Wales, has probably reached more people than what's happened in Tully. (Seasonal climate forecasting project team member)

The irrigation project team members were satisfied that they had reached a richer level of understanding because of the participatory research approach:

...I felt that they [case study group participants]...became part of our project team, albeit contributing different insights, and contributing in different ways. So, as a result of that, I believe we got a much richer understanding about the issues and the scope of farmer knowledge and aspirations. So if we had had two identical groups in two regions, we would, I think, have had less insight than what we have. So, looking at the complexities that we've got in front of us then gives us a much better understanding about the limitations of technology like this, to have success out there. But all the farmers in both groups saw value in what we were doing, believed that it would have some impact on themselves, and could see a value for their industry. And therefore, they were prepared to continue for the whole duration of the project. So in both groups, people continued to participate even though they were at very different levels and progressing at different rates. (Irrigation project team)

Oh look, in the end I'm very happy with the way a few growers have understood what we've been doing and appreciated it. ...But yeah, in the end I realised there was a long way to go for us to understand how these people operate and what they need and I'm very happy that we've done that. We've understood where they're coming from and they've understood what we can offer. Even though it's a small number of growers. And I can see that could really, over time, convince a lot of growers. (Irrigation project team)

There were mixed views within the nitrogen management team. One of the members described working with the case study group as a satisfying experience:

I found it both enjoyable and also I felt as if it was giving the growers value as well, which is satisfying. (Nitrogen management project team member)

The other nitrogen management team member noted that it was hard to keep momentum because of the relatively infrequent meetings:

Essentially, we met with them twice a year and that was difficult. Things were going a bit cold in between, so that was a resource constraint. We could have done a better job if we had more resources, so we were resource limited at the end of the day. (Nitrogen management project team member)

This team member went on to note that he was a little disappointed with the result of nitrogen management work:

It became apparent at the end - the old thing, if we had have known some of the things that we found out they were thinking at the end, had we known that at the beginning, we might have done it a bit differently, and I suppose that specifically they were hoping for a miracle and that when we were asking for feedback on some of the scenarios we were running and proposing, you would say, 'okay, this is a hassle, would you really do this on the farm?', and they would say, 'yeah, yeah, no sweat, that's all right', and then we said, 'look, that looks like a good thing to do', and then all of a sudden, it was 'actually it is a hassle'. They were being a bit cavalier in the case study and maybe undervaluing our time and what we could do. We went in there idealistically thinking, if we get something, we can make a change. (Nitrogen management project team member)

Suggestions for improvement

When asked how their experiences could have been improved three of the project team members commented that it would have been good to have a couple of local co-ordinators to help ensure continuing in the local support:

You would probably need to have a couple of local coordinators, that's probably the main thing there that I definitely would have done differently. (Seasonal climate forecasting project team member)

...I think what really does help is a local sort of champion and in Plane Creek we didn't really have that. We had people coordinating meetings and arranging them but they kept on changing. The turnover of staff there was large, whereas in Bundaberg it was one or two people and that made a big difference. I think that somebody who's locally interested in what you're doing and trying to promote that, makes a huge difference. (Irrigation project team member)

Certainly with Plane Creek, having a local facilitator who was working in the irrigation field with these farmers, would've meant that the project would've moved faster with that group of farmers. (Irrigation project team member)

The nitrogen management team members noted that they would have like to have had more frequent interactions with the case study group over a shorter time frame:

I would probably have made a number of interactions, a shorter time between interactions. ...if you could do it six weekly or something like that, once every two months, somewhere between a four and eight week time frame, have your meetings that far apart, over six months, a lot happens and you also end up with different people so you don't have that consistency of people coming along. I would try and have more frequent interactions. Even monthly. What

we're doing with the modelling work, it's not as if we're going away and conducting experiments and coming back. I guess that one solves another area, which is a consistency of participation by the people. You get different people turning up. ...Yes, well you have to start over for two reasons. One, you have to remember what you did six months ago and two, you've got new people that weren't there six months ago. (Nitrogen management project team member)

Ideally, you would like to have more frequent interactions, you would want to put more resources into it and you would want them to put in more resources, or else if those resources weren't available, going to a less interactive model, more a classical outside expert model. (Nitrogen management project team member)