Department of Agriculture and Fisheries – Drought and Climate Adaptation Program

DCAP Project Final Report

Project ID	USQ 15 - Economic value of SCF in agriculture
Grantee Name	USQ

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1. Executive Summary

Seasonal climate forecasts (SCFs) have potential to improve productivity and profitability in agricultural industries. However, they are often underutilised, mainly because there is insufficient evidence to demonstrate the economic value of the forecasts, especially when there is a level of uncertainty associated with SCFs.

In this study, we have developed a bio-economic model of forecast use which explicitly incorporates forecast uncertainty to test the value of seasonal climate forecasts in farm management decision making. We employ a seasonal climate forecast system based on ENSO phases and parameterised by forecast quality for forecasting seasonal precipitation tercile (i.e. wet, normal, dry) categories. Using agricultural systems production simulation softwares (e.g. APSIM, GRASP, NABSA) calibrated using case study information (from irrigated sugar cane and grazing systems), we simulate production under different climatic conditions and management scenarios. This approach allows optimal decisions to be determined across the production calendar given forecasted ENSO phases. We then employ (i) an expected profit approach to derive optimal profits, rather than the conventional production outputs (e.g. optimal yields), or (ii) a regret and value function approach, which helps quantify the potential economic values of using SCFs as beneficial information in farm management. We anticipate that such an integrated frameworks can serve as a decision support tool, providing a pathway for better communication with end users to support improved use of forecasts in agricultural decision making.

Applying these approach, we show that skilled SCF systems have considerable economic value. With the current seasonal climate forecast skill of 60% (a skill level that is presently achieved with the SOI-phase system for the November to March period), a gain of AUD 4.5 ha^{-1} was realised in sugarcane irrigation decisions; and a forecast value of AUD 6000 was realised in a typical grazing enterprise. Improvements in the skill and reliability of SCFs are important for wider uptake of climate forecasts in agricultural decision making. An improvement of 10% in forecast skill would potentially result in an additional AUD 3.9 ha^{-1} benefits to canegrowers and AUD 2000 for a typical grazing farmer.

2. Project Background

Agricultural decision makers have always been concerned about climate variability because of its effects on decision makers' and societal welfare. Although weather and climatic events are uncontrollable, climate forecasts may assist decision makers in coping with the variability (Mjelde et al., 1993; Hill et al., 1999). In Australia, and particularly in the northern regions of the continent, agricultural production systems face a number of risks associated with an extremely variable climate (Hammer et al., 1996). In these regions, rainfall is summer dominant but variable and often limiting, rarely exceeding evaporative demand in any month (Hammer et al., 1996) and posing a range of challenging management issues for agricultural production, especially cropping and grazing enterprises.

In such a climatically variability environment, seasonal climate forecasts can play an important role in agricultural risk management and potentially add significantly to enterprise profitability. It is noteworthy that SCFs are largely underutilised by farmers in making key farming management decisions, even though estimated values from the literature (e.g. McIntosh et al., 2007; Meza et al., 2008; Klemm and McPherson, 2017) imply that, in many cases, they could significantly benefit from forecasts. This is attributed to the perception that SCFs are far from certain, despite significant advances in their ability over recent decades (e.g. Doblas-Reyes et al., 2013; Kirtman and Pirani, 2009). While many farmers and advisers will point to the need to improve the accuracy of the forecasts, there is, nevertheless, substantial unrealised potential in existing SCF information that offers considerable economic value. Improved seasonal forecasts together with better communication, understanding and capacity to use seasonal climate forecasts will have immediate benefits in terms of risk management. Indeed, theoretical research has shown that, properly interpreted, climate forecasts can lead to increases in long-term average production and decreased production risk (Carberry et al., 2000; Gunda et al., 2017), with investment losses minimised in poor years and opportunities maximised in good years.

3. Project Methodology

In this study, we have developed a bio-economic model of forecast use explicitly incorporating forecast uncertainty to test the value of seasonal climate forecasts in farm management decision making. We employ a seasonal climate forecast system based on ENSO phases and parameterised by forecast quality for forecasting seasonal precipitation tercile (i.e. wet, neutral, dry) categories. Such a parameterised forecast structure allows analysis of the impact of forecast quality (i.e. from no skill to perfect skill) on the economic value of the forecast, and thus the value of any current forecast system, based on its skill level, can be readily determined. Using agricultural systems production simulation software (e.g. APSIM, GRASP, NABSA) calibrated using case study information, we simulate production under different climatic conditions and management scenarios. This approach allows optimal decisions or better options to be determined across the production calendar given forecasted ENSO phases. We then employ an expected profit approach achieving optimal profits, rather than the conventional production outputs (e.g. optimal yields), which helps quantify the potential economic values of using SCFs as beneficial information in decision making. We anticipate that such an integrated framework can serve as a decision support tool, providing a pathway for better communication with end users to support improved use of forecasts in agricultural decision making.

A forecast is usually associated with a level of uncertainty, and so is never perfect. Therefore, any valuation methodology needs to account for the 'fail' outcomes of the forecast system and users need to be aware of those fail outcomes in making decisions. We use ENSO phases as predictors to forecast the likelihood of seasonal precipitation tercile outcomes and account for forecast uncertainty (Kusunose & Rezaul, 2016) by considering hindcast data of both forecasts and outcomes. Each observation can be categorised by what was forecast and what actually occurred. However, forecast quality is not a simple characteristic to describe quantitatively (Chavas & Pope, 1984). Quantitative measures of different aspects of quality such as probability score (Murphy & Thompson, 1977), entropy (Mjelde, 1986), and variance of the forecast (Katz et al., 1987) have been employed in previous studies. Of the many measures used to quantify forecast quality, *post agreement rate* (the rate of correct forecasts) is one of the most commonly used (Kusunose & Rezaul, 2016).

We have conducted case studies on irrigation scheduling decisions for the sugar industry in the Burdekin (full irrigation) and Bundaberg (supplementary irrigation) regions. APSIM-Sugar has been calibrated using information from the case studies and simulations run. Full details for the full irrigation modelling are provided in the attached paper. Modelling for supplementary irrigation scenarios, with water trade included, is more complex and ongoing.

We are also analysing the value of SCFs for a grazing case study by constructing regret and value functions. Here we have employed the parameterised forecast system to identify forecast values for different levels of pasture growth/feed availability i.e. low, medium, and high. To do this, we have used GRASP for the biophysical modelling of pasture growth and status and NABSA for the enterprise economic analysis. The case study is Charters Towers.

Forecast values have been identified for a full range of forecast quality (from no skill to perfect skill). Again, this is a complex exercise and investigations are ongoing.

4. Project Results

4.1. Achievements and Outcomes

Assessment of sugarcane irrigation decisions:

Burdekin (full irrigation) case study

Employing the parameterised forecast structure, we quantified economic values across a full and continuous range of forecast skill levels, thus not only allowing assessment of the economic impacts of current seasonal climate systems but also those of improvements in forecast skill. Forecast value was obtained for a full range of forecast quality from 33% (no skill) to 100% (perfect skill). While forecast value changes with the different stages of the sugarcane crop (i.e. the plant crop and ratoons), in each case the value continuously increased with the increase in forecast quality (Figure 1). Using the expected profit approach, the difference in optimal gross margins in the three climatic conditions would drive the values of forecasts, resulting in highest forecast values for ratoon 3 (up to AUD 27 ha^{-1} for a perfect forecast), following by ratoon 2 (up to AUD 13 ha^{-1}), ratoon 1 (up to AUD 12 ha^{-1}), ratoon 4 (up to AUD 10 ha^{-1}) and the plant crop (up to AUD 3 ha^{-1}).

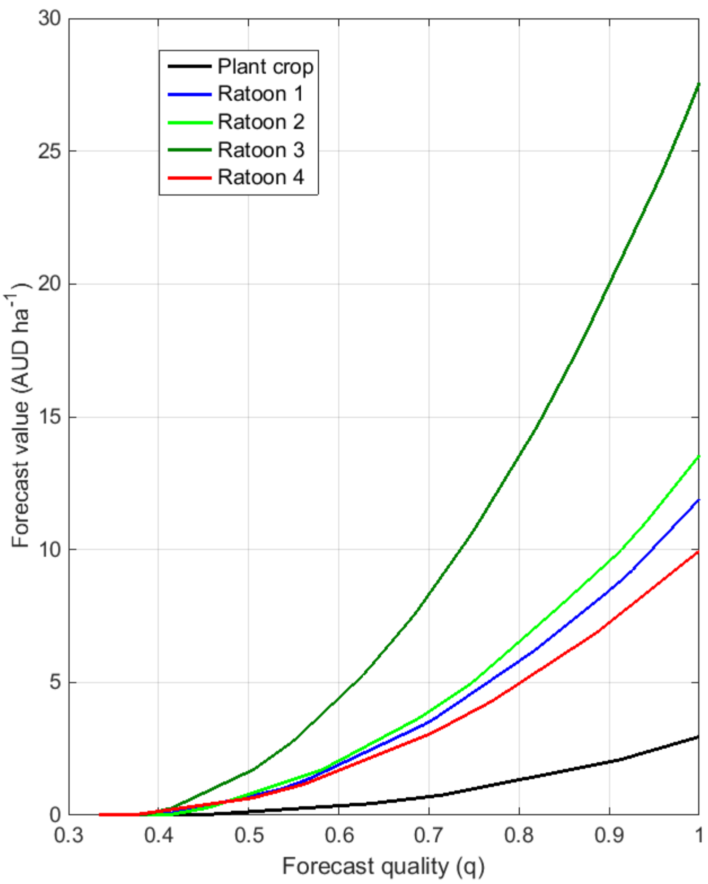

Figure 1. Forecast value as a function of forecast quality for the plant crop and 4 ratoons at Burdekin district.

Importantly, assuming that the current seasonal climate forecast skill is around 60% (a skill level that can be achieved with the SOI-phase system for the period of focus rainfall at Burdekin from November to March), the forecast can help in delivering a gain of up to AUD 4.5 ha^{-1}. We calculate that a 10% improvement in forecast skill would result up to an additional AUD 3.9 ha^{-1}. Additional improvement in forecast quality would result in more economic value gained by farmers. Hence, while our modelling indicates that canegrowers can potentially gain up to AUD 27 ha^{-1} with a perfect forecast, there is still additional value in using SCFs in irrigation decision making in sugar cane farming even with less than perfect forecast skill.

The integrated forecast use model developed in this project allows canegrowers to make decisions on irrigation water amounts when they receive a seasonal climate forecast. The canegrower's decisions here are dynamic, depending on not only the received forecast but also the canegrower's perceived forecast quality levels and the stage of the crop cycle (Figure 2). Generally, the model detected the highest optimal irrigation water amounts for the plant crop, followed by ratoon 1, ratoon 2, ratoon 3, and ratoon 4. Optimal irrigation water amounts were more sensitive to forecast quality in the La Niña and El Niño forecasts (Figure 2a & 2c) than in the Neutral forecast (Figure 2b). Interestingly, while optimal irrigation water amounts reduce with improved quality of the La Niña forecast, better El Niño forecasts indicate higher optimal irrigation amounts. This is reasonable, given that if farmers are more certain about a wet seasonal climatic condition they would likely reduce irrigation water to avoid problems associated with overwatering such as waterlogging which reduces yield and economic returns. On the other hand, if farmers are more certain about dry climatic conditions they would be more likely to increase irrigation water to optimise yield and economic returns. It can be seen that by improving cane growers' perceptions around forecast quality, irrigation water resources can be used more effectively.

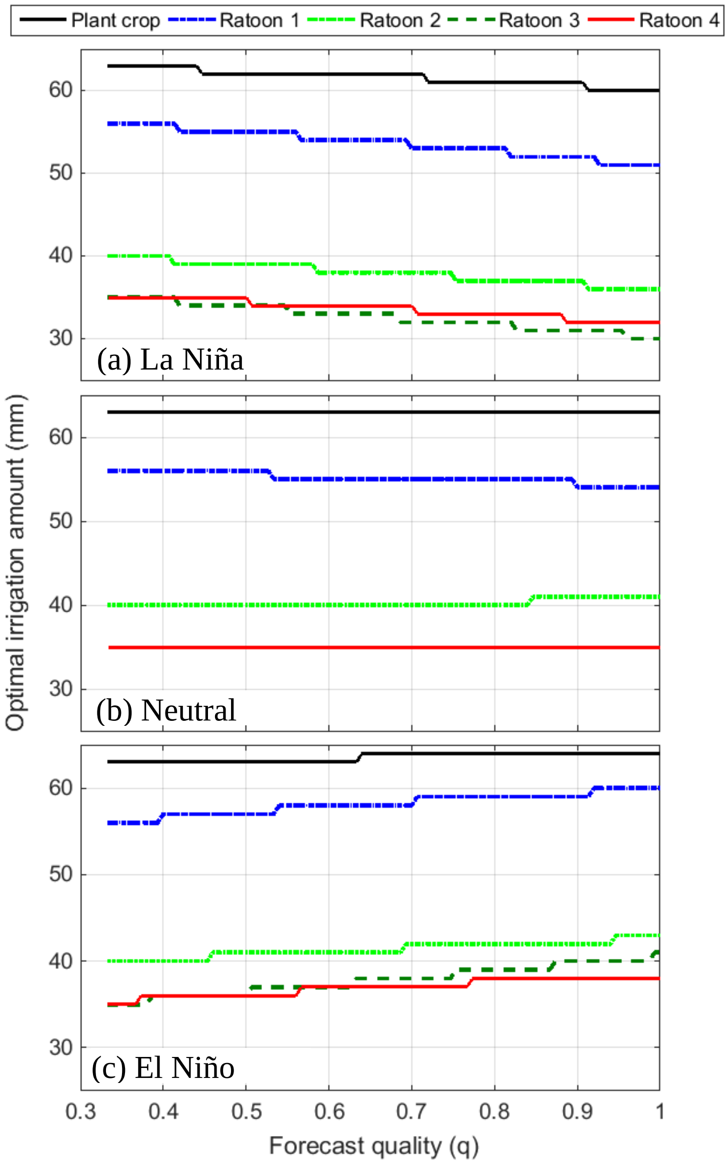

Figure 2. Optimal irrigation amount as a function of forecast quality for the simulated plant crop and 4 ratoons, Burdekin district. The optimal irrigation amount also depends on the specific forecast received, which can be (a) a La Niña forecast, (b) a Neutral forecast, or (c) an El Niño forecast. Note that in (b), results of ratoon 3 was overlapped by those of ratoon 4.

Assessment of sugarcane irrigation decisions:

Bundaberg (supplementary irrigation) case study

Using a similar methodology, we calibrated the model using case study information from the Bundaberg region, where, due to smaller water storages and limited water availability in the catchment, irrigation is used to supplement rainfall. Water trading, enabling access to additional water over allocated volumes but at cost, is an option in this region. Forecast value under these conditions was still apparent, but at lower levels than in the full irrigation regime of the Burdekin region (Figure 3).

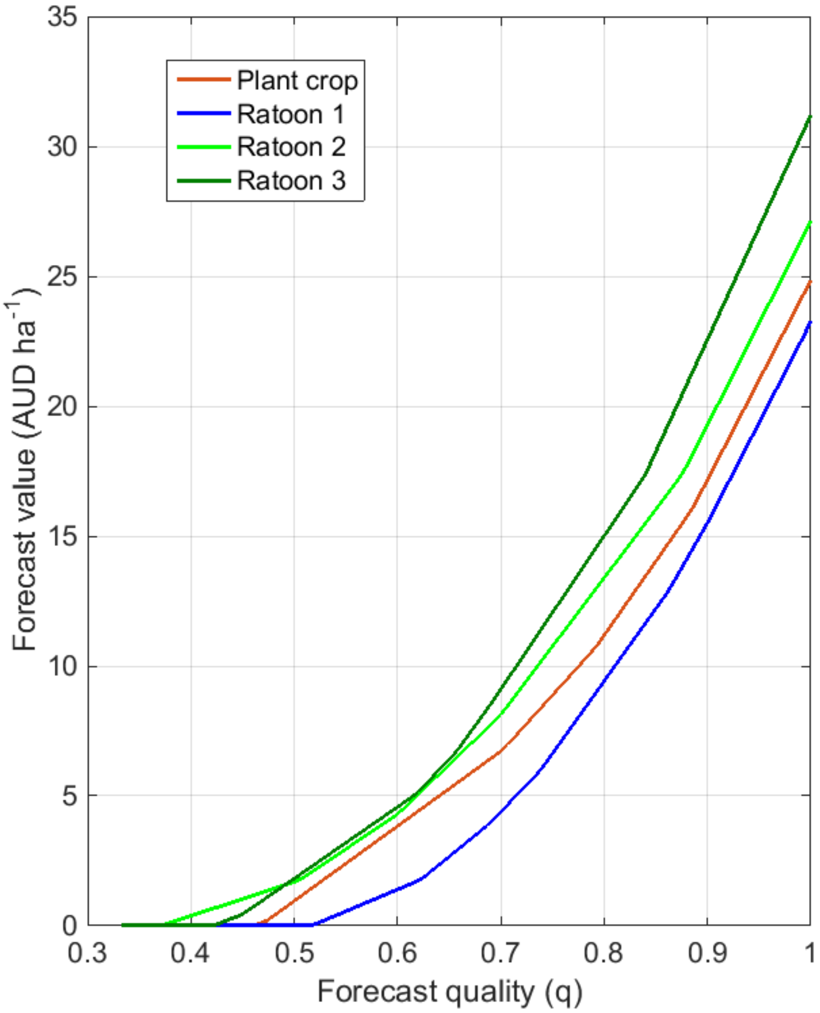

Figure 3. Forecast value as a function of forecast quality for the plant crop and 3 ratoons at Bundaberg district.

Assessment of grazing management decision and associated economic value:

We demonstrated the value of seasonal climate forecast for a grazing enterprise case study at Charters Towers. By constructing the regret function and value function as functions of forecast quality the value of any skilful imperfect forecast system were determined. In this study, regret and value functions were constructed for each ENSO phase forecast in the three feed supply options. Value of the ENSO phase forecast was estimated at up to about 10% of the average annual economic return of the farm.

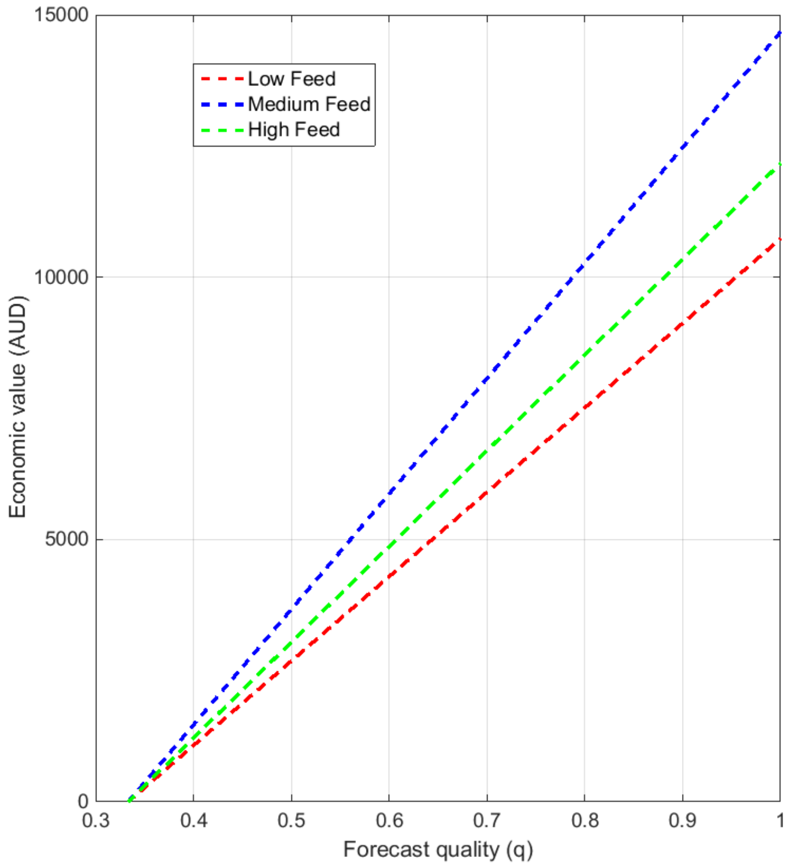

Figure 4: Economic values of the forecast system as functions of forecast quality in the three feed supply scenarios (Low Feed, Medium Feed, and High Feed) for a whole farm case study at Charters Towers.

4.2 Unintended Outcomes

n/a.

4.3 Partnership Formation

Improved and closer collaboration with sugar and grazing industries. Also valuable collaboration across different DCAP projects (especially with DSITI).

4.4. Lessons Learned

In a climatic variability environment in Queensland and northern Australia, seasonal climate forecasts can play an important role in agricultural risk management and potentially add significantly to enterprise profitability. Currently, however, SCFs are largely underutilised by farmers in Australia and over the world in making key farming management decisions. This is attributed to (i) not enough demonstration of the forecast values in primary sectors, and (ii) the perception that SCFs are far from certain.

Our research has shown that, properly interpreted, existing climate forecasts with current levels of forecasting skills offers considerable potential to increase long-term average yield and decreased production risks, with investment losses minimised in poor years and opportunities maximised in good years.

4.5 Implications for the Future

Here, we have demonstrated that the values of SCFs are significant in sugarcane irrigation scheduling decisions and grazing feeding supply options. In fact, seasonal nature of agricultural business would have even greater economic potential of seasonal climate forecast because any associated decision can be improved with better use of forecast information. The research and demonstration of forecast economic values should be extended to many other agricultural sectors, and be specific for each agricultural sector in Queensland and northern Australia.

In the era of big data, decision makers can approach more and more information in their daily business. However, without capacity of effective use of information decision makers are easily overwhelmed with information given that information is typically associated with uncertainty. This is also the case with seasonal climate forecast and its currently low adoption rates via key messages from our farmer surveys. There is thus an urgent need of developing innovative models of forecast use so that the information provided to farmers is the best decision or option without any uncertainty. This is a large motivation that this project is aiming to address a part of it. More research effort would be definitely essential for Queensland and Australia's farmers and agricultural industries.

5. Conclusion

So far, this project has developed an innovative integrated framework for quantifying the economic value of seasonal climate forecast systems (SCFs) for sugarcane farm irrigation water management and feed supply management in the grazing industry. This framework can quantify the economic value for a full range of forecast skill levels and thus not only allows assessment of the economic impact of current seasonal climate systems but also the economic impact of improvements in forecast quality. The developed framework is an initial step toward an operational model of forecast use for different agricultural industries in Queensland and northern Australia.

6. Financial Statement (Revenue received/Expenses paid/Revenue unspent

TBA

7. Additional Information

Additional information can be found in the project report *Drought Climate Adaptation Program. Project 15: Value of seasonal climate forecasts. Final report, June 2017.*

8. References

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9. Appendices/Attachments

9.1 Milestone Reports

9.2 Case Studies

Case study 1. Full irrigation Burdekin (PDF)
Case study 2. Partial irrigation Bundaberg (PDF)
Case study 3. Grazing case study

9.3 Project Reports

Drought Climate Adaptation Program. Project 15: Value of seasonal climate forecasts. Final report, June 2017

9.4 Scientific Papers

An-Vo et al., Value of seasonal forecast for sugarcane farm irrigation scheduling decisions (submitted, ERL, see attached)
An-Vo et al., Value of seasonal forecast for planning use of limited irrigation water in sugarcane (in prep.)

9.5 Products/Product Descriptions

9.6 Other Relevant Attachments

Case study 1. Full irrigation Burdekin (PDF)

CaseStudy1_Burdekin.pdf

Case study 2. Partial irrigation Bundaberg (PDF)

CaseStudy2_Bundaberg.pdf

Case study 3. Grazing case study

Grazing DCAP1 Final_v3.pdf

Scientific Paper, An-Vo et al., Value of seasonal forecast for sugarcane farm irrigation scheduling decisions (submitted, ERL)

Irrigation case study paper.pdf