KIT 5.1

Improve the accuracy of short-range and medium-range weather forecasting

Impact	**Growers have access to accurate weather forecasts (out to 14 days) that enable improved decision-making and risk management on farm.**
Summary	• Growers can confidently interpret and understand weather forecasts. • Growers can extract maximum value from weather forecasting systems to aid with on-farm decision-making. • Growers have access to short-to-medium range weather forecasts (1–14 days) with enough accuracy to optimise on-farm decision-making.

OVERVIEW

Australian grain growers require access to more accurate weather forecasts with longer lead times (e.g. 7 to 14 days) to better manage on-farm risk which in turn maximise profit and minimise losses. Further to improvements in the accuracy of forecasts there is a clear opportunity to extract greater value from current weather forecasting systems. GRDC's investment approach to Key Investment Target (KIT) 5.1 involves three broad outcome stages;

1. growers gaining an improved understanding of the accuracy and other features of current weather forecasting systems and having the skills to easily use these forecasts to inform improved on-farm decision making;
2. Enabling grain growers to extract the greatest value possible from current weather forecast systems,
3. Improving the accuracy and other features of weather forecasts to enable Australian grain growers to make more profitable decisions.

GRDC will invest in delivering these outcomes via a cross-sectoral approach in collaboration with other RDCs where possible. GRDC will also continue investing in RD&E that delivers improved forecasts beyond 14-days through cross-sectoral initiatives such as the Managing Climate Variability Program and the joint Climate Research Strategy for Primary Industries.

Australian grain growers rely daily on weather forecasts to guide a wide range of tactical and operational on-farm decisions. Generally, the shorter the forecast lead-time the greater the confidence growers have with the forecast. Most growers tend to access multiple weather forecasting products from different providers . This access can occur via multiple channels extending from meterological organisations that issue forecasts and third-party platform providers, such as weather apps and farm management dashboards who deliver forecast products to growers. The manner in which forecast information is displayed can impact how a grower uses that information on-farm and in turn can affect the perception of that forecast's accuracy[2].

How growers extract value from a weather forecast depends on many factors. Importantly, the quality of a weather forecast, as measured by accuracy and other attributes, is different to its value. A weather forecast with high quality is one that predicts weather conditions well according to a set of predefined criteria. Those criteria can be based on factors such as a forecast's accuracy, a forecast's skill (its relative accuracy compared to a reference forecast), its spatial resolution and other factors. From an on-farm perspective the criteria used to assess value are driven by consideration of what a grower deems most useful in informing their decision making. Accuracy is defined as the difference between the forecasted weather and the actual weather observation and is simply one measure of forecast quality. Other key measures, as defined by the World Weather Research Programme's Joint Working Group on Forecast Verification[3], include but are not limited to:

- Bias – the difference between the mean forecast and mean observation.
- Skill – the relative accuracy of a given forecast system over a reference forecast system (a baseline measure). The reference forecast may be based on random chance or simply climatology - the probability of different events based on historical records.

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- Reliability – the average agreement behind the forecast values and the observed values. If the forecasts over 'n' segments are considered together then the overall reliability is the same as the 'bias'. If the forecasts are segmented into different categories n_1, n_2, n_3 (e.g. seasons in which the forecasts are issued, locations they're issued for, or other segments.) then the reliability is the same as the 'conditional bias'.
- Resolution – a forecast has resolution if it can resolve one set of events into subsets with different frequency distributions. A forecast has resolution if it can separate one type of outcome from another, as in the presentation of a forecast with decile probabilities compared to a binary (above or below) forecast.
- Sharpness – the tendency of a forecast to predict extreme values. For example, a forecast of climatology (the average based on historical records) has no sharpness.

Contrary to quality, the value of a forecast is dependent on how a forecast helps the end user make a better decision. The value is measured against a set of criteria determined by the end-user. In addition to the accuracy and skill of the forecast, factors such as lead-time, the environmental variable in question (e.g. temperature, rainfall, wind speed) and the timing of the forecast affect the value growers may derive from a forecast. The value derived is primarily affected by the characteristics of the on-farm decisions which are being made based on the forecast[4,5]. The upside and downside risk posed at different decision-points will affect whether a forecast has value, and if so, what aspects of a forecast's quality are most important for it to have value. Accuracy and skill are attributes of forecast quality which are traditionally emphasised. However, oftentimes other attributes such as reliability and sharpness will have a strong impact on the value of a forecast to a grower. Some of the key on-farm decisions that are made with reference to a 1 to 7-day weather forecast are identified in table 1.

Table 1. Summary of key tactical on-farm decision points that are made with reference to a potential 1 to 7-day weather forecast and the typical impact of those decision points on a grower's profit per hectare[6].

Decision point/consideration	Required weather information	Potential impact on profit per hectare	Pathway to KIT objective
Sowing: when to sow to ensure establishment and at what depth	Total rainfall Rainfall intensity Timing of rainfall	High	Maximise profit
Starter fertiliser: minimsing the risk of seedling toxicity	Total rainfall Timing of rainfall	Moderate	Minimise loss
In-crop fertilisers: timing, application rate and form.	Total rainfall Rainfall intensity Timing of rainfall	High	Maximise profit
Crop protection: application of herbicides, fungicides and insecticides.	Wind speed and direction Humidity Temperature Timing of rainfall	High	Maximising profit
Hay cutting: timing of hay cutting to avoid spoilage from rain damage	Total rainfall Rainfall timing	High	Minimise loss
Frost and heat: understanding the likely yield or quality losses from frost and heat events during crop reproductive phases, as well as the herbicide efficacy and dual purpose crop grazing strategies.	The timing and duration of the maximum and minimum temperature	High	Minimise loss
Harvest: optimise the timing and sequence of harvesting operations to minimise the risk of pre-harvest head loss, pod shatter, pre-harvest sprouting and weather-induced grain defects.	Wind speed Timing of rainfall Total rainfall Temperature	High	Minimise loss

FUTURE RD&E FOCUS

Investment principles

The following are general investment principles that guide GRDC's investments within the scope of KIT 5.1:

- Wherever there is purposeful alignment, GRDC will seek to co-invest with other RDCs in delivering mutually beneficial outcomes across the Australian agricultural industry.
- Investments to develop and explore the value of new forecast products are within the investment scope, yet investment in supporting or maintaining weather forecasting services to Australian grain growers are outside the scope of GRDC's investments in RD&E, as are: direct investments with public or private entities to purchase and/or subsidise the cost of acquiring infrastructure (i.e. super-computing facilities) to support the operation of high-resolution weather forecasting models, and investments to compare the accuracy, precision, cost or other parameters of commercially available weather monitoring stations.

SCOPE – Improved understanding of weather forecasts

GRDC is targeting the following outcomes within the scope of enabling an improved understanding of weather forecasts:

Investment Outcome 5.1.1 – Growers have easy-to-use access to weather forecasts to aid decision making.

Investment Outcome 5.1.2 – Growers are able to correctly and confidently understand and interpret weather forecasts.

Growers are accustomed to assessing a forecast's value by its accuracy. However, a sole focus on improving forecast accuracy can be at the expense of other approaches to improving value to the grower. Knowing the reliability of the forecast for rainfall in May (a common winter-crop seeding window) and improving its resolution can provide clear value to a grower within a decision-making process. For example, a weather forecast product for rainfall over the next seven days that includes understandable information on the reliability of the forecast and contains greater resolution (e.g. rainfall probabilities presented as quintile brackets) could enable growers to make more informed decisions about crop sowing strategies. Australian grain growers are well equipped at managing risk when presented with the information required to do so. Communicating the right quality attributes of a weather forecast in easily interpretable formats would likely result in forecasts with greater value to growers, irrespective of efforts to improve a forecast's skill or accuracy.

There is a further opportunity to develop tailored or 'niche' weather forecasting products that could provide great value to Australian grain growers if they were made available. The cross-RDC Rural R&D for Profit Program investment *'Forewarned is Forearmed: equipping farmers and agricultural value chains to proactively manage the impacts of extreme climate events'* has begun to elucidate the value of new forecast products based on heat and cold load/indices which could have clear value to agricultural production systems[7]. There is great scope to further identify the types of forecast products that could provide value to growers, and to be able to quantify their potential value in economic terms both at the farm gate and in relation to broader environmental and social impact factors. Data on the economic, environmental and social benefits that could arise from the use of new tailored weather forecasts is key to the development of a business case that could be used by the BoM and/or commercial companies to justify the costs involved in making those tailored forecasts available to grain growers.

SCOPE – Improved capture of the value of weather forecasts

Growers have access to the tools and knowledge required to extract the maximum value from current weather forecasts.

GRDC is targeting the following outcomes within the scope of improved capture of the value of weather forecasts:

Investment Outcome 5.1.3 – Growers and other industry participants have access to the tools and knowledge to calibrate regional weather forecasts to inform on-farm weather predictions.

Investment Outcome 5.1.4 – Growers are equipped to make more informed on-farm decisions by integrating weather forecasts into agronomic and business decision-making.

There are key opportunities to leverage the inherent value from weather forecasts by integrating on-farm data layers and agronomic modelling tools which in turn could provide additional value to decision making processes[8,9,10]. On-farm weather stations are popular instruments to provide granular on-farm information to advise effective pesticide application decisions, enable more precise recording of rainfall and support various other decision making processes. Data collected via on-farm weather stations could be an effective mechansim to calibrate/localise forecasts issued by a third partry (whether via the BoM are another entity). This in turn could provide a basis to extract greater value from both on-farm data and current weather forecast systems.

Integrating weather forecasts with agronomic models is another method that could enable growers to extract greater value from current weather forecasting systems. Growers are consistently making tactical decisions based on the expected response of a biophysical process (e.g. the progression of a disease in the crop canopy) to changes in the weather. Weather drives the majority of agronomic decisions by growers, yet few data driven agronomic models that take into account changing weather conditions are made broadly accessible to growers. Tools to enable the integration of agronomic models within weather forecasts could provide growers with more granular information and generate broader knowlegde on how to optimise input allocation decisions on-farm.

GRDC investments within KIT 3.2 will aim to provide complementary enablers in the form of modular, agronomic and farming systems models that could be integrated with different weather forecasting capabilities. The aim is to provide researchers and commercial third parties with the opportunity to iterate/test and further develop these integrated models with a view that the 'front-end' software solutions would generally be developed and taken to market via commercial third parties.

SCOPE – Improved accuracy of weather forecasts

Growers have access to accurate forecasts at farm and/or paddock scale out to 14 days.

GRDC is targeting the following outcomes within the scope of improved accuracy of weather forecasts:

Investment Outcome 5.1.5 – Growers and other industry participants have access to weather forecasting models that can identify localised meteorological events at the farm and/or paddock scale (less than five kilometres).

Investment Outcome 5.1.6 – Growers can accurately forecast rainfall and temperature at the farm and/or paddock scale.

The aim to improve the accuracy of weather forecasts is a complementary focus to the aim of extracting greater value from existing weather forecast models. While improvements in accuracy are clearly valuable, the focus should be on delivering improved information at key decision-points faced by growers taking into consideration the range of factors that affect a forecast's value at each of those decision points.

GRDC will be targeting its investments in the area of forecast accuracy in areas where one or more demonstrable link to an increase in value for grain growers can be demonstrated. Opportunities involving the development of an ensemble distribution (a set of combined weather forecasts) or a model downscaling method may not relate to an improvement in accuracy *per se* but may be key steps toward generating improved value for grain growers.

The results from economic analyses that identify potential value to be gained on-farm and across the grains industry via a measurable improvement in forecast accuracy could be leveraged by forecast providers (public and private) to help justify further R&D investments. The cost, complexity and risk associated with technical approaches to improve accuracy at a given decision point, and the potential impact of that decision point on grower profitability will affect the business case that governs investments in R&D in this area. Direct investments in super-computing facilities to enable more localised model outputs are outside scope of this investment strategy.

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