Managing the risks of frost and heat in wheat, barley, canola, chickpea and lentil

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Abstract

The Frost and Heat Management Analytics (FAHMA) project, which commenced July 2022, is a GRDC-funded project led by CSIRO and comprises an additional 15 organisations, including eight commercial partners, state departments and universities. The FAHMA project aims to develop and commercialise temperature mapping and crop modelling technologies to help growers and advisers manage the impacts of frost and heat in wheat, barley, canola, chickpeas, and lentils. These technologies are targeted at enabling improved sowing decisions, in-crop management decisions, and underpin the development of new risk management tools. A key objective is to deliver these solutions to growers, agronomists, and others in the grains industry through commercial partnerships with multiple AgTech businesses.

This paper outlines the progress to date on the FAHMA project. A key objective is to create and bring to market analytics-driven technologies that assist farmers and advisors in mitigating the effects of frost and heat on wheat, barley, canola, chickpeas, and lentils. Spanning the commercialisation, development and research continuum, the project has developed prototypes with commercial partners for mapping temperature in grower's fields to enable usability testing with agronomists and growers. Additionally, the team have reused data from prior investments to improve the frost and heat damage functions in the Agricultural Production Systems simulator (APSIM) crop model for wheat, barley and canola. Together these will enable growers and advisers to assess the likely yield reduction across paddocks after frost and heat events.

Keywords

Land surface temperature, APSIM, phenology, user research, product design.

Introduction

Frost and or heat events that occur during the critical reproductive development period (Dreccer et al. 2018; Sadras and Dreccer 2015) of grain and oilseed crops can cause significant reductions in potential yield. While estimating the total economic losses to the Australian grains industry is challenging, frost alone accounts for approximately $360M in annual losses (GRDC 2016). Anecdotally, this can result in significant operational stress for growers and their advisers. Prior efforts have targeted the development of improved varieties and potential agronomic management options to reduce the impacts of frost and heat (DPIRD 2019). For example, identifying frost prone paddocks, diversifying the enterprise with increased crop types and livestock, increasing the capacity of the soil to store heat, manipulating flowering times through varying sowing time and cultivar selection. This has led to sowing time recommendations targeted at managing the risk of frost and heat through appropriate selection of varieties, based on phenology and the specific geographic location (Flohr et al. 2017; Lilley et al. 2019). This approach seeks to minimise the exposure of the crop to damaging frost and heat events during the critical reproductive development period, based on the historical climate data. For frost, although the development of improved reproductive tolerance within the crop would provide an economic benefit (An-Vo et al. 2018), frost-tolerant varieties are not considered imminent.

Once the crop is sown and the growing season is underway, options to manage the risks of frost and heat occurrence are considerably reduced. Currently, if a frost event occurs, growers and agronomists rely on visual assessment of the crop several days afterwards by manually inspecting individual reproductive organs for damage (DPIRD 2019). Using this approach to quantify the spatial extent of likely crop loss due to frost and heat is laborious and requires a trained person. Presently, there is no objective, reliable information enabling growers to assess the likely crop loss from frost and heat across a large area in a timely manner. A first step to respond and adapt management (e.g. sowing time, crop choice, managing failed crop) is to have access to information quantifying the risk at the scale at which decisions are made.

Our team has developed two core scientific technologies aimed at providing growers and agronomists with timely information to manage the risks of frost and heat. The first is overnight temperature mapping of the land surface temperature (LST) at resolutions of either 2 km or 30 m, every 10 min. The second enhances the APSIM NextGen (Holzworth et al. 2014) crop model by enabling it to account for the impact of frost and heat events through reduced yield, depending on the severity and phenological timing of the event. This paper describes how we are enabling these technologies to provide useful benefits to growers and advisers.

Methods

Translating the foundational science of LST mapping and APSIM damage functions into analytics-based data products involved iterating through the following steps: (1) identifying the core problem experienced by growers and advisers; (2) developing product concepts and model operationalisation in an appropriate technology platform (Eratos Platform); (3) evaluation and feedback by commercial partners to address any technology shortcomings and incorporate improvements.

Problem identification and prioritisation

We undertook user research at the outset of the project to further define the desired outputs. This comprised contextual inquiries with a total of 38 growers and agronomists across grain growing regions in Western Australian, South Australia, Victoria, New South Wales and Queensland. We sought to understand how growers and advisers currently manage frost and heat in their programs, their pain points and the opportunities for improvements. Three key research questions were addressed through contextual inquiry: (1) understand how frost and heat risks are incorporated into the key decision points in the season (planning, sowing, and in-season decisions); (2) understand how growers plan their farm operations amid constraints including crop selection, sowing time, labour, machinery and the need to sow a full program across the farm; (3) understand the use of any tools or advice currently used as input to their decision-making process.

Development of product concepts and their operationalisation in the Eratos Platform

Based on the Himawari-8 geostationary meteorological satellite images (JMA), a workflow was developed to produce overnight temperature mapping of LST at resolutions of either 2 km or 30 m, every 10 min (CSIRO).

A second workflow was developed to produce the % yield reduction caused by frost and heat events at 90 m spatial resolution, based on wheat and canola frost and heat damage functions developed for APSIM NextGen. This model required the cultivar and sowing date, in addition to air temperature. The latter was acquired at 90 m resolution using a thin plate spline interpolation (TPSI) technique (Webb and Minasny 2020). The workflows were implemented on the Eratos Platform (https://www.eratos.com/). This enables programmatic access, via application programming interface (API) and software development kit (SDK), for research and commercial partners alike for testing and evaluation.

Evaluation, feedback and improvement of data products by commercial partners

A national on-farm testing and evaluation network was established with the project commercial partners for evaluating the data products. The following sites were chosen; Albury, Wagga, Harden, Grenfell, Dubbo, Boorowa (NSW), Roseworthy, Jamestown, Loxton (SA), Swan Hill (VIC), Narrogin, Esperance, Wongan Hills, Merredin, Tamin, Kojonup, Dumbleyung, Wandering (WA). Each site was chosen because of its high propensity for frost, based on grower and advisor knowledge, and sown to wheat for the 2024 growing season.

Results

From the user research, conversations and workshops with advisers it was revealed that growers and advisers respond differently to heat events compared to frost events. Timely temperature mapping of frost events at sub-paddock scale and likely yield damage were identified as potentially valuable to growers and agronomists for one or multiple events. In contrast, for heat events, growers and advisers were not looking to specifically map their paddock for failed crop in the way they would after a frost event. Heat is typically cumulative across multiple events and unlikely to vary spatially to the same extent that frost does. In addition, the yield loss caused by heat is likely to be coupled with reduced water supply. There was no evidence of demand for either single-event or sub-paddock mapping information of heat per se.

For these reasons, effort was prioritised towards providing overnight LST information to enable mapping at both regional and sub-paddock scale, to provide timely information on severity and extent of possible frost events during the growing season. Figure 1 encapsulates key learnings from the user research, identifying the challenges experienced by growers and advisers because of the dearth of information on likely damage from frost and the inordinate effort currently required to map the damage from a frost event.

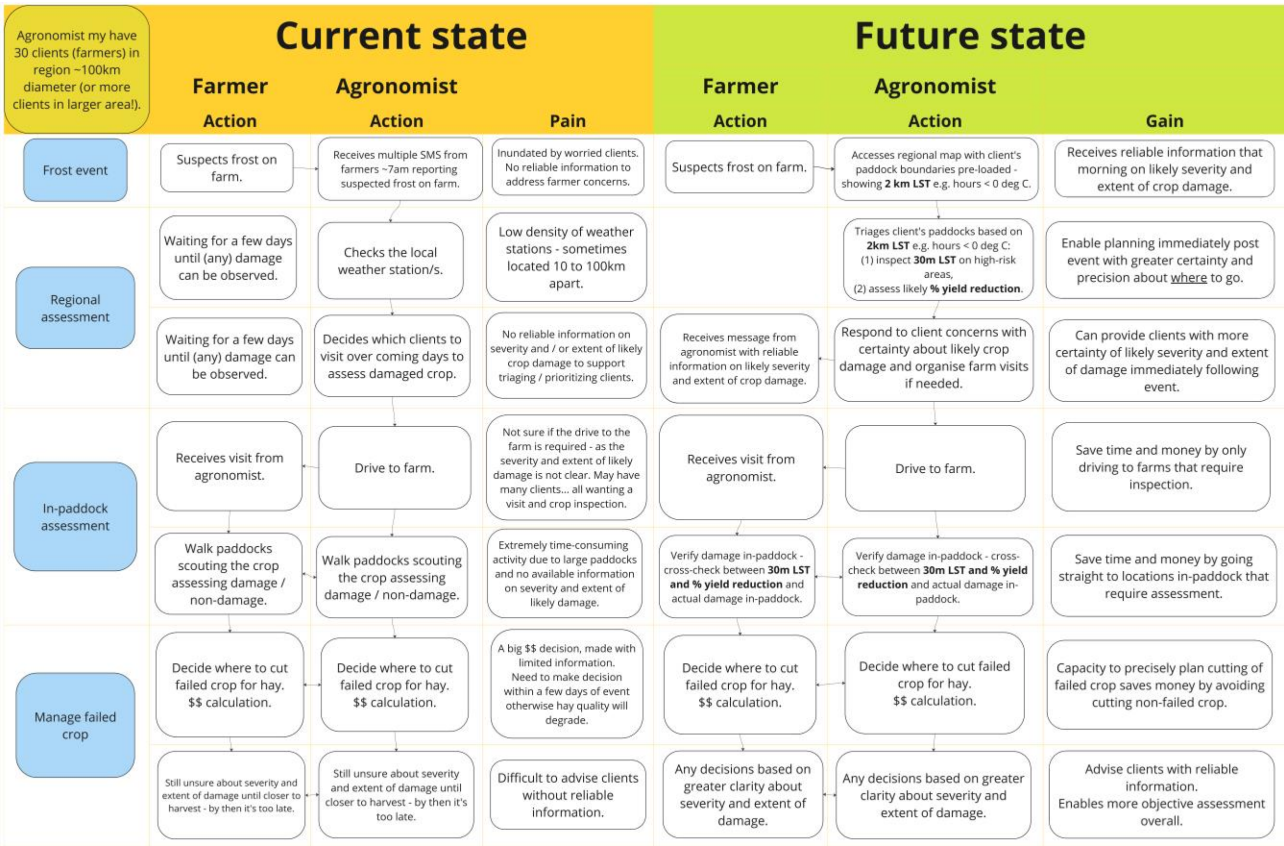

Figure 1. The current and future state journey mapping of a personified farmer and agronomist responding to a possible frost event. The current state highlights the challenges ("Pain") currently experienced by farmers and agronomists managing spring frosts. The future state shows how the 2km LST, 30m LST and % yield reduction data products can potentially mitigate these challenges ("Gain").

Conclusion

LST maps at 2 km and 30 m resolution, and % yield reduction data products were created that are expected to provide considerable benefits by enabling growers and advisers to respond to in-season frost and heat events. The data products will be tested by commercial partners during the 2024 winter growing season, across a national network of on-farm sites spanning the Australian winter cereal growing area. This evaluation will establish the technology efficacy and enable incorporation of improvements.

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