Transformational agronomy by growing summer crops in winter: Predicting soil temperatures using outputs from crop and climate models

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Abstract
Winter sown sorghum offers farmers the opportunity to increase profits and reduce risks in both rainfed and irrigated cropping. However, sowing sorghum in winter requires crops to uniformly germinate and emerge in cold soils (cooler than the recommended 16ºC). Prolonged emergence periods and reduced total emergence can decrease canopy uniformity with negative impacts on yield. The minimum soil temperature required for a uniform crop emergence appears to be 12ºC at sowing depth. The soil temperature ideally increases over time. Here we present an assessment of the value of combining outputs of BoM's ACCESS S1 seasonal climate forecasting system and APSIM Sorghum to predict soil temperatures and the likelihood of frosts after planting over the few following weeks after sowing a sorghum in winter.

Keywords
Forecasting, winter sown sorghum, climate risk

Introduction
Summer cropping in the northern grains region of Australia has long been characterised as operating in an uncertain, potentially hostile environment(Hammer et al., 2001), and with the advent of climate change, the incidence of hot, dry spells around flowering has increased (Hudson et al., 2013). Several adaptation options are available to farmers to mitigate these risks, including increasing tolerance through plant breeding activities(Singh et al., 2015), or avoidance – planting the crops earlier to place the reproductive phase in a non-hostile environment (Prasad et al., 2017). Avoidance of heat stresses around flowering in sorghum entails sowing a summer crop earlier in winter into cooler soils than usually recommended. Therefore, early planting of summer crops does not come without risk – it involves trading a reduction in the risk of heat exposure during flowering against the risk of establishment occurring during suboptimal conditions, specifically poor germination and emergence that can lead to patchy, uneven stands with a consequent reduction in grain quality and yield (Howden et al., 2007). Temperature and moisture are the key drivers of G&E – and while the G&E process is not a simple matter of reaching a threshold, it is commonly held that soil temperatures above 12C are sufficient to ensure a well-established crop (Eyre, et al., 2021, this conference). Live prediction of soil temperature in a forecast setting is currently unavailable, though here we show that APSIM (Holzworth et al., 2014) combined with daily rainfall & temperature forecasts from BoM's ACCESS-S1 model (Hudson et al, 2017) can predict soil temperatures and that can be used to inform on sowing a summer crop in winter.

Methods
Observed soil temperature at a range of times and locations is available from the BoM as part of its Station Network (www.bom.gov.au). The data is sparse, with only a handful of stations within the Northern Grains Region contributing more than 20 years of continuous data. Yet as this is a measured (as opposed to modelled) observation, a trend calculation is possible

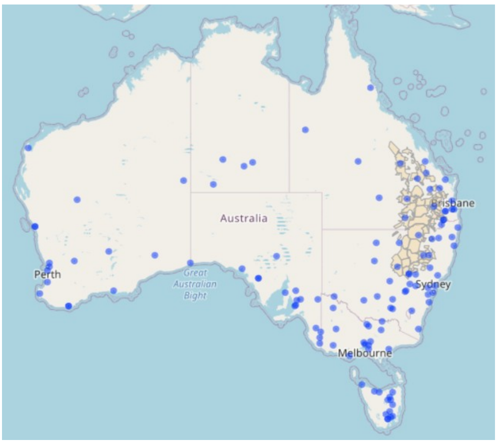

Figure 1 Location of Stations reporting Soil Temperature (blue) overlaid across the summer grains growing region (yellow) of Australia

On-farm experiments across the region (Eyre, et al., 2021, this conference) covering two seasons have collected emergence rates that demonstrate declining emergence rates associated with low and high soil temperatures.

APSIM's soil temperature model (Campbell, 1985) is implemented as a resistive array of soil layers; each layer responding to any temperature gradient between adjacent layers. Solar Radiation and (min, max) air temperature drive energy inputs to the surface layer, with the bottom layer set to the annual average temperature.

In this exercise, ACCESS-S1 provides a 33-member lagged ensemble forecast (using 3 successive forecasts of 11 members each) on the 1st and 15th of each month; each ensemble member is used by APSIM to generate an average minimum soil temperature series for the coming month. The soil temperatures for each day and site are plotted as quartiles to visualise the spread.

Results

Trends (Fig 2) in the first day of soil temperatures higher than > 12°C initially appear inconsistent, yet once coastal and extreme southern zones are removed, there is a tendency for northern sites to occur earlier, and southern sites later, indicating opportunity to advance sowing days into the late winter.

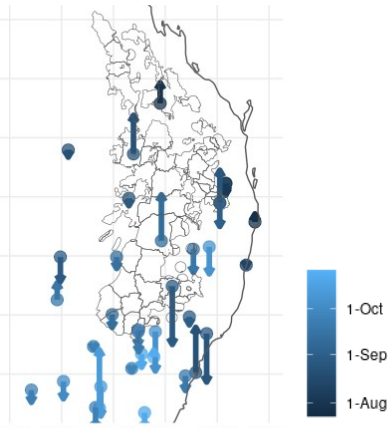

Figure 2 Date (colour) and Trend (days/year, Arrow) of the first day of the year when soil temperatures are higher than 12°C. The length of the arrow is proportional to the largest trend of the stations shown, an upwards direction indicates earlier occurrence, downwards the converse. Each site is selected from BoM stations with continuous recording longer than 20 years.

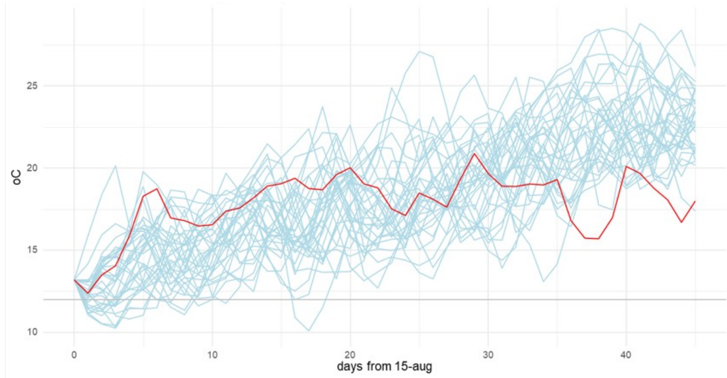

Figure 3 A forecast plume from APSIM's soil temperature module using ACCESS-S1 data. The red line is the observed series, the blue lines the 33 ensemble members.

Forecasts of soil temperature from ACCESS-S1 and APSIM (Fig 3) were assessed for percent consistence. Percent consistent refers to the percentage of forecasts that were consistent with the category later observed (BOM, 2021), a measure of skill also described in Hudson et al., 2017 (Fig 4).

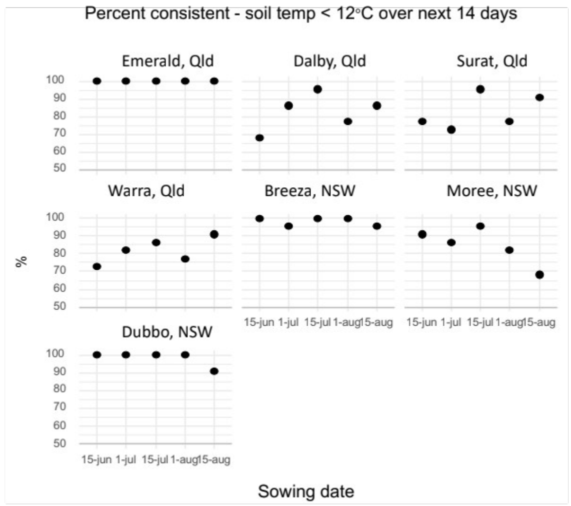

Figure 4 Percent consistent (%, percentage of forecasts that were consistent with the category later observed) for the forecasted soil temperatures lower than 12°C across Qld and NSW using ACCESS S1 – APSIM.

Figure 4 shows that the forecast of soil temperature obtained with ACCESS S1 – APSIM had high values of skill (percent consistent) at Emerald in Qld, and Breeza and Dubbo in NSW. For the other tested sites the value of percent consistent varied with the planting time .

Conclusions

The initial results from this study show that there is potential from using outputs from ACCESS S1 and APSIM to predict soil temperatures for at least two weeks after sowing from June to early August. Though the skill of the forecast appears to be highly dependent on site and month. Further studies are being completed.

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References

BOM 2021, http://www.bom.gov.au/climate/ahead/about-percent-consistent.shtml
Campbell GS, 1985, Soil Physics with Basic, Elsevier, Amsterdam.

Eyre J, et al., 2021 Transformational agronomy by growing summer crops in winter: Crop establishment into cold soils. 20th Australian Agronomy Conference, Toowoomba Qld

Hammer GL et al., 2001. Advances in application of climate prediction in agriculture. Agricultural Systems 70, 515–553.

Holzworth DP, et al., , 2014. APSIM - Evolution towards a new generation of agricultural systems simulation. Environmental Modelling & Software 62, 327–350. doi:10.1016/j.envsoft.2014.07.009

Howden SM et al., 2007. Adapting agriculture to climate change. Proceedings of the National Academy of Sciences 104, 19691–19696. doi:10.1073/pnas.0701890104

Hudson D, et al., 2013. Improving Intra-seasonal Prediction with a New Ensemble Generation Strategy. Mon. Wea. Rev. 141, 4429–4449. doi:10.1175/MWR-D-13-00059.1

Hudson D et al. 2017, Journal of Southern Hemisphere Earth Systems Science 67:3

Prasad PVV et al., 2017. Field crops and the fear of heat stress—Opportunities, challenges and future directions. Field Crops Research 200, 114–121. doi:10.1016/j.fcr.2016.09.024

Rodriguez D, et al., 2021 Transformational agronomy by growing summer crops in winter: Winter sown sorghum. 20th Australian Agronomy Conference, Toowoomba Qld

Singh V et al., 2015. Sorghum genotypes differ in high temperature responses for seed set. Field Crops Research 171, 32–40. doi:10.1016/j.fcr.2014.11.003