A Climate Resilience Platform for Agriculture

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ABSTRACT

The changing climate will see an increase in the frequency, scale, and intensity of future natural disasters. While communities and governments need to work together to mitigate the impact of these emergency events, the business community will also need to adapt to ensure the ongoing sustainability of their enterprises. This is especially true of the agricultural sector which is exposed to climate variability. The Climate Services for Agriculture (CSA) tool is an online interactive digital platform bringing together a variety of climate information specifically for farmers and the agricultural sector. It will enable agricultural businesses, planners, and communities to explore various climate related datasets to better understand how the expected future climate may impact different regions and commodities. This will help people to anticipate and plan for the impacts of a variable and changing climate. We present the CSA tool, available at https://climateservicesforag.indraweb.io/, outlining how it is being developed in collaboration with key stakeholders in the Australian farming community, the climate data available and usage scenarios.

Keywords

Climate, Climate Change, Adaption, Resilience, Agriculture

INTRODUCTION

In recent years, Australia has seen an increase in frequency and intensity of natural disasters, from the drought of 2017-19, the 2019/20 bushfires to the various floods in NSW and Queensland in 2022. These events could become a new normal because of climate change. As well as the immediate impact on communities these emergency events pose, the changing climate exposes the agriculture sector to an increase of business volatility and food security if action isn't taken to adapt.

To help with this adjustment process, in 2018 the Australian Government established the Future Drought Fund (FDF) (DAFF, 2020) managed by the Department of Agriculture, Fisheries and Forestry (DAFF) (DAFF, 2022a) to assist the agriculture sector to adapt to drought and climate variability. Initial funding supports a four-year work plan from 2020 through to 2024 to build drought resilience in regional Australia.

Drought is a common occurrence throughout the Australian continent and one which has ongoing economic, social, and environmental impacts. The FDF aims to drive adoption of new drought resilient technologies and practices, delivered through various work programs. Key to the success of the FDF is making climate variability and resilience data more accessible to the agricultural sector to help Australian farmers and farm business better understand drought and other climate risks.

The Climate Services for Agriculture (CSA) project (DAFF, 2022b) is one of nine programs under the Future Drought Fund. The aim of CSA is to help Australian farmers understand the impact to their business of climate variability and related trends. This is achieved through a combination of historical weather data, seasonal forecasts and future climate projections made available through an online tool.

The impacts from climate change and future extreme weather events can be mitigated by providing the agricultural sector with the information they need to assess possible future scenarios and to plan adaption strategies. For this to occur, it is essential to have access to authoritative, accurate, reliable and region specific climate information tailored for farmers and the wider rural sector. This is the goal of the CSA tool.

The rest of the paper is organised as follows. First background information is presented about the Climate Services for Agriculture project, including the development process used, the data that's available and the current work plan. Then we provide an overview of the online CSA web tool. Example case studies of how the CSA tool can be used to explore the future climate are then presented. The paper concludes with an outline of future work and a summary of our findings, highlighting how the CSA tool will be a valuable resource for farmers to plan for a future that will be impacted by a changing climate.

BACKGROUND

As noted above, the Australian Government's Future Drought Fund is designed to provide secure, continuous funding for drought resilience initiatives to help Australian farms and communities prepare for the impacts of drought. The first round of FDF funding in 2020 included financial support for the Climate Services for Agriculture project, a collaboration between CSIRO and the Bureau of Meteorology (BOM) to deliver a public website that describes common climate driven agriculture relevant risks for anywhere in Australia.

The partnership between CSIRO and the BOM leverages their respective expertise in agriculture, climate science and their track record of delivering operational science-based systems supporting the Australian community. The BOM is leading the customer engagement and climate data work activities while CSIRO is building the operational online system, managing state engagement activities and the governance oversight.

The CSA project has progressed through several key organisational factors:

- Pilot Regions
  While the CSA tool is a national resource providing climate information for all regions in the country, to focus the development initial regions of interest have been defined. These pilot regions (DAFF, 2022) allow the project team to establish ongoing engagement with key stakeholders and to nurture relationships with target users to ensure the developed system meets their needs.
  The first for pilot regions, decided in March 2021, were the Queensland Dry Tropics, Condamine and the Northern Tablelands, Victorian Mallee and south-east South Australia, and the Western Australian Wheatbelt. Another four pilot regions were announced in November 2021: Tropical North, Central West New South Wales, Riverina and Goulburn-Murray, and Gippsland and Northern Tasmania.
- User centred design
  The CSA tool is being developed through a co-design methodology, to ensure that outputs are fit-for-purpose and are used by the target audience across the agricultural sector.
- Climate Data
  The CSA tool uses various existing climate datasets including historical weather data (temperature and rainfall), seasonal forecasts from the BOM and future climate projections, specifically rainfall and temperature projections for 2030, 2050 and 2070 from CSIRO and the Bureau of Meteorology for medium and high emissions scenarios.
- Commodities
  A commodity is the primary agricultural product or farm output such as wheat, barley, sheep or beef. Each commodity has specific climate and production conditions such as sowing and harvesting times, ideal growing conditions, adverse temperature or rainfall thresholds for example heat stress or frost risk and so on. The CSA tool provides appropriate climate information customised to individual commodities for specific regions.
- Operational System
  The CSA tool has been developed using an agile development methodology, deployed using a Continuous Integration/Continuous Deployment process on a cloud infrastructure.

THE CSA TOOL

The CSA tool is intended to assist Australian farmers and producers to better understand the risks and opportunities facing them over the next 30-70 years. This is done by providing climate data tailored to commodities at specific regions. The data includes historical data (1961-2021), seasonal forecasts (1-3 months) as well as future climate projections (2030, 2050, 2070) for a given location.

Example CSA Interaction

The online tool has been developed under a user led co-design methodology focusing on the user journey. To provide a motivating example of its use, we present the steps taken to interact with the CSA tool for someone interested in the sugar cane commodity in the Cairns region. Several screen shots from the tool will be shown and explained, but the reader is encouraged to follow this example on the web site to explore the many features available. These examples can be repeated using a common web browser (for example Edge, Firefox or Chrome) on a laptop or desktop device. The web site also works on tablets and mobile devices, however the web page presentation will differ from that shown below.

An example interaction with the tool would be as follows:

1. Navigate a web browser to the tool home page: https://climateservicesforag.indraweb.io/.
   The user is presented with a disclaimer that must be accepted before continuing.

2. Select a region.
   This is done by entering a place name, 'Cairns' in this case, or navigating the presented map to the region of interest. This automatically takes the user to the explore page.

3. Explore your future climate.
   This page is divided into two sections 'Climate data to explore' and 'Select specific data sets', described below:

   A. Climate data to explore.
      Choose the climate data to explore. The data options available are:

      i. Key climate indicators for a commodity
         Explore how climate change impacts a chosen commodity at the region of interest. The tool prompts the user to choose from a list of commodities appropriate to the previously chosen region, in this case they are: Dairy, Sugarcane, Northern Beef, Southern Beef. An overview of the commodities available in which regions is described below.

         The user is then presented with three panels showing relevant climate information for the chosen region and commodity, with options to explore different climate change scenarios, see Figure 1. This figure shows that two future climate change scenarios can be chosen (medium or high emissions) for three future 30 year time periods (2016-2045, 2036-2065 or 2056-2085) in reference to two historical reference time periods.

         Various climate information is presented, in this example rainfall and temperature since they are relevant to sugar cane, also shown in Figure 1.

         The third panel shows the various graphs and plots of climate projection data, with examples shown in Figures 2 and 3 below. These show the historical record and future projections of the average minimum temperature at ripening for sugarcane in Cairns for the period May – July.

      ii. General climate trends
         As well as showing climate data for specific commodities, there is an option to show general climate information for the chosen region. This includes annual and seasonal rainfall, various temperate profiles (average maximum and minimums, heat and frost risk) and seasonal evapotranspiration information. As the commodity name suggests, this is general climate information that is expected to be of interest and usual for farmers throughout Australia regardless of location.

      iii. Seasonal outlook
         This presents the expected rainfall for the season ahead by selecting a time period of seasonal or monthly.

   B. Select specific data sets.

The options above have been customised to present the relevant climate data for the selected commodity. Instead of using these tailored interfaces, the user can scroll down the 'Explore your future climate' page, to select a specific commodity and the data sets they are interested in seeing.

Climate Data

Figure 1 (left) shows an example of how the user can select different climate data sets. This example is for the sugar cane commodity in Cairns, but similar options are available for all regions and commodities shown by the tool. Note there are two historical time periods that can be chosen. The first, 1961-1990 and 1991-2020 compares the recent period of 1991 – 2020 to the past period of 1961 – 1990. Similarly, the other time period available, 1962-1991 and 1992-2021 compares the recent period of 1992 – 2021 to the past period of 1962 – 1991. These comparisons allow the user to see if there have been any recorded changes in climate in the selected region over time, providing context for any projected climate changes in your region.

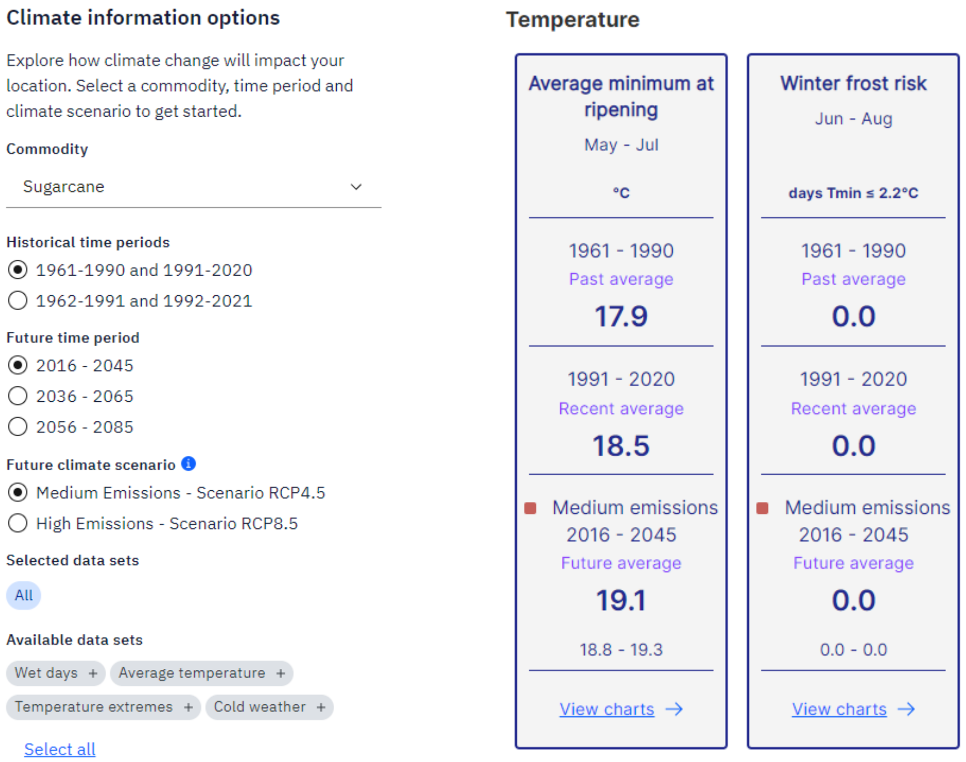

Figure 1: Climate options (left) and Temperature factors relevant to sugarcane (right).

Thirty years is an internationally recognised standard time frame used to describe the observed climate in a region. This is considered long enough to allow for a mix of expected weather conditions, for example some dry, some wet, some cold and some hot periods, allowing a reliable depiction of the climate to be presented.

In Figure 1 (left), there are three 'Future time periods' options available: 2016-2045, 2036-2065, and 2056-2085, corresponding to the different future climate projection periods.

Also, the available emissions scenarios, medium and high, represent two plausible future climate change possibilities. The scenarios used for the Coupled Model Intercomparison Project Phase 5 (CMIP5) are known as Representative Concentration Pathways (RCPs) and results for two RCPs are shown in CSA: RCP4.5 (medium emissions) and RCP8.5 (high emissions) (CSIRO and Bureau of Meteorology, 2015). The RCP numbers relate to the amount of excess energy in the climate because of additional greenhouse gases. RCP8.5 assumes emissions continue to increase through to 2100 (Hausfather, 2019). RCP4.5 assumes emissions peak around 2040, and then decline to below current emission levels by 2100.

Note that the actual future emissions will depend on global action on climate change. In order to evaluate the potential impact on your commodity, it is useful to consider both the best and worst possible future climates.

Figure 1 (right) shows the temperature factors relevant to sugarcane in Cairns and is indicative of how commodity specific climate information is presented by CSA. In this example, two important features of temperature for sugarcane are the minimum temperatures during the ripening months of May through to July and the frost risk for the period June to August. Note that sugarcane is not frost tolerant. Here we see that the trend of average ripening temperatures is increasing for a medium emission scenario while there continues to be no frost risk in this region.

The depiction of these climate factors in CSA are referred to as 'cards' and are clickable by the user, as indicated by the link titled 'View charts' at the bottom of the card in Figure 2 (right). Doing so updates the plots and graphs shown in the third panel on the right of the climate data explorer page. This was done, selecting the 'Average minimum at ripening' card shown in Figure 1 (right), and the results are shown in Figures 2 and 3 below.

Figure 2 shows the historical record of the average minimum temperature at ripening, comparing the historical 30 years periods of 1961-1990 and 1991-2020. Sugarcane needs a lot of water during cultivation and as noted above is not frost tolerant, preferring warmer temperatures. Figure 2 indicates that the average minimum temperatures have been increasing when comparing the period 1961-1990 to 1991-2020.

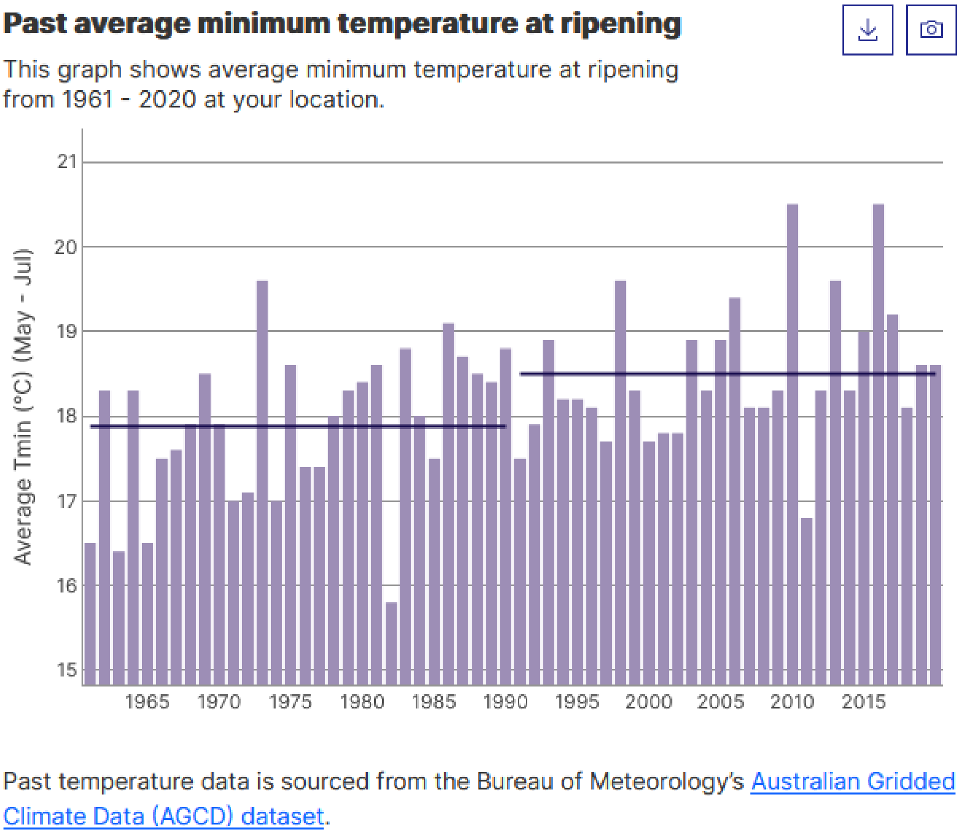

Figure 2: Past average minimum temperature at ripening for sugarcane in Cairns.

Figure 3 shows the future average minimum temperatures at ripening during the months of May through to July for the medium and high future climate scenarios for the three future projection periods. The two historical minimums are also shown for comparison purposes. Again, we see that the average minimum temperatures are rising over time, with increases being greater for the high emission scenario.

There is further climate information available when the 'Seasonal outlook' is selected. This information is not shown here due to space constraints however the information available is the short term rainfall expected, either for the next month or for the upcoming season.

Commodities

The current list of available commodities includes general, cotton, dairy, oranges, sorghum, sugarcane, wine grapes, northern beef, southern beef, northern sheep and southern sheep. These commodities are representative of the major agricultural sectors in Australia and combined represent 95% of Australia's farmed area; 15 of the top 20 agricultural commodities by gross value and approximately 86% of the gross value of Australia's agricultural production.

For each commodity, the main production regions were defined in consultation with respective commodity experts, using the pre-defined Australian Agricultural and Grazing Industries Survey (AAGIS) boundaries (ABARES, 2022). These regions define the various cropping and livestock predominantly found across Australia and consists of 32 regions corresponding to areas of climatic conditions suitable to support various farming production activities.

The commodity selection is a key aspect of the CSA tool: by choosing a commodity the climate information presented is customised to be relevant for that commodity. The sugarcane example in Cairns provides an example: the important factors for growing sugarcane are the number of wet days at harvest (calculated from the average rainfall from June to November), the average minimum temperatures at ripening (calculated from temperature data for the period May through to July) and the frost risk (also from the temperature data but for the period June through to August).

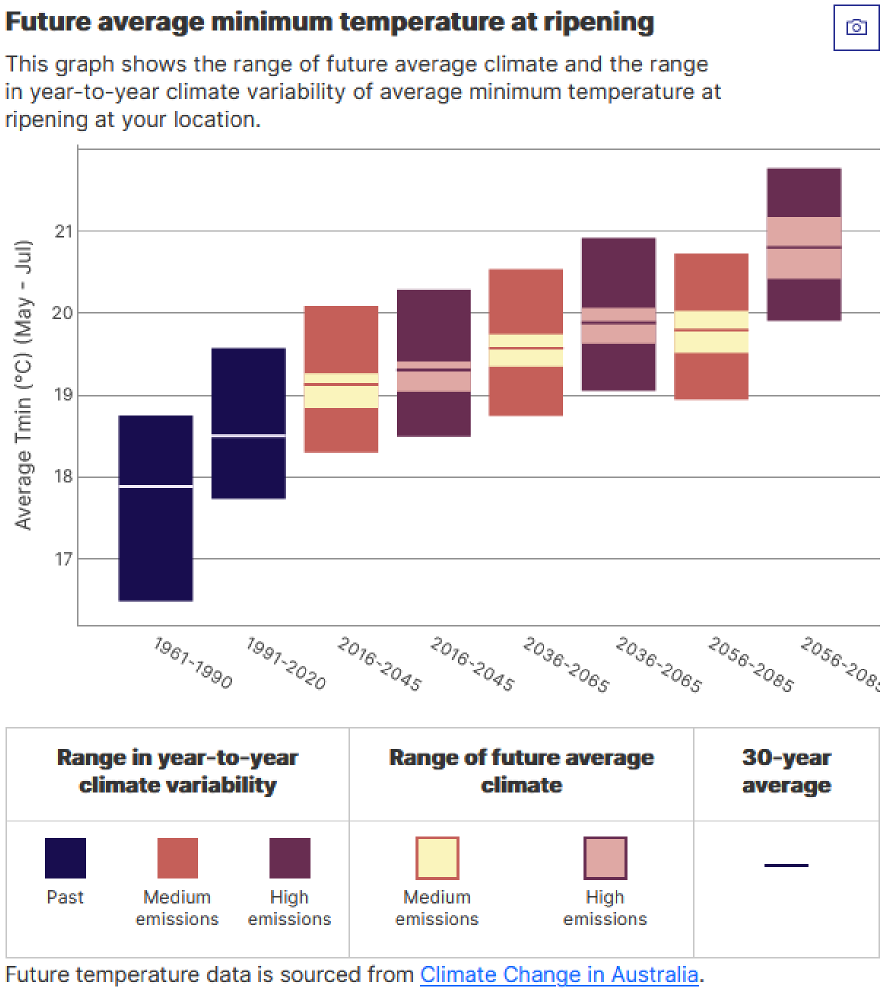

Figure 3: Future average minimum temperature at ripening for sugarcane in Cairns.

This association of the relevant agricultural climate metrics to the commodities were defined through scientific review and an expert consultation process, which included the farming community. Subject matter experts were also consulted to provide expert opinion to ensure these metrics were relevant to agricultural production of the commodities.

Note that there is the option of the general commodity. This allows the user to view common rainfall, temperature and evapotranspiration data sets for the chosen region that are not specific to any commodity, for example annual rainfall.

CASE STUDIES

The detailed example described above provides a simple introduction of how the CSA tool can be used to explore the impact of climate change for a specific commodity (sugarcane) at a specific location (Cairns). The project contributors and tool developers initially envisioned several use cases that we expected would be relevant to farmers and the wider agricultural sector. These use cases were along the lines of:

- As a farmer growing canola near Cowra, how will the growing conditions compare in 20 years to now?
- What crops would be best to cultivate for future climatic conditions in my area?
- As a bank, how does climate change impact our agricultural investment portfolio in the future?

These initial use cases were useful for early development but to ensure the long term fit for purpose of the tool, an extensive co-design methodology was undertaken by a cohort with diverse skill sets including user experience experts, agriculture sector researchers, social science specialists, customer engagement coordinators along with various representative end users, from farmers, financial providers, government agencies and others from the agricultural sector. This is an ongoing long-term engagement that has focused on an evolving co-design process that has resulted in a focus on user journeys.

As part of this process, we have captured several high-level case studies that explain the utility of the CSA tool in terms of the user goals and needs. Some of these are outlined in Table 1 below.

Table 1: Example Case Study Summaries.

Goal	Need
Provide accurate advice about long-term future climate projections for clients/farmers in a specific place/industry.	I want to be informed so that I can advise others, whether they're clients or in my community.
Assess, adapt and possibly transform agricultural enterprise by altering their farming practice, industry and/or location.	I'm looking to pivot the way my farm operates so that I can be more profitable or diversify my risk profile.
Gather a range of information that includes climate data to help take advantage of opportunities to diversify or generate additional windfall.	I have an opportunity to take advantage of favourable conditions, but I want to be sure I'm protecting myself from risk.
Gather further (or different) climate information to help them make smart business decisions about their enterprise investments.	I want information that is going to support me to change the way my business runs into the future.
Determine what impacts seasonal climate information will have on day-to-day operations so they can plan effectively.	I have lots of operational upkeep to do and I want to make sure I'm doing it at the optimal time.

FUTURE WORK

The first release of the CSA platform occurred in June 2021 and since then there have been two other releases at six monthly intervals in December 2021 and July 2022. These releases have seen changes to the user interface based on interactions with end users, the inclusion of more commodities and system performance improvements. The CSA project has secured funding to mid-2024 and over this time the release cycles are expected to occur every three months. These release cycles will continue the integration of more commodities and an ongoing engagement with the user community to ensure its fit for purpose. We also have plans to make the tool more appropriate for mobile devices such as tablets and phones.

Future extreme weather events are of particular interest to farmers and we have plans to include new indices such as the Forest Fire Danger Index (FFDI) (CSIRO, 2022) which can be used to predict the likelihood of bushfires in the area and the Standardised Precipitation Index (SPI) (McKee et al., 1993) that can be used to predict extremely wet or dry periods of 6 months or more. Other indices that we may include are: Standardised Precipitation-Evapotranspiration Index (SPEI) (Beguería et al., 2022) and Excess Heat Factor (EHF) (Nairn and Fawcett, 2015).

There are other specific areas of future research work that will be included in the platform. The climate change data is currently point based. When the user selects a location, the information presented corresponds to the data from the corresponding gridded climate datasets. A farm asset can span multiple gird cells and we are exploring new ways of aggregating and summarizing this information in meaningful and accurate ways. For large regions it is not practical to simply present all the data available, nor is it always appropriate to just give an average of all the available data. For example, when the region of interest crosses areas of different topographic and climatic conditions, presenting averages of future climate scenarios are unlikely to be representative of the variability across the region. While such outputs may be relevant for some use cases, it is important that this summary information is not used for the wrong purposes. This is aligned with the challenges of ensuring the tool is fit for purpose with end users and requires extensive user experience expertise to achieve appropriate outcomes.

Another area of research interest is to investigate climate analogues. This uses projected climate change information at a location of interest to find matching locations that have similar conditions now. For example, a farmer could be cultivating specific commodities today but be aware that due to the changing climate, their climatic conditions in the future will be similar to other regions in Australia. By identifying these other regions, the commodities being farmed there would provide a pathway for what they could choose to produce in the future. This could be a useful long term planning tool. Such tools already exist, see for example the Climate Change in Australia Climate Analogues tool (CSIRO and Bureau of Meteorology, 2020), however this task provides an opportunity to undertake further research about improved methods of determining regions of similarity based on past, current and future climatic conditions.

Lastly, we are working to make our system compatible and interoperable with other similar initiatives. Specifically, we are working closely with another FDF project, the Drought Resilience Self-Assessment Tool (DR-SAT) (DAFF, 2022c). DR-SAT currently uses some of the data available in the CSA back end and we will continue to ensure our system is compatible with theirs and provides the information they need as their tool evolves. We also have plans to integrate some of our features with the CliMate tool (CliMate, 2016). This engagement is in its infancy, but it provides an opportunity for CSA to be made available with the extensive CliMate user base who are already familiar with and understand climate datasets for the agriculture sector.

CONCLUSION

The Intergovernmental Panel on Climate Change (IPCC), the United Nations inter-governmental group responsible for advancing knowledge on climate change, recently released their sixth assessment report (IPCC, 2022a). As part of this process, the IPCC distribute regional fact sheets of key findings, with the fact sheet for Australasia noting a high confidence of:

> *Disruption and decline in agricultural production and increased stress in rural communities in south-western, southern and eastern mainland Australia due to hotter and drier conditions* (IPCC, 2022b)

This disruption from climate change can be considered an emergency event. This can be mitigated by providing appropriate climate change information to the agricultural sector customized to their needs.

The Climate Services for Agriculture tool is an example of such an online interactive digital platform bringing together a variety of climate information specifically for farmers and the agricultural sector. It will enable agricultural businesses, planners, and communities to explore various climate related datasets to better understand how the expected future climate may impact different regions and commodities. This will help people to anticipate and plan for the impacts of a variable and changing climate.

CSA is also an education tool. By engaging with farmers and the broader agricultural sector about the possible impact of climate change to their businesses in the years ahead, we are also advancing the general knowledge of key climate science concepts such as climate models, the available historical data and how it has been produced, the applicability of climate projections, the assumptions underlying different emissions scenarios, agricultural climate metrics and so on. This literacy involves communicating complex climate science concepts in a way that engages them and the wider community.

ACKNOWLEDGMENTS

The Climate Services for Agriculture Platform has been funded by the Australian Federal Government Department of Agriculture, Fisheries and Forestry (DAFF) through its Future Drought Fund Programs. Further details about the programs and various initiatives can be found at (DAFF, 2020).

The authors would like to thank the contributions of the CSA project team from CSIRO and BOM and our partners in DAFF.

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