Co-designing Climate Services for Agriculture – reflecting on successes, setbacks and early lessons learned

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Abstract. Climate Services for Agriculture (CSA) is a program of work that aims to improve the use of long-term (out to 2070) climate projections, to adapt Australian agriculture to climate change. The large, federally funded program aims to incorporate co-design with users to assure relevance and useability of the tool. Based on reflections on the program grounded in 84 interviews with farmers, advisors and researchers, this paper outlines some of the successes arising from different efforts to incorporate co-design into the program. These include design of different forms of engagement to maximise adoption and internal processes to encourage interdisciplinary innovation. We also outline some of the lessons learned through these efforts. We suggest co-design should include objective setting and problem framing with stakeholders before the work starts, and that co-development and co-delivery can still work even if co-design of objectives comes too late. The findings demonstrate the importance of ensuring the objectives underpinning co-design and co-development are outcome driven and relevant to user needs to improve adoption.

Keywords: climate projections, climate adaptation, Australian agriculture, climate advice

Introduction

The escalating effects of climate change on vulnerable ecosystems worldwide are well evidenced (Wulff 2021). New innovations, skills, and creativity are required to adapt to and reduce the impact of climate change (Zuccaro et al. 2020). More importantly, these innovations need to be adopted to achieve the desired outcome of climate risk management and they need to be *responsible*, i.e., sustainable, ethical, and not cause undesirable consequences (Stilgoe et al. 2013).

Although climate change will impact every sector, agricultural systems are both heavily impacted by, and simultaneously a significant contributor/mitigator of, climate change (FAO 2020). In Australia, the effects of drought, flood, and other extreme events (storms, cyclones, heatwaves, frosts) can be highly damaging for agriculture. Climate change poses significant risks to the nation's food production, exportation of agricultural produce and related economy (Malik et al. 2022). Therefore, agriculture is of particular importance in adapting to, and mitigating, climate change. Both new technologies and forms of knowledge system integration will be required to support and extend traditional practices.

Farmers frequently use weather and seasonal information for farm risk management, which enables them to choose suitable locations to plant crops, vary planting dates, and choose appropriate farming techniques to maximise production (Shannon & Motha 2015; Komarek et al. 2020). The use of short-term weather and seasonal forecasts are common, with many farmers accessing multiple weather forecasts daily (Lacoste & Kragt 2018). Several paid and free-of-charge digital platforms are currently available and widely used in Australia. For example, the Bureau of Meteorology produces climate outlooks that provide seasonal forecasts, which get updated every week (Commonwealth of Australia 2023).

To increase the resilience of the agricultural sector, farmers also need to integrate future climate risk into their long-term risk management plans (Tall et al. 2018; Naab et al. 2019). This integration can help farmers to make better long-term strategic decisions, such as those concerning future business investment and infrastructure development (Vaughan et al. 2017). However, fewer longer-term climate projections exist compared to shorter-term climate services (Vaughan et al. 2018). In addition, there appears to be limited use of existing long-term climate projections in on-farm decision making (Vaughan et al. 2018). Therefore, improving their relevance and application is challenging (Jagannathan et al. 2023). To improve the relevance of climate projections and thus increase their application in decision making, co-design is needed to improve the useability and adoption of long-term climate projections.

This paper focuses on current efforts to, and early lessons learned from, attempts at co-designing the Climate Services for Agriculture program of work and the My Climate View product.

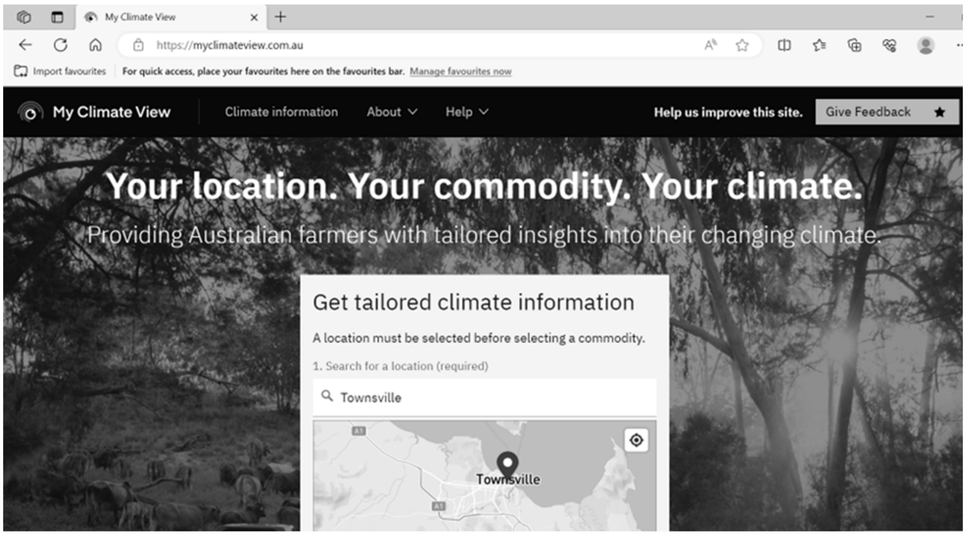
Case study: Climate Services for Agriculture program and the 'My Climate View' product

To combat climate change and safeguard agriculture and farmer livelihoods, the Australian government is investing in a broad suite of work to enhance resilience through the Future Drought Fund (FDF) (Department of Agriculture, Forestry and Fisheries 2023a). The FDF is aiming to support proactive, rather than reactive responses to drought resilience and includes $29 million for the Climate Services for Agriculture (CSA) program from 2020-2024, jointly delivered by CSIRO and the Bureau of Meteorology (the Bureau).

The key objective of the CSA program is to help Australian farmers adapt to climate variability and prepare for change in (especially longer-term) weather-related conditions. This in turn is expected to increase the viability of farm businesses by providing climate insights that are based on location-specific and agricultural commodity-relevant future climate projections (Department of Agriculture, Forestry and Fisheries 2023b). The CSA front-end (user interface) is primarily aimed at farmers and farm advisors but is expected to have relevance to a wide range of different users (advisors, financiers, insurers, educators etc).

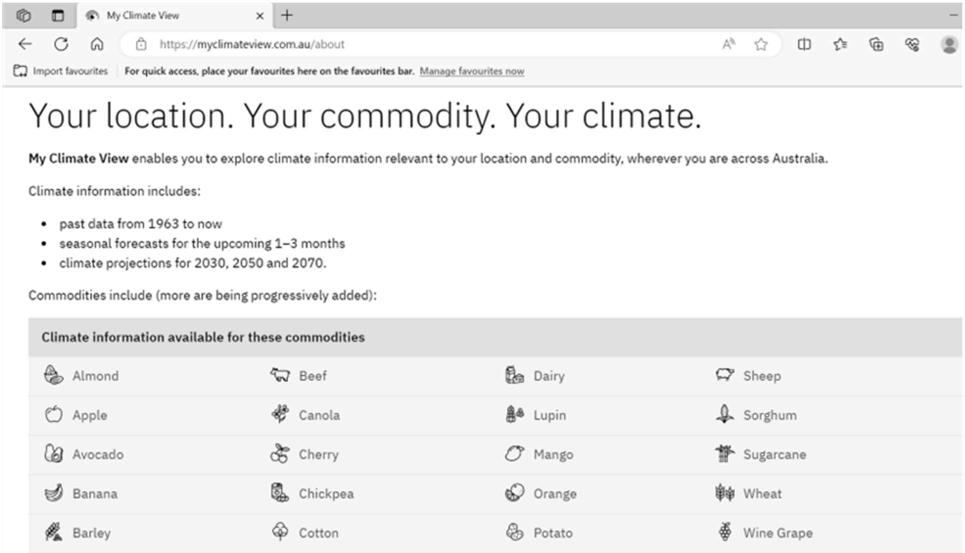
To better support the use of long-term climate data in agricultural decision making, the CSA program team are building an innovative digital prototype called My Climate View, which provides historical climate data, along with seasonal forecasts and future climate projection data (up to 2070), together in one web application. My Climate View is the first of its kind because it is a tool that not only consolidates historical climate data (1961-2021) but also provides longer-term climate projections (2030, 2050, and 2070) for a given location (see Figure 1).

Figure 1. A screenshot of the landing page of the 'My Climate View' tool



Importantly, the My Climate View tool provides bespoke commodity-based climate information. The tool has currently listed 20 commodities (see Figure 2), with more in development. My Climate View aims to inform farmers about key climate indicators, such as rainfall, temperature, soil moisture, and potential evapotranspiration. For example, a dairy farmer can get tailored climate information on heat waves and frost risks, while a grain grower can look at rainfall at harvest and adjust season start and end dates. As a program of work, CSA aims to be co-designed with end users, to make products such as My Climate View that are relevant and user friendly (Fleming et al. 2022).

Figure 2. A screenshot of the commodity list for the 'My Climate View' tool

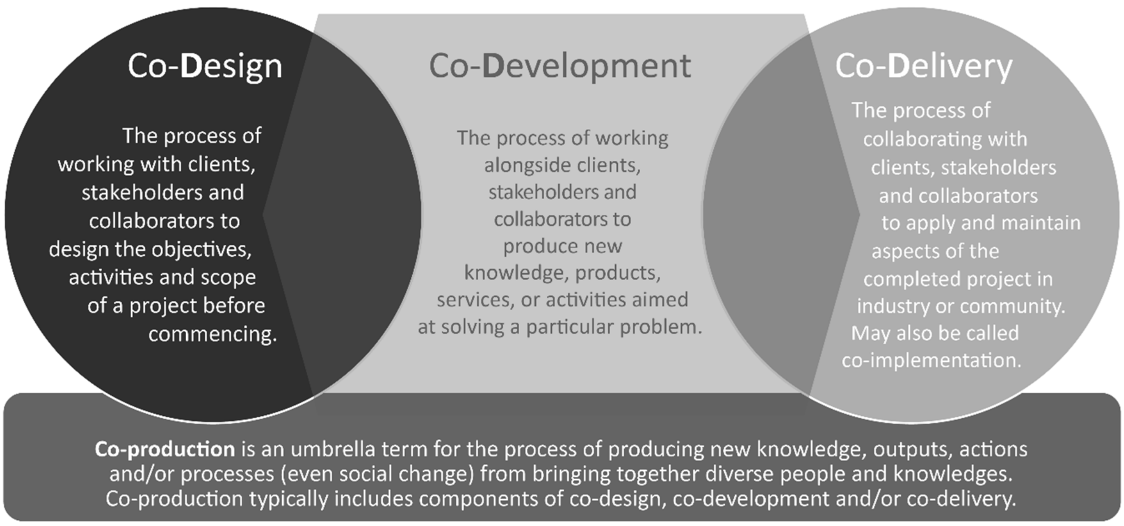


Theoretical framework: co-design, co-development, and co-delivery

Participatory approaches, including co-design of projects, co-development of new knowledge and co-delivery of outcomes (an umbrella term for these is co-production) are becoming more common in innovation and now generally regarded as best practice for achieving higher and more meaningful levels of adoption (Eastwood et al. 2012; Fielke et al. 2023). However, debate persists about the choice of 'co-' terms and their definitions and distinctions, the 'right way' to apply these processes (Norström 2020; Hakkarainen et al. 2021; Pérez Rubi & Hack 2021), and their aims and objectives, ranging from producing new knowledge or outputs to social change and transformation (Wyborn et al. 2019; Hakarrainen et al. 2021). No matter which 'co' approach is used, knowledge and action are inseparable and continually interact, which is especially important where local, historical, experiential, or cultural knowledges from traditional owners and/or land managers need to be recognised as important knowledge holders to include (Maclean et al. 2021).

Although the CSA program aims to be co-designed, co-development is likely a more apt description. According to social science and agricultural innovation definitions, co-design refers to the work with clients, stakeholders, and collaborators to design the objectives, activities and scope of work *before commencing* (see Figure 3). While co-design is concerned with setting joint research agendas, research questions and planning implementation (Hakkarainen et al. 2021), in the CSA program, the work with clients, stakeholders and collaborators has occurred after the objective setting stage and is more related to producing new knowledge and delivering findings and approaches into industry (co-development and co-delivery).

Figure 3. Definitions of co-design, co-development, co-delivery and co-production



Source: Adapted from Fleming et al. (2023)

The co-development process within the CSA program aims to crystallise My Climate View's value proposition (the reason it is useful), to build trust in the tool, and to partner with different groups to support interpretation, experimentation, and implementation. The process of co-development began with feedback from target users informing the development and iteration of the prototype (from early 2021 to the third release in July 2022). Ongoing workshops and engagement with other sector organisations also occurred throughout this period. The co-development and co-delivery processes are still on-going at the time of writing (August 2023), through collaboration with users, scientists (agricultural, data, climate, social and user experience), as well as farmers, advisors, extension and knowledge brokers, government, industry, and financial institution employees. This demonstrates how the scale of engagement for national platforms requires significant institutional coordination, multi-sectoral engagement, and policy support (Kim et al. 2022).

In this paper we apply the theories of co-design, co-development and co-delivery to reflect on some of the engagement and collaboration efforts involved in the CSA program and draw out early lessons. In such a large body of work, it is important to reflect on the *process* of the work, in addition to the outputs. We also apply these theories to the themes emerging from the body of social science work conducted over the duration of the program to date.

Reflection is an important technique to apply because it allows the more invisible processes involved in the work to be considered alongside the activities and outputs. Examples of invisible processes needed to underpin successful outcomes include the relationships, between individual team members, between organisations, between the program and end users and between the program and government (funder) (van Kerkhoff & Lebel 2015; Norström et al. 2020). Relationships are interconnected with other invisible processes that also impact outcomes, such as communication, interdisciplinary integration, responses to changing political contexts and skill development (capacity building).

These reflections have relevance for other programs looking to promote adoption of digital tools and technologies which require some form of behaviour change, and for approaches to funding collaborative and co-produced projects, especially (but not only) at larger scales.

Methods

This paper synthesises the high-level findings of 84 interviews with farmers and advisors (with more interviews and engagements planned) and reflects on the experience of the broader team. Interviews were conducted by social science members of My Climate View (among the authors of this paper) from 2021-2023. Interviews were conducted in different groups, analysed separately to answer different research questions, as shown in Table 1. Some interviews were analysed using qualitative methods, including coding for meanings and recurrent themes and some were analysed using quantitative methods to compare counts of key concepts (see Table 1).

This paper is a synthesis of the higher-level insights from this work not captured in the other outputs. Fleming et al. (2022) outlines more detail on the CSA adoption pathway, including co-production and the importance of user perceptions related to complexity, accuracy and trust. Malakar et al. (in review) describes risk as an important hook into CSA and the difference between user perceptions of short (weather) and long-term (climate) risk. Snow et al. (in review) outlines examples of farmers current use of weather apps and websites and identifies recommendations for improving climate projection platforms from this capability base. Cornish et al. (in prep) outlines the evolution of My Climate View as a digital tool aimed at supporting behaviour change and the role of knowledge brokers and governance structures to encourage and facilitate this change. Jakku et al. (in prep) outlines the role of advisor networks in supporting My Climate View development.

Results

Emerging lessons: moving beyond thinking about adoption as the final stage of product 'delivery' to integrating responsible innovation processes as part of tool development

Although work on CSA is on-going, there are several key lessons emerging. Not least is the need for funders of large-scale programs to reframe their thinking about adoption, from optimising quantitative metrics of individualised product delivery towards better understanding user pull and benefit distribution beyond the individual. The experience of the work so far highlights important reflections on barriers and opportunities for achieving adoption and introduces a new way of thinking about users' interactions with, and requirements for, climate projections, including My Climate View. These are summarised in Figure 4 and then related specifically to the example of CSA and My Climate View below.

Table 1. Summary of the different data sources synthesised in this paper

Interview summary	Description	Themes	Outputs	Total
Key focus of questions on the potential use and value of CSA.	In 2021, 25 farmers, 6 advisors.	Trust, uncertainty and complexity. Most interviewees were supportive of the CSA concept.	Fleming et al. 2022	31
	In 2021, this data set was re-analysed for use of weather forecasts.	Multiple weather forecasts accessed daily to inform decisions. Climate forecasts used less commonly and more uncertainly.	Snow et al. in review.	
Key focus on actual use and value of CSA	In 2023, 15 advisors	CSA is useful in achieving other objectives (e.g. resilience plans), and best supported by advisors.	Jakku et al. in prep	15
Program team reflections	In 2022, 4 team members. In 2023, 10 team members	Principles for co-production. Trust and knowledge dissemination through brokers.	Fleming et al. 2023 Cornish et al. in prep	14
Focus on risk, and pre and post perceptions of CSA demonstration	In 2023 22 farmers	Users tended to focus on short term risks. CSA showed promise in shifting users to consider longer-term risks.	Malakar et al. in review	24
Total				84

Note: the product was termed Climate Services for Agriculture during the interviews. The My Climate View branding was an outcome of co-development and is now used as the product identity.

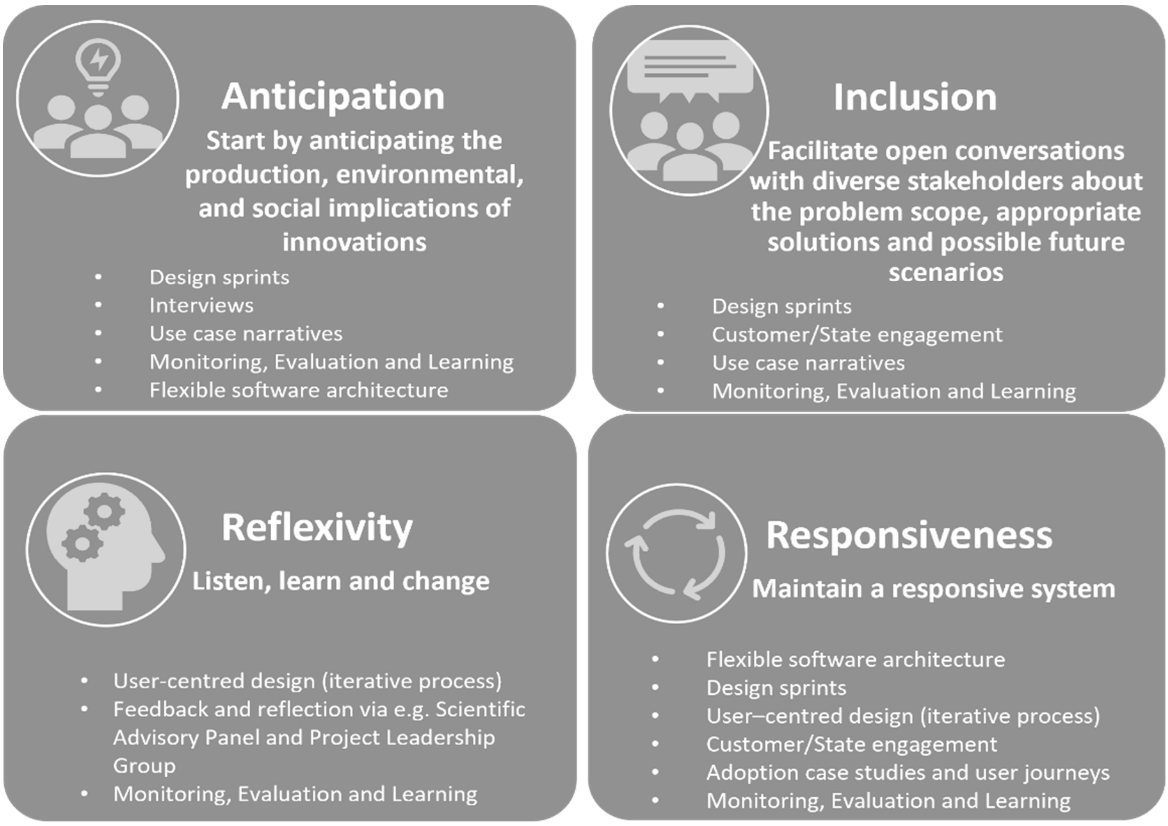
Figure 4. Summary of the opportunities and barriers in the literature relating to technology adoption in agriculture. The list on the left side represents opportunities for increasing adoption, the list on the right side represents barriers to adoption

Source: Adapted from Fleming et al. (2022).

Best practice in a 'no right way' of engagement context

Technology is used within a context and as part of multiple systems which overlap, interact, and differ in different contexts (social systems, environmental systems, technical systems). More holistic views of users of specific technologies, their values, objectives, and resources, as well as the structures and cultures around them that could support or inhibit change, are essential to understand the 'pathway to adoption' of new technologies. Theories of responsible innovation require consideration of the ethics and inclusivity of innovation and can be a helpful guide to considering this broader context more holistically from the target users' point of view (e.g., Robinson et al. 2021). Approaches that aim to work with, and for, end users, build trust and longer-term commitments to working together, and share and enable wider benefits, are a promising pathway to addressing wicked problems. Figure 5 expands on some techniques and approaches that the CSA program team members have used to achieve these goals through dimensions of anticipation, inclusion, reflexivity, and responsiveness – drawing on one framework of responsible innovation (Stilgoe et al. 2013).

Figure 5: A model for best practice technology co-production



Source: Adapted from Jakku et al. (2021)

Anticipation through commitment to co-production

To develop something of benefit and relevance to users, 'use cases' were developed to guide the content, look and feel of My Climate View. The use cases are examples of different reasons why a user would come to My Climate View. One farmer may wish to check the suitability of a particular crop or regular management strategy (such as irrigation or spraying) at a particular location, considering the historical climate, seasonal forecast and/or future projections. Another user may be looking to plan future farm operations as part of succession planning, and another may be looking to advise on suitable investments such as property purchases or infrastructure developments. The way farmers and advisors use My Climate View might be different in each case. Each of the use cases were designed through engagement with farmers and advisors, in asking about their needs, decision points, frustrations and preferences. This information was then used by user-experience designers to develop design features and steps to guide users through the tool. This of course takes significant time and relies on processes to determine use cases that are evidence-based and broadly relevant. It also requires significant expertise to guide a large team through the process of planning for different types of end users and then further testing and iteration of the resulting output. In the CSA and My Climate View experience, it has been a challenge to align the internal team to focus on a manageable number of evidence-based use cases and identify a sufficiently powerful value proposition. My Climate View cannot be all things to all people, but drawing the boundary around what is, and what is not included, is difficult. A practical implication from this experience is that leadership is required to clearly identify, manage and be accountable for, how these boundaries are drawn.

Inclusion as a means to an evolving understanding of how ag-tech is used

The successful development of programs such as CSA depend on ensuring that the design and implementation of technologies are responsive to stakeholder needs and dynamics, including the way in which these novel technologies are understood, adopted, and adapted in practice by farmers and other potential users (Jakku et al. 2019; Fielke et al. 2020). Trusted information and advice networks are likely to be central to helping farmers to mediate risks and benefits of new technologies, which is why the inclusion of farmers and their trusted information and advisory networks in the co-design, co-production and co-delivery of these tools is so important (Taylor & Van Grieken 2015; Jakku et al. 2019; Fielke et al. 2021; Fielke et al. 2022).

Building trusted relationships requires being flexible to respond to end user availability and interest in being involved (Rose et al. 2018). Some stakeholders may not be in the right place (personally or professionally) to contribute to co-innovation processes and may not see the value of doing so when they have other pressing demands. Flexibility does not mix well with rushed timeframes or with trying to coordinate large groups of people. But working with existing relationships and finding the areas of overlap with end-user objectives so that people can get excited about the potential of the tool can lead to momentum, positivity, and new opportunities. The importance of trusted information and trusted advice networks is increasingly being recognised (Jakku et al. 2019; Fielke et al. 2022) and is leading to the development of new brokerage roles and recognition that there is value in the facilitation, fostering and leveraging of trust within industry social networks (van Kerkhoff & Lebel 2015; Cvitanovic et al. 2016). There continues to be a need for knowledge and innovation brokers to demonstrate the usefulness (and useability) of relevant climate and weather tools, and their role creates a fluid knowledge exchange between farmers and researchers.

Establishing trust in a long-term climate projections tool such as My Climate View is complex. Farmers may be hesitant about trusting data projections of the future climate, whereas many farmers already place their trust in agronomists, advisors, and intermediaries such as grower groups in advising on longer-term investments and decisions. Therefore, building trust in the CSA program and the My Climate View tool requires both building trust in the data supporting the tool, as well as building capacity for use of the tool by trusted advisors and agronomists.

Key principles for reflexivity concerning adoption of digital tools

One of the key insights that has been demonstrated over the CSA and My Climate View case study so far is that adoption is not an end point to aim for, but an on-going process of change that will continue to evolve and develop. While this might seem self-evident in the context of adoption theory, it is hard to secure funders willing to evolve program objectives and outcomes. There is a need for new methods that enable early evaluation (within the funding window) of programs that aim to achieve systemic change. In the CSA case, narrative accounts are being trialled to capture diverse examples of how the My Climate View tool is being used in a range of contexts and leading to longer-term outcomes and potential adoption. If adoption is recognised as a journey rather than a destination, how value is achieved shifts to outcomes throughout the whole process, rather than only at the end. Change is complex and cannot be separated from the social context in which it sits, including social networks, training, peer learning, incentives, policy, and funding programs as well as other changes in economic, environmental, and social conditions. These other factors are often over-looked as being important determinants for adoption. Individual change is best facilitated in concert with structural and social changes to support and reinforce the change in the context of what else is happening in the world.

Reflections on this process of involvement in the CSA case to date reveal an uncomfortable tension between how programs are funded and how they play out in practice. Although information is an important part of creating change, information alone is not sufficient to drive change because it is often the structures, social issues and barriers that limits change. Realising this at the individual level can feel overwhelming and reduce agency (e.g., van Mierlo et al. 2010). However, when considered collectively, this understanding can also galvanise new social connections and a more communal and shared point of view than usually promoted in behaviour change literature, which can be highly motivating and rewarding. This demonstrates that there is a need for a shift in thinking from the individual to the social/system level, not just for technology developers and those aiming to achieve adoption (funders), but also for individual users as part of a collective – it is a shared (and cultural) shift and rarely achieved by single or short-term projects.

Another insight out of the CSA and My Climate View case study is that partnership, whereby multiple parties commit to change with a humble and learning mindset, is vital to perceptions of trust. Adoption of new technology is not a transfer of knowledge, but about learning, understanding, and adapting behaviour (Dufva & Dufva 2019). This is a shift away from a delivery mindset, towards a partnership approach. Again, while this is clear within adoption theories, in practice it is commonly ignored in projects looking to deliver time bound and concrete outcomes. Climate projection tools exemplify this (Findlater et al. 2021), because the urgency of climate action coupled with the slow speed of technology diffusion can lead funders to favour familiar tech-push behaviour change agendas, over those that appear less certain, due to being user led.

Instead, partnership requires recognising and embracing the diversity of individuals who can participate and use technology in different ways. Approaching adoption with a generic approach for all users or even a rigid predetermined set of categories of users is a significant barrier to success. Allowing space for technology to be actively experimented with and to support tinkering and appropriation by users increases the chance that it will be adopted, adapted, and evolve (Higgins et al. 2023). Finally, the way intellectual property is currently managed in many projects is a potential barrier for true partnership and is an area that needs to be further examined and developed, to better reflect multiple inputs into technology developments, especially when private and public outcomes overlap or are in conflict (Fleming et al. 2023). The CSA program is committed to making My Climate View a free service, but this remains a challenging area to navigate as funding is limited, economic return on investment is difficult to quantify in the short term, and new sources of revenue may be required to continue operations.

Responsiveness to users and flexibility leading to broader benefits

Adoption can occur in ways that are not planned for or expected if tools can be used flexibly. Unexpectedly, My Climate View has been picked up for use in education in Australian high schools. Students used My Climate View to understand how much rainfall their area had received over 10 years, taking averages of those data points, and comparing it to the rainfall needs of different crops (Microsoft Australia News Centre 2022). This example of implementation was not driven by the CSA program team but came about through a separate outreach and engagement group who found My Climate View and used it to develop engaging student programs for hands on learning related to climate change and digital agriculture. This use demonstrates how the tool could be used to build the capacity of the next generation of farmers, through education and training programs, to develop skills to plan for longer-term time horizons of decisions and different time scales of climate adaptation.

Another example of emergent implementation is the increasing move towards users being able to customise commodities and indices based on their own needs and preferences. This is possible because the back end of the CSA program platform (data) is fully abstracted from the front end (interface), so there is significant freedom and flexibility in the design, which can be quickly adapted and changed. In a more monolithic design this flexibility is difficult to achieve. A lack of flexibility in the software architecture also leads to the risk that significant work will be wasted. Developing a software architecture where the data, data pipeline, the Application Programming Interface (API) structure and front end are all independent of each other increases agility, affords rapid updates, and hence supports an iterative and user-led design process while maximising value. This allows only components of the software needing to be changed to be updated based on continual learning from users. The opportunity for flexibility needs to be planned for and built in, to allow systems to be modular and editable.

Both examples above involve openness and responsiveness but show how adoption of a technology can 'piggy-back' on other objectives (learning, customisation). Adoption of the tool is not the end point, but part of a larger process of achieving behaviour change. In this way, understanding the range of different types of uses and outcomes the tool supports are a better mark of adoption than number of subscribers, hits on a website, or other quantitative metrics. Finding examples of where there is alignment of objectives and opportunities for use beyond the initial goal are difficult to guarantee, or schedule in a road map. However, creating an environment where spontaneous and agile responses can be made as opportunities arise can be key to achieving lasting adoption and distributing the benefits of a new technology more widely than may have been originally expected. Unexpected and diverse examples of use should be considered as indicators of successful collaboration and adoption.

Finally, who is engaged will necessarily impact co-development. Diversity of engagement is important to increase the likelihood that the product will still have value for individuals and groups that do not participate. It is not possible to include everyone, but it is important to keep note of who is participating and keep trying to increase diversity.

Conclusion

Agriculture is facing major challenges related to climate change. Climate projections are one source of information to help farmers adapt. To help farmers use climate projections, better methods to co-design, co-develop and co-deliver these services need to be developed. Our work synthesised high level findings from the Climate Services for Agriculture program and the My Climate View product and reflected on our experiences to help inform early lessons for how to apply climate information on Australian farms. Reflection on processes, as well as program findings, are important ways to improve co-production. We found that relationships within the team, with users, and with partners act as a foundation for trust, honest communication, and allow for understanding of each other to develop into opportunities for mutual benefits. Relationships also help to shift thinking away from 'delivery' of a product or service as an 'endpoint', to a continued partnership of shared learning and working together, where a tool is one part of the journey that is expected to evolve and change. These reflections point to the need to be flexible to co-produce with users, allowing users to drive (or at least negotiate) the direction of use, building flexible software architecture, committing to trust and longer-term relationships, and reflexively positioning ourselves and our evolving roles as researchers and developers as part of the (system) change. This paper has outlined experiences across a large, national program developing the Climate Services for Agriculture program and My Climate View product to enable better use of longer-term climate projections in agricultural decision-making. As with any new technology, it is the relationship between the tool and the social context and relational connections that surround and support it that will ultimately determine its success or failure. Our experience highlights the importance of viewing adoption as part of on-going process, and that best practice co-production requires reflexivity, flexibility and a commitment to inclusion and diversity.

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