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Advisors as key partners for achieving adoption at scale: embedding "My Climate View" into agricultural advisory networks

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Introduction: This paper examines the role of agricultural advisors as key partners for scaling adoption of long-term climate information. Agri-food sectors across the world face significant challenges in responding to climate change, which intersect with broader pressures driving transitions to more climate resilient and sustainable agri-food systems. Making better climate information available to farmers is a key part of responding to these challenges, since relevant and usable climate information can help farmers to adapt to future climate conditions. The development of climate services, which seek to provide climate information to assist with decision making, has therefore increased significantly over the last decade. The Climate Services for Agriculture (CSA) program provides long-term climate projections to help the Australian agriculture sector prepare for and adapt to future climate conditions. 'My Climate View' is an online tool produced by CSA, which provides localised and contextualised, commodity-specific climate information, through historic weather data and multi-decadal projections of future climate, aimed at Australian famers and farm advisors. Agricultural advisors have a critical yet often underutilised role as climate information intermediaries, through assisting farmers translate climate information into action.

Methods: This paper uses CSA as a case study to examine farmer-advisor interactions as a key adoption pathway for My Climate View. We interviewed 52 farmers and 24 advisors across Australia to examine the role of advisors as key partners in helping farmers to understand climate information and explore on-farm climate adaptation options.

Results and discussion: Interactions between farmers and their trusted advisors are an essential part of the enabling environment required to ensure that this long-term climate information can be used at the farm scale to inform longer-term decisions about climate adaptation. We use the concept of an interaction space to investigate farmer-advisor interactions in the adoption and sustained use of My Climate View. We find that although My Climate View is not a transformational technology on its own, its ability to enable farmers and advisors to explore and discuss future climate conditions and consider climate adaptation options has the potential to support transformational changes on-farm that are needed to meet the sustainability transition pressures that climate change presents.

KEYWORDS

climate services, climate projections, climate adaptation, Australian agriculture, agricultural innovation, behaviour change

1 Introduction

The global agri-food sector faces well-documented challenges in responding to climate change, which intersect with broader pressures, driving transitions to more climate resilient and sustainable agri-food systems (Howden et al., 2007; Zuccaro et al., 2020). Providing farmers with better climate information is a key component of responding to these challenges, where relevant and usable climate information can help support farmers to understand and respond to future climate conditions (Stone and Meinke, 2006). As a result, the development of climate services, which seek to provide climate information to assist with decision making, has increased significantly over the last decade (Jacobs and Street, 2020; Webber, 2019). In Australia, the Climate Services for Agriculture (CSA) program aims to provide multi-decadal climate projections (out to 2080s) to help the Australian agriculture sector prepare for and adapt to future climate conditions, funded by the Department of Agriculture, Fisheries and Forestry (DAFF) as part of the Future Drought Fund (FDF). CSA is a research and development program, involving scientific research, engagement, software development, product strategy and many other aspects of science and technology delivery, through collaboration between Australia's national science agency the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and the Australian Bureau of Meteorology. "My Climate View"[1] is an online tool produced by CSA, which provides localized and contextualized, commodity-specific climate information, through historic weather data and multi-decadal projections of future climate, aimed at Australian famers and farm advisors (Webb et al., 2023). My Climate View has a potentially valuable role to play in helping farmers explore long-term climate projections for their specific context and consider ways they could apply that information in their on-farm planning (Malakar et al., 2024a,b; Snow et al., 2024b). Interactions between farmers and their trusted advisors are an essential part of the enabling environment required to ensure that this long-term climate information can be used at the farm scale to inform longer-term decisions about climate adaptation (George et al., 2018).

This paper uses CSA as a case study to examine farmer-advisor interactions as a key adoption pathway for My Climate View. We draw on the concept of an interaction space (Hermans et al., 2023) to investigate farmer-advisor interactions in the adoption and sustained use of My Climate View. We examine the role of advisors as key partners in helping farmers to understand complex climate information and consider strategies for on-farm adaptations to future climate conditions, including the potential for advisors to act as climate intermediaries. In so doing, we explore how CSA is working in partnership with local advisory networks to ensure that My Climate View is accessible and useful for supporting climate adaptation decisions. We find that although My Climate View in and of itself is not a transformational technology, its ability to enable farmers and advisors to explore and discuss future climate conditions and consider implementing climate change adaptation actions has the potential to support transformational changes on-farm that are needed to respond to the transition pressures brought about by climate change. In the next section, we provide an overview of the theoretical background to our research, focusing on the literature on agricultural innovation systems and introducing the conceptual framework of an agricultural innovation interaction space. We then provide details on our materials and methods before presenting key themes from our research results, and then discuss the implications of our findings.

1 https://myclimateview.com.au/

2 Theoretical background: agricultural innovation systems and advisors as climate intermediaries

Our focus on the role of advisors as key innovation partners for scaling adoption is theoretically informed by the literature on Agricultural Innovation Systems (AIS) and Agricultural Knowledge and Innovation Systems (AKIS), a branch of innovation studies that provides a foundation for understanding the complex social processes and multiple networks that shape innovations in agriculture (Hall et al., 2003; Kernecker et al., 2021; Klerkx and Leeuwis, 2009a; Morriss et al., 2006; Turner et al., 2016). An underpinning feature of the AIS perspective is a recognition of the limitations of linear, transfer of technology approaches, which assume that knowledge about an innovation is transferred from "experts" (e.g., researchers) to intermediaries (e.g., advisors), and then on to farmers for "adoption" (Klerkx et al., 2012; Kuehne et al., 2017; Vanclay and Lawrence, 1994). However, this simplistic technology transfer and adoption approach fails to account for the complex interactions between networks of people, organizations and contextual factors, all of which are an integral part of the dynamic process of agricultural innovation (Hermans et al., 2023; Klerkx et al., 2012; Montes de Oca Munguia et al., 2021). The related concept of scaling, which refers to the increased use of innovations beyond those involved in the initial design and testing, is also subject to similar critiques regarding simplistic, linear models of technology adoption (Hermans et al., 2021; Sartas et al., 2020; Woltering et al., 2019). The social context of technology development and use is critical to adoption in agriculture (Glover et al., 2019; Hermans et al., 2023; Montes de Oca Munguia et al., 2021), as is the case in technology adoption more generally (Talukder and Quazi, 2011). An AIS or AKIS approach recognizes that technologies are shaped by dynamic processes across time and space, in response to local contexts and through ongoing social learning and development, and the process of scaling innovations is complex and dynamic (Glover et al., 2019; Hermans et al., 2023; Sartas et al., 2020; Wigboldus et al., 2016).

The AIS approach focuses on the range of actors and coordinated interactions involved in research, development, support and implementation of technological innovations in agriculture (Klerkx et al., 2012). This shift away from linear transfer of technology approaches includes an emphasis on participatory and collaborative approaches to innovation, which highlights the value of co-creating research questions and collaboratively conducting research and technology development (Lee et al., 2012; Srinivasan et al., 2019). This also involves coordinating social, economic, and regulatory systems to provide an enabling environment that results in innovations that are better suited to their context of use, enhancing their uptake and impact (Fielke and Srinivasan, 2018; Klerkx and Nettle, 2013; Klerkx et al., 2017b). Processes of participatory design and collaboration are identified as important factors for the successful implementation of agricultural innovations (Ayre et al., 2019; Fielke et al., 2017; Rijswijk et al., 2019; Stitzlein et al., 2020). As a result, there has been a rise in projects focusing on co-design, co-development and other forms of collaboration in climate and agricultural services, collectively referred to as "co-production" (Dolinska et al., 2023; Fleming et al., 2023; Lu et al., 2022).

Agricultural advisory services are an important part of the agricultural innovation system (Klerkx et al., 2017a). Within AIS scholarship, agricultural advisory services are defined in a very broad sense, to include "the entire set of organizations that support and facilitate people engaged in agricultural production to solve problems and to obtain information, skills, and technologies to improve their livelihoods and wellbeing" (Birner et al., 2009, p. 342). Therefore, we use the term advisors to encompass the wide range of professions in public, private and civil sector organizations with a role in sharing information and advice to support farmers and enhance their skills (Klerkx and Proctor, 2013; Knierim et al., 2017; Sutherland and Labarthe, 2022). Advisors can assist farmers with operational decisions (such as technical advice on crop selection, fertilizer inputs, or soil management), or strategic decisions (such as farm business planning or land management decisions), as well as providing support to meet regulatory requirements (Klerkx and Proctor, 2013; Nettle et al., 2018). Depending on geographical and commodity contexts, these advisors play different roles and may describe themselves as agronomists, extension officers, knowledge brokers, trainers, or consultants (Fielke et al., 2020; Sutherland and Labarthe, 2022). Advisors can also be part of more informal networks, such as industry representatives, committees, community leaders, mentors, social connections, friends and family, with roles such as network building and social support (Bechtet, 2023; Fielke et al., 2020). Furthermore, trends such as privatization, pluralism and digitalization are shaping agricultural advisory services, leading to institutional changes and an increasingly complex and dynamic context for advisors (Fielke et al., 2020; Knierim et al., 2017; Nettle et al., 2018; Rijswijk et al., 2019).

Advisors are key intermediaries within the AIS, due to their role in connecting multiple other actors (Kivimaa et al., 2019). Advisors can intermediate in different ways, including network-building and brokering for knowledge exchange (Bäumle et al., 2023; Hernberg and Hyysalo, 2024; Moss, 2009), as well as configuring knowledge to make it locally relevant (Duncan et al., 2020; Hakkarainen and Hyysalo, 2016; Hernberg and Hyysalo, 2024). Agricultural advisors are therefore excellently positioned "to act as climate information intermediaries and influence the use of climate science" because they already assist farmers to identify opportunities and support farmers with day-to-day decisions and future challenges (Haigh et al., 2015, p. 84). Prokopy et al. (2013) identify how advisors incorporate weather and climate information in their advice to farmers. Decisions are grouped into three temporal categories of: operational (lead time of days to weeks- e.g., when to spray); tactical (lead time of months- e.g., choice of varieties for next season); and strategic (lead time of a year or more- e.g., investment in irrigation, drainage or adoption of conservation practices). However, similar to farmers, advisors' use of climate information is often still predominantly concentrated around operational and tactical decisions, and long-term climate information is used less in advisors' day-to-day work than weather or seasonal climate information (Prokopy et al., 2013).

Nevertheless, given their important role as climate information intermediaries, advisors are key partners in co-production efforts along with farmers because advisors are often a key end-user of climate services. Co-production demonstrably increases user "fit" and improves relevance, usability and inclusivity (Fleming et al., 2023; Lu et al., 2022). Efforts to co-produce climate services with advisors include: MED-GOLD (Europe) (Dainelli et al., 2022), Climate Services for Agriculture (Australia) (Snow et al., 2024a), and Useful to Usable (USA) (Prokopy et al., 2017). However, "co-production alone does not guarantee dissemination" (Lu et al., 2022, p. 254). "Scaling" climate services additionally involves substantial effort into engagement and marketing of tools to build awareness and skills for use (Lu et al., 2022). Therefore, in addition to their role in co-production, advisors can play a central role in scaling climate services and supporting adaptive decisions. Compared with farmers, agricultural advisors were found more likely to be aware of available climate-decision-support tools, and more willing to use and recommend the tools to others (Lu et al., 2022). The centrality of advisors' role here is underscored by findings that 10% of farmers who identified they would not use the decision support tools, cited that they relied on advisors for those decisions (Lu et al., 2022). Therefore, advisors can assist with scaling in different ways. For instance, advisors often have large networks so they can scale climate services through personal recommendations. Moreover, advisors can disseminate information from climate services by incorporating it into their advice to farmers, even if they do not use or mention the climate service directly to the farmer.

2.1 Conceptual framework: agricultural innovation interaction space

Drawing on the AIS approach, Hermans et al. (2023) developed the concept of an interaction space, which they define as "a specific grounded space in such [AIS] systems, where social interactions and exchanges of information between different actors and institutions play out in practice" (Hermans et al., 2023, p. 2). As Figure 1 illustrates, this interaction space occurs at the interface between the research and development networks and farm system networks and features co-production and knowledge intermediation activities.

In this framework on agricultural innovation interaction space, the research and development networks (R&D) are driven by public and private sector agricultural research and development programs and projects and associated extension activities focused on developing and scaling innovations, while the farm system networks are the formal and informal networks of farmers and farmer groups where knowledge and information about innovations is shared, experimented with and shaped by the specific social, cultural and environmental contexts of local areas (Hermans et al., 2023). In the context of agricultural innovations, these interaction spaces therefore provide opportunities for researchers, funders, advisors and farmers involved in agricultural projects to exchange and construct socio-political and technical knowledge in a way that shapes the innovation process and outcomes. Trust is an important feature of innovation interaction spaces, with relational ties built on trust being central to innovation, knowledge sharing, and farmer and advisor relationships (Carolan, 2006; Eastwood et al., 2022; Hermans et al., 2023; Sligo and Massey, 2007). While there are multiple definitions and dimensions of trust (Blomqvist, 1997), personal or relational trust (Curry, 2010; Giddens, 1990) and institutional trust (Giddens, 1990; Putnam et al., 1993) are particularly important within agricultural innovation interaction spaces (Sutherland et al., 2013). Furthermore, trust in technology is

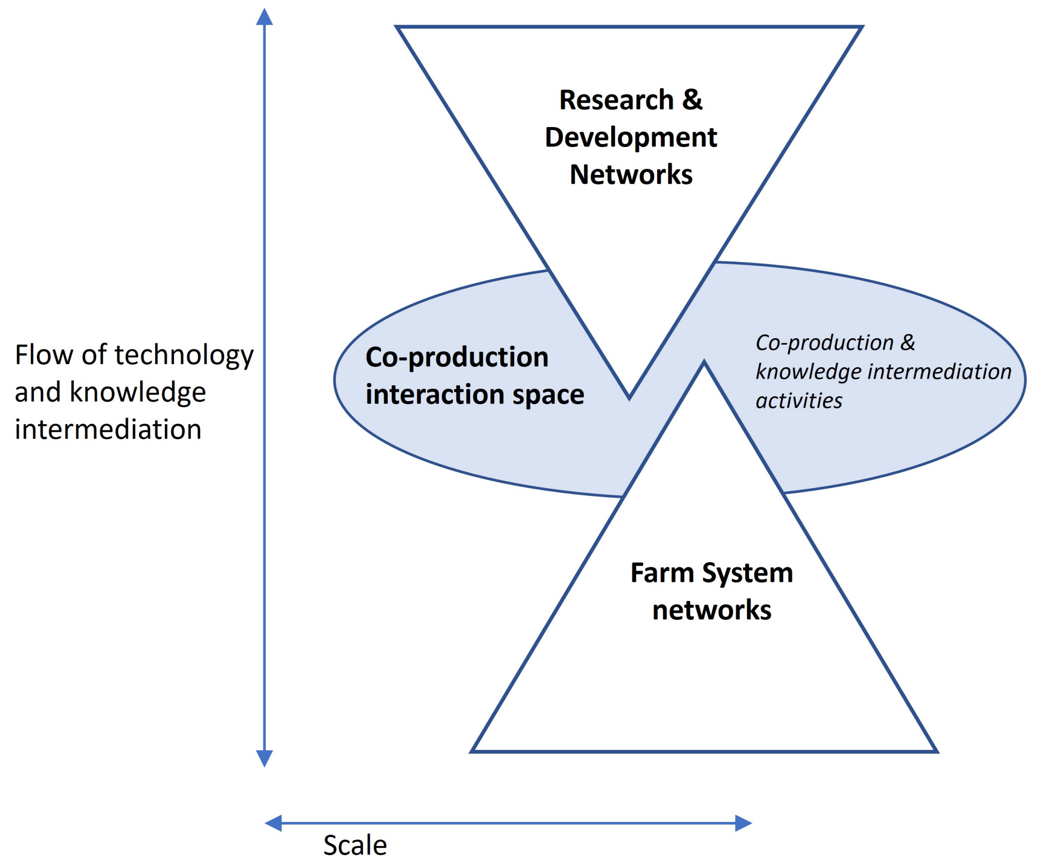

FIGURE 1
Agricultural innovation interaction space, adapted from Hermans et al. (2023, p. 3).

another important factor within the interaction space, which includes expectations about the relevance or usefulness of particular technologies featured within the interaction space (McKnight et al., 2011; Yeo and Keske, 2024). This is likely to be particularly relevant where there are multiple, sometimes conflicting, technological innovations within an interaction space, as can be the case with climate services.

Farmer engagement in the interaction space is vital, but so is the role of advisors as knowledge brokers and intermediaries in the social and technical innovation dynamics that shape the interaction space (Hermans et al., 2023). Using the conceptual lens of an interaction space to explore these innovation dynamics in our CSA case study allows us to examine "where and how socio-technical change is shaped by the relationships between agricultural development interventions, actors, local knowledge exchange and (social) learning processes" (Hermans et al., 2023, p. 2). The pivotal role of advisors in brokering knowledge between groups and catalyzing innovation is already well established, and the focus of a substantial body of literature (Caloffi et al., 2023; Feser, 2023; Howells, 2006; Klerkx et al., 2012). Knowledge brokers are a specific form of intermediaries, defined as individuals or organizations that mediate the flow of knowledge and information between a pair of unconnected actors (Boari and Riboldazzi, 2014; Burt, 2007). Their role can facilitate the introduction, understanding and adoption of digital technologies. Knowledge brokers are known and trusted "knowledge sources that support the exchange and integration of knowledge" (Crupi et al., 2020, p. 1264). The literature on knowledge brokers and intermediaries emphasizes the dynamic nature of intermediation (Kivimaa et al., 2019), the need to embed knowledge brokers in different levels of innovation structures (Kanda et al., 2019; Klerkx and Leeuwis, 2009b) and how relationships between advisors and farmers often extend well beyond the provision of technical advice (Cook et al., 2021). Much less explored, however, is the role of advisors as climate information intermediaries with respect to future climate information (Haigh et al., 2015).

We use the conceptual lens of an interaction space to explore the innovation dynamics in our CSA case study, to examine the role of agricultural advisors as key partners for scaling climate information. Our research objective is to understand how advisors can be important partners throughout the development of climate services and the dissemination of climate information at scale. Therefore, understanding how advisors perceive and use multi-decadal climate services helps us identify how agricultural advisors can help to scale adoption of this information.

3 Materials and methods

3.1 Case study context: Climate Services for Agriculture and "My Climate View"

The effects of climate change, including drought and other extreme events such as flood, fire, extreme heat, or greater rainfall variability, are expected to put Australia's agricultural industries and regional communities under increasing environmental, economic, and social pressure (Darbyshire et al., 2022; Howden et al., 2007). The Australian Government's Future Drought Fund (FDF) was established to help support Australian farmers and associated communities to prepare for, and become more resilient to, the impacts of future climate risks, including drought. The CSA program contributes to the FDF's objective to provide better climate information, which will help farmers prepare and adapt to future climate conditions and therefore improve drought resilience in Australia. The first phase of CSA was a $29 million program of work during 2020–2024, which focused on co-developing the online tool "My Climate View" to help Australian farmers and farm advisors better understand the future climate risks and opportunities they face over the next 50 years.

The My Climate View brand was released in 2023, with earlier protypes called "Climate Services for Agriculture." My Climate View provides localized and contextualized, commodity specific climate information, including historic weather data, seasonal forecasts, and multi-decadal projections of future climate. The online dashboard allows users to select their location and commodities, and then explore commodity-specific information about the future climate in their area. They can also explore more general climate information for their chosen area, as well as modify certain commodity specific variables, such as growing season length or extreme heat thresholds. Other Australian climate service products currently available focus on either a specific locations or commodity groups. My Climate View provides national scale climate information, tailored to 22 different agricultural commodities, ranging from tree crops such as almonds and apples, grains such as wheat, barley and canola, as well as livestock such as beef, sheep and pork. More commodities are being progressively added as the tool is updated.

Extensive research and engagement activities contributed to the design and development of My Climate View, including demonstrations, webinars, field days and training sessions, usability tests, visits with Indigenous landholders on Country, as well as qualitative interviews with farmers and farm advisors (Snow et al., 2024a). A dedicated Indigenous engagement team liaised with Indigenous agricultural businesses and community groups to seek feedback on CSA. These discussions highlighted the potential for Map View versions of My Climate View to better support custodians of land areas larger than typical farms. While beyond the scope of this paper, indigenous engagement continues to be an important focus of CSA (for further details, see Snow et al., 2024a). The FDF's Drought Resilience Adoption and Innovation Hubs (Drought Hubs) have also been an important focus of CSA's research and engagement activities. Established across Australia as part of the FDF program, the eight Drought Hubs create a network of local and regional stakeholders focused on developing, extending and encouraging the adoption and commercialisation of drought resilient practices and technologies (Australian Government, 2024a,b). Drought Hubs support farmers and communities to prepare for drought by providing access to innovative tools and technologies, through practical extension and adoption activities that meet local needs. The Drought Hubs therefore have the potential to contribute to improved drought resilience, including through promoting locally led transformational change needed for Australia's agricultural sector and regional communities to adapt to future climate conditions.

3.2 Participant recruitment and data collection

This paper synthesizes findings from semi-structured, qualitative interviews conducted with 52 farmers and 24 advisors in 2021 and 2023, as part of CSA's social science research on farmer-advisor interactions (see Table 1).

Participants were invited through informal networks, previous engagements with My Climate View demonstrations, field days and events where they registered their interest. In the case of advisors, our selection criteria included all participants who identified as performing a role which provided advice to farmers. Although the term advisor includes both formal and informal providers of information and advice, the advisors we interviewed were all professional advisors, meaning those who provide advice in a professional capacity in a range of private and public sector organizations. In 2021, we interviewed 25 farmers and six agronomic advisors from a range of commodity types and regions across Australia, exploring farmer and advisor perceptions on how climate information can help with on-farm decision-making, and how the CSA prototype could potentially help with accessing this information. In 2023, we conducted further interviews with 27 farmers and 18 advisors from across Australia. We explored in more detail farmer-advisor interactions and the role of different types of advisors as key partners in achieving adoption of My Climate View at scale. Of the 18 advisors we interviewed in 2023, eight were agronomic or industry-based advisors, while ten were based in public sector organizations that receive government funding to provide

TABLE 1 Interview participant summary by year, role, gender, and number of participants.

Year	Participant roles and interview codes	Participants by gender	Total participants
2021 (R1)	Farmers (F)	Male: 14; Female: 11	25
	Agronomic and industry advisors (A)	Male: 5; Female: 1	6
2023 (R2)	Farmers (F)	Male: 21; Female: 6	27
	Agronomic and industry advisors (A)	Male: 3; Female: 5	8
	Natural resource management extension officers and knowledge brokers (AE)	Male: 7; Female: 3	10
Total farmer interviews		Male: 35; Female: 17	52
Total advisor and extension interviews		Male: 15; Female: 9	24
Total interviews			76

information and advice to land managers on natural resource management and drought resilience. Eight of these advisors were affiliated with several of the Drought Hubs across Australia. However, to maintain participant privacy we have not identified their specific organizational affiliations.

Interview participants were recruited with the assistance of our research partner FarmLink, or through existing contacts among the research team. This research was approved by CSIRO's Social and Interdisciplinary Science Human Research Ethics Committee (approval number 001/21). The interviews were on average 40 min in duration and were conducted via phone or video conferencing software. The interview questions covered four main sections: participant background; current use of climate information to help with on-farm decision-making; feedback on the CSA prototype (in 2021 and early 2023) or My Climate View (in late 2023); and thoughts on how climate information could help with adapting to future climate conditions.

3.3 Data analysis

Both rounds of interviews were audio recorded and professionally transcribed. We used the qualitative data analysis software QSR NVivo® to aid the coding, analysis, and management of the data. Interview transcripts were analyzed using "bottom up" and iterative coding followed by thematic analysis, resulting in a hierarchical coding structure of themes and sub-themes through multiple rounds of coding. This paper focuses specifically on the subset of themes relevant to interactions between farmers and advisors.

4 Results

Our study explored the role of advisors as key intermediaries within the My Climate View interaction space, including concepts of trust, shared learning and scaling opportunities within farmer and advisor interactions around understanding climate information and exploring climate adaptation options.

4.1 Advisors as key intermediaries within the My Climate View interaction space

The role of advisors as key intermediaries was a recurring theme in our interviews. We interviewed advisors from private agronomic services and industry-specific advisory organizations, as well as advisors with a focus on natural resource management (NRM) extension. Many of the NRM extension officers and knowledge brokers that we interviewed were based within several of the Drought Hubs across Australia, which are part of the FDF initiative. As these advisors explain, their primary role in the Drought Hubs involves sharing information and facilitating connections between researchers and farmers:

> So obviously you become that kind of connection point for the Hub activities… There's a lot of programs and opportunities and grants and…it's just really trying to provide that role of connecting…[and] making sure that other people are aware of those programs. And then, obviously, if there's landholders… wanting to get involved in something, we can also point them in the right direction. (R2-AE8)[2]

> And our role is really to connect researchers and producers, and producers with researchers. So, both ways. …We tend to be more working with other farming systems groups, which are groups of producers or researchers going down the way, taking research to producers. (R2-AE12)

Private sector advisors, such as agronomic and agribusiness consultants, as well as agricultural input providers or resellers, were also identified as key influencers on farmer decisions:

> Those people that influence decision making on farms, so they tend to be the agronomists, the farm business consultants, the resellers, they have a big say in what farmers do. …But the big three are the private consultants, the resellers and the business consultants. (R2-AE11)

Given their importance in sharing information and brokering connections within their social networks, advisors have an important role in the My Climate View interaction space. For instance, advisors can play a key role in connecting people interested in climate information with My Climate View:

> But obviously having the platform that CSA has there, again, it's that kind of connecting people, so that if you do have somebody, somebody who's interested in looking into that sort of stuff, you can point them in the right direction …And I would say, we have a number of … extension staff that go out on property, I mean, you want that sitting in the back of everybody's head that they can show it off to somebody if that suits their situation. (R2-AE8)

The advisors we interviewed identified various ways that My Climate View might help them to provide advice to farmers on climate related decisions, such as strategic or investment planning, natural resource management planning, broader land management decisions, or succession planning. Some advisors described how they had already shared outputs and data from My Climate View in reports, presentations, or analysis, to help communicate climate information relevant to their region:

> And I found that [CSA prototype] really interesting, and I made sure to share some of those graphs… [at a symposium] last year. And I did highlight that our region is warming up and then you can find more information of different industries and all that on the website. (R2-AE3)

Most advisors focused on the potential for My Climate View to support long-term, strategic decisions, given its focus on future climate information:

2 Interview participants are categorized according to the interview round (i.e., R1 for 2021 interviews and R2 for 2023 interviews) and role (i.e., A=agronomic/industry advisor interviews, AE=extension and knowledge broker interviews, and F=farmer interviews).

> Well, I think mainly those long-term decisions obviously, in terms of investment, so if I'm investing in long term things, is this going to impact it? Because some of these long-term decisions, if I'm looking at somebody buying a farm, that's at least a 20-year decision or more, so we need to understand how climate might impact that. …I guess in some ways, it would help justify some of those shorter-term decisions in machinery investment. And what enterprises we should be looking to incorporate within our farming system. (R1-A2)
>
> People wanting to trial things. And it might be complete changes in what people are doing. …I can see it as a great tool for decision making and future planning. (R2-AE13)

Advisors also identified the potential for My Climate View to help to “stress test” longer-term, strategic decisions (e.g., investment decisions, or crop changes) for future climate scenarios:

> So, the idea is…that I have a good base for understanding how the business has performed over the last five or 10 years, I then use that information to derive an average scenario, and then I'll look at stress testing that scenario. So, if we're looking to buy a property, or looking to have a big investment in machinery or something like that, then I'll make sure that they're year in year out, I call it the year and year out situation, will work. If the situation works, then it's got one tick. If the balance sheet can afford it, it's not going to put them in a very risky position in terms of too much debt, that sort of thing, you get another tick. And then I stress test it for, let’s say we have a drought, let's say we have a very poor year, what say we have two poor years? How does that look, does the business still survive in that sense? (R1-A4)

Similarly, advisors also described how they saw potential for integrating My Climate View into their extension and advice activities related to farm planning and climate resilience, as well as broader natural resource management planning:

> …I thought your tool [My Climate View] was very helpful in how I am intending to promote technology like this or resources to be incorporated into farm planning to be more climate resilient (R2-AE13).

Several of the advisors we interviewed identified the Farm Business Resilience Plans as an opportunity to integrate My Climate View into on-farm climate adaptation decisions:

> …at the more farmer level, I think that all comes back to integration with farm plans and my understanding is that a lot of farms are now embracing doing plans and incorporating resilience into it, just that longer term thing, I think. (R2-AE7)

Our interviews therefore highlight the way that advisors are key climate information intermediaries within the My Climate View interaction space, providing a range of advice and support to farmers on different types of decisions, including strategic and operational planning, investment, risk, and succession planning. Advisors provide information and support in diverse ways as well, in reports, in one-on-one conversations, through group presentations, which also scales their impact, making them key partners in scaling adoption within the My Climate View interaction space.

4.2 Trust and climate information intermediation in the My Climate View interaction space

Our interviews with both farmers and advisors demonstrated how trust in advisors is a key feature of farmer-advisor interactions in agricultural advisory networks, including climate information and advice networks. For instance, growers and grower groups trust advisors to provide targeted information and support:

> The local grower group…they work closely with us…when it comes to extending new information to growers. If the growers within their membership and their executive, if they highlight a priority that they think, well then they will discuss with us, well they want to look at this, can you help us do that? (R2-A15)

Similarly, the farmers we interviewed reinforced the trust that farmers placed in advisors as a source of information and support. For instance, farmers described the many ways their trusted advisors provided support for on-farm planning and decision-making:

> …one thing I've learned is to get professional advice and we use an agronomist who is a scientist and if we moved into a new crop, I'd be getting him to look at the soil, look at the climate, and give me advice on what crops are going to be the most productive on the basis of what he looks at rather than just launch into it. (R2-F15)
>
> She’s [advisor] part of the program and we’d be talking about what we’re planning with her and that sort of thing. And she would be indicating if there’s any problems or whatever. I mean, yeah, she doesn’t come along and say ‘you must do’. I mean it’s really an advice thing. (R2-F19)

Our farmer interviews also highlighted the important role for advisors in helping farmers to access and interpret climate information. In our first round of farmer interviews, concepts of trust and the complexity of climate information were key themes. Given the complexity of climate information, we found that trust in this context often relates to participants’ perceptions of accuracy of the climate information. As this farmer explains, farmer’s trust in climate information is often influenced by their assessments of the trustworthiness of the information source:

> Well, I suppose it comes down to how much you trust information that comes to you. So, I've got a large degree of trust in what we get from the Bureau [of Meteorology]. So, I suppose if you read something that's a bit out there, they get back to the Bureau and see what they say. (R1-F18)

Our interviews showed that farmers are unlikely to act on climate projection information alone. Rather, they synthesize it with a wide range of other information, including both external advice

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and local knowledge. This is because the information needs to be put in their specific local context, and every context is different. As a result, farmers described how they triangulated a range of information sources, including different forecasting apps and services, their own experience and intuition, and advice from trusted and long held relationships with peers, networks, and/or advisors, to help make sense of climate information and how it could apply to their situation.

Trust is also relevant to the question of whether farmers and advisors saw potential for My Climate View to help inform future climate adaptation decisions. Our second round of farmer interviews also revealed a range of different levels of trust that farmers placed in My Climate View as a source of climate information. Some farmers trusted and valued the information that My Climate View provided, finding it useful as: evidence in lobbying (R2-F22), as basis for future water availability modeling (R2-F23), to inform ongoing deliberations around whether to invest in indoor growing (R2-F18, F25), in considering orientations of future vine planting, canopy maintenance regimes (F26) and validation of previous decisions (R2-F18, F22). Some farmers said that they did not completely trust the information, but still intended to use it again, taking the projections with 'a grain of salt' (R2-F1, F4, F26), or reasoning it was "better than my guess" (R2-F8).

In contrast, some farmers trusted the information from My Climate View but did not intend to use it. Usefulness and intention to use were moderated by factors such life-stage, with some farmers (R2F15 and R2F20) who were looking to exit agriculture in the coming years trusted the information but had no intention of using it. Furthermore, other farmers (R2-F5) interpreted the future climate information as beneficial to their crops, which they perceived as reducing the likelihood of them needing to engage with My Climate View further. The range of farmer responses illustrates the challenges associated with using long-term climate information for on-farm decisions.

The farmer responses to My Climate View also reveal the breadth of opportunities for advisors to work with farmers to explore different scenarios for how information about future climate could inform on-farm decisions, including ways that advisors could tailor their advice to suit the needs of different farmers. For instance, farmers described how their agronomist might be able to use My Climate View to help inform on-farm decisions such as new crops:

> If I get a proper agronomist showing I want to grow mung beans or soybeans through the harvest season in the Burdekin and what best time is it for me to plant? They can get on your website, the CSA website and plan, and tell you what variety to plant, when to plant because it gives you enough of an indication. (R2-F17)

The role of advisors as trusted climate intermediaries means they are important partners in scaling adoption of My Climate View, as these advisors explain:

> I think we have to do it too, as [local organisation name omitted], because the thing with adoption is trust. So, if you're just coming in from nowhere and saying, "trust me", that takes effort and time. But, if you work with someone they already trust, I think the adoption may be a bit better. (R2-AE17)

> I think initially it [My Climate View] would probably be adopted by the extension officers first and then when they sit down with the farmers and show them things, I think you will start to pick up some farmers along the way who are interested and think, what's that? Can I use that? So yeah, I think a bit of both, but it might be a process where extension comes first and then the farmers themselves. (R2-AE7)

> I think that the information that's displayed on the Climate Services for Agricultural website is very handy to know. …I definitely would be interested in learning a bit more about it, also how to navigate it because I would then try to explain that to the graziers. I would then try and go about my own system of knowing how the graziers think and how would be the best way to explain the data to them in a way that would make sense. (R2-AE5)

Given their role as trusted climate intermediaries, the advisors we interviewed highlighted the importance of making sure My Climate View was embedded within existing programs and local groups:

> The first impression [of the CSA prototype] is that there's a lot of really interesting medium- and longer-term data there, and it'll be really great if we linked into the existing support services…and that this information will be able to really support other services and other services will be able to help the CSA platform too. And it's much, much further down the track, but it would be really useful I think if the CSA were to partner up with very broad extension strategies so that it was embedded within them just to make it quite seamless. (R2-AE6)

> That's one of the approaches is working with those groups. It's particularly the farming systems groups, I think. Yes, some of those farming systems groups are really progressive, and they are wanting to, at this point in time, think about and even have demonstration areas or sites of what a farm might look like, or need to look like in that time. (R2-AE12)

Therefore, trust is an important factor within the My Climate View interaction space, both in terms of how advisors themselves trust the climate information it provides, and how they mediate trust in new forms climate information with farmers, which is an important part of scaling adoption. Advisors can help to achieve scale through introducing climate projections to a broad range of local networks and contexts, even non-agriculture ones. Advisors can therefore play a key role in supporting discussions about how to interpret and contextualize the information from My Climate View, which is a vital part of making such information accessible and useful for supporting on-farm decision-making.

4.3 Learning and scaling within the My Climate View interaction space

Although many advisors could see ways that they might use My Climate View in their interactions with farmers, the complexity of doing so meant that most advisors we interviewed noted that additional support and training would be valuable. For example, this advisor discusses the need for further training before they would feel confident using My Climate View with a farmer:

> I probably at the moment wouldn't show them the [CSA prototype] website. I might show it to them and introduce it to them, but I just know that as it is, I feel like I would be lost if I tried to explain how it worked… (R2-AE5)

Providing support to advisors is therefore an important component of the My Climate View adoption and engagement strategy, which includes various awareness raising and training activities with farmers and advisors across Australia. The value of peer learning was also highlighted in both farmer and advisor interviews. For example, these advisors emphasized the importance of creating opportunities for peer learning for farmers in the context of supporting on-farm climate adaptation:

> …the big thing that we've found, is case studies and people talking about what they're doing…is what our members take home and think, "Oh, I couldn't do everything he's doing because—but I might be able to do this little bit of it." So, yeah, I think that peer group thing is what they mainly learn from. …I think that's how farmers learn, from each other, and the social side of it and there's that support…like, we were having coffee mornings on Zoom just to keep the connection and people being able—you know, "It's not just me" (R1-A3)
>
> Peer-to-peer learnings are probably the biggest out here. If they see, "Oh, mate, how did you know that," and they say, "Oh, well, I looked at this." I think that's probably the only way we can start getting that information and training out there as producer groups training. (R2-AE9)

Similarly, one of the advisors who attended a training session on My Climate View suggested that creating a space for ongoing peer learning among advisors would be valuable for supporting scaling of My Climate View:

> And you could have engaged the people who did the workshop together so that then they form a small, what would you say, a peer-to-peer group, which then can talk to each other a bit more. The opportunities for connection with this could enhance its uptake as well. (R2-A17)

The need to create opportunities for shared learning within the My Climate View interaction space reinforces the way in which the co-production of climate services should be underpinned by a partnership approach that builds climate resilience within local contexts, rather than a simplistic transfer of technology approach.

5 Discussion

Using the conceptual framework of an agricultural innovation interaction space, our CSA case study illustrates how advisors are valuable intermediaries, performing many different types of intermediation in the development of multi-decadal climate information services, since they can help to ensure the information is accessible and useable at the farm scale. This is vital to ensure that climate information is able to be used on-farm to support longer-term decisions about climate adaptation (Andrieu et al., 2019). The My Climate View interaction space is characterized by multi-stakeholder relationships, spanning both the R&D networks (i.e., the CSA project team and partners within the broader FDF initiative) that are developing the My Climate View tool, and the Farming System networks, involving key partners in the co-production of My Climate View and engagement with the broader CSA program.

Within this interaction space, advisors play a key role as trusted climate information intermediaries, which means they are valuable partners for scaling adoption of My Climate View. Interactions between farmers and their trusted advisors are fundamental in shaping long-term on-farm decisions (Haigh et al., 2015; Prokopy et al., 2017; Prokopy et al., 2013). We found that advisors bring together experience across multiple farming and local contexts, and often their own personal situation involves farming, so they can represent a broad perspective of farms and understand how climate information may impact different farm contexts in different ways, and the range of actions that can be undertaken in response. As illustrated in Figure 2, the different intermediation roles played by advisors are: (1) key networkers for sharing information; (2) key mediators of trusted information; and (3) key knowledge brokers for new forms of digital information within the CSA co-production interaction space. These farmer-advisor interactions are a catalyst to long-term climate information being used at the farm scale to inform longer-term decisions about climate adaptation.

5.1 Advisors are key networkers for sharing information

Our case study illustrates how advisors can intermediate in different ways, including network-building and brokering for knowledge exchange (Bäumle et al., 2023; Hernberg and Hyysalo, 2024; Moss, 2009). Within agricultural innovation interaction spaces, social networks are important to share expertise, and to ensure that advisors can keep up-to-date and learn from, and with, their peers. This is particularly important as knowledge proliferates online and advisors need to synthesize complex or competing information, which is often the case for climate adaptation (Cradock-Henry et al., 2020). Social networks also feedback into foundations for personal or relational trust (Carolan, 2006). If many social connections (such as friends, family, neighbors, and trusted advisors) have similar views, that may support information to be trusted. In terms of climate change, social networks may underpin climate denial as well as climate activism, with agriculture often highlighted as a cohort that includes climate skeptics (Robertson and Murray-Prior, 2016), but there are signs momentum is shifting through groups such as Farmers for Climate Action (Hinkson, 2022), and younger generations. However, climate skeptics and activists alike can still find benefit in different uses of the climate information in CSA, such as looking at trends or historical data without focusing on future projections or the causes of change (Snow et al., 2024b).

Advisors do more than just share information, they often need to adapt information to share with different types of networks within the interaction space, in different forms. The different forms of interaction can range from verbal conversations one-on-one with

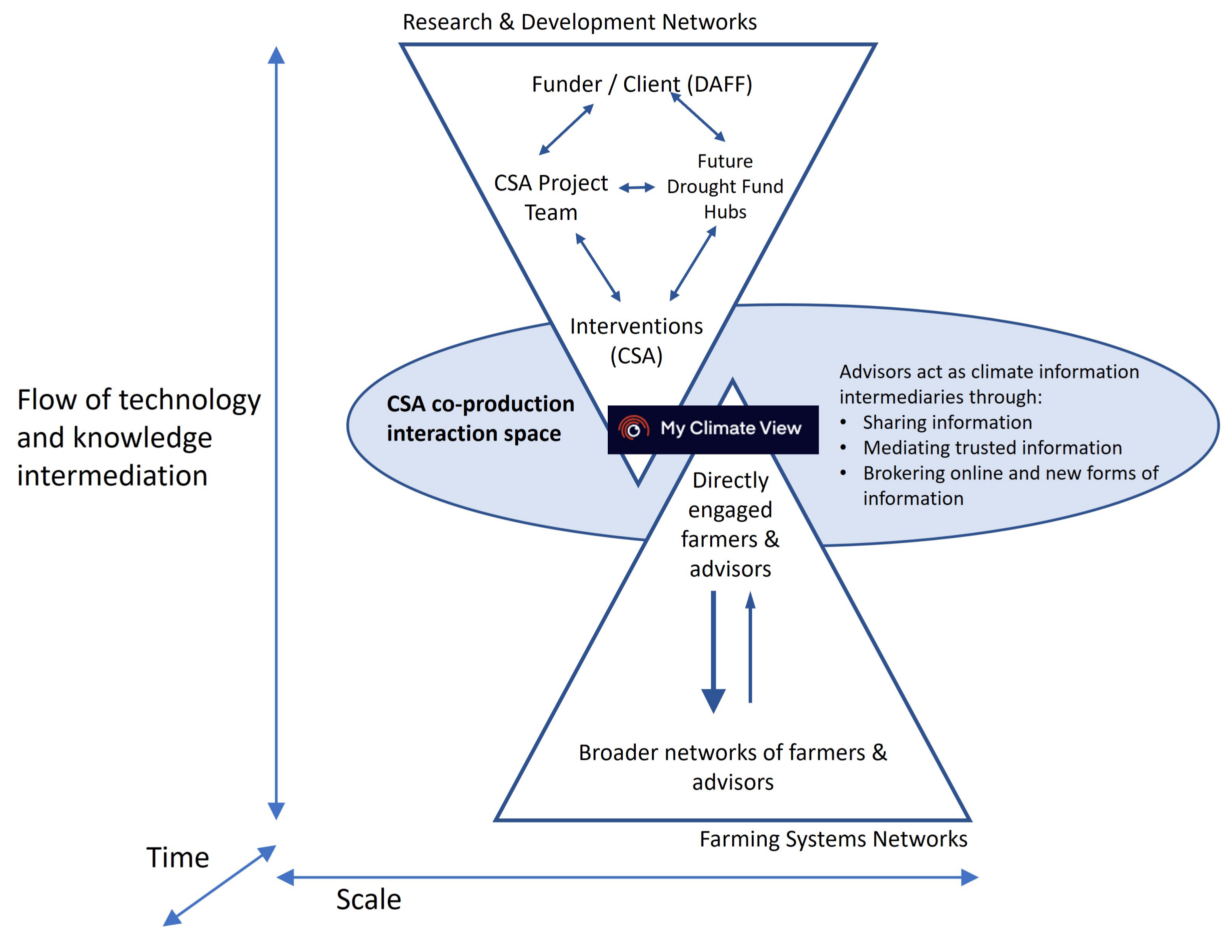

FIGURE 2
CSA and "My Climate View" co-production interaction space, adapted from Hermans et al. (2023, p. 8).

farmers, or in groups, to written interactions in emails, or through newsletter updates. This means that advisors are an important mechanism to reach different types of people, with different types of messages about climate. Through this intermediation process of configuration, advisors create brokered knowledge, which helps to make information useful to different actor groups (Meyer, 2010). Given the complexity of climate information, we found that advisors provide valuable support for interpreting the practical implications of future climate projections for on-farm decisions, such as providing advice on suitable commodities considering future climate conditions or helping to interpret what a possible change in future climate conditions (such as increased temperature or decreased rainfall) means for specific commodities in different regions. Advisors can also help with on-farm strategic planning, through initiatives such as Farm Business Resilience Plans (Australian Government, 2024c), trialing new practices and informing strategic investment decisions, all of which can be informed by better climate information. Advisors therefore add value by adapting information to local contexts, enabling the translation of climate information into action on-farm. However, advisors must be supported by their organizations to keep up to date and have access to information, as well as encourage information seeking and sharing and thinking about risks and opportunities (Lemos et al., 2014).

5.2 Advisors are key mediators of trusted information

As trusted and credible sources of information and support, advisors can help to bridge the gap between climate science information and on-farm decisions (Haigh et al., 2015; Prokopy et al., 2017). Agricultural advisors often (but not always) have longstanding relationships with their clients, share their local knowledge and social connections and are much more trusted as a result (Ingram, 2008; Juntti and Potter, 2002). In agriculture, studies have explored the development of trust between farmers and advisors and found that experience and trust are interconnected (Sutherland et al., 2013) and trust is often earned slowly (Hilkens et al., 2018). Trusted advisors may also be called upon to support farmers outside of technical decisions (Cook et al., 2021). The potential impacts of climate change on agriculture can be overwhelming and distressing for some people, but a trusted advisor can support farmers' wellbeing by making practical suggestions for action and being a source of connection and understanding (Hammersley et al., 2022). How climate change will impact individual farms is highly uncertain, and climate projection tools like My Climate View provide future climate information that needs interpretation to be applied to specific decision contexts while at the same time considering the inherent uncertainty of these projections (Haines, 2019;

Lemos et al., 2014; Robertson and Murray-Prior, 2016). Such uncertainty can affect the uptake of new technologies (Eastwood and Renwick, 2020), including climate services such as My Climate View. Advisors can help with navigating this complexity and uncertainty, including providing advice on which of the different climate service tools available could be most useful in different contexts (Haines, 2019). Therefore, the trusted roles of advisors are vital to allowing frank discussions around uncertainty, personal circumstances and practical ways forward. In some cases, no action may be the best course to take, but looking ahead and thinking about possible impacts and planning ways to prepare is important. Advisors can be critical in encouraging early adaptation planning and are often willing to give advice based on climate information despite uncertainty (Lemos et al., 2014).

For advisors to trust climate information enough to use it in their own work and planning decisions and/or recommend it to others, it helps if they are part of the development of the information so they can better understand the information itself, as well as provide feedback on how to make this information more useful and accessible (Fleming et al., 2023). Partnering with developers of climate information helps advisors to learn what information is available and how it could be used while having input into what information exists and how they interact with it. If advisors trust and use the climate information regularly, over time this embeds the legacy of the CSA program, and the practice of considering long-term climate projections, into the Australian agricultural innovation system. Such an approach to incremental technological transformation of a sector helps to achieve impact and supports transformational change on-farm, without strictly predefining what that impact is or could be. It is also worth noting that the Australian FDF initiative has provided an institutional incentive for advisors to engage with climate information, which contrasts with barriers reported elsewhere to advisors trusting and using climate information (Prokopy et al., 2013).

5.3 Advisors are key knowledge brokers for new forms of digital information

Farmers have different levels of digital literacy, and different capacities to access and use digital information, due to factors such as access to and speed of internet connections, serviceability, and cost discrepancies across rural–urban divides (Fielke et al., 2020; Marshall et al., 2020). This variability means that advisors are key knowledge brokers within the My Climate View interaction space, facilitating connections between climate information developers and farmers, feeding key insights of relevance and interpretability to developers, and insights and recommendations to farmers. Other studies have highlighted that open discussion and dialogue between farmers and advisors is an important part of building confidence in such online climate information tools (Malakar et al., 2024b). Advisors can therefore be critical conduits for farmers to access information online and help bridge the "aspirations-impact" gap common to climate information, namely the tendency for climate information not to be adopted or considered in decision making processes (Findlater et al., 2021). Understanding the role that advisors can play allows those developing online climate services to be able to work more effectively with specific advisor groups (Haigh et al., 2015).

Recognizing the role of advisors as key knowledge brokers within the My Climate View interaction space also highlights the importance of moving beyond a focus on individual farmer decision-making, to better understand the wider network of stakeholder relationships that are engaging with My Climate View (Hermans et al., 2023). This in turn underscores the importance of providing advisors with the training and support they need to be able to have confidence in using My Climate View in their interactions with farmers and even other natural resource management stakeholders. Appreciating the complexity of farmer and advisor interactions within the My Climate View interaction space emphasizes that the potential impact pathways or uses of My Climate View are potentially more diverse than initially imagined, and could extend to other sectors beyond agriculture, including broader natural resource management planning, or even educational settings, such as climate education in schools or universities. The non-linear nature of adoption of climate information emphasizes the importance of designing online climate services in a way that is aware of and responsive to the needs and connections between different types of users of climate information, rather than just focusing on either famers or advisors (Rijswijk et al., 2019; Snow et al., 2024a). Many individuals can play an advisory role, even if they are not employed as farm advisors or agronomists. This means that thinking about agricultural advisors broadly, and the institutional arrangements that underpin these interactions and relationships is also important. Engaging broadly to develop new climate tools can therefore be beneficial to build trust and collaboration and ease integration of climate tools into institutional processes (Lemos et al., 2014). Integration into social and institutional processes is a key part of scaling adoption.

6 Conclusion

Advisors play a central role in scaling climate services and supporting adaptive decisions. This recognition of the importance of farmer and advisor interactions within the My Climate View interaction space has helped to shape the development and engagement activities within the CSA program. Interactions between farmers and their trusted advisors are fundamental to helping farmers to better understand what future climate conditions might mean for their specific commodity and regional contexts. These farmer-advisor interactions are therefore a catalyst to multi-decadal climate information being used at the farm scale to inform decisions about climate adaptation. The co-development and scaling of My Climate View is an ongoing journey that will take years. Reflecting on how My Climate View fits within a "co-production interaction space" highlights the way that collaborative relationships need to be actively fostered to encourage on-going learning, collaboration, and knowledge brokering networks, to encourage and guide the changes in practice over time that are needed to collectively adapt to future climate conditions. The next phase of the CSA program will need to continue to maintain ongoing partnerships that are needed to continue to co-develop scaling of information, sharing learning and implementing action (Schut et al., 2020). While My Climate View is not a transformational technology on its own, it can be part of a conversation between farmers and advisors, enabling them to explore and discuss future climate conditions and consider implementing strategic climate adaptation measures that are tailored to specific, local contexts. Therefore, when climate services such as My Climate View are developed in a partnership approach and embedded within local advisory networks, they have the potential to support transformational changes on-farm that are necessary to meet the sustainability transition pressures that climate change presents.

Data availability statement

The datasets presented in this article are not readily available because of ethics conditions to protect the anonymity of respondents. Requests to access the datasets should be directed to emma.jakku@csiro.au.

Ethics statement

The studies involving humans were approved by the CSIRO Social and Interdisciplinary Science Human Research Ethics Committee. The studies were conducted in accordance with the local legislation and institutional requirements. The ethics committee/institutional review board waived the requirement of written informed consent for participation from the participants or the participants' legal guardians/next of kin because we obtained verbal informed consent at the start of interviews instead.

Author contributions

EJ: Conceptualization, Formal analysis, Methodology, Writing – original draft. AF: Conceptualization, Formal analysis, Methodology, Writing – original draft. SF: Conceptualization, Formal analysis, Methodology, Writing – review & editing. SS: Conceptualization, Formal analysis, Methodology, Writing – review & editing. YM: Writing – review & editing. GC: Writing – review & editing. RH: Writing – review & editing. LW: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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