Exploring the value proposition of digital technologies in smart farming: an approach co-designed by agricultural advisors

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Abstract: *The promise of technology development in agriculture is well publicised with some claiming that 'digital disruption' will transform the way farming and food production is done (Australian Farm Institute, 2017; Hall, 2007). However despite the recognised potential and proliferation of digital technologies for agriculture, there has been an unexpectedly slow uptake of some tools and services by farmers and agricultural advisors worldwide. In Australia, a pluralistic Agricultural Innovation System (AIS) is characterised by a changing mix of private and public interests with government investment in extension being gradually withdrawn over the past two decades. In this context, private agricultural advisors increasingly work with farmers and others to support farm management using digital technologies. To better understand the role of these advisors in supporting the capacity of producers to gain benefits from digital technologies in smart farming contexts, we undertook collaborative research to investigate the opportunities and constraints for advisors to engage with smart farming, as well as the kinds of interventions and practices that might enable or strengthen this engagement. In this paper we report on a particular research-practice intervention co-designed with agricultural advisors from the Australian sugar, cotton and horticultural industries. Through a facilitated, action research process inspired by participatory technology assessment approaches, the advisors in this intervention co-created a Digital Value Assessment Tool (DVA Tool) for assessing the costs and benefits of a smart farming tool or service. Findings from this research demonstrate that the DVA Tool is strategic decision support tool (DST) for agricultural advisors and their clients to reduce risk and enhance benefits related to engaging with digital agricultural tools and services. This decision support tool is enacted through self-directed inquiry by professional advisors and has the potential to be integrated into their routine business practices to maximise the opportunities from engaging with digital technologies. There is a role for agricultural industry bodies to support advisors with such decision support by hosting and promoting the DVA Tool (and other DST like it) and continually engaging with their constitutents, including advisors, on issues of how to harnass and mobilise diverse skills and knowledge for agricultural innovation in a digitally disrupted world.*

Keywords: *smart farming; technology assessment; private advisory capacity*

Introduction

The promise of technology development in agriculture is well publicised with some claiming that 'digital disruption' will transform the way farming and food production is done in the future (Australian Farm Institute, 2017; European Parliamentary Research Service, 2016; Zhang, Jakku, Llewellyn, & Bake, 2018).

Some of the key developments include: automation of farm practices (e.g. smart irrigation and automatic milking systems); technological systems to remotely regulate animal behaviour (e.g. virtual fencing) (Banhazi et al., 2012); the potential to capture, integrate and access data (Wolfert, Ge, Verdouw, & Bogaardt, 2017) on farm performance and farm practices (e.g. smart tractor technology); and, tools for sensing spatio-temporal differences across farming systems and applying management interventions (e.g. drones and Geographic Information Systems) (Krishna, 2016). The potential impacts of these actual and anticipated developments include: changes in type and extent of human labour and capabilities on-farm; potential for tracking, understanding and demonstrating accountability of farm and value chain performance; and, new insights into opportunities and constraints for resource use productivity (State Government Victoria, 2015).

However, despite the recognised potential and proliferation of digital technologies for agriculture (Griffith et al., 2013; Walter, Finger, Huber, & Buchmann, 2017), there has been an unexpectedly slow uptake of so-called ‘smart farming’ tools and services by farmers and agricultural advisors worldwide and in Australia (Jago, Eastwood, Kerrisk, & Yule, 2013; Tey & Brindal, 2012; Zhang et al., 2018). For many in agriculture, the actual and potential impacts of these technologies are uncertain and therefore their application in farming systems is a matter of confusion and sometimes even concern. This is a challenge of agricultural innovation whereby learning processes and changes in farming practices emerge from engaging diverse innovation actors in managing the inherent complexity and uncertainty of smart farming for improved production outcomes (Nettle, Crawford, & Brightling, 2018). Eastwood et al. (2017) have noted that collaboration between private and public extension roles has becoming increasingly important for innovation in smart farming contexts due to the vast range of technologies available, different scales of activity involved adn the need for skills development and new institutional arrangements. In the Australian sugar industry, for example, it is recognised that many financial, as well as social and environmental, benefits of smart farming are yet to be realised (CSIRO/SRA/SQU, 2015) and that ‘there are a bewildering array of technologies with many evolving at exponential rates‘ (Davis, 2007).

This paper presents a case study of how the uncertainty and complexity of smart farming has been productively addressed by agricultural advisors in Australia. It reports on a particular action research-based intervention with advisors and addresses the question: How can private agricultural advisors engage with smart farming technologies to maximise the benefits and minimise the risks of investment for their businesses? We describe this intervention by a community of practice (Wenger, 2000) of private agricultural advisors in the Australian sugar, cotton and horticulture industries which involved the co-design (Storni, Binder, Linde, & Stuedahl, 2015) of a participatory technology assessment tool for smart farming technologies. Others have identified the need to better understand the role and contributions of the private advisory sector in support for on-farm practice change in pluralistic agricultural advisory systems (Labarthe & Laurent, 2013). In relation to smart farming in Australia, this is particularly relevant, as the demands for new skills and knowledge/s required to realise the benefits of smart farming technologies must be met by an advisory sector currently characterised by fragmentation, diverse commercial interests and reduced government influence (Paschen, Reichelt, King, Ayre, & Nettle, 2017). Findings from this research suggest that participatory technology assessment (pTA) enables strategic niche innovation dynamics for private agricultural advisors and their clients to reduce risk and enhance benefits related to smart farming.

Participatory Technology Assessment (pTA) in Agriculture

The new era of so-called ‘digital disruption‘ for people working in agricultural advisory practice or (what is often called ‘private extension‘ in Australia) is characterised by: an expansive and diverse market of smart farming tools and services; complexity of new knowledge related to smart farming applications and their benefits (Eastwood, Klerkx, & Nettle, 2017; Pierpaoli, Carli, Pignatti, & Canavari, 2013; Trindall, Rainbow, & Leonard, 2018); and uncertainty about the potential opportunities and benefits of smart tools and services to their clients and their own businesses. Dealing with this diversity, complexity and uncertainty-related smart farming technologies is an everyday innovation challenge of advisors. Due to the fact that these technologies represent a significant departure from routine practice for many people (including advisors) in agriculture, this means that new socio-technical processes and dynamics are required to support learning and capacity building for innovation.

One response to the innovation challenges associated with new technologies is the approach known as Participatory Technology Assessment (pTA) (Geels, 2007; Joss & Bellucci, 2002) where technology co-design and development processes involve people other than technical design experts. Popularised from the 1980s, this methodology is characterised by regular interactions between design experts and other societal actors in a given context (e.g. farmers and producers in agriculture) and which involve processes of reflexivity and mutual learning (Schot, 2001). pTA is focussed on optimising technology through iterative and deliberative (Durant, 1999) consideration of technological design specifications along with potential markets and social implications (Ibid: 45). It entails carefully facilitated interactions between innovation actors in networks supported by the key role of 'innovation brokers' (Laurens Klerkx, Hall, & Leeuwis, 2009). Scholars recognise that pTA engenders wider consideration of issues relevant to the use of technological innovations than traditional, technocentric technology assessment. This includes ethical, environmental, health and political issues (Joss & Bellucci, 2002; Stirling, 2008).

Conceptual Framework

In this paper we broadly conceptualise the engagement of advisors in smart farming as an innovation challenge. It is well recognised by scholars in the fields of innovation studies and Agricultural Innovation Systems (AIS) that innovation emerges from the strategic coordination of diverse people and their knowledges and practices, institutions, materials, regulating mechanisms and other factors at different scales within a given Innovation System (Geels & Schot, 2007; L. Klerkx, van Mierlo, & Leeuwis, 2012; Leeuwis & Aarts, 2011). The Multi Level Perspective (MLP) on innovation proposes that technological innovation can ‚be facilitated by the management of technological niches, i.e. protected spaces that allow nurturing and experimentation with the co-evolution of technology, user practices and regulatory structures (Schot & Geels, 2007: 538). In this farming, 'niche innovations' are 'assumed to emerge through collective enactment' (Ibid: 538) and their successful development is characterised by three key social processes. These processes are: the articulation of expectations and visions; the building of social networks; and, learning processes at multiple dimensions (Ibid: 540; Geels, 2007).

We apply the conceptual framework of niche innovation processes to describe how the DVA Tool action research intervention enabled agricultural advisors to build their capacity to engage with smart farming technologies. For each of the processes of 'visioning', 'social networking' and 'learning' we present empirical evidence from the intervention based on participant observation, insights from participants and materials and representations produced. However, in order to fully describe these dynamics we also draw on practice theory proposed by science studies scholars, Shove and Walker (2010), which emphasises the different, everyday practices that both constitute and emerge from innovation efforts. By paying attention to all forms of practice—'forms of practical know-how, bodily activities, meanings, ideas and understandings, as well as to materials, infrastructures and socio-technical configurations'—Shove and Walker (2010:476) suggest that the dynamics of innovation processes can be revealed and the potential for sustaining novel and effective new routines of practice enhanced. They assert that: 'when practices change they do so as an emergent outcome of the actions and inactions of all (including materials, infrastructures, not only humans) involved' (p. 478). Therefore, in order to understand how an action research intervention can support advisors to improve their capacity to enact or 'do' smart farming technologies, we pay attention here to heterogeneous practices (Higgins, Bryant, Howell, & Battersby, 2017) as they emerge in the collective action of advisors as they co-design a practical response to managing the opportunities and risks of smart farming technologies together (Vanclay, Russell, & Kimber, 2013).

Methodology

This paper describes research undertaken as an action research intervention involving members of the Australian agricultural innovation system with an interest in the roles and engagement of private advisors in smart farming. This intervention is linked to a collaborative research project called, 'Stimulating private sector extension for increasing returns from R & D in Australian agriculture' and it was cooperatively developed as part of this larger project through a series of discussions and engagement with stakeholders in the Australian agricultural sector, notably through three regional forums held in 2015/16. Forum participants were asked to identify and validate priority issues for engaging the private advisory sector in agricultural extension. Four key issues were identified, including the issue of enhancing the capacity of the private agricultural advisory sector to engage with smart farming technologies. Subsequently, representatives from the cotton, sugar and horticulture industries committed to exploring this issue together in this action research intervention based in Queensland.

The invention to support the engagement of private advisors in smart farming was designed iteratively according to the input and participation of key participants. It consisted of the following elements: a Project Team (consisting of three representatives of the industry bodies for sugar (2) and cotton (1), a researcher and a Project Officer); a Review Team of six key participants who are advisors in the cotton (3), sugar (2) and horticulture (1) sectors; and a broader 'community of practice' (Wenger, 2000) which included smart farming researchers, industry and government personnel and private advisors. The aim of the intervention was to enhance the capacity of private sector advisors to engage with Research and Development (R & D) and commercial opportunities in smart farming.

Table 1 below summaries the activities in the intervention and associated research activities and methods.

Table 1. Research-practice activities in the smart farming action research intervention process

PHASE 1 ESTABLISHMENT PHASE	Convene regional Forums (in 'Stimulating the private sector for increased returns from R & D in Australian agriculture' project)	To identify and validate key issues in capacity building for the private agricultural advisory sector in Australia to be addressed in four action research interventions	2016 Gippsland, Vic Adelaide, SA Toowoomba, Qld, 5 March 2017	150 advisors
	Establish a Community of Practice (CoP) of Private Agricultural Advisors in Digital agriculture at regional Scoping Workshop	To create a Project Team (PT) of agricultural industry extension experts and researchers • Private agricultural advisors from the cotton, sugar and horticulture sectors with key government and industry extension experts and researchers convene at Scoping Workshop • Priority issue to address in the action research intervention identified; *determining the value proposition for smart farming technologies to advisors' businesses*	8 March, 2017, Toowoomba, Qld.	15 advisors, researchers, industry representatives with Trial Team (5)
	Develop Trial 2 Activity Plan for the action research intervention developed by Project Team and CoP members	To agree on a timeline of action research activities including: development of selection criteria for Review Team (Review Team); background analysis of proposed Review Team members' businesses; collaboration on Review Team workshop design and outcomes.	April/June 2017	Review Team (6), Project Team (5)
PHASE 2: INTERVENTION ACTION PHASE	Hold Review Team workshop (with Project Team members)	To confirm interest and commitment to participate of expert agricultural advisors in a Review Team for addressing the priority issue • To co-design a process for determining the value proposition for smart farming technologies • Outputs from workshop: ○ Participatory Technology Assessment Framework (pTAF) for Agricultural Advisors (the Digital Value Assessment (DVA) tool)	14/15th August, 2017 Toowoomba	Review Team (6), Project Team (5) agricultural accountant (1)

		○ Development of Case Study Plan for individual advisors in the Review Team to assess the value of a digital agricultural technology to their businesses		
PHASE 3: FUTURE ACTION PHASE	Convene two teleconferences with Project Team and Review Team members	To discuss Review Team members' progress in their case studies and provide support and feedback to members	19 October 2017 15 December 2017	11 8
	Video interviews with Review Team members	To track progress in Review Team members' case studies and gain insights on the DVA Tool from their experiences.	25 Nov; 10 Dec 2017; Jan 10 2018	Review Team (6) members
	Evaluation questionnaires completed by all participants at three workshops	To collect feedback and insights on the action research intervention process and its outcomes related to capacity development of advisors and engagement with smart farming.	8 March 2017; 14/15 August 2017; 21 Feb 2018	14 11 11
	Peer review of DVA Tool with targeted group of key agricultural advisory sector and industry experts	To critically review and refine the DVA tool for use by a wider audience. To ensure its applicability to multiple contexts and stakeholders.	May/June 2018	6-8 people with Trial Team
	Recommendations on future use of DVA tool and communication of research findings	To work with stakeholders and collaborating industries to refine the DVA tool for use beyond this project including: exploring avenues for creating an appropriate platform for the Tool (i.e. smartphone App. or online portal). To communicate project findings and utility of DVA tool to a wide audience	June 2018	Agricultural industry collaborators, Trial Team

Results and Discussion

We report here on the outputs from the action research intervention which aimed to build and support the capacity of private agricultural advisors to engage with smart farming technologies. We discuss these outputs according to the conceptual framework of 'niche innovation' processes (as described above) and demonstrate that it embodied the three key processes of niche innovation; visioning, social networks and learning at multiple levels (Shot and Geels 2007; Geels, 2007). In doing so, this intervention process contains possibilities for change related to the way advisors engage with smart farming technologies to maximise the benefits and minimise to their businesses. These ways of engaging are located in new everyday, heterogenous practices (Mol, Moser, & Pols, 2010; Suchman, 2003) of advisors that emerged through the intervention. A key example of this is the DVA Tool developed by advisors which is both a material, symbolic and social practice and operates as a boundary object (Star & Greismer, 1999) to facilitate the production of new knowledge about the potential of smart farming tools and services within advisors' businesses.

There were four key outputs from the action research intervention: 1) vision statements for improving the capacity of private agricultural advisors to engage with smart farming technologies (see Table 2); 2) a list of agreed priority issues for improving the capacity of private agricultural advisors to engage with smart farming technologies; 3) the establishment of a Review Team of six private agricultural advisors supported by agricultural industry extension experts and researchers; and, 4) the generation of a participatory technology assessment tool for agricultural advisors caled the Digital Value Assessment Tool (the DVA Tool). We show that each of these outputs is evidence of niche innovation processes of: articulation of expectations and vision (1 and 2); building of social networks (3) and learning processes at multiple dimensions (4) (Schot & Geels, 2007: 540) respectively.

Visioning and identifying shared priority issues in advisor engagement with smart farming

The first key output of the action research intervention was a series of vision statements for building capacity of private agricultural advisors to engage in smart farming. These emerged as part of the sense-making (Wallis, Ison, & Samson, 2013) process within the Project Team as members shared ideas about what the purpose of the intervention should be and how it might proceed. As a result of this visioning, a shared activity question was agreed to by participants: 'Why would you use smart farming technologies in your farm advisory service business?'

With a shared activity question to focus our planning, the Project Team convened a Scoping Workshop involving agricultural advisors to further refine the focus and aims of the intervention. Participants at the workshop (on 8th March, 2017; see Table 1) identified a list of actions for building the capacity of private advisors to engage with smart farming technologies (see Table 3). They then ranked these actions from lowest to highest priority and the number one priority issue emerged as: *Determining the 'value' proposition of smart farming technologies for advisors' businesses.* Participants then discussed and recorded potential activities to address this priority issue (see Table 4).

Table 2. Vision statements for an action research intervention to build capacity of private agricultural advisors to engage in smart farming (5th March, 2016)

Vision Statements

- To explore a different way of doing advisory and extension business.
- An effective co-development process for Precision Agriculture [Smart Farming]
- To 'push the envelope'- to try different ways of doing business in smart farming.
- To explore if there is a role for Research and Development Corporations in the future in terms of sustaining and developing advisor capacity in Precision Agriculture [smart farming]
- To understand the needs and interests of advisors with respect to their capacity to deliver Precision Agriculture [Smart Farming Technologies]
- For cotton- for smart farming technology to work even better with Research & Development to deliver more value to producers. To develop advisor capacity in smart farming
- For sugar- to achieve more precision in production overall and to support capacity building for advisors in smart farming [smart farming]

Table 3. Priority Issues for building agricultural advisors' capacity to engage with smart farming technology (as identified by action research intervention participants, 8th March, 2016).

Ranking of Priority Issues ***(1 (highest priority)-5 (lowest priority)***	**Priority Issue**
1	Determining the 'value' proposition for smart farming tools and techniques for advisors
2	More/different case studies of use of smart farming technologies from consultants themselves
3	Need to demonstrate requirements by industry for smart farming technologies
4	Economic analyses (whole of system) of smart farming technologies (involving consultants)
5	Appreciation of smart farming technology in relation to value adding (to consultants' and producers' businesses)

This process of identifying and sharing vision statements and determining and agreeing on priority issues for enhancing advisor capacity to engage in smart farming is a niche innovation process of 'the articulation of expectations and visions' (Shot and Geels 2007: 540). This is a process of consolidating past experiences and knowledge/s as well as aspirations for the intervention in order to proceed with a clear direction and commitment to collective action.

Table 4: Proposed action research activities to address the priority issue of identifying a process to determine the value proposition of smart farming technology for private agricultural advisors

Action research activities proposed by participants at workshop on 8th March, 2017, Toowoomba, Qld. (NB. These are verbatim statements from workshop data)
• Provide a valuation model for agricultural data • Involve farmers in practical applications of smart farming technology • Learn from past mistakes of the application of smart farming technologies • Roll out a specific smart farming technology to industry • Development of smart farming demonstration sites across multiple industries • Major economic evaluations of blue sky/new technologies before entering agriculture • Producer demonstration sites related to smart farming technology and services development • Economic case study of the innovations on the University of New England Smart Farm • On farm demonstration of new smart farming technology • Facilitation of case study of new smart farming technologies including economic analysis • Case studies on different smart farming technology applications to advisors, growers and industry • Case Study on smart farming technology applications • Case studies of smart farming technology and services development at farmers' level • Live demonstrations of value propositions for new smart farming technologies • Case Study on smart farming technology applications • Proven examples/stories that look at dollars saved by utilizing smart farming technology. This would be done specific to agricultural industry (i.e. horticulture) • Develop farm case studies of smart farming technology use and benefit in small teams (i.e. 2 advisors, 1 researcher and 5 farms) • Economic business case studies of smart farming technologies (related to advisory businesses) • Consultant group develop the "top 5" revenue stream options for businesses related to smart farming technologies • A workshop and follow-up for new advisers (<5 years) focussed on digital agricultural advice, test/trial new smart farming technology service delivery on some farms

Developing social networks to support advisor engagement in smart farming

The second key output of the action research intervention was the establishment of a Review Team of six private agricultural advisors supported by agricultural industry extension experts and researchers. The Review Team had members from two agricultural industries—cotton, sugar—and a range of advisory business models were represented (e.g. sole trader, Small/Medium Enterprise (SME), rural reseller). Members recognised the Review Team as a locus of collaboration and opportunity for gaining new knowledge due to the diversity of people and industries involved and their attendant skills and perspectives:

> *[The most valuable aspects of the intervention for me were...] Having people with different skill sets and from different areas to add their input.*
>
> *[The most valuable aspects of the intervention for me were...] Cross-collaboration, valuable project team formed.*
>
> *[The most valuable aspects of the intervention for me were...] Speaking to advisors from other agricultural industries and developing ideas in the process that hadn't been part of the thought process in the past.*
>
> *[The most valuable aspects of the intervention for me were...] Interactions with other industries and knowledge sharing.*
>
> (Members of the Review Team, 15/8/17)

This Review Team is an emergent social network (Schot & Geels, 2007) enabled by the intervention and generated and sustained in the co-design process for the DVA Tool. Members noted the value of this network which was characterised by a diversity of people and skills represented:

> *[It was valuable...]Having outside people with different skill sets involved to come in and help us with building the evaluation framework.* (Review Team member 6, 9/1/18) *People who were involved in the project from other industries were good to work with and was great to share knowledge amongst those businesses outside the sugar industry*. (Review Team member 2, 18/1/18)
>
> *[I valued]…the involvement with universities and trialling Precision Agriculture on ground. And creating contacts and a network for better outcomes.* (participant 1, 8/3/17).

A key role in the emergent social network of the Review Team is the Project Officer in the intervention. She used her current networks to source potential participants in the project and interacted regularly with Review Team members both face-to-face and remotely to ensure they were provided with adequate support and felt connected to the process. This innovation broker (L. Klerkx & Leeuwis, 2008) capacity was a key function of the Review Team network. As s/he was able to facilitate linkages amongst the participants and perform a range of tasks such as administering communications among members, convening face-to-face interactions (i.e. workshops) and fostering learning (Laurens Klerkx et al., 2009: 413)

A learning process for advisors to engage with smart farming

The fourth key output of the action research intervention in smart farming was a DVA Tool for Agricultural Advisors (Table 6). As a result of the March 2017 workshop, participants agreed that the proposed activities (see Table 4) could be summarised in an approach to explore the 'value proposition' of smart farming technologies within agricultural advisory businesses. Therefore, at a subsequent workshop on 14/15 August 2017, members of the Review Team of six expert advisors co-designed such an approach in the form of a *DVA Tool for Agricultural Advisors* (the Tool). The aim of this Tool is to support advisors to self-assess the 'value' (the benefits, risks and opportunities) of a smart farming technology to their businesses.

In group discussions at the two day-workshop, Review Team members iteratively identified a range of 'considerations', 'components' and 'questions' that form the content of the DVA Tool and agreed that these could be best presented in an Excel spreadsheet. See Table 6 for a sample of the Tool which covers the Technology Considerations related to investment in a digital technology for advisors. To test the function and relevance of the Tool, members then identified a range of smart farming technologies as case studies, for example, drones, new software and new systems for data integration (see Table 5 for details of the six case study technologies). Over a four month period from August to December 2018, they then used the DVA Tool to evaluate their case study technology in the context of their businesses.

Table 5. Smart farming technologies selected as case studies to test the Participatory Technology Assessment Tool (DVA Tool) for Agricultural Advisors

Smart Technology Case Study
1. Adoption of SST Sirrus Software with irrigated cotton grower clients
2. Import and export of data to and from vehicle on-board computer systems
3. The implementation of spatial software systems across the Herbert cane industry
4. Streamline digital farm management planning processes
5. Weed identification and mapping using weed Information Technology- type software on drones
6. Looking at the capacity for drones to replace All Terrain Vehicles and/or motor bikes in our business

Table 6. Sample of the Digital Value Assessment Tool for Private Agricultural Advisors

Consideration	Self-Assessment Questions
TECHNOLOGY *What is the technology and does it fit within our businesses?*	What is the capability of this technology? What is the job we want the technology to do? *Will it address the issue/goal we have defined?* Is it fit for purpose? Do we really need this technology? What problem are we addressing with this technology? Are there other service providers offering this technology? Have you fully evaluated alternative supply of this technology? *(i.e. has an assessment of market/economics/support already been done?* Are there alternative tools or services available? Is it user-friendly? (i.e. *Evidence from others regarding its use. How much time does it take to operate/clean etc.?*) *How well can the technology be shared with customers? i.e. how can data be transferred to customers?* Do you need extra training to implement the technology? Will the technology work for all users under a range of circumstances? Can the technology be integrated into your current business advisory system?

Advisors' capacity to engage with smart farming was enhanced by use of the DVA Tool

Evidence from reflections of Review Team members on the process of co-designing and applying the DVA Tool demonstrates that learning occurred in multiple dimensions (Schot & Geels, 2007): at the individual level of learning about the benefits and risks associated with a particular smart farming technology; and, at the level of collective learning about the value of the action research intervention process for enhancing advisors‘ capacity to engage with smart farming. For example, members commented on how the Tool supported them to address the full range of considerations relevant to their case study smart farming technology beyond just the technical and economic considerations—e.g. social license, legal, community, environmental, human and market.
As one person reflected:

> *There were a lot of things that we [Review Team members] had not thought about prior to having built this Tool such as the maintenance of the machine, depreciation, returns on investment, and some of the social things such as the extension and feel from the growers to make the change to use the technology.* (Review Team member 2, 18/1/18)

Another person commented on how the Tool has enabled a strategic process of deliberation and decision making about the benefits, risks and opportunities related to technological innovation:

> *This [the Tool] gave me a process to 'walk' through, step-by-step; where I could think about all the things that are in the Tool and what impacts the technology would have, what ramifications it might have, what return on investment we would get from it [soil mapping] technology…* (Review Team member 3, 18/1/18)

Review Team members also indicated that the DVA Tool provided a new set of routine considerations related to smart farming technology and recognised the importance of these to their future business practices:

> [the Tool has...] *Given us good direction and [a] set of questions to work through that actually look at the viability of it [smart farming technology]; rather than just sitting down and working out the economics from the get go and seeing if it will fit within our business.* (Review Team member 6, 9/1/18)

The Tool has allowed me not just to look at the cost analysis,...but also the legal ramifications, the information around IP [intellectual property] and who owns IP, where to go to source this information and evaluate it a bit more rigorously. We [advisors] all tend to do just the costs but what are the other things behind it? For me [in my advisory business], it could be staff savings, time savings?...(Review Team member 4, 18/1/18)

The co-design process of the DVA Tool generated learning outcomes for advisors by virtue of the different advisory business types, industries, perspectives and ‚problem solving' approaches represnted in the intervention. By engaging openly with people from within and outside of their own agricultural industries with different skills and knowledge for innovation, these outcomes were enabled:

It [the co-design process of the DVA Tool] allowed for a wide range of varying experiences [to be drawn on] and peer feedback during [its] development. (Review Team members, 15/8/17)

They [participants from other agricultural industries] had different issues and different problem solving so was good to talk to them and work through some of the issues we are facing. (Review Team member 2, 18/1/18)

[I] Found the project [action research intervention] to be a very good process for developing the Tool. [I] Found it to be very interactive and inclusive of everyone's ideas and I think that by using this approach— brainstorming sessions with all the people—I think this has developed some really good outcomes. (Review Team member 5, 13/12/17)

The DVA Tool also supported Review Team members to communicate with other key innovation actors about the benefits and risks of smart farming technologies, as one person noted:

It [the DVA Tool] has allowed me to work right through from the business case, present it to the Board [of my organisation] and look at the pros and cons [of the soil mapping technology]. So, it [the Tool] actually gave me a process to work through and think and walk my Board through it. (Review Team member 3, 18/1/18)

The DVA Tool described here can be broadly understood as a decision support tool (DST). DSTs are widely recognised as having a role in supporting transitions and practice change in agriculture, however there has been lower than expected uptake of many available examples (Rose et al., 2016) including in Australia (Hochman & Carberry, 2011). Factors impacting the effective design of DSS/Ts have been identified including the relevance to user, ease of use, performance, trust and farmer-advisor compatabiity (Rose et al., 2016). These factors represent desirable 'characteristics' of a DSS/T and are suggested as a guide to assessing tool 'quality' (Ibid; 173). Jakku and Thornburn (2010) have argued that DSS/Ts can be understood, not just as instrumental devices or techniques, but as 'boundary objects' through which different meanings and knowledge/s can be negotiated and shared. We suggest that the DVA Tool we describe here is such a 'boundary object' (Star & Greismer, 1999) that emerges from and enables creative exchanges between different advisors in the Review Team and with other people in their businesses. However, the Tool does more than support cognition; it also enables action through the re-configuration of advisors' practices in new routines of self-assesment of technology. As a working boundary object it is both performed in and performative of the sets of emergent practices of advsiors as they address the challenge of 'doing' smart farming together. For example, the Tool co-design process supported Review Team members to both understand its various 'uses' and 'applications' as well as recognise its role in 'formalising' their current practices and 'justifying' and guiding their future actions:

The Tool can be used by multi-commodity groups.

[the Tool and intervention] Allowed for real-world discussions and application of skills and knowledge

Very worthwhile [action research intervention] process to formalise a framework [technology assessment] process that most participants were doing subconsciously.

[the Tool] Formalised what had previously been an 'ad hoc' process [of advisors assessing smart farming technologies]. [It] Results in quantifiable justification for action [by advisors and their clients].

(Members of Review Team, 15/8/17)

The Tool will be useful in the future to address other issues that come up. (Review Team member 2, 18/1/18)

Understanding the DVA Tool as a boundary object helps us to recognise its role as part of the strategic niche innovation dynamics of visioning, learning and networking. This role is not merely as a static repository of information or data related to the digital technology case studies that the advisors in the Review Team completed. It includes its role in supporting advisors to both think and act differently for new responses to smart farming innovation challenges. As a result of using the DVA Tool, advisors reported on the formation of new connections, new decisions and new knowledge for adaptation of (Higgins et al., 2017) their smart farming practices.

Next steps towards a typology of innovation challenges and responses of advisors in smart farming

In analysing the outcomes of the six case studies in Trial 2, we identified a set of different types of response/s that the pTA process and the application of the DVA Tool enabled. These responses can be summarised as: the ability to identify the 'value proposition' for investment in digital tools/services for advisors' businesses; demonstrating 'value' to the client of digital agricultural technologies; enhanced capacity, including confidence, credibility and creativity, to manage risks and pursue benefits of digital technologies; and, strengthened engagement with clients. By further understanding and recognising these different types of responses, we can characterise the smart farming innovation challenges for different advisory businesses and how these can be productively and strategically addressed through interventions (such as the one detailed here) and policy. While others have recognised the need to meet the challenges of transitioning to smart agricutlural business and production models and capture value from digital technologies in Australia (Trindall et al., 2018{Darnell, 2018 #2169)}, the role of private sector extension in achieving this has not been examined.

Members of the Review Team noted how they would know if the DVA Tool had helped to build advisor capacity to engage with smart farming beyond the scope of the action research intervention:

If it [the Tool] is adopted and used by industry.
If it [the Tool] works and others adopt/utilise it.

[If a] Private advisor has made an informed decision about whether a digital technology of interest is of value [to their business] (Members of Review Team, 15/8/18)

This will be tested as part of the Future Action Phase (see Table 1) of the intervention describe here. The DVA Tool is being peer reviewed by another group of six private agricultural advisors in May/June 2018. With additional data from this phase, we will develop an emergent typology of advisory businesses and relevant innovation challenges related to their effective engagement with digital tools and services. Such a typology will contribute to both agricultural industry and advisory services capacity to engage with digital technologies as it will allow them to determine priorities for professional development, investment in decision support and governance approaches to enable collaboration.

Table 7: Summary of Outcomes of Digital Value Assessment Case Studies

Name:	Private Advisor 1	Private Advisor 2	Private Advisor 3	Private Advisor 4	Private Advisor 5	Private Advisor 6
Advisory Business Type	Small business	Small business	Rural reseller	Medium business	Small business	Small (family) business
Outcome of use of DVT tool	Developed smartphone App to remotely extract data from machine (e.g. tractor) to a central database through the cloud.	Use of DVA Tool enabled the realisation of an integrated software platform (SST-CIRRUS) which agronomists, farmers and farm managers can use.	Used DVA Tool to research the use of new services from drones. Economic feasibility confirmed. DVA Tool will be used to discuss potential for investment with business owners.	Used DVA Tool to construct a business case about the purchase of a Duel EM machine to take to the [company] Board. Based on the business case, the [company] Board decided to invest in the software.	Use of DVA Tool showed that drones would not work for weed identification due to the geographical area that they would need to fly. Technical and legal issues identified and decision made to investigate drone use over smaller areas.	Implemented use of software for spatial data analysis into advisory service delivery. Used the DVA Tool to discuss application of the software to farm decision making with client.

Conclusion

The action research intervention described here enhanced the capacity of agricultural advisors to engage with smart farming through: determining and enacting advisors' expectations and visions for this engagement; developing new social networks for advisors; and supporting advisors to learn together through the co-design of a Digital Value Assessment Tool to assess challenges and opportunities of smart farming technologies. We have shown how the three niche innovation processes of 'visioning', 'network development' and 'learning' can support advisors to engage with new smart farming challenges in ways that strengthen their professional connections, add to their skills base, credit their expert judgements and build new knowledge of their own and their clients' businesses. The potential for niche innovation to enable new and effective responses to key challenges of agricultural innovation, such as engagement in smart farming technologies, lies in the capacity for people and institutions to work together in ways that support new forms of learning (European Parliamentary Research Service, 2016: 25; Paschen et al., 2017) and network building. There is a role for agricultural industry bodies and R & D institutions to support niche innovation processes by engaging with their constitutents, including advisors, on how to harnass and mobilise diverse skills, knowledge/s, materials and representations for agricultural innovation. Rather than baulking at the apparent messiness (Law, 2004) of diverse, complex and uncertain practices in agricultural innovation, we also seek to recognise that practices coalesce in particular boundary objects (such as decision supoprt tools in agriculture.) These 'objects' contain strategic possiblities for translation between, and mobilisation of, disparate people, their knowledges, institutions and resources and hence create avenues for effective action (or 'innovation journeys', (Schot & Geels, 2008) in a digitally disrupted world.

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