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Research paper

Supporting and practising digital innovation with advisers in smart farming

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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 in the future. For farm advisers, engaging in smart farming involves managing the proliferation of new forms of information, new knowledge and networks and new technical devices that produce digitised representations of farm performance. The nature and effects of digital practices in particular poses challenges for farm advisers as they seek to understand how digital tools and services can be integrated into their service delivery for improved farm decision making. In this paper we present insights from a co-design process with private farm advisers and ask: What enables farm advisers to engage with digital innovation? And, how can digital innovation be supported and practiced in smart farming contexts? Digital innovation presents challenges for farmers and advisers due to the new relationships, skills, arrangements, techniques and devices required to realise value for farm production and profitability from digital tools and services. We show how a co-design process supported farm advisers to adapt their routine advisory practices through recognising and engaging with the social, material and symbolic practices of digiware in smart farming. We demonstrate the need to recognise 'digiware as constituted in and by heterogeneous practices from which possibilities for digital innovation emerge. These possibilities include the increased capacity of farm advisers to identify the value proposition of smart farming tools and services for theirs and their clients' businesses, and the adaptation of advisory services in ways that harnass and mobilise diverse skills, knowledge/s, materials and representations for translating digital data, digital infrastructure and digital capacities into better decisions for farm management.

1. Introduction

Within smart farming contexts, the process of digital innovation is critical to the capacity for farmers and farm advisers to realise the benefits of new technical devices and digital capabiliies to produce new products, services and on-farm production and profitability outcomes. In the Australian sugar industry, 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 et al., 2007). We define smart farming as the use of information and communication technologies (ICT) to identify, monitor, analyse and represent spatial characteristics of agricultural production in digital formats (such as digital data and devices). The overall aim of smart farming is to support decision making for improved agricultural productivity. Scholars and practitioners have noted that smart farming represents a significant innovation challenge for farmers and farm advisers related to three key areas: information systems management for data collection, storage, interpretation and dissemination; precision agriculture for management of spatial and temporal variability of farm scale processes using various techniques and devices; and, automation and robotics including artificial intelligence (Smart Farming Thematic Network, 2019). Engaging in these areas for farmers and advisers involves managing 'new combinations of digital and physical components

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to produce novel products or services '(Yoo, Henfridsson et al. 2010) as well as adapting businesses (Darnell, Robertson et al. 2018) to embed digital information and communications technology (ICTs) into traditionally non-digital products and services. This is the work of digital innovation.

While innovation is well theorised by Agricultural Innovation Systems (AIS) scholars (Darnhofer et al., 2012; Hall, 2007; Klerkx et al., 2012b), the nature and dynamics of digital innovation in agriculture have received relatively little attention to date. Digital innovation involves managing social (e.g. 'networks'), material (e.g. technical devices) and symbolic (e.g. 'contents 'or 'data') elements (Farrell and Weiser 2003 in Yoo, Henfridsson et al. 2010) for the development and management of new digital products and services. While farmers are currently grappling with the challenges of digital innovation in smart farming contexts, so too are other key actors in pluralistic AIS, such as private farm advisers. The role of private farm advisers is known to be important in innovation in such systems, including digital innovation (Eastwood, Klerkx et al. 2017), as they work to 'broker' (Klerkx and Leeuwis, 2008a,b,c, Klerkx, Hall et al. 2009; Klerkx et al., 2012a) or 'intermediate' (Klerkx and Leeuwis, 2008a,b,c, Kivimaa et al., 2018) between farmers and new sources and types of information, knowledge, skills, techniques and technical devices in smart farming. For these farm advisers, managing the diversity, complexity and uncertainty of smart farming is an everyday challenge, as for many, the effective implementation of digital technologies is a significant departure from their routine advisory practices (Nettle et al., 2018). The importance of collaboration between private and public extension roles in smart farming contexts has been recognised as critical to manage this challenge including the different scales of activity, new skills development and institutional arrangements involved (Eastwood, Klerkx et al. 2017). However, there is little known about what supports farm advisers to engage with digital innovation and how their service delivery could be enhanced as a result of stronger engagement in smart farming.

Co-design is a process of 'joint inquiry and imagination, involving the organisation of iterative processes of problem setting and solution finding '(Steen, 2015: 289). This process has grown in importance over recent years as the complexities and uncertainties of innovation for addressing complex issues of sustainability and technological development are recognised and addressed (Sanders and Stappers, 2014; Storni et al., 2015). In this paper we report on a co-design process involving private farm advisers and ask: How can digital innovation be supported and practised in smart farming contexts? Digital innovation presents new challenges for advisers due to the new relationships, knowledge, skills, transactional arrangements (Wiseman et al., 2018) and techniques and devices required to realise value for farm production and profitability from digital tools and services. We show how a co-design process enabled advisers to assess the 'value proposition' (Jago et al., 2013) for investment in digital tools and services for their businesses. By 'value proposition' we refer to a consideration or review of the costs and benefits that a digital tool or service can produce. This is a matter of perceived 'value' and how this value can be represented and communicated within advisory and farm businesses. We found that one part of the co-design process, the development of a Decision Support Tool (DST), supported private farm advisers to increase their capacity to engage with digital innovation in smart farming contexts. In co-creating and applying this DST, farm advisers recognised the systemic and diverse nature of digitial innovation practices required to realise the value of digital technologies. They also demonstrated unique innovation practices that we characterise together as 'digiware'.

2. Conceptual framework

It is well recognised by scholars in the fields of innovation studies (Geels and Schot, 2007; Schot and Geels, 2008) and Agricultural Innovation Systems (AIS) (Geels and Schot, 2007; Leeuwis and Aarts, 2011; Klerkx et al., 2012b) that innovation emerges from the strategic coordination of diverse people and their knowledge/s and practices, institutions, materials, regulation mechanisms and other factors at different scales of activity. These entities and processes have been codified orginally by Dobrov (1979) in the widely used conceptualistion of innovation which identifies process elements of 'software, orgware and hardware '(Hekkert et al., 2007; Leeuwis and Aarts, 2011). In this framing, 'software 'includes 'concepts attitudes, skills and knowledge'; 'hardware 'is the 'technical means' of innovation including machines, materials and computers; and, 'orgware 'is the 'policy/power' or institutional arrangements including laws and rules and organisational structures (Dobrov, 1979: 82). Here we apply this heuristic to understand digital innovation as a feature of smart farming.

To address the question of 'what enables farm advisers to engage with digital innovation?', we focus on 'doing 'digital innovation as part of farm advisory practice. We take inspiration from social constructivist practice theory developed by Elizabeth Shove and colleagues (Shove, 2010; Shove and Walker, 2010), which emphasises the different, everyday practices that both constitute, and emerge from, innovation efforts. Shove and Walker (2010) 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). By paying attention to all forms of practice, they suggest that the dynamics of innovation processes can be revealed and the potential for sustaining novel and effective new routines of practice enhanced. This includes: '…forms of practical know-how, bodily activities, meanings, ideas and understandings, as well as to materials, infrastructures and socio-technical configurations' (Ibid: 476). Therefore, to fully attend to the heterogeneous nature of innovation practices, we also draw on a typology of 'technologies' (or what we call 'practices') of knowledge production' proposed by science and technology studies (STS) scholars Shapin and Schaffer (1986) in our analysis. This typology emphasises the importance of *symbolic* or representational practices, alongside *material* and *social practices* in technoscientific knowledge production and innovation. Arguably the 'orgware, hardware, software' heuristic includes the dimension of representational or symbolic resources in the category of 'software'. However, we contend that this is not explicit enough to account for the unique scope and pace of symbolic practices in digital innovation in smart farming contexts.

Symbolic practices in innovation include the practices of creating and mobilising representations of materiality and sociality in words, images and numbers. We posit that symbolic practices are particularly important in the case of digital innovation in smart farming because, compared to conventional technologies, ICTs and their attendant digitisationpractices, allow for the proliferation of representations of farm production resources and attributes on new scales, at new speeds and for an expanded audience in new times and places. Carolan (2018) has defined such phenonmena as: '… held together by practices, communities, and/or socio-legal structures and habits of the mind, like code and digital (farming) techniques' (p. 746). To date, the impacts and implications of the scope and ubiquity of digitisation practices and related digital data curation and management needs of farm advisers (and farmers) have been underexamined in the published literature.

3. Methodology

This paper describes collaborative research with private farm advisers, industry professionals and researchers from the Australian cotton, sugar and horticultural sectors. It focusses on a co-design intervention to enhance the capacity of private farm advisers to engage with Research and Development (R & D) and commercial opportunities in smart farming.

One methodological response to the innovation challenges associated with new technologies in agriculture has been Participatory Technology Assessment (pTA) (Joss and Bellucci, 2002; Geels, 2007) where technology design and development processes involve people such as farmers and farm advisers working alongside technical design

Table 1
Action research activities and data collection.

Phase of co-design process	Research-practice activity	Purpose and outcomes	Timing and location	Participants	Data collected
Phase 1: Establishment Phase	Convene regional Forums on Private Advisory Capacity (in 'Stimulating the private sector for increased returns from R & D in Australian agriculture' project)	Purpose: 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 Outcome: Smart Farming identified as area of research interest for private advisers and others.	March-April, 2016 Gippsland, Vic Adelaide, SA Toowoomba, Qld	150 farm advisers, government, industry and community persons and researchers	Summary of discussions amongst participants scribed. Evaluation questionnaires.
Phase 2: Visioning and Priority Setting Phase	Convene teleconferences to formally establish the Project Team	Purpose: To create a Project Team of agricultural industry extension experts and researchers. Outcome: Project Team established	August-December, 2016	5 (3 agricultural industry extension experts; 1 adviser/facilitator; 1 action researcher)	Minutes of meetings
	Conduct Scoping Workshop on Private Advisory Capacity in Smart Farming (Scoping workshop)	Purpose: To identify a vision and priority issues for building the capacity of private farm advisers to engage with smart farming Outcome/s: Priority issue identified: *determining the value proposition for smart farming technologies to advisors' businesses;* Project Team developed Activity Plan for the action research intervention including: selection criteria for Review Team (RT).	5 March 2017, Toowoomba	Private farm advisors from the cotton, sugar and horticulture sectors (5), government (4) and industry extension experts 2) and researchers (3)	Transcripts of group discussions at the workshop; researchers' written records of facilitated discussions; evaluation questionnaires.
Phase 3: Decision Support Tool (DST)	Establish Review Team (RT) of private farm advisors	Purpose: To engage key private farm advisers with and interest in and commitment to digital innovation in a process to determine the value of smart farming technologies to advisory businesses. Outcome: Collaboration by Project Team on RT workshop design and outcomes.	June-July 2017	Review Team of farm advisers from cotton (3) and sugar (3)	Background analysis of RT members' businesses;
	Co-design workshop 1	Purpose: To co-design a DST for determining the value of smart farming technologies (tools and services) for farm advisers. Outcome/s: Development of a draft participatory Technology Assessment Framework (PTAF) for Agricultural Advisors (the Digital Value Assessment Tool (DVA Tool); development of a smart farming case study plan for individual advisers in the Review Team to assess the 'value' of a smart farming technology to their businesses.	14/15th August, 2017, Toowoomba	Review Team of farm advisers from cotton (3) and sugar (3) and Project Team members (5)	Workshop activities recorded in: researchers' notes of facilitated discussions; transcriptions of facilitated group discussions; evaluation questionnaires.
	Review Team teleconferences	Purpose/s: To discuss Review Team reflections on the application of the DVA Tool in their individual smart farming case studies; to refine the DVA Tool based on application in six smart farming case studies; to provide support to Review Team members in the conduct of their case studies.	19 October 2017 15 December 2017	Review Team of farm advisers from cotton (3) and sugar (3) and Project Team members (5)	Minutes of meetings
	Co-design workshop 2	Purpose: To discuss Review Team reflections on the application of the DVA Tool in their individual smart farming case studies. Outcomes: Refinement of the DVA Tool based on application in six smart farming case studies; feedback and insights collected on the co-design process and its outcomes related to capacity development of advisers and engagement with digital innovation.	12 March, 2018, Toowoomba	Review Team of farm advisers from cotton (3) and sugar (3) and Project Team members (5)	Workshop activities recorded: In notes of facilitated discussions In audio recording (transcribed) Evaluation questionnaires Video interviews with Review Team members (transcribed)

(*continued on next page*)

Table 1 (*continued*)

Phase of co-design process	Research-practice activity	Purpose and outcomes	Timing and location	Participants	Data collected
Phase 4: Peer Review		Purpose/s: To understand the potential for wider application of the DVA Tool; to engage other key extension professionals in the research. Outcomes: Informal, qualitative review of the DVA Tool through structured conversations (face-to-face and by phone)	May-June 2018	Six new private farm advisers. Project Officer.	Written summary by Project Officer of peer reviewers' perspectives on the wider application of the DVA Tool.

experts. Popularised from the 1980s, this methodology is characterised by regular interactions between design experts and these other societal actors in a given context and involve mutual learning to determine the costs and benefits of technology implementation. 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 faciliated interactions between innovation actors in networks supported by the key role of ‘innovation brokers ‘(Klerkx et al., 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 and Bellucci, 2002; Stirling, 2008).

However, while pTA can be a useful way of evaluating a technology in a given context, recent advances in technology design and organisational studies disciplines have promoted the important role of ‘co-design ‘in technology development. This includes promoting principles of: engaging with the diversity of skills and knowledge relevant to a problem context; working with uncertainty and complexity; and, supporting iterative processes of joint inquiry and social learning including collaboration (Binder, Brandt et al. 2008; Storni, Binder et al. 2015). Here we bring these design principles to bear in a case of digital innovation in agriculture.

The action research reported here was undertaken in four main phases: 1) Establishment; 2) Visioning and Priority Setting; 3) Co-design of Decision Support Tool (DST); and, 4) Peer Review of Digital Value Assessment Tool. In Phase 1, three regional forums were conducted to engage people with interests and expertise in smart farming on issues related to capacity building and opportunities for collaboration. As a result of this engagement, the need to build adviser capacity in smart farming was identified as an area for further research. To undertake this research, a Project Team was established involving a Project Officer, action researcher and cotton (1) and sugar industry (2) extension experts.

In Phase 2, an initial Scoping Workshop on Private Advisory Capacity in Smart Farming was convened (see Table 1) involving government and industry extension personnel, smart farming researchers and private farm advisers from the horticulture, cotton and sugar industries. At this workshop, opportunities and constraints for farm advisers to engage with smart farming technologies were identified, along with a set of priority actions for addressing these.

In Phase 3, a smaller group of six participants (private farm advisers working in the cotton (3) and sugar (3) industries) co-designed a process for farm advisers to assess the ‘value’ (i.e. assess the costs and benefits) of digital tools and services to advisers’ businesses. The resultant Digital Value Assessment Tool (the DVA Tool) is a DST in the form of structured decision support framework. The aim of the DVA Tool is to assist farm advisers undertake an assessment of a given smart farming technology in relation to its performance, costs, benefits, relevance, fit and implications for themselves, their clients and their business.Through two co-design workshops and six Smart Farming case studies, participants refined, implemented and evaluated the DVA Tool to identify its utility and applications for supporting farm advisers to engage with smart farming technologies. Phase 4 was an informal Peer Review of the DVA Tool involving six new farm advisers. See Fig. 1 for a diagram of the co-design process activities and outputs.

Research methods used were: semi-structured interviews; meetings and workshop discussions; participatory workshops; and, evaluation questionnaires. Table 1 summaries the research activities in the co-design intervention and the data collected. NVIVO software was used to thematically analyse transcripts of interviews, discussions and researchers’ notes based on the conceptual framework described above. For example, the testimonies and observations of farm advisers at workshops and meetings (see Table 4) were coded against the typology proposed by Shapin and Schaffer (1986) to identify their key social, material and symbolic digital innovation practices.

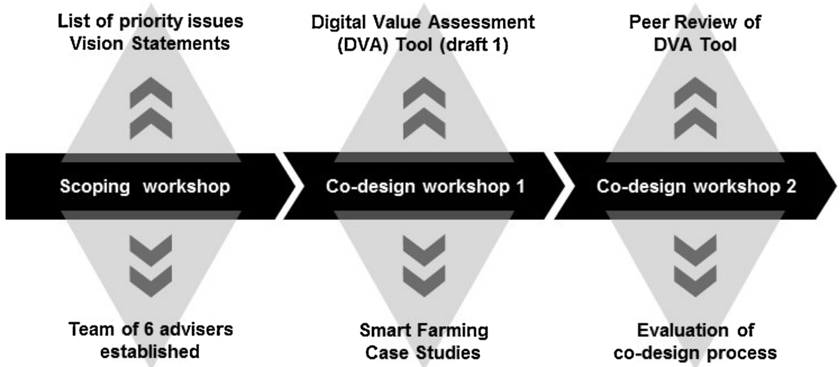

Fig. 1. Activities and outputs from the co-design process.

4. Results

There are three main sets of results from the co-design of the DVA Tool. These are: 1) Outcomes of the priority setting and visioning process; 2) The Digital Value Assessment Tool (DVA Tool); and, 3) Outcomes of six smart farming case studies.

4.1. Outcomes of visioning and priority setting

At the Scoping Workshop, the Project Team facilitated a visioning process (Orlowski et al., 2018) amongst advisers, researchers, industry and government extension experts. Participants discussed and prioritised 'priority issues' and 'actions' related to enhancing the capacity of advisers to engage with smart farming using a deliberative strategic questioning method (called the ORID (Observational, Reflective, Interpretative, Decisional) method (Stanfield, 2000)). They drew on their own expertise and experiences in smart farming and shared ideas and perspectives in both small and large group interactions. The highest priority issue that emerged from the visioning process was: *determining the value proposition of smart farming technologies for advisers' businesses.* Actions to address this priority issue were then co-developed in a brainstorming session where participants recorded their own ideas and shared and discussed them with the larger group. A list of actions (see Table 2) was produced. The actions were further discussed and consolidated by participants who resolved that a process for assessing the 'value' of a smart farming technology to advisory businesses was a desired outcome from the project.

In facilitated group discussions throughout the co-design process, participants noted key aspects of the process such as the diversity of people involved and the different approaches to addressing the issue of digital innovation, for example:

> *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.* (adviser 2, 18/1/18)
> *[The best thing about the co-design process was…] Hearing points of view of a cross section of [advisers from different agricultural] industries to collaborate on ideas.* (Scoping Workshop participant, 8/3/17)

4.2. The digital value assessment tool (DVA tool)

At a Co-design Workshop (1), the Review Team and Project team members discussed and recorded their ideas on what a process to evaluate a digital technology would need to involve. In structured decision making sessions in the workshop, they identified a set of nine 'considerations' for assessing the 'value' of a smart farming tool or service (technology) to agricultural advisory businesses. For each of the nine considerations, they then identified relevant 'questions' and associated 'prompts' to assist advisers to systematically evaluate a particular

Table 2
Proposed actions to address the priority issue of determining the value proposition of smart farming technologies for advisers' businesses.

- 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 advisers, growers and industry.
- Case Study-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 an agricultural industry (i.e. horticulture).
- Develop farm case studies of smart farming technology use and benefit in small teams (i.e. 2 advisers, 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 experience) focussed on digital agricultural advice, test/trial new smart farming technology service delivery on some farms.

digital tool or service. These considerations, questions and prompts were then later arranged by the Project Officer in an Excel spreadsheet to produce what the Review Team called the Digital Value Assessment Tool (DVA Tool). Fig. 2 is a schematic of the DVA Tool which shows the different 'considerations' it addresses. Table 3 provides an example of the questions and prompts associated with the technology considerations in the DVA Tool where 'technology' is the technical device or service being assessed.

The six advisers in the Review Team applied the DVA Tool in an individual digital innovation case study by filling in relevant written responses against the various prompts and questions contained in the Excel spreadsheet. The case studies focussed on the use of: drones for weed identification and crop management (2); computer software applications (1); soil mapping technology (1) and, systems for digital data management. Depending on what digital technology they chose to focus on, this involved a range of digital innovation practices including advisers: researching the costs and functionality of the digital technology; talking to colleagues, technology suppliers and others to gain

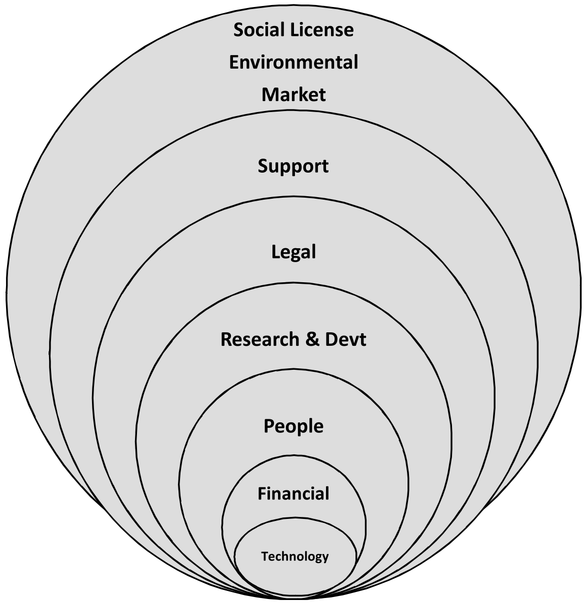

Fig. 2. Schematic of the DVA Tool showing the nine considerations for smart farming technology assessment identified by advisers.

information on licensing, technical specifications and training opportunities related to digital products; consulting with farmer clients on their interest in new services related to the digital technology; creating and managing digital data (e.g. transferring data collected from farm machinery to software) and integrating different digital data sets; learning to use and build new digital infrastructure (e.g. digital platforms for collating and combining digital farm production data); and, in the case of one adviser, using the completed DVA Tool to inform a business case for investment in a new digital techology (see Table 4).

From interviews and teleconference discussions with Review Team members, it is evident that the DVA Tool enabled them to both learn about and take into account the systemic (Ison, 2010) and multi-dimensional (Schot and Geels, 2007) nature of smart farming technologies. For example, one adviser reflected:

> *There were a lot of things that we had not thought about prior to having built this [DVA] Tool such as the maintenance of the [smart farming] 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 [smart farming] technology*. (adviser 2, 18/1/18)

Another adviser commented on how the DVA Tool enabled a process of individual deliberation and decision making about the benefits, risks and opportunities related to smart farming technologies:

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

The DVA Tool also enabled advisers to interact with other key innovation actors about the benefits and risks of smart farming technologies:

> *It [the DVA* Tool*] has allowed me to work right through from the business case [for the soil mapping technology], present it to the Board [of my organisation] and look at the pros and cons [of the soil mapping technology]. So, it [the DVA Tool] actually gave me a process to work through and think about it and walk my Board through it.* (adviser 3, 18/1/18)
> *The best use of the DVA tool is to support communication [with clients and others]*. (adviser 1, 21/2/2018)
> *[The DVA* tool *provides] credibility for your [advisory] business—that you can show [farmer clients] that you've considered all options [to address a smart farming issue]—this goes a long way*. (adviser 2, 21/2/2018)

It also supported them to adapt their advisory practices through strategic consideration of different implications of smart farming technologies. This created efficiencies for their clients' businesses and risk management for their own:

> *The power of the [DVA Tool] framework is that it helps you think about things differently.'* (adviser 5, 21/0/2018).

[The DVA tool] helps you identify areas to investigate. [It provides a…] Great safety net for deciding whether to implement a [digital] technology. Really helps sift and filter and organise. (adviser 3, 21/02/2018).

> *… having gone through the [DVA Tool] process…to see their [farmers'] business operating more effectively and functionally and actually being able to do more with [their] data and link it to other [computer] software.…it [the DVA Tool] enabled data management within their [farmer's] business.* (Adviser 5, 17/2/2018).

Overall the advisers agreed that the co-design process of the DVA Tool had supported them to strategically assess the range of benefits, risks and opportunities of digital technologies for their businesses and to communicate these to their clients:

> *[The DVA too allowed me to…] demonstrate to clients the value proposition [of a digital tool/service*]. (adviser 4, 21/0/2018)
> [the DVA Tool has…] *Given us [farm advisers] good direction and [a] set of questions to work through that and actually look at the viability of it [the smart farming technology]; rather than just sitting down and working out the economics from the get go and seeing if it will fit within*

Table 3
Questions and prompts in the DVA Tool related to 'technology' considerations of a smart farming tool or service.

Questions	Prompts
What is the capability of this smart farming technology (tool or service)?	What is it's technical function? What does it do (technically)? How does it work?
What is the job we want the tool or service to do? (Will it address the issue/goal we have defined?)	Provide statement
Is the tool or service fit -for -purpose?	If yes, what makes it a good fit? If no, what would need to happen or change for it to be a good fit?
Do we really need this tool or service?	Yes/No If yes, then how will it address the issue the objectives/goals? And who will benefit from or use it?
What problem are we addressing with this tool or service?	Statement
Are there other service providers offering this tool or service?	Yes/No If yes, who are they? What is their service?

Table 4
Smart farming case studies conducted by farm advisers.

No	Case Study Description	Case Study Outcomes	Key Issues for Smart Farming Technology Application to Advisers 'Businesses	Outcomes of DVA Tool Application	Digital Innovation Practices
1	Adoption of [XX] [spatial analysis of farm production data] software with irrigated cotton grower clients	More efficient crop scouting with higher data confidence level	Seperated out commercial clients needs and grower clients 'needs	DVA Tool used with clients to assess use and value of integrated software platform	Integration of different computer data infrastructures into a package to augment farm production and performance information for adviser and his/her farner clients
		Streamline data capture and recording	Role of computer software in demonstrating grower compliance with best management practice	All farm records and spatial data feeding into the new system so that information can be used to advise on better crop management decisions.	Liasing with software providers to get historical data for ground truthing
		More even cotton crops due to variable rate application Better defoliation due to more even crops	Contribute to Best Management Plan development	Decision to adapt service delivery by integrating new platform into current practice	Managing and integrating large digital data sets of diverse farm production parameters Negotiating with computer software service providers to access computer software Targeting use of digital imagery and GPS to streamline digital data collection on farm
2	Import and export of data to and from vehicle on-board computer systems	Reports compatible with BMP[a] requirements	Tractor digital data can be extracted directly into computer software (third party required to extract and provide data)	Specifications and digital infrastructure developed to turn machine data into usable data by building a smart phone app to download dta in the machine to a database Built	Finding ways to extract and interpret farm production digital data collected automatically by farm machines
		Analysis of information against other relevant datasets Benchmark production		Yield maps produced as part of agronomist's advisory service delivery	Managing large and multiple digital data sets of farm production parameters Identifying, managing and curating digital data required for adviser and grower use Creating digital data infrastructure (i.e. smartphone app) to enable transferal and accessibility of yield data Using USB Wi-Fi to download machine (i.e. tractor) digital data and avoid third party involvement (i.e. from machinery developer) Negotiating digital data ownership (i.e. some data encrypted by commercial tractor company)
3	Viability of dual Electro Magnetic (EM) machine for soil (spatial/ digital data) mapping	To assess the use of EM machine including new service delivery options	Maintenance of the machine	Business case developed for new advisory service delivery based on the EM technology	Developing new digital soil mapping capability and skills
			Depreciation	Investment decision made and EM technology integrated into advisory services	Demonstrating use of EM machine to Board members for investment decision
			Return on Investment Extension support required Appetite for change amongst growers		Collecting, analysing and integrating digital data on farm production spatial parameters into whole farm planning advice
4	Streamline digital farm management planning processes	Reduce time spent to create farm NMPs[b] by harvest round and output as pdf and prescription maps, order sheet	Legal ramifications	New computer software (informal) licensing arrangement with software product developer	Using new computer software to interpret growers 'digital data from automated tractors
			Labour and time savings implications in business	Service delivery will be adapted to apply new digital capabilities in farm management advice	Creation of digital database with increased capacity is planned
			Workplace Health and Safety		Analysing digital data for farmer decision making which raises issues of negotiating data ownership between advisers and farmers
			Information around Intellectual Property and data ownership and controle		Integrating digital soil data and yield imagery digital data for the creation of fertiliser prescription maps and whole farm Nutrient Management Plans

(*continued on next page*)

Table 4 (*continued*)

No	Case Study Description	Case Study Outcomes	Key Issues for Smart Farming Technology Application to Advisers 'Businesses	Outcomes of DVA Tool Application	Digital Innovation Practices
5	Weed identification and mapping using weed Information Technology- type software on drones	Hardware and software that can be utilised with drones to accurately measure and identify weed species and densities and develop a decision making matrix/platform using generated digital data	Technical feasibility of drone application to problem context explored Legal/regulatory arrangements and their implications for drone use Economic cost/benefit analysis of equipment (i.e. drone) purchase	Decision not to invest due to issues of drone technology not being able to address geographical scale required Poor quality imagery	Aligning business strategy and new digital service delivery with technical attributes of the drone technology requires more work Investigating technical aspects of drone capability (i.e. flight range and cameras) to ascertain potential for digital data collected to inform farm management decisions Understanding what kind of digital data can be effectively collected on weeds
6	Capacity for drones to replace All Terrain Vehicles (ATVs) and/or motorbikes	Finding a potential replacement for motorbike/ATV use in agronomy practices due to pending changes in ATV legislation that will heavily restrict their use	Feasibility of drone use for weed scouting (not identification) Intergration of drone data with farm management (spatial) computer software	Service delivery feasibility explored and confirmed (investment decision not yet made)	Adapting use of the drone (already purchased but underutilised) to generate useful digital data for farmer clients (new digital service delivery) Trialling drone capacity to support improved farm decision making in agronomic practice Further demonstrating new service delivery opportunities through drone application in trials

[a] Best Management Practice.
[b] Nutrient Management Plans.

our business. (adviser 6, 9/1/18)
The DVA 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 [farm advisers] 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… (adviser 4, 18/1/18)
[The DVA tool] helps you identify areas to investigate. Great safety net for deciding whether to implement a technology. Really helps sift and filter and organise.(adviser 3, 21/2/18).
[The DVA tool provides] credibility - that you can show [clients] that you've considered all options - it goes a long way. (adviser 2, 21/2/18)

An informal peer review of the DVA Tool was conducted by the Project Officer and involved six farm advisers from the cotton and sugar industries. In this phase, the objective was to ascertain whether others outside of participants in the co-design process described here perceived the utility and potential applications of the Tool. As a result of face-to-face and telephone discussions with people in the review process, the Review Team and Project Team members agreed that the DVA Tool did have potential for wider application and are now exploring new opportunites to further refine and expand it including the development of a web-based interface or smartphone application.

4.3. Outcomes of smart farming case studies

Six smart farming case studies were conducted by private farm advisers to understand the potential of different digital tools and services to create value for their businesses. Table 4 summarises these and includes: a brief description of the case study; outcomes from the case study; the key considerations identified by advisers; key issues for smart farming technology application to adviser's business; the outcomes of application of the DVA Tool; and, the digital innovation practices applied in each case study. However, it does not include an output for each case study because the result of applying of the DVA Tool is not a single quantified figure as for some other DSTs for new technology (for example, the ADOPT Tool (Kuehne, Llewellyn et al. 2017)). The output/s is a set of qualitative and quantitative responses to the prompts in the Tool; in written format, and collated in an Excel spreadsheet. For their case studies, advisers used the spreadsheet to record their responses to prompts of the DVA Tool and some chose to share these with the Project Team and Review Team members at a second co-design workshop (see Table 1). Others reported verbally on their responses. Review Team members analysed and interpreted the responses they had made in an informal, individual deliberation on the overall perceived 'value 'of investing in the digital technology under consideration in their case study.

5. Discussion

5.1. Co-design supported innovation in a smart farming context

The co-design process described in this paper supported private farm advisers to evaluate the costs and benefits of digital technologies for their businesses. Key co-design elements of this process were: the visioning process which supported advisers to deliberate with other extension professionals and identify the priority issues and agreed actions for engaging with smart farming, and the co-creation of a DST, the DVA Tool, which supported advisers to understand and act upon the implications of applying new digital tools and services in their businesses.

The visioning process consolidated the mutual interest and commitment of participants to addressing the agreed priority issue of adviser capacity to engage in digital innovation through a collaborative process to understand the ‚value proposition 'of digital technologies for advisory businesses. By agreeing on this priority issue and associated action, advisers and others resolved to work together to address an innnovation challenge that is widely recognised but notoriously difficult to progress. While smart farming technologies are acknowledged as having a role in supporting transitions and practice change in agriculture, there has been lower than expected uptake of many available examples (Eastwood, Chapman et al. 2012; Kerselaers, Rogge et al. 2015; Rose, Sutherland et al. 2016) including in Australia (Hochman and Carberry, 2011).

Subsequently, participants in the co-design process, created the DVA Tool (see Fig. 2), to support farm advisers to identify the costs and benfits of smart farming technologies for their businesses. Smart farming requires advisers to access, apply, and integrate different digital technologies within their businesses (Eastwood, Ayre et al., 2019). This adaption of their routine advisory practices requires advisers to coordinate and align understandings, arrangements and resources to do the work of digital innovation. By applying the conceptual framework of 'orgware, hardware, software' (Dobrov, 1979), we demonstrate that the DVA Tool supported advisers to do this digital innovation work by enabling them to both recognise and act upon the systemic nature of digital innovation in smart farming. Systems scholars suggest that complex problems of sustainability and human endeavour require approaches to analysing problems and creating solutions that account for interactions and emergence of diverse components and effects in sociotechnical systems (Collins and Ison, 2010; Ison, 2010). The nine considerations of the DVA Tool encompass 'hardware', 'software' and 'orgware' (Dobrov, 1979) innovation domains symmetrically (see Fig. 3) thus prompting advisers to comprehensively consider the range of characteristics of a particular digital tool or service and what these might mean for their businesses.

Jakku and Thorburn (2010) have insightfully argued that DSTs can be understood, not just as instrumental devices, but as 'boundary objects 'through which different meanings and knowledge/s are negotiated and shared. We suggest that the DVA Tool we describe here is such a 'boundary object' (Star and Greismer, 1999) that emerged from and enabled creative exchanges between different farm advisers and with others, including their farmer clients. It enabled action through new routines of self-assesment of digital technology by advisers (Fig. 4).

5.2. Practicing digital innovation in smart farming contexts

In a second analytical step in this research we applied the typology of knowledge practices of (Shapin and Schaffer 1986) to identify the digital innovation practices of advisers enact to capture the benefits and realise the promise of digital tools and services (see Table 4). This analysis highlights the scope and diversity of innovation practices demonstrated by advisers in conducting their digital innovation case studies. Material practices of digital innovation from the case studies included: purchase and use of: drones and digital cameras; sensors on machinery, in paddocks and on animals; digital data storage and transfer devices such as USBs and computer tablets; automated farm machinery and equipment that generates, transfers and stores digital data for crop yield and soil heath monitoring and ameiloration including variable rate application of fertilisers and pesticides/herbicides (i.e. EM machines). Social practices included: advisers sharing, managing and interpreting digital data both on their own and with their farmer clients, and commercial actors (i.e. computer software suppliers); new institutional relationships including the roles of agricultural industry bodies, (computer) software developers/suppliers and others with intermediation roles (Klerkx and Leeuwis, 2008a,b,c) in creating, supplying and curating digital data; and, new skills for acquiring, interpreting, storing and combining digital data of current and future (i.e. through forecasting) farm production. Symbolic practices related to digitisation of farm attributes included handling, managing and using digital data and data infrastructures to support farm decision making.

In all the digital innovation case studies, advisers were grappling with the effects and features of digitisation including digital data collection, curation, application and interpretation. For them a key challenge of digital innovation is digital data management for farm decision making (as noted in Table 4) which involves: practices of developing new data infrastructures; new knowledge and skills; and, new transactional relationships and arrangements. For example, advisers noted that they are faced with investment decisions about digital data infrastructure which provides ways to integrate, manage and interprete digital data. This involves engaging with (computer) software for digital data transmission, sharing, and analysis (i.e. digital databases), as well as practices of uploading and downloading data and making it deciferable and accessible. Cushing et al. (2005) identify such challenges as characterising a 'problem space' in 'eco-informatics' where resource managers (which could include farmers and their advisers) must manage 'data presentation' problems such as: geographic data gaps where data sets are disjunct and have spatial and temporal gaps; lack of identified tools to support digital innovation; and, indicator problems (such as aligning complex farm production parameters measured with value and relevance to farm decision making) (p. 381). Two particular issues of digital data management highlighted by advisers in this research were commercialisation and ownership of farm information including Intellectual Property rights (see Table 4). These issues both generate power effects as large commerical entities in smart farming capture, amass, utilise and re-distribute so-called Big Data (Wolfert, Ge et al. 2017) from technologies purchased by farmers including automated farm equipment and sensing systems. As science studies scholars remind us, data doesn't come from 'nowhere' (Bowker and Gitelman, 2013)—and digital data is no exception. [Digital] Data itself; '…produces and is produced by the operations of knowledge production more broadly' (Ibid.) Advisers in this study expressed concern about how to maintain control of their digital data as they seek to augment their service delivery by engaging with smart farming.

A second key challenge of digital innovation for advisers was revealed through use of the DVA Tool: the integration of smart farming devices with (computer) software platforms. The interoperability of measuring and sensing devices (e.g. case study devices used in this study such as drones, tractors, EM machines), with relevant (computer) software, relies on methods for coding and translating farming systems attributes into digital forms that can be stored, analysed and (re)combined for particular purposes, including machine learning. In their digital innovation case studies, advisers demonstrated new practices of configuring the connections between digital devices and (computer) software in order to accumulate and present digital data in useful representations upon which farm production decisions can be made. Examples include the production of Best Management Practice reports (Case Study 1) and Nutrient Management Plans (Case Study 4).

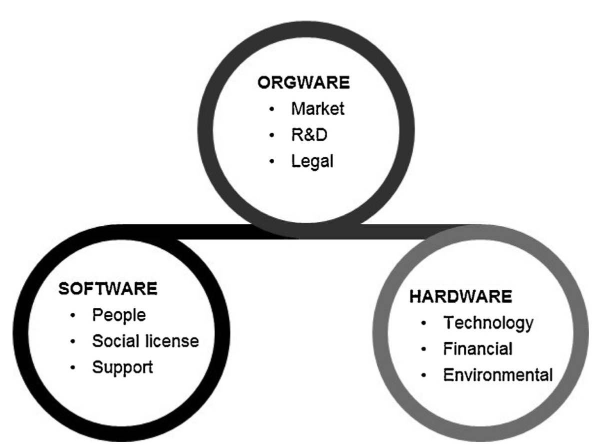

Fig. 3. Considerations for smart farming technology assessment in the Digital Value Assessment Tool categoried according to the Dobrov (1979) framework.

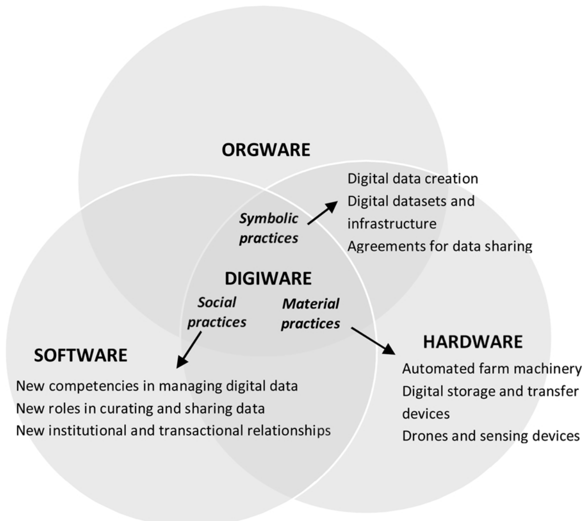

Fig. 4. The conceptualisation of digiware as an innovation domain in smart farming.

5.3. Digiware: an innovation domain in smart farming

From this research it is evident that advisers (along with farmers) currently perform diverse and complex digital innovation practices in smart farming contexts. Arguably, these digital innovation practices identified here can be readily categorised according to the relevant innovation domains in the Dobrov (1979) innovation framework. For example, the digital innovation practices of 'hardware' include managing technical (digital) devices (e.g. drones, tractors, EM machines etc). The digital innovation practices of 'software' include the skills and knowledge of using (computer) software to organise and analyse digital data and the social networks of advisers, (computer) software developers, researchers, growers and others with whom they explored and negotiated new advisory services. And, the digital innovation practices of 'orgware' includes the sets of regulations, proprietary arrangements and agreements related to new technical devices, (computer) software and data management platforms. However, we contend that there is a unique aspect to the digital innovation work of advisers in smart farming contexts that is currently not adequately accounted for in the Dobrov (1986) framework; this is the symbolic practices of digitisation that produce digital data and its effects.

The symbolic practices of knowledge production (Shapin and Schaffer 1986) for digital innovation are arguably different in form and scope compared to conventional innovation. Digital innovation relies on digitisation which is the encoding of analog information into digital formats of different kinds. Digitisation encodes symbols of objects or phenomena that enable the mobilisation of attributes of farming systems to other times and places. These attributes can be proliferated and accumulated through digitisation processes, including the production of digital data, at a scope and rate that conventional data cannot achieve. Thus, digital data in smart farming are what some Actor Network Theory (ANT) scholars might call a 'cascade of inscriptions '(Latour, 1999). These inscriptions take various digital forms such as GPS coordinates, measurements from sensing devices, numerical inputs to models and so on. There are multiple challenges for both farmers and their advisers in managing these varied digital inscriptions including: trust and confidence in the source, quality and relevance of digital data (Zhang, Jakku et al. 2018); commercialistion of digital data (Trindall, Rainbow et al. 2018); the ownership and control of digital data (Wiseman, Sanderson et al. 2018); and, the pace of generation and scale of data generated from smart devices and powerful computing and sensing techniques.

While data are traditionally understood as 'symbols referring to facts' (Thoben, Wognum et al. 1999: 176), a critical science studies perspective on all kinds of data holds that it emmanates from the collective imagination and is performed by, and performative of, the operations of scientific knowledge production (Bowker and Gitelman, 2013). Data are indeed symbols, and as such they represent, rather than reflect, so-called objective 'facts'. These symbols or representations are created by and through the relational activities of human and non-humans in networks of technoscientific practices or scientific work. While all data are representations, digital data and digital data infrastructure are recognised for their unique representational functions of 'communication, memory, programmability and traceability' (Bowker, 2005: 725, Yoo, Henfridsson et al. 2010) where the rapid pace and scope of digital innovation demands new skills (Eastwood, Jago et al. 2016; Darnell, Robertson et al. 2018) and 'ways of organising [digital] innovation work' (Nylén and Holmström, 2015: 63).

We suggest the unique practices of digital innovation in smart farming, including digitisation, can be conceptualised in an innovation domain of 'digiware'. While digiware has been described by Thoben et al. (1999) in instrumental terms as consisting of 'electronic files, data bases and knowledge bases' (p.3), here we conceptualise it as an innovation domain that comprises social, material *and* symbolic practices that together translate on-farm attributes into new forms (or 'phenomena' (Hacking, 1983)) upon which decisions and action can be based. While others have drawn attention to the materiality of smart farming (Higgins, Bryant et al. 2017), here we add to insights on digital innovation by asserting the importance and role of the symbolic practices in smart farming. These symbolic practices are characterised by digitisation as a key process of digital innovation which 'transforms objects into signs' (Latour, 2008: 4) at an accelerated rate, and often more expansive scale, compared to analog processes—with digital data being the key artefact of this process.

Symbolic practices of digiware performed by farm advisers in this research are noted in Table 4 and included: demonstrating digital data quality and digital data compatibility; managing outputs of digital data manipulation and analysis such as yield maps; implementing interpretative frameworks and digital data infrastructures to combine disparate digital datasets (i.e. spatial and temporal) for integrated analyses; negotiating new written agreements to enshrine digital data ownership, controlling and distributing benefits from the use of digital data; and, capturing and curating satellite and aerial (digital) imagery and formats (i.e. Global Positioning Systems) of farm attributes such as weeds and soil.

By highlighting digiware as a domain in smart farming innovation we seek to supplement the heuristic of 'orgware, hardware, software' (Dobrov, 1979) that has been widely applied in scholarship on Agricultural Innovation Systems (Hekkert, Suurs et al. 2007; Klerkx and Leeuwis, 2008a,b,c, Leeuwis and Aarts, 2011). We supplement it to include digiware practices as unique sets of social, material and symbolic practices that both perform and are performative (Mol et al., 2010) of digital innovation. We emphasise the importance of understanding and supporting the symbolic practices of digital innovation in smart farming contexts; as the effects of digitisation challenge farm advisers (and others) to strategically coordinate and align diverse representations, socio-technical arrangements and networks of relationships in order to adapt (Eastwood, Ayre et al. 2019; Nettle, Crawford et al. 2018) or change/s their routines of advisory businesses. Fig. 3 represents how the material, social and symbolic practices constitute an innovation domain of digiware within the established heuristic of 'orgware, hardware, software'.

Having asserted the importance of understanding digiware as an innovation domain, we must now ask: what difference does it make to conceptualise digital innovation in this way? Digiware contains strategic possiblities for the mobilisation of different people, their knowledges, institutions and resources and hence the creation of avenues for effective action (or' innovation journeys '(Schot and Geels, 2008)) in a digitally disrupted world. We contend that by developing a more nuanced understanding of the nature of digital innovation (as experienced by advisers), possibilities for supporting and practicing digital agency in smart farming are enhanced. For example, digital agency was enabled by the co-design process of the DVA Tool which supported both cognition (i.e. decision support), as well as adaption of advisers' service delivery (adviser 1, 15/08/2017) to include improved communication with clients and risk management, as well as demonstrating due diligence and strategic investment, for advisory businesses. Critical to the digital agency of advisers is also their ability to realise the value of digital tools and services which the co-design process of the DVA Tool also enabled.

6. Conclusion

The promise of smart farming is well publicised, with some claiming that rapid technological change will transform the way farming and food production is done in the future (Hall, 2007). The era of so-called 'digital disruption' in agriculture is characterised by: a complex and expansive range of smart farming technologies; a need for new knowledge and skills acquisition (Pierpaoli, Carli et al. 2013); and, uncertainty about the potential benefits and risks of smart farming tools and services for both farmers and farm advisers (Eastwood, Jago et al. 2016). Challenges for farm advisers include managing the proliferation and multiplicity of digitised forms and effects that characterise digital innovation and which coalesce in the heterogeneous innovation practices of what we call, digiware. Within this innovation domain of digiware, attention must be paid to the symbolic practices of digitisation which present unique challenges for advisors as they play a burgeoning role in collecting, curating, analysing and (re)-interpreting multiple digital forms for on-farm decision making.

This research shows that a co-design process supported farm advisers to enhance their digital agency through enabling them to recognise and act upon the systemic nature of digital innovation. Advisors applied a participatory Technology Assessment Framework, the DVA Tool, to self-assess the value of smart farming technologies within their businesses and thereby met a key challenge of doing digital innovation in smart farming—understanding the value proposition of different smart farming technologies. Paying attention to supporting digital agency is important as it connotes issues of power, equity and equality in access to outcomes and opportunities from digital innovation in smart farming. Our research also demonstrates that possibilities for effective adaptation of advisory businesses to smart farming futures emerge from the diverse digital innovation practices of advisors. These innovation practices are evolving in response to the interest, commitment and capacities of advisors as they develop new knowledge/s, skills, networks and resources to engage with, for example, digital data management, applications of smart devices, software development etc, through processes such as the one we have described here.

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