Farm advisors need to adapt to provide value to farmers in a smart farming future

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Abstract: *Increased use of data from smart farming technologies presents an opportunity for farmers to better understand their farm systems, and thereby improve outcomes for productivity, sustainability, and animal care. In this study, our research questions were: how are farmers and advisors currently interacting with smart technologies? and, what are the implications for farm advisor capability and roles in a future where farmers use more smart technologies? We studied advisory roles, advisor-farmer interactions, and new technologies in the context of three case studies: automated cow body condition scoring and precision grazing management in the New Zealand dairy industry, and the Soil Water Outlook tool in the Australian grains and lamb sectors. The case study technologies exhibited potentially disruptive features for farm management, necessitating greater input from a farmer's network of practice to facilitate optimal farm system adaptation. This has implications for the nature of the advisory relationship, where advisory capabilities evolve to include skills on determining technology value propositions alongside farmers and new skills are built for linking data to better decision-making on farm. New relationships between extension providers (both government and private) are also emergent because smart farming tools, involving large-scale data collection and analysis (such as climate and rainfall outlooks), require advisors to provide systemic support for new skills development of producers. Findings from this study highlight the need to include advisors in a collective process with farmers and technology developers during the implementation of smart farming. Further adaptation of advisory business models is required to enable greater value from smart farming technologies to be captured by farmers.*

Keywords: *Advisors, smart dairy; social interaction; trust; data driven decisions*

Introduction

Agriculture is becoming increasingly influenced by digital technologies and data capture devices, including sensors for animals, plants, soil, and water (Rutten et al., 2013, Hostiou et al., 2017, Neethirajan, 2017). A decade ago such data were collected in on-farm data 'silos' – farm management software located on the home computer. Remote server 'cloud-based' data housing and internet accessible decision support tools are opening up opportunities for farmers and advisors to access data from anywhere, via their computers or smartphones (Wolfert et al., 2017). This has implications for how advisors interact with farmers, for example their monitoring of key performance indicators, use of benchmarking, and the use of data for tactical and strategic management advice (Eastwood et al., 2016).

Success factors behind adoption of technology in agriculture have been widely studied (Rogers, 1995, Pannell et al., 2006, Kuehne et al., 2017), with a focus on the wider technological innovation system (TIS) in recent years (Douthwaite et al., 2001, Hekkert et al., 2007). TIS scholars emphasize the importance of having different actors involved in the innovation process, and the roles of technology suppliers, farmers, and research and extension actors has been explored in a smart farming context (Kutter et al., 2011, Busse et al., 2015, Eastwood et al., 2017b). Public and private farm advisors have been shown to be important in reducing the uncertainty associated with new technology, for example the roles of private contractor (Kutter et al., 2011) and advisors in the use of animal monitoring systems (Busse et al., 2015). Another study of smart farming in Germany (Busse et al., 2014) identified public advisory services that were underperforming, and gaps between science and practice. Inadequate support structures for smart farming, for example lack of technicians who understand farm systems, have also been identified in several studies (Oreszczyn et al., 2010, Eastwood et al., 2012, Garb and Friedlander, 2014).

The farm advisory sector has undergone significant change in recent decades with reduced government investment in agricultural extension, including in Australia and New Zealand (Sewell et al., 2017, Nettle et al., 2018). Also, where advisors were historically subject matter experts focused on farm productivity improvements, they may now have a wider remit including environment and animal welfare, as well as health and safety. This brief also includes working with farmers to prepare their business for managing complex issues such as climate change (Ingram, 2008, Rose et al., 2018) and a role in supporting farmers to identify and decide on technology investments (Jakku and Thorburn, 2010). There is a need, therefore, for advisors to continually build their level of understanding and participation in smart farming innovation (Eastwood et al., 2016).

There are a range of agricultural advisory business models that support interactions between advisors, producers and technology suppliers related to smart farming technologies. These models include: public extension; farmer-funded producer organizations; private fee-for-service; and, complimentary advice associated with a smart farming product or service (e.g. fertilizer or feed company advisors). Depending on their business model, advisors interact with farmers via methods such as: as one-to-one meetings; group discussions; virtual meetings (e.g. phone or webinar); and, through information dissemination (e.g. newsletters, blogs) (Prager et al., 2016). Among these, the individual farm visit is still an important knowledge exchange practice (Ingram, 2008) however the geographically distributed nature of the agricultural sector, especially in countries like New Zealand and Australia, can make farm visits a costly exercise. New smart farming tools, such as data capturing sensors and online data platforms, have the potential to change farmer-advisor interactions, and new data-rich farming paradigms may be disruptive to advisory business models (Nettle et al., 2018). This is because they represent new ways of engaging with clients for advisors that in turn demand: new ways of sourcing and disseminating information, new skills development for advisors in remote sensing data curation and management; and strengthened networks with technology providers and R & D in smart farming.

Future farming systems will involve collection and use of more digital data (Eastwood et al., 2017a, Wolfert et al., 2017), however little is known about how digitalization of agriculture will impact advisory services. Our study sought to address this issue by asking: how are farmers and advisors currently interacting around smart technologies? and what are the implications for farm advisor capability and roles in a future where farmers use more smart technologies? Using capability requirements and knowledge exchange factors from a novel technology assessment framework, we studied the experiences of farmers and advisors in the context of three smart farming case studies.

Analytical framework

The development of smart farming technologies over the past two decades has been has been focused on the needs of farmers or researchers, but limited consideration has been given to the roles of other actors who influence successful adoption of agricultural technologies (Bramley, 2009, Eastwood et al., 2017b). To understand these wider influences, a technology assessment framework (Table 1) was developed specifically focused on smart farming innovation and adaptation (Eastwood, 2014). This Smart Farming Framework (the Framework) was based on prior studies of smart farming implementation and adaptation (Eastwood and Kenny, 2009, Eastwood et al., 2012). In addition, it incorporated aspects of existing theoretical frameworks of adoption and innovation in agriculture, such as the ADOPT approach (Kuehne et al., 2017), innovation systems frameworks (Hekkert et al., 2007, Meijer et al., 2007), animal monitoring innovation systems (Busse et al., 2015), and the orgware, hardware, and software typology (Klerkx and Leeuwis, 2009), to identify key considerations in technology assessment.

The Framework was designed as a practical tool to help researchers, technology developers, and funding and policy agencies consider the wider implications of new farming technologies. The Framework has three aspects, the first is ‘Characteristics of the target population and market’ which addresses features of the probable market, pre-existing needs of farmers, potential farming community perceptions, the main actors needed to ensure success, and the potential for wider implications for the industry. The second aspect is ‘technological design and innovation’, a *hardware* aspect, which examines whether an innovation is technically feasible including development lead times, the interaction/integration with existing technologies and thoughts on ongoing development based on user feedback. The final aspect, ‘Capability requirements and knowledge exchange’, assesses *orgware* and *software* aspects such as the adaptation required by farmers to use the technology, the new skills required for the farm team, capability required in the relevant network of practice (e.g. advisors), who is best placed to develop the capability, and how actors can be organized and connected to share knowledge around best practice. In this current paper, factor 3 (in grey in Table 1) is used as an analytical framework to guide analysis of the case studies.

Table 1. Smart Farming Framework for assessing technological innovations

Factor	Main aspect	Questions for consideration
1. Characteristics of the target population and market	1. Gap in knowledge or technology	Does it address a pre-existing need in farming systems?
	2. Expectations of users	What are the minimum performance requirements for end users?
	3. Enterprise or market scale	What is the probable market?
	4. Impacts of the innovation	Does the innovation have wider implications (e.g. for the sector or public?)
	5. Influential actors	Who are the main actors who will influence the successful implementation of the tool?
	6. Innovation uncertainty	What are the potential perceptions amongst the network of practice and how can uncertainty amongst end users be minimized?
2. Technology design and innovation	7. Platform integration	How will it integrate with other relevant technologies?
	8. Continual learning and feedback loops	How will ongoing innovation be captured and utilized for continual product improvement?
	9. Technology performance	Does the technology function well (i.e. will it do what it is supposed to in relation to ‘aspect 2’)?
	10. Design and development timelines	What are the implications of the lead time to take it right through to commercialization?
3. Capability requirements and knowledge exchange	11. On farm adaptation	How much farm management adaptation will be required to use the technology?
	12. Learning load	What are the new skills required to effectively integrate the tool into farm practice?
	13. Capability mapping	Where are the skills/capability required?
	14. Human capital in innovation system	How can the main actors be organized to develop and share knowledge, and create legitimacy around the innovation?
	15. Capability development needs	Who is best placed to develop capability?

Methods

Outline of the research method and case study description

We applied the Smart Farming Framework in three case studies, outlined below and in Table 2. For the current paper, we used factor 3 ‘capability requirements and knowledge exchange’ to guide the analysis as it was most relevant for considering the role of advisors, and relationships between advisors and farmers.

Case study 1 – Automated cow body condition scoring for dairy farming

Body condition scoring (BCS) for cattle is an important tool for dairy farmers to assess animal health and feed demand, particularly at key times of year such as the end of lactation, pre-calving and pre-mating (Roche et al., 2009). Traditionally, BCS has been assessed manually by farmers or trained advisors, typically involving assessment of a proportion of the herd at three to four times of the year. In 2015, an automated BCS (aBCS) device was commercially released, enabling users to collect daily BCS data at an individual cow level. The device was released in New Zealand (NZ), and in the 2016/17 milking season, four farmers were interviewed regarding their experiences with aBCS. The aim of this study was to identify changes in practice and the potential value proposition of regular individual cow BCS status and how this might change relationships between farmers and advisors. Farmers were identified via aBCS suppliers. Interviews were conducted twice with each farmer, at the start and the end of the milking season. A semi-structured interview method was used with interviews recorded and transcribed. Interview themes included: farm system background, animal management, previous use of BCS data, reasons for investment, use of aBCS data, and interaction with advisor networks.

Case study 2 - Precision grazing management in the New Zealand dairy industry

Grazing management is a key profit driver in pasture-based dairy systems, such as in NZ (Beukes et al., 2018). Relatively few NZ dairy farmers regularly use pasture measurement tools and decision support software, however, with the advent of cloud-based software, improved rural internet connectivity, and smart farming technologies, farmers have access to a greater range of products and services (Eastwood et al., 2017a). The aim of this case study was to understand of how farmers and advisors were interacting around pasture data and technology. We investigated the use of pasture data and decision support with five experienced farm consultants (February to March 2016) and twelve NZ dairy farmers through semi-structured interviews (November 2015 to April 2016). The interviews were transcribed and thematically analyzed.

Case study 3 - Soil Water Outlook tool in the Australian grain and lamb sector.

Managing the impact of climate variability is a challenge for all agricultural industries particularly in the light of currently projected changes in global temperatures, rainfall and extreme weather events. For those agricultural industries in Australia that rely heavily on seasonal rainfall for crop and pasture production, the role of soil moisture information in farm management is a critical component of both seasonal and longer-term planning (Klemm and McPherson, 2017). This case study describes a process to evaluate a prototype soil water information technology, a Soil Water Outlook (SWO) (forecasting) service. The aim of this case study was to understand the interaction of producers and their advisors around a climate-driven forecasting tool. The method involved two participatory workshops; the first with 10 broadacre cropping farmers from the farmer organization the ‘Birchip Cropping Group’ (BCG), Victoria (17th October 2014), and the second with 8 lamb graziers at Redesdale, Victoria (21st May 2015). At each workshop, there was also an interdisciplinary team of researchers (e.g. social scientists and engineers) from the University of Melbourne and the Australian Bureau of Meteorology (BoM). In each case, the Framework was used to design an interactive workshop process, including a pre-workshop questionnaire and workshop discussion questions, and to analyze the data gathered during the workshops including a formal evaluation of the process. Some workshop discussions were recorded, transcribed and analyzed.

Table 2. Summary of data collection for the three case studies

Case study	Data collection

1	Automated cow body condition scoring	Semi-structured interviews with 4 dairy farmers, conducted twice with each farmer (in 2016 and 2017).
2	Precision grazing management	Semi-structured interviews with 5 farm advisors and 12 dairy farmers from 2015 to 2016.
3	Soil Water Outlook tool	Two participatory workshops in 2014 (10 cropping farmers) and 2015 (8 graziers). Workshops also involved social scientists and engineers from the University of Melbourne, and representatives from the Australian Bureau of Meteorology (BoM).

Results

In this section, we present the key results from the case studies in relation to factor 3 in the Framework, the ‘capability requirements and knowledge exchange’ to facilitate data interpretation (Table 3).

On farm adaptation

We found that all the smart farming tools in the case studies required some on farm practice adaptation, particularly around the collection and use of data. In the case of aBCS there was a need for accompanying infrastructure such as automated sorting to achieve efficiency benefits of the individual cow BCS data. Some of the advisors interviewed in the precision grazing study adapted their practices, for example logging on to cloud-based software platforms to examine data prior to, or between, actual farm visits. One advisor had clients who would send him the latest pasture growth data and then call him to discuss the implications.

> *‘I’ve got third party access, I go and have a look at it then a conversation on the phone decisions from there. So, that’s what I’m trying to encourage all the guys I deal with as much as possible is to get onto MINDA on the web (a software product) if their broadband will allow them.’* (Advisor 1, Grazing study 2016)

We found that access to the smart farming tools could lead to adapted decision making, for example participants in the technology assessment process of the SWO tool, testified that it could influence crop rotation, timing of planting, crop selection, or decisions related to stocking densities of sheep.

Learning load

Overall the process of applying the Framework demonstrated that there was an increased learning load for farmers and the farm team from using smart farming tools. For example, having the data from the aBCS or SWO tools created decision options at different granularities than the farmers previously used, e.g. weekly averages of BCS data instead of every three months, or soil moisture predictions three months ahead instead of a few weeks. This increased access to data through the season also created opportunities for new decision points (e.g. using BCS for feeding decisions) but this also required additional learning. In case studies 1 and 2, advisors were identified as having a potential role in assuming some of this decision making, or working with farmers to create and test new decision-making regimes based on the data flows.

The use of grazing management software in case study 2 (for example) was found to increase the need for quality data among some advisors, leading them to encourage their clients to adapt their practice to increase diligence around data capture. This was particularly the case for advisors using data to drive their client benchmarking services, or when they needed to report farm performance to a Board of Directors in larger corporate farming businesses.

Capability mapping

The capability mapping aspect highlighted the range of skills that were important across the case studies. The aBCS tool is relatively new and little market competition exists, so the technology providers were an important source of advice for farmers. While they may know the technical aspects of the tool, their farm systems knowledge, or specific animal production and health knowledge, may be less than veterinarians or farm consultants. Therefore, the potential for stronger links between the technology providers and other actors was identified. In the precision grazing example, there is existing knowledge of data use for grazing management among farmers and advisors, therefore technology providers have less of a role. The subsequent challenge identified for advisors was to develop processes with farmers where online interactions could be increased, without undermining the link that hands-on grazing interactions (e.g. pasture walks) provides.

Human capital and capability development needs

Human capital and capability requirements associated with use of the Soil Water Outlook were focused around ongoing co-development with scientists and farmers, along with the future role of Government (as the tool provider) to link with, and train, farm advisors in use of the tool. In the SWO case, producers recognized the role of public extension in the application of the proposed new SWO tool, in addition to a role for private advisors in interpreting the proposed SWO tool for producers to enhance its application and relevance for farm-level decision making. For example, one participant noted:

> *Well you'd run some training then with all the local agronomists to show them how to talk about it [the Soil Water Outlook]… like the Birchip Cropping Group [BCG] Industry Day…where everyone comes along and there are 100 agronomists—that would be really useful. There's a mixture of private consultancies [who attend]. (Participant 10, SWO study 2014)*

Table 3. Capability requirements & knowledge exchange factors of the three case studies

Main aspects (see Table 1)	**Lessons from three smart farming case studies**		
	Automated body condition score (BCS)	**Precision grazing**	**Soil Water Outlook (SWO)**
On farm adaptation	• Limited, some changes in practice (for example running cows through the sensor) • Some complementary infrastructure required, such as automatic sorting gates	• To collect pasture data weekly there can be a significant mindset change required • Allocating time to review data can require changing on farm practice	• Getting access to additional data is needed for the SWO tool to be more useful, such as site-specific current soil water content and soil characteristics • Integration of new forecasting information into current cropping and grazing decision making is needed
Learning load	• More emphasis on farmer use of BCS data (rather than interpretation by advisors) • Increased computer time	• Better decision making from collected data • Skills in operating more complicated farm system models	• More knowledge of basic production factors such as plant available water • Interpretation of forecasting information and graphs showing projected (3 month) soil moisture
Capability mapping	• Increased data analysis skills needed for farmers and/or advisors. Potentially the data analysis could become a task undertaken by advisors remotely. • Development of decision	• Farm teams need skills in collecting accurate pasture data • Advisors can access the pasture data regularly from their office, therefore skills are	• Interpretation of graphs and data facilitated by trained advisors would be needed by some farmers • Tutorials/training resources needed to help users including advisors interpret the graphs

	rules are required to make informed decisions from data	required to interpret data and determine advice without physical visits. • Skills are required to integrate pasture data with other data like herd demand • Advisors need skills to maintain communication with clients remotely	• Combining the SWO graphs with seasonal climate outlooks needed to help users put them in context
Human capital in the innovation system	• Main actors are farmers and the farm team, technology providers, Veterinarians, and farm consultants • Technology providers need to work closely with Vets to develop legitimacy of the aBCS tool among farmers and their network of practice	• Main actors are farmers and the farm team, technology providers, and farm consultants • Greater discussion about data use for grazing decision making through advisory interactions	• Main actors are researchers, farmers and government personnel (e.g. BoM) and advisors • Technology developers (researchers with BoM) continue to engage with farmers and with advisors to develop trust in the SWO tool • The ‘skill’ of the SWO tool needs to be improved to reduce uncertainty associated with predictions
Capability development needs	• The effective use of BCS (such as from aBCS) is a whole of industry issue, therefore development of capability in data use represents an opportunity at primary industry training organizations, and industry-good organizations	• There is an opportunity for advisors to increase use of online grazing tools, which may require capability building • Industry organizations could lead programmes focused on raising awareness of precision grazing options	• There is potential for advisors to facilitate use and application of the SWO tool to farm decision making for producers • Government could provide the tool and develop training materials and engage with advisors to develop capability to support producers’ use of the SWO tool

Discussion

In our analysis of the case studies, we identified main themes that relate to the roles and capabilities of advisors in supporting smart farming transitions. These include: how advisors were (or potentially would be) interacting with digital tools; changes to interactions between farmers and advisors; the changing roles of farmers in a digital age; and potential changes to advisory business models. In this section, we discuss these themes in relation to the research questions.

How are farmers and advisors currently interacting around smart technologies?

In our case studies, there was a range of interactions between advisors and digital tools from proactive approaches where advisors were leading farmer engagement with and use of such tools, to a basic level characterized by manual entry of data and simplistic approaches to data management. An example was the varied use of commercial grazing software products, with some advisors preferring to create their own (e.g. spreadsheets) to achieve specific functionality and to create their own value-add niche with clients. This suggests advisors were creating a ‘hybrid knowledge’ (Rose et al., 2018) where their knowledge of farm systems was being combined with outputs from the digital tools. Advisors were sometimes acting as an intermediary between the farmer and advanced software, such as the farm system analysis software ‘Farmax’ (Bryant et al., 2010). Some of these tools can be complicated and require significant training and ongoing use to maintain competency, one advisor noted:

> *‘There’s another subset of farmers who like using Farmax but aren’t interested in the computer and the software, they just want the results. So for some for those guys we’re*

> *running more of a bureau service where they will email me the pasture covers I will load it in and send them the results'* (Advisor 2, Grazing study, 2016)

In the aBCS study, farm consultants or veterinarians were yet to engage with the BCS data or the associated software. This may have been a consequence of this technology being in the early stages of adoption in New Zealand, but there were also indicators of a transition to the technology provider as advisory support. In the SWO case study, producers in the workshops recognized that, for some farmers, the data (graphs) presented to them in the prototype version of the SWO tool *'will need to be explained (by advisors) or presented in a simpler form for farmer interpretation'* (Participant 3, SWO study). We identified positive and negative aspects in relation to interactions between advisors and farmers associated with the three smart farming tools. For example, one advisor was not comfortable always using a grazing management software tool on behalf of clients, but felt there were benefits, stating:

> *'To me it (doing analysis for the farmer) doesn't give them true ownership of what's going on but it's better than nothing. It enables me to go onto the farm and you know hit the ground running because I know the growth rates, I know the cover and I've got a feed plan ahead of me so it sharpens up the consultancy quite a lot.'* (Advisor 2, Grazing study 2016)

Increasingly, smart farming tools and software platforms may enable long distance interactions between advisors and their producer clients, where the online database acts as a boundary object (Klerkx et al., 2012) around which farmers and their advisor network can interact and connect. However, one farmer in the aBCS case study highly valued the personal interaction with advisors and other farmers via methods such as discussion groups, stating that while they could no longer attend their local group:

> *'I really miss the farm discussion groups, I seriously miss that. It was just a get together and discussing your farm's doing this and I'm doing silage or whatever.'* (Farmer 2, aBCS study 2017)

In their research with decision support tool use, (Rose et al., 2018) also found that farmers still valued interaction with agronomists rather than using decision support tools due to the 'mental history' the agronomist had of their farm, and experience with results of previous management changes.

What are the implications for farm advisor capability and roles in a future where farmers use more smart technologies?

Smart farming tools can provide farmers with analytical power that they may have previously relied on advisors for. Smart farming tools, such as the SWO, have the potential to provide information to inform strategic farm management decisions based on predicted impacts of climate. However, producers recognized that they will still require on-demand extension and advisory support such as online seminars and tutorials to achieve full benefit from such tools. One-on-one advice to interpret data from a tool such as the SWO or aBCS may also still be required and valued. In their study of farm decision making tools, (Rose et al., 2018) found 'the further erosion of human-human contact on farm was worrying to many farmer respondents' (pg17). A co-development approach should be used for building the capability to use smart farming tools as this would help advisors to determine where they can add value in data-driven farming. Training for farmers and their advisors needs to participatory in nature, as this been shown to be important for learning around data and technology, for example in supporting the use of seasonal climate information (Patt et al., 2005).

The case study results highlighted potential changes for the role and practice of farmers, for example farmers identified a need for new knowledge about how to aggregate data, and advice on when it is (or isn't) useful for on farm decisions, as one farmer stated:

> *'Getting non-stop access to condition score information would be really useful, as long as you understand why. You've got to understand your condition score's a really good*

> *tool for making the right calls for a cow, health and production and reproduction.'* (Farmer 2 – aBCS study 2017)

The case duties also highlighted implications for managing increased complexity and understanding the uncertainty related to some smart farming tools. For example, the SWO (which is partly based on modelling predictions) poses a challenge for farmers in interpreting the usefulness and relevance of information for their localized farming practices. The increased uncertainty and complexity of a smart farming innovation can have a significant impact on its eventual uptake (Meijer et al., 2007) and advisors have a significant role in managing this innovation uncertainty.

There are several implications for advisors working with farmers using a data-driven, smart farming approach. Demand for some advisory business models may significantly diminish (e.g. accountancy, animal health) through smart technologies, therefore new advisory models arise where the role of advisors focusses on helping farmers through the more complex social and environmental issues they will face (Nettle et al., 2018). Additionally, although public extension has been reduced over the past decade in most OCED countries including NZ and Australia (Prager et al., 2016), governments still have a role in providing access to useable public good information such as climate and water information. For example, given the scope and capability required to collect and analyze such data, government is best placed to provide a tool such as the SWO. However, in responding to producers' needs, a government agency like the BoM is seeking to apply co-innovation (Botha et al., 2014) principles in the development of new smart farming technologies (as demonstrated by the SWO case).

The nature of the advisory relationship may also evolve in smart farming contexts to less physical farm visits by advisors, and more remote monitoring of management progress via assessing data against key performance indicators. Advisors will need to manage this changing relationship as those interviewed in this study indicated personal interactions as being a highly valuable feature of advisory services. Personal interactions are still possible using video conferencing methods, and advisors may need to expand their use of these technologies, as has happened in other business sectors in recent decades.

The digitalization of expert knowledge into decision support tools or via artificial intelligence (Wolfert et al., 2017) has the potential to reduce part of the advisor's role. This was indicated by farmers in our studies:

> *I do email him (the Vet) the results… It's been very interesting, even though he's had the results, the condition score's been very similar…I can't think what the difference was, there was 0.2 or something like that difference between them, and the camera I think was about 14 days ahead of what he was. And we thought, well maybe we don't need the advisor as often'* (Farmer 1 – aBCS study 2017)
>
> *'If the system can get up and running and it automatically drafts them (separates the cows) for me, or puts them in a group even to look at. It's all done, it's simple. So really it's a waste of time having a farm consultant' (*Farmer 2 – aBCS study 2017)

Other studies have noted such changes, for example (Rose et al., 2018) found that some advisors were cognizant of the potential of decision support tools to change their interactions with farmers, or reduce farmer demand for advisors. The ability to react to a changing environment requires learning of new data analysis and technology related skills. However, (Prager et al., 2016) noted that private advisory services can struggle with integration of new knowledge into their service offerings. However, (Nettle et al., 2018) contend that such changes in farming systems can be an impetus for advisors to question their current capability and to engage with learning opportunities that help unlock new business opportunities.

In terms of the Smart Farming Framework, the workshop process described here in the SWO case is an example of how it represents more than just an instrumental assessment tool. Applied in a participatory setting, as it was in the SWO workshops, it enabled robust discussion and appraisal of a new smart farming tool through interactions between technology developers, researchers, producers, producer-led R & D groups (e.g. Birchip Cropping Group) and government extension programmes (e.g. lamb grazier discussion group).

Conclusions

In this study, emergent changes in the farmer-advisory relationship in smart farming contexts were illustrated through three case studies.

Advisory business models, which have changed significantly in Australia and New Zealand in the past two decades, will need to evolve to incorporate the transformation to data driven smart farming. This evolution will see advisors building knowledge on smart farming tools, and analysis of the data, both with and on behalf of farmers. New relationships between extension providers (both government and private) are also emergent because smart farming tools, involving large-scale data collection and analysis (such as climate and rainfall outlooks), require both government and private agricultural advisors to provide systemic support for new skills development of producers. Future advisory business models may also be focused on helping farmers interpret data for better decision making, particularly in relation to more complex environmental and social issues such as social license for operate and regulation that are currently beyond the capability of decision support and artificial intelligence tools.

Use of the Smart Farming Framework facilitated a dissection of different human capital and capability implications for the three case studies. Through the Framework we could identify the role of different actors in each of the case studies, including the potential interactions between advisors and producers in realizing the benefits from the implementation of smart farming technologies. The Framework, for example in the Soil Water Outlook interactive workshops, also operated as a Participatory Technology Assessment tool (Durant, 1999, Schot, 2001). Further research is needed to refine the Framework for assessment of smart farming technology development and as a guide for farmers when investing in these new technologies.

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References

Beukes, P. C., S. McCarthy, C. M. Wims, P. Gregorini, and A. J. Romera. 2018. Regular estimates of herbage mass can improve profitability of pasture-based dairy systems. Animal Production Science Online Early.

Botha, N., L. Klerkx, B. Small, and J. Turner. 2014. Lessons on transdisciplinary research in a co-innovation programme in the New Zealand Agricultural Sector. Outlook on Agriculture 43(3):219-223.

Bramley, R. 2009. Lessons from nearly 20 years of Precision Agriculture research, development, and adoption as a guide to its appropriate application. Crop and Pasture Science 60(3):197-217.

Bryant, J. R., G. Ogle, P. R. Marshall, C. B. Glassey, J. A. S. Lancaster, S. C. García, and C. W. Holmes. 2010. Description and evaluation of the Farmax Dairy Pro decision support model. New Zealand Journal of Agricultural Research 53(1):13-28.

Busse, M., A. Doernberg, R. Siebert, A. Kuntosch, W. Schwerdtner, B. König, and W. Bokelmann. 2014. Innovation mechanisms in German precision farming. Precision Agriculture 15(4):403-426.

Busse, M., W. Schwerdtner, R. Siebert, A. Doernberg, A. Kuntosch, B. König, and W. Bokelmann. 2015. Analysis of animal monitoring technologies in Germany from an innovation system perspective. Agricultural Systems 138(0):55-65.

Douthwaite, B., J. D. H. Keatinge, and J. R. Park. 2001. Why promising technologies fail: the neglected role of user innovation during adoption. Research Policy 30(5):819-836.

Durant, J. 1999. Participatory technology assessment and the democratic model of the public understanding of science. Science and Public Policy 26(5):313-319.

Eastwood, C. R. 2014. An innovation systems approach to developing precision technologies. in Australian and New Zealand Spatially Enabled Livestock Management Symposium. Hamilton, New Zealand, 18 November, 2014.

Eastwood, C. R., D. F. Chapman, and M. S. Paine. 2012. Networks of practice for co-construction of agricultural decision support systems: Case studies of precision dairy farms in Australia. Agricultural Systems 108:10-18.

Eastwood, C. R., J. G. Jago, J. P. Edwards, and J. K. Burke. 2016. Getting the most out of advanced farm management technologies: roles of technology suppliers and dairy industry organisations in supporting precision dairy farmers. Animal Production Science 56(10):1752-1760.

Eastwood, C. R. and S. Kenny. 2009. Art or science? Heuristic versus data driven grazing management on dairy farms. Extension Farming Systems Journal 5(1):95-102.

Eastwood, C. R., L. Klerkx, M. Ayre, and B. Dela Rue. 2017a. Managing Socio-Ethical Challenges in the Development of Smart Farming: From a Fragmented to a Comprehensive Approach for Responsible Research and Innovation. Journal of Agricultural and Environmental Ethics Online Early.

Eastwood, C. R., L. Klerkx, and R. Nettle. 2017b. Dynamics and distribution of public and private research and extension roles for technological innovation and diffusion: Case studies of the implementation and adaptation of precision farming technologies. Journal of Rural Studies 49:1-12.

Garb, Y. and L. Friedlander. 2014. From transfer to translation: Using systemic understandings of technology to understand drip irrigation uptake. Agricultural Systems 128:13-24.

Hekkert, M. P., R. A. A. Suurs, S. O. Negro, S. Kuhlmann, and R. E. H. M. Smits. 2007. Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change 74(4):413-432.

Hostiou, N., J. Fagon, S. Chauvat, A. Turlot, F. Kling-Eveillard, X. Boivin, and C. Allain. 2017. Impact of precision livestock farming on work and human-animal interactions on dairy farms. A review. Biotechnology, Agronomy, Society and Environment 21:1-8.

Ingram, J. 2008. Are farmers in England equipped to meet the knowledge challenge of sustainable soil management? An analysis of farmer and advisor views. Journal of Environmental Management 86(1):214-228.

Jakku, E. and P. J. Thorburn. 2010. A conceptual framework for guiding the participatory development of agricultural decision support systems. Agricultural Systems 103(9):675-682.

Klemm, T. and R. A. McPherson. 2017. The development of seasonal climate forecasting for agricultural producers. Agricultural and forest meteorology 232:384-399.

Klerkx, L. and C. Leeuwis. 2009. Establishment and embedding of innovation brokers at different innovation system levels: Insights from the Dutch agricultural sector. Technological Forecasting and Social Change 76(6):849-860.

Klerkx, L., S. van Bommel, B. Bos, H. Holster, J. V. Zwartkruis, and N. Aarts. 2012. Design process outputs as boundary objects in agricultural innovation projects: Functions and limitations. Agricultural Systems 113(0):39-49.

Kuehne, G., R. Llewellyn, D. J. Pannell, R. Wilkinson, P. Dolling, J. Ouzman, and M. Ewing. 2017. Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy. Agricultural Systems 156:115-125.

Kutter, T., S. Tiemann, R. Siebert, and S. Fountas. 2011. The role of communication and co-operation in the adoption of precision farming. Precision Agriculture 12(1):2-17.

Meijer, I. S. M., M. P. Hekkert, and J. F. M. Koppenjan. 2007. The influence of perceived uncertainty on entrepreneurial action in emerging renewable energy technology; biomass gasification projects in the Netherlands. Energy Policy 35(11):5836-5854.

Neethirajan, S. 2017. Recent advances in wearable sensors for animal health management. Sensing and Bio-Sensing Research 12:15-29.

Nettle, R., A. Crawford, and P. Brightling. 2018. How private-sector farm advisors change their practices: An Australian case study. Journal of Rural Studies 58:20-27.

Oreszczyn, S., A. Lane, and S. Carr. 2010. The role of networks of practice and webs of influencers on farmers' engagement with and learning about agricultural innovations. Journal of Rural Studies 26(4):404-417.

Pannell, D. J., G. R. Marshall, N. Barr, A. Curtis, F. Vanclay, and R. Wilkinson. 2006. Understanding and promoting adoption of conservation practices by rural landholders. Australian Journal of Experimental Agriculture 46:1407-1424.

Patt, A., P. Suarez, and C. Gwata. 2005. Effects of seasonal climate forecasts and participatory workshops among subsistence farmers in Zimbabwe. Proceedings of the National Academy of Sciences of the United States of America 102(35):12623-12628.

Prager, K., P. Labarthe, M. Caggiano, and A. Lorenzo-Arribas. 2016. How does commercialisation impact on the provision of farm advisory services? Evidence from Belgium, Italy, Ireland and the UK. Land Use Policy 52:329-344.

Roche, J. R., N. C. Friggens, J. K. Kay, M. W. Fisher, K. J. Stafford, and D. P. Berry. 2009. Invited review: Body condition score and its association with dairy cow productivity, health, and welfare. Journal of Dairy Science 92(12):5769-5801.

Rogers, E. M. 1995. Diffusion of innovations. 4th ed. Free Press, New York.

Rose, D. C., C. Morris, M. Lobley, M. Winter, W. J. Sutherland, and L. V. Dicks. 2018. Exploring the spatialities of technological and user re-scripting: The case of decision support tools in UK agriculture. Geoforum 89:11-18.

Rutten, C. J., A. G. J. Velthuis, W. Steeneveld, and H. Hogeveen. 2013. Invited review: Sensors to support health management on dairy farms. Journal of Dairy Science 96(4):1928-1952.

Schot, J. 2001. Towards New Forms of Participatory Technology Development. Technology Analysis & Strategic Management 13(1):39-52.

Sewell, A. M., M. K. Hartnett, D. I. Gray, H. T. Blair, P. D. Kemp, P. R. Kenyon, S. T. Morris, and B. A. Wood. 2017. Using educational theory and research to refine agricultural extension: affordances and barriers for farmers’ learning and practice change. The Journal of Agricultural Education and Extension 23(4):313-333.

Wolfert, S., L. Ge, C. Verdouw, and M.-J. Bogaardt. 2017. Big Data in Smart Farming – A review. Agricultural Systems 153:69-80.