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Digiwork: how agriculture 4.0 is changing work for farm advisers

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Introduction: Advisers are commonly involved in supporting farmers navigate the smart farming transition, however their experiences in such roles, and any changes to their working lives, has not received a great deal of empirical attention. Knowledge about these changes would enable greater anticipation of disruptions to advisory work and help support strategies to maintain and build advisory capacity. This is important for stakeholders seeking to strengthen the advisory system as part of the Agriculture 4.0 era. This paper reports on a study of advisers in the UK and Australia who work with farmers in implementing Smart Farming Technologies (SFTs), to examine the ways in which their work is changing. Changes to the work of advisers is a less explored topic within smart farming yet is an important aspect to the way the Agriculture 4.0 is unfolding.

Method: We developed a multidisciplinary framework from the literature relating to work and working life to collect and analyse data with an overarching theoretical framing of advisory practice as socio-symbolic and socio-material relations. We interviewed 22 advisers and 4 Agricultural technology (AgTech) company representatives about changes to their work as their farming clients implement SFTs.

Results: Based on qualitative analysis of the interview transcripts, and applying grounded theory techniques of constant comparison, we found a range of changes to work including: the diversity of advisory roles; integration work or the emerging 'side office' at the nexus of the office and the farm; demands in work duration and changes in work efficiency and effectiveness; increased workload in learning and developing new knowledge and skills and in the work of building and adapting business models fit for smart farming.

Discussion: We discuss three contributions to the understanding of changes to advisory work: the evolution in advisory roles (including bifurcation and specialisation of roles) expanded knowledge brokering and intermediary work and digiwork, or the work of integrating social, material and symbolic practices in smart farming. These changes have implications for the functioning of the advisory system which, without collective support from government or industry, will privilege technology-centric, commercial and privatised advisory efforts.

KEYWORDS

consultants, digital agriculture, value-proposition, smart farming technologies, extension, advisory system, agricultural innovation system

1 Introduction

As a result of the fourth agricultural revolution, also referred to as Agriculture 4.0[1] (Klerkx and Rose, 2020), farmers and farm advisers are increasingly involved in managing the proliferation of new technical devices, new forms of information and new knowledge and networks that produce digitised representations of farm performance and changes to agricultural processes interconnecting different systems and actors in the agricultural value chain (Ayre et al., 2019; Charatsari et al., 2022; Maffezzoli et al., 2022). The Agriculture 4.0 term encompasses the technologies, socio-cultural and socio-behavioral practices of actors in the agricultural innovation system (Klerkx et al., 2019) and incorporates precision farming, smart farming and digital agriculture. The issues faced by farmers in this transition has received a great deal of attention (e.g., Tey and Brindal, 2022; Giua et al., 2022), however the implications for farm advisers have been less of a focus, despite their role being described as key 'sensemakers' for farmers (Eastwood et al., 2017). Studies have identified a range of roles and challenges for advisers in the context of smart farming. For instance, farm advisers are considered key in the adoption phase of technologies, helping with farmer decisions and guiding the process, either as generalists across all areas of farm management (for instance as agronomists, farm management consultants, extension officers, farm input suppliers, veterinarians) or as smart farming and digital agricultural specialists (e.g., remote sensing and data interpretation) (Klerkx et al., 2019). The disruption to farm advisers from new actors such as software developers, data analysts and Ag-Tech specialists has also been acknowledged (Wolfert et al., 2017; Ingram and Maye, 2020; Ingram et al., 2022a, 2022b; Klerkx, 2020, 2021). However, the potential changes for their work patterns and routines and professional identities have only more recently come into focus (e.g., Bryant and Higgins, 2021; Charatsari et al., 2022).

While it is acknowledged that technologies are contributing to a reorganisation of the labour process in agriculture (e.g., Prause, 2021), the changes to the roles and work of advisers and the experience of advisers in this transition have not received a great deal of empirical attention. Where studies have been undertaken, the emphasis has not been directed to the overall changes to work, but has focused on changes to professional identities (Charatsari et al., 2022), changes to the farmer-adviser relationship (Dockès et al., 2019; Eastwood et al., 2019) or advisers' 'digi-grasping' (i.e., how advisers handle uncertainty and understand their roles in agricultural digitalisation) (Rijswijk et al., 2019) including navigation of 'digiware', that is, the socio-material changes of digitalisation for farm advisers (Ayre et al., 2019). Farm advisers' knowledge-brokering and intermediary work is also recognised as increasingly important in the context of these transitions and critical in helping farmers and technology developers manage the uncertainty and complexity of these transitions (Klerkx et al., 2019; Klerkx, 2021).

Given the critical role advisers play in facilitating on-farm change and the uncertainty regarding new roles and disruption to the advisory system, it is important to understand the lived experience of farm advisers in supporting farmers' implementation of smart farming technologies and how work is changing for them. Our interest in the work of advisers stems from this, and the responsible innovation agenda, which calls for better anticipation of the social and ethical dilemmas associated with the emergence of Agriculture 4.0 (Eastwood et al., 2019; Lioutas et al., 2019; Lioutas and Charatsari, 2022; Rose and Chilvers, 2018).

This paper reports on a study of farm advisers who work with farmers in implementing Smart Farming Technologies (SFTs), to examine how their work is changing. In this paper, we apply the definition of SFTs provided by Balafoutis et al. (2020) being the application of autonomous systems and information and communication technologies (ICT) into agriculture, such as variable rate applicators, Internet of Things (IoT), geo-positioning systems, big data, unmanned aerial vehicles (UAVs, drones), automation and robotics. While Agriculture 4.0, being considered a system-level transformation, provides the context for our study, we focused on smart farming technologies to ground our study in the everyday work of farm advisers and their engagement with the technologies implemented or demanded by farmers. The study was conducted with advisers in the UK and Australia where they are actively engaging with SFTs. The next section reviews the literature articulating various visions of the smart farming future for advisers and changes in advisory roles. In studying the changes to advisory work, we seek to contribute to knowledge and the theorisation of the unique and important role and practices of farm advisers and farm advisory systems in the Agriculture 4.0 context.

2 Expected advisory changes with the transition to agriculture 4.0

Changes to advisory roles and responsibilities in smart farming are predominantly suggested to be toward greater specialisation, with field and farmer-facing 'front office' roles and remote or on-line 'back-office' roles such as in providing remote sensing or farm data analytic services from afar (Laurent and Labarthe, 2013; Rijswijk et al., 2019; Klerkx, 2020, 2021). Such changes are suggested to bring new responsibilities and changes to professional trajectories and professional identities (Charatsari et al., 2022). With respect to specific changes in the work of advising, Ayre et al. (2019) report greater focus on data collection, organisation and interpretation, with advisers having to make complex hardware and software investment choices, determine the value that technology offers for farmers and consider the broader sustainability issues of digitisation (Ayre et al., 2019; Cook et al., 2022). The symbols, materials and social roles and relationships that farmers and consultants employ and manage to gain benefit from digital tools and technologies was termed 'digiware' by Ayre et al. (2019) to distinguish an innovation category in digital agricultural contexts. This change is reported to bring new forms of knowledge, and new demands on data interpretation, with advisers needing to understand the functions and processes behind the working of digital technologies and data processing practices, a shift further elaborated by McCampbell et al. (2022) and Ingram and Maye (2023) in their studies related to digital rights and capacities for digital agriculture.

1 Agriculture 4.0 refers to a set of sophisticated technologies, like the Internet of Things, Big Data, Artificial Intelligence, machine learning, decision support systems, blockchain technologies and remote sensing. Encompassing terms such as 'digital agriculture', 'smart farming' or 'data-driven farming' (Klerkx and Rose, 2020).

Another area of change is suggested to be the new relationships advisers are making or need to make with new partners and in changes to communication patterns with farmers (Rijswijk et al., 2019; Fielke et al., 2021), with farm advisers playing a double-mediating role of adviser-advisory work and adviser-farmer relationships (Klerkx, 2020). Farm advisers are therefore fulfilling 'process intermediary' or 'user intermediary' functions (Kivimaa et al., 2019, p 106) translating and interpreting technology attributes for farmer preferences and working both with technology developers and farmers to qualify the value of technology offers at an individual farmer or project scale. Such activities can extend to knowledge brokering when they enable knowledge flows between different technology developers and farmers (Klerkx et al., 2012). It has been suggested that with these roles there is potential for greater occupational stress whereby the time saving in (for instance) remote monitoring of the data of farm clients may be outweighed by the threat of big organisations replacing their advisory role (Charatsari et al., 2022). While change to advisory work practices and routines and the creation of new roles is considered critical to support farmers in dealing with new uncertainties (Bryant and Higgins, 2021), there is limited detail about these changes. A greater understanding of the changes to work for advisers is therefore critical to how the implementation of SFTs is better supported.

Further, advisory knowledge, skills and competencies change. It has been found that with SFTs comes a need for advisers to place greater emphasis on farmers' needs assessment, facilitation, intermediation and value generation (Charatsari et al., 2022; Reichelt and Nettle, 2023). These authors argue that the Agriculture 4.0 transition creates gaps in competency, including that of working with ethical challenges such as where data and technology are considered more reliable than human advice. This is balanced with recognition that the traditional duties of farm advisers remain, in offering tailor-made advice and products to their clients (Rijswijk et al., 2019; Charatsari et al., 2022, p. 350). However, the extent to which advisers are challenged in their work to balance traditional advisory roles with smart farming transitions is not well understood, yet these changes have implications for the day-to-day work of farm advisers and the experience of those working in new roles in smart farming. Changes to advisory work has been acknowledged in the domain of farmers' sustainability transitions such as to agroecology (Coquil et al., 2018). The research reported in this paper seeks to add to current knowledge on the changes to work that are enabling and constraining the application of SFTs. The research question guiding the study is: *How is work changing for advisers in the UK and Australia when supporting farmers to implement SFTs?* Our objective is to consider the implications of changes to advisory work in the context of the challenges and opportunities of the Agriculture 4.0 transition. In this paper we show that the work practices represent a particular function and role for advisers in smart farming, being that of knowledge integration.

2.1 SFTs and the advisory system in the UK and Australia

We chose the UK and Australia to conduct our study as governments in both countries envisage an agricultural transition underpinned by SFTs. They share similar timelines and trajectories both with respect to implementation and strategies for fostering public and to private collaboration and investment in research and development across key sectors (Agri-Tech Centre, 2024; Department of Agriculture, Water and the Environment (DAWE), 2022). Both countries have a privatised agricultural knowledge and innovation system (AKIS) and seemingly limited outward support to advisers in this transition, despite the new demands on advisory work and skills shortages (KPMG, 2019). The implications for advisers' work are just becoming apparent in both countries (Ayre et al., 2019; Ingram et al., 2022b).

This section outlines the support to Agriculture 4.0 in both countries and the role of the advisory sector in contemporary agricultural transitions.

2.1.1 UK: Innovate UK and the transforming food production challenge

As part of the UK government's agricultural transition plan post-Brexit (Downing et al., 2018), there has been a focus on creating an enabling environment of funding and support to help businesses, researchers and industry to transform food production, including promoting the development and use of new technologies on-farm. Through Innovate UK, the government established the UK Agri-Tech Centre. The Centre supports partnerships between farmers, advisers, researchers, and technology companies to accelerate the deployment of SFTs (Agri-Tech Centre, 2024; CHAP, 2024). While the Transforming Food Production Challenge Fund Programme (UKRI, 2023) has invested in collaborative projects which focus on productivity, reducing the environmental impact of farming (biodiversity, water, nutrient management), and catalysing net zero. SFTs for on-farm monitoring for compliance with supply chain standards is a further driver. More generally, digital literacy is being promoted in the wider workforce, with local skills improvement plans (LSIPS) developed to assist further education providers align their efforts to sectoral needs, including in agri-tech (Business West, 2024).

Efforts to support farm advisers in their role, or with supporting the development of knowledge and skills. Are largely absent in the AKIS in the UK. Despite this, advisers are increasingly taking up roles as intermediaries and knowledge brokers in smart farming projects involving farmers and technology companies or as part of the government's Farming Innovation Programme. With a privatised, fragmented and devolved advisory system system (Prager and Thomson, 2014), advisers' experience of SFTs across the UK are variable. Some might be engaged in research projects assessing or using SFTs. While others, employed by larger consultancy or input suppliers, will use proprietary SFTs and have in-house support. However, there is no overall government program of support for building adviser skills related to SFTs.

2.1.2 Australia: supporting start-up companies and digital agriculture strategies

In Australia, national government investment to support research and development into smart farming technologies and practices is made via the rural research and development corporations (Rural R&D corporations, 2024). A national Digital Agriculture Strategy (Department of Agriculture, Water and the Environment (DAWE), 2022) seeks to support the adoption of digital technologies through: improving digital infrastructure (e.g., the National Broadband Network (NBN) support to IoT devices for data collection); data management; and access to technology for farmers. The National Farmers' Federation's (NFF) in Australia has developed a farm data

TABLE 1 A conceptual framework to consider work changes for advisers in supporting SFT implementation.

Concepts in understanding advisory work	Key Authors	The interpretation and application of the concept in this study
1. Workload	Warhurst and Knox (2022); Eastwood et al. (2017)	The amount of work in a given period, the overall duration of work and the intensity of work including the demands required to complete work tasks. We include physical, cognitive and affective aspects of work including learning load or the time spent learning and gaining new skills… Workload is linked to the working conditions and job quality of advisers.
2. Work organisation	Laurent and Labarthe (2013); Eastwood et al. (2019).	How work is organised including specialisation in job roles such as the front and back office or changes to established work routines such as engaging with farmers remotely rather than farm visits.
3. Professional identity	Charatsari et al. (2022); Nettle et al. (2018); Rijswijk et al. (2019); Gosetti (2017).	Including subjectivity and emotions in work and the meaning of work. This includes quality of working life and aspects such as stress at work, work satisfaction, work recognition, self-determination and autonomy in work, feelings of coherence in work.
4. Knowledge brokering work	Klerkx et al. (2012); Klerkx and Leeuwis (2008).	Activities and processes to exchange and translate individual knowledge stocks into shared knowledge. The work involves actors facilitating connections, enabling coordination and creating opportunities for learning.
5. Intermediary work	Klerkx and Leeuwis (2008); Kivimaa et al. (2019)	Relates to the role of advisers in the agricultural innovation system between users and producers of knowledge. They can be 'process' or 'user' intermediaries (Kivimaa et al., 2019, p 106) in translating and interpreting technology attributes for farmer preferences and working both with technology developers and farmers to qualify the value of technology offers at an individual farmer or project scale.
6. Knowledge, skills, competence	Eastwood et al. (2019); Ingram and Maye (2023).	Workforce qualifications and experience, and changes to skills arising from SFT's including iterative processes of adapting and integrating digital tools and services and interpreting and hybridising with their own knowledge. There is overlap with workload (learning) load.

code (NFF, 2023) and strategies to guide government policies and industry initiatives in technology and innovation in agriculture to improve productivity, sustainability, and resilience. There is a range of government support to enable and promote agri-tech entrepreneurship including technology incubators and accelerators for new agri-tech ideas (Renando, 2023). This is further supported through national platforms and events to bring researchers, technology companies and farmers together with potential venture capitalists (i.e., evokeAG and growAG) (AgriFutures, 2024).

Some Australian State governments provide support to technology companies and farmers to work together to trial solutions such as in Internet of things (Agriculture Victoria, 2024) and there are targeted grants, subsidies, and tax incentives to farmers and agricultural businesses for adopting smart farming technologies and practices such as in offsetting the initial costs of implementing new technologies. A recent report commissioned on the digital capabilities of the Australian agricultural workforce identified a need to increase the 'digital maturity' (KPMG, 2019, p. 7) of Australian agriculture and identifies the application and management of digital data in farm production as a significant issue and where a critical capacity is required (ibid).

However, there is no overall government program in Australia for building adviser skills related to SFTs. The Australian pluralistic agricultural extension and advisory system involves diverse government, commercial and public/private actors (Nettle et al., 2021), and there is fragmentation in support to smart farming (Fleming et al., 2021). There is also a dependence on farmer organisations or professional associations to support advisers in building smart farming capacity and capability (e.g., Crop Consultants Australia, 2024).

3 Conceptual framework

To understand the roles and functions of advisory work in the Agriculture 4.0 era and the application of SFTs, we developed a conceptual framework to structure data collection and analyse empirical data from interviews with advisers. This framework is multidisciplinary, combining theories and frameworks from agricultural innovation systems and the study of work and quality of working life, consistent with an understanding of advisory practice as socio-symbolic and socio-material relations (Ayre et al., 2019; Higgins et al., 2023). Key concepts are summarised in Table 1.

4 Methods

We chose a qualitative approach to examine the subjective experiences of advisers and their work with farmers who had implemented any or multiple SFTs, with a view to examine how their work was changing. Our first selection criterion was to include advisers from across the main farming sectors in both countries (arable/broadacre farming, mixed farming crops and livestock), livestock farms (sheep, beef or dairy farms) and horticulture, and the second criterion was to include advisers with experience working with farmers with respect to their implementation of SFTs. We also sought to include advisers who represented a diversity of business types including: independent advisory businesses, rural resellers; commercial adviser companies, technology companies, public-sector, industry bodies and not-for-profit organisations. As advisers were recruited, we monitored the emerging demographic profile to ensure gender and age diversity. Advisers from the UK and Australia were recruited through a

combination of key informant networks of the authors (UK and Australia), a farm consultants' association (Australia), snowball sampling (Parker et al., 2019) through primary respondents, and a public call in the UK, circulated through newsletters of agricultural organisations, inviting advisers to register interest in participating in the research. The call for participants included photos of different technologies used on farms and the heading: *Are you a farmer or adviser using smart tools and technologies (precision farming, sensors, robotics, data tools and automated systems)?* Followed by wording: *We would like to hear from farmers and advisers about their experiences using smart/digital tools and technologies. For more information, please leave your contact details [google form] and a researcher will be in touch.* Information about the researchers and their organisation affiliation was also provided. A google-document format was used so that interested respondents could provide their information privately. A link to the public call is provided in the Appendix.

The sample of interview respondents is summarised in Table 2. The research received human ethics approval from the University of Melbourne, Australia (ID Number: 26115 and ID Number 21284).

Semi-structured interviews with 22 advisers (7 in Australia and 15 in the UK) and 4 AgTech company founders (3 in Australia, 1 in UK) were conducted between 3rd March and 6th June 2022 (Aus) and April 15–July 15, 2023 (UK). Interviews were conducted over Zoom and by phone. Interview questions covered the adviser's work history and context for working with farmers, the nature of their work with farmers, how this had changed and anticipated future changes. We did not collect information about the advisers' salaries, income, or other benefits received or how this had changed with respect to their work in smart farming. However, we note that specialist advisers tended to work more in commercial companies and with the broadacre/arable farming or horticulture sector where the use of drones or variable rate technologies and precision agriculture and data driven decision-making was more prevalent. On the other hand, the livestock sector had more public sector, industry or independent farm management consultants supporting farmers with smart farming technologies like cow collars or robotic milking.

Advisers fulfilled varied roles in providing support to farmers including as generalists (18 advisers, including independent agronomy businesses, farm management and livestock consultants, farm input suppliers, project facilitators, public sector advisers) and specialists (8 advisers or companies specialising in smart farming, including remote sensing and data interpretation). Fifteen advisers were male, and 7 were female, and advisers worked across the arable farming (cropping/broadacre farms), livestock (sheep, cattle, dairy) and horticulture (fruit and vegetables) sectors (Table 2.)

Interviews were audio-transcribed and analysed to generate themes about the features of work-related changes for advisers in supporting farmers to implement SFTs. Qualitative data was coded using NVIVO™ software by applying the conceptual framework (see Table 1) whereby text was coded to the dimension of work category to which the content was most closely aligned. Codes included: 'adviser perspectives of SFTs'; 'adviser roles'; 'adviser skills'; 'back-office work'; 'frontline work'; 'farm service models'; 'intermediary work'; and, 'training and education'. Text in each of these categories was then reviewed to examine the patterns and interrelationships within and between each category, including discourse related to challenges or opportunities from changes in work and how these are framed. We applied a descriptive rather than critical lens (Gee, 2011, p. 8) and, consistent with our inductive approach, adapted analytical techniques from grounded theory, including a constant comparison method, whereby each interview was coded and compared to the following interview text to test for fit (or deviation) between the data and the emerging categories, and to test the fit between the emerging concepts and processes and new data coming from additional interviews (Charmaz, 2024; Charmaz and Thornberg, 2021). In the following results section we present the key themes from this analysis. We use the generic term 'adviser' or 'consultant' to describe the participants, except where they are digital agriculture specialists and have SFT expertise.

5 Results

5.1 Smart farming technologies used by advisers in their work

The advisers in this study noted they used a range of smart farming tools and technologies in their advisory work (Table 3), illustrating a diverse scope of application across different agricultural sectors. Most advisers and companies were also developing their own smart farming tools and services. These bespoke tools and services ranged from software platforms developed in-house by large commercial agronomy companies for their advisers, to excel spread sheets created by individual advisers as a way of integrating data systems.

5.2 Diversity of advisory roles in supporting smart farming technologies

Participants in the study described different roles in supporting farmers to decide on and implement SFTs. Some described their role as precision agricultural experts or specialist consultants. Their consultancy business model was based on charging clients for these services and this in turn affected the type and extent of smart farming expertise offered as part of the service delivery:

> *'So, I've worked in precision farming for 16 years now, mainly looking at soil nutrition. That's sort of where I started out, and where our main focus is …still soil nutrition….remote sensing, satellite sensing, looking at variable rate nitrogen, looking at intelligent field walking…crop scouting' (UK, Adviser 17).*

Other role descriptions included: an agronomist or generalist farm adviser; consultants who work independently or with these specialists to provide better advice to clients or worked with technology developers to validate or improve their products. These roles were about giving confidence to their clients if they wanted to take on smart farming products. They saw their role as intermediaries in the smart farming transition, and highlighted the importance of working together with farmers and specialists:

> *'You've got to get a few people working together… the grower… the agronomist… a precision agriculture expert that does all the maps. And it's just getting all that to crossover at the right time. And then make sure they [the grower] can implement it… and it's all going to work' (Australia, Adviser 2).*

TABLE 2 Adviser roles, advisory organisations and interview details for this study.

Adviser Code	Advisory Role	Business Type	Location	Interview Date
Adviser 1	Agronomist (cropping)	Independent agronomy business	Australia	09/03/22
Adviser 2	Agronomist (cropping)	Farm input reseller	Australia	10/06/22
Adviser 3	Agronomist (cropping)	Farm input reseller	Australia	03/03/22
Adviser 4	Agronomist (cropping)	Independent agronomy business	Australia	23/11/22
Adviser 5	Agronomist and digital agriculture consultant (cropping)	Independent agronomy business	Australia	18/11/22
Adviser 6	Agronomist (cropping)	Independent agronomy business	Australia	14/02/23
Adviser 7	Agronomist (cropping)	Independent agronomy business	Australia	18/11/22
Adviser 8	Agronomist (cropping)	Large private company providing advisory services	UK	02/05/23
Adviser 9	Horticulture consultant	Large advisory and research consultancy /Public advisory service Wales	UK	12/05/23
Adviser 10	Agronomist (cropping)	Large private company providing advisory services	UK	12/06/23
Adviser 11	Horticulture consultant	Associate of research institute	UK	07/06/23
Adviser 12	Dairy	Public advisory service Wales	UK	19/05/23
Adviser 13	Agronomist (cropping)	Large private company providing advisory services	UK	24/05/23
Adviser 14	Independent farm management consultant, dairy/livestock	Solo operator	UK	11/05/23
Adviser 15	Independent farm management consultant, business and finance dairy/livestock	Large private company providing consultancy, policy and research services	UK	3/05/23
Adviser 16	Agri and Environment Consultant, livestock	Large private company providing advisory and research services	UK	9/05/23
Adviser 17	Specialist adviser (remote sensing and precision agriculture)	Large private company providing farm inputs and advisory services -	UK	17/05/23
Adviser 18	Intermediary /facilitator for a AgTech project in the livestock sector	Environmental Management company	UK	3/05/23
Adviser 19	Livestock technologist	Public advisory services	UK	10/05/23
Adviser 20	Project manager, digital value chains (livestock sector innovation, skills and capabilities).	Education and research organisation	UK	19/06/23
Adviser 21	Independent consultant, livestock technologies	Solo operator	UK	21/06/23
Adviser 22	Adviser and educator	Education and research organisation	UK	26/5/23
Company 1	Livestock AgTech	AgTech company founder	Australia	13/4/23
Company 2	Robotic company (horticulture)	AgTech company founder	UK	2/5/23
Company 3	Grazing AgTech Company	AgTech company founder	Australia	4/5/23
Company 4	Insurance AgTech start-up	AgTech company founder	Australia	23/8/23

This role advisers fulfill of being an intermediary was considered a role for generating trust in technologies with farmers:

> *'If you have built up that relationship, that trust there, between you as the consultant and the grower, they tend to trust if you think that that technology's going to offer a reasonable response in service' (Australia, Adviser 6).*

When trying to bring in technology specialists, generalist farm advisers noted some challenges with calling on this expertise which included aligning work schedules:

> *'You've got to get the experts in. I'm not the expert on everything, so sometimes I have to get other advice to get it to work. And then there are issues. Everyone is so time poor these days…' (Australia, Adviser 2).*

Some advisers who were part of farm input supply firms or technology company staff described their role as 'spending time in the office' (UK, Adviser 17, see below) which included remote sensing specialists, software developers including coders and producers of dashboards and software engineers. There was a delineation between 'field roles' and 'office roles', with 'office roles' mainly being remote

TABLE 3 Summary of smart farming technologies used by advisers.

Type of Tool or Technology	Application/s and sector	Tools and Technologies Used by Advisers in this Study
Spatial data management (Geospatial Information Systems)	Assessing and predicting crop production dynamics and	Precision Cropping Technologies (PCT-AgCloud®) is a geospatial data management platform. Satamap® is a web-based platform for accessing satellite imagery globally. CERES Imaging® uses satellite and other data to predict plant growth and manage risk to crop health
General farm production data management	All sectors	Excel® software is used for data organisation and management. Farmplan ™ is a farm management and data software program. Agworld®is an integrated data management system for farm management. Muddy Boots ™ is a cloud based software platform that supports crop production and data management. Omnia Digital farming® is a software tool that enables customised farm mapping for soil and carbon mapping
Hardware and equipment	Equipment for precision applications and monitoring of inputs	Automated tractor steering and data collection (e.g., Trimble®, Geographic Positioning Systems) Precision seeding technology Soil moisture probes (sensors) Drones Camera sprayers Canopy sensors Soil temp sensors with LoRaWAN (long range wireless area network)
Hardware-livestock	Livestock management and monitoring	Gallagher HR5® electronic identification tool for livestock CowManager ®
Specific agronomic decisions	Crop disease predictions and crop management	Predicta B ® is a digital soil testing service that quantifies the amount of soil-borne pathogen DNA. Soilmate® is a software program that supports soil and plant nutrition agronomy. Yardley® Eu app https://horizon-openagri.eu/open-source-catalogue/soilmate/ WEED-IT® is a digital weed detection technology to support efficient herbicide application. Garford Robocrop-® computerised in row weeder Rootwave ® electric dock weeder
Farm operations and planning	Production systems and project management	Trello® is a visual work management tool. Terra Map ™ is an app for navigation and accessing geographical data. Terra Plus ™ is an app that supports soil data management.
Seasonal and weather forecasting	Cropping and other production decisions	Bureau of Meterology (Australia) app provides current and historical climate data and outlooks. Cli-MATE ® is a tool that analyses long term climate data and trends.

sensing, GIS and data oriented. For instance, a remote sensing specialist described his office work:

> *'… my role has gone from being very field-based to very not field-based anymore. I spend a lot of time in the office. Building the respect of our sales team…an agronomist rang me … "There's some patches in a crop…. "they suspect it might be a pH issue, … So I've said, "We'll just take some remote sensing data. We'll have a look at if we can see it from satellite data, then we'll just give you the satellite data"…' (UK, Adviser 17).*

Field roles were also covered by a diversity of advisers, for instance in the supply of digitally enabled weather stations, where the role included installation, monitoring, servicing and data support. A consultant in Australia described how they assessed the moisture variation in a large paddock with satellite imagery and altered the planting density based on different moisture zones. This generated a large saving in seed costs. In another example, satellite imagery was used to plan the timing and process of cutting hay from a canola crop to maximise economic gain. In the last 10 years or so, with tablets and mobile phone technology and interconnectivity, there has been a lot of progress in the usefulness and applicability of smart farming technologies to decision making, despite ongoing issues with accessibility in many regions in Australia, as one consultant in Australia noted:

> *'About 10 years ago I'd say, there was a definite change … and people had connectivity outside the office, then things really started to ramp up and we are definitely being hamstrung now by just not being enough connectivity to allow a lot of these things to do what they are supposed to do…' (Australia, Adviser 1).*

Facilitation roles of advisers were also more common in Wales in the UK, where there has been government investment in supporting interactions between growers, adviser and technology developers:

> *'I'm not an IT whiz … I'm much more about providing farmer support … and then bringing in the services that I need, so I learnt loads about livestock tracking. I was there to help farmer groups trial novel ways of working within their farm businesses… an innovation broker they called us. I'm an agricultural consultant. There's an acknowledgement in Wales, in order to make these … farmer-led projects happen, they all needed facilitation services' (UK, Adviser 16).*

Some advisers were working to fill a gap in providing support to farmers in working better with what they already had in the way of technologies, rather than suggesting or promoting new technologies.

> *'There's no one doing what we are doing …working with predominantly the … proven technologies, …I'm still being faced with farmers … that aren't using any form of what you'd define as agritech. … people thought that farmers were against or tech averse. That's actually not the case, they are completely open, they just need to be shown and have that conversation' (UK, Adviser 22).*

5.3 Integration work

The role of advisers in performing integration work was described by respondents as addressing two main integration challenges: (1) the integration of new and existing technologies and data into current farming practice and; (2) the integration of different equipment, digital data and digital tools and/or platforms for functionality to address interoperability issues and support farm decision making.

Many consultants described creating their own solutions for integrating digital information and data sources for their clients. For example, some respondents have developed tailored spreadsheets (for example, in Excel®) to manage digital data from different sources and produce reports that can be used in discussions with clients.

> *'…our consulting side of things, we do not use any of the technology, we just create our own platform… create our own spreadsheet' (Australia, Adviser 6).*

Farm advisers in both countries noted the importance of software products that they and/or their clients used as integrative platforms for farm data. In Australia, Agworld®® was described by some as a 'game changer' for their consultancy service provision (Consultant 2) with the ability to combine data in a single place and provide a 'history of the paddock all in one spot' (*Ibid.*), providing an historical record of farm characteristics and performance (i.e., yields). Common farm management software platforms in the UK included Muddy Boots ™ and Farmplan ™, however advisers noted that new software products were often not compatible with these. Advisers also mentioned that some standardised data platforms were proprietary owned, meaning only clients of a particular company could have access to the platform.

Farm management consultants also described working with technology developers to understand the tools being offered so that they could discuss features and benefits with their clients, which was then influencing the level of trust in the tools by farmers:

> *'… if it's a trust thing, they'll [technology developer] try to highlight how the data goes through [and is created and stored], so that we [consultants] know that the data is true and legit' (Australia, Adviser 1).*

Part of the adviser's work with technology and software developers was to encourage developers to work with what farmers were already using:

> *'…what they [farmers] do not want is new bits of software coming in that they then have to start using. What they really, really want is for everything to be seamlessly linked' (UK, Adviser 11).*

Overall, much of the work of the generalist advisers was to help the farmer integrate data and use the diversity of equipment and data sources to better effect, as described by both Australian and UK advisers:

> *'…a bit of a frustration is that they might have spray records on their tractor, they might have a weather station on their farm, they might have sensors in their grain store, they might have satellite imagery they want to utilise, but yet they are having to use all five, six different systems to view all that information. And we cannot find anybody who just wants to invest the money to bring that all into one place (UK, Adviser 17).*
>
> *'There's that many different technologies you can provide [to farmers], companies coming through with different things, that the challenge is getting it to integrate together, talk together, to have one base, essentially' (Australia, Adviser 6).*

Two other advisers described their role, and the challenges, in the integration of different digital technologies:

> *'The other challenge is the integration between, and the flow of data from, one business to another, or from one app to another app, or from one support tool to another support tool' (Australia, Adviser 1).*
>
> *…it's just kind of navigating that [smart farming] space. There's so many different platforms and programs and things that do not all talk to each other (Australia, Adviser 2).*

Generalist advisers and farm consultants suggested that by performing this integration work and using SFTs themselves, they were contributing to efficiencies in farming:

> *'… I do see agri-tech [agricultural technology] as being more for us as advisers than for the farmer…they get us to do it [the data interpretation]…. More and more, they are overwhelmed, just trying to do the basics of farming' (UK, Adviser 8).*

5.4 Increasing work efficiency and effectiveness and workload

Respondents highlighted the time commitment required to trial and adapt new tools and technologies, as well as invest in skills development in data management and analysis techniques. The workload for advisers, mainly in work duration or time spent, was associated with developing the capacity to assess what the various capabilities of tools/technologies are, and then how to integrate them in ways that support farm decision making. One adviser described this experience:

> *'You have to know how to pull it all together into one place and have a place to put it. I think that's a massive challenge…and it's time consuming' (Australia, Adviser 5).*

For tools and technologies to support the consultancy relationship, they must provide not only opportunities for time saving on the part of the consultant, but also direct decision support for productivity gains for the farmer, as one adviser explained:

> *'… to me the only thing that can help me is the time it takes. If I can do something so much quicker, more efficiently than I could in the past, well that's what helps our business. Or if it [tool or technology] helps the grower, then it helps the grower and if it can do both those, if it makes my time quicker and helps the grower, then it's a win-win' (Australia, Adviser 1).*

Another adviser described the way they had integrated drone services into their advising role in the horticultural sector to create efficiencies across all their work areas:

> *'We use it [drone technology] for our trials department. We use it for things like black grass mapping, insurance claims. We use it for fruit sectors…so we … count blossom clusters…we look at vigour… the fruit sector is where that [drone technology] really comes into its own' (UK, Adviser 17).*

Assessing the value of tools or services remains a challenge of consultancy businesses with advisers reporting that they receive minimal or delayed support from technology developers. This included delays in getting service support:

> *'…the serviceability on such [technology] products. If something broke down, you are out here [in a remote area]. To be honest, you cannot afford the few days to wait to be fixed. Then it depends if you can call upon the expert [that] is four hours away … -and then whether there's a problem that can be talked through, or a problem that needs to be addressed by the service provider' (Australia, Adviser 6).*

5.5 Learning and developing new knowledge and skills: workload implications

A key dimension to the work of advisers in smart farming is learning and developing new skills and knowledge that expands their traditional roles which adds to their workload. Advisers commented that they can spend considerable time teaching themselves how to access, run and integrate software programs and associated costs can sometimes be high for smaller consultancy businesses or sole operators. In contrast, larger agricultural service providers, such as rural re-sellers, arguably have a greater ability to absorb some of the costs associated with trialing and using new tools and technologies as part of their services.

Several respondents identified that the range of specialist skills required to provide consultancy advice in smart farming exists on a spectrum from expert field-based knowledge of the farming systems context (i.e., agronomic expertise) to proficiency with analytical and integration techniques using digital tools and technologies. Some advisers emphasised the value of connecting and communicating with others in their professional networks to source specialised advice, for example:

> *'…it's always good to get other consultants' points of view too… if they have dealt with it [a tool/technology] or had experience with it' (Australia, Adviser 6).*

Whereas people in large companies providing technologies and services to farmers had access to in-house training and development, most of the independent advisers or sole operators interviewed described being self-taught and with no or limited access to training in smart farming:

> *'So, I am not qualified [in digital agriculture tools and techniques] … I've built knowledge over time. So, I've adapted to … what growers want, what [digital] technology is out there—I've developed with it, … when satellites first came out, … data was a real challenge to deal with [I've learnt it] … reading tutorials about QGIS and then reading peer review papers … picking that up and making it mainstream' (UK, Adviser 17).*

Advisers working in smart farming contexts noted that they spend a lot of time working independently to learn about various tools and software, including learning new concepts, data collection practices, curation and analytical techniques, as well as digital systems (i.e., software systems). Many tools and programs are updated regularly which also means that it is a challenge for them to keep up with changes, particularly when they may only use a tool/technology annually based on the production cycle (i.e., to assess crop yield):

> *'I think it's a massive challenge—learning all these different bits of software…there are no real shortcuts…not unless you know someone that's willing to sit down and teach you how to use it' (Australia, Adviser 5).*

The time spent was necessary because it was about the adviser being confident and capable in oneself and knowing the technology or product well enough to be able to recommend it with confidence to clients. For example, one consultant explained:

> *'I do not really like recommending [a tool/technology] unless I can understand it fully myself, personally, from my personal experience as a consultant … as long as it's got advantages that outweigh any of the risks associated, or the cost effectiveness of it' (Australia, Adviser 6).*

> *'However, this time commitment can be difficult to justify in some circumstances, as one respondent noted: I think if you were a field agronomist, you would find it [the time commitment to learn] very hard to justify…and how to charge for that [new tool/technology/service]…' (Australia, Adviser 5).*

Some advisers struggled to see a benefit to spending time on learning about new tools/technologies:

> *'If we do not have the time to do it [use tools/technologies] well, then we are not doing it. It's like when drones first came out…we cannot charge the grower for that. Because they can go and buy the drone themselves. So, if we cannot add value to what we are already doing by using it [a drone], then we cannot do it' (Australia, Adviser 4).*

However, other advisers reported saw the benefits of investing time in improving their software skills in developing and delivering effective advisory services:

> *'…what I sell to them [farmer clients] is my advice and the value of me. And if software can make me more valuable and more successful…' (UK, Adviser 8).*

Some consultants interviewed noted that learning about the benefits of new tools and technologies can be constrained by the need to pay to use them before trialling or testing them for example, subscriptions to new software programs. Currently, the cost of some tools/technologies can also be prohibitive for some consultancy businesses and their clients. This can restrict the ability of consultants to experiment and try new tools/technologies. In some cases, short term trials of tools/technologies are offered by software developers, however this is not enough time to know if a tool/technology is a good fit or can add value to a consultancy service or business.

5.6 Building and adapting consultancy/ advisory business models

Another change to agricultural advisory/consultancy work was the development of new advisory/consultancy business models, and for many this was something developed over time and with the pace of agriculture technology development. A remote sensing specialist in a farm input supply firm explained how they developed additional services for variable rate fertiliser application:

> *'… So, soil sampling is where we started [with agriculture technology/SFTs] because it was … the obvious way that people wanted to go …we now make our money out of soil sampling, … If you have got a variable rate spreader, you are doing variable rate P and K. What's the next step? Well… they can do variable rate nitrogen based on satellite imagery' (UK, Adviser 17).*

Many of the respondents actively grappling with options and opportunities for their services, which included negotiating new roles, as one person noted:

> *'where does the horticultural adviser fit [if the relationship is between the robot weeder supplier and the farmer]? [They can provide consultancy] Advice on crop spraying spacings maybe? The crop varieties? The type of crops you are growing? Nutritional requirements?… [still] what gives that plant the best opportunity to thrive?' (UK, Adviser 9).*

Another adviser was looking for efficiencies in their service model:

> *'I'd like to get to a point where agronomy advice is not provided solely from field walking, … for example, an agronomist would walk 10 to 15,000 acres a year. I think we could get one agronomist to 100,000 acres if we use the right technology' (UK, Adviser 17).*

A company founder described how they planned to incrementally adapt their business model as they gained expertise to consider strategies for providing services related to robotic harvesting systems:

> *'…we want to put ourselves in the driver's seat here with this 'harvester as a service model' … where [instead of] operating the robots ourselves, … we need to switch this to a model where the farmer operates our robots, and we are a service provider, and provide … maintenance [and] advice, but still taking the robots away when they are done' (UK, Company 2).*

Generalist advisers described changing their business models away from advice per hectare to hourly charges, given the additional time spent in the office analysing data in additional field visits:

> *'…what has changed somewhat is probably how we [agricultural consultants] value ourselves. ….for quite a lot of clients now taking a different approach in terms of the way that we charge them, I charge them for my time' (UK, Adviser 8).*

A number of advisers, associated with SFT companies, spoke about the shift to on-line consultancy services:

> *'We believe in purely online [consultancy service provision]. We do not believe in putting boots on the ground' (Australia, Company 3).*

> *'And I'll just log on to this … platform that I'm using, and they [clients] can log on to the same thing. I'm like, you click on that Scout report and look at that picture. And they are like, Ah, okay, I see what you mean… so we can talk through it… that's quite productive' (UK, Adviser 10).*

5.7 Intermediary work

Advisers play important intermediation roles which is a largely neutral and client-centric approach rather than championing any particular SFT. These roles can include playing a facilitating and supporting function with respect to projects (e.g., UK, Adviser 16), helping the farmer integrate SFTs effectively into day-to-day activities, acting as a filter often in the capacity as peer user or tester, as a convenor and source of network knowledge, or as a conduit between farmers and SFT companies.

Advisers described their work in assessing tools being offered to their clients as well as working with technology providers. For one adviser, the expectation of their clients was to bring knowledge of other farmers' experiences with particular tools:

> *'… they [clients/farmers] look for new information. But they kind of rely on me to see what everyone else is doing, what's working, what is not. And suggestions from me on what [tools/technologies] they should be trialing' (Australia, Adviser 2).*

> *'…finding out exactly what the reliability of things [tools/ technologies] are before advising on them,…. having an idea of [what] … problems might be …and then trying to get your head around it yourself, and between the service provider, so that they can be called upon in those worst-case scenarios…' (Australia, Adviser 6).*

Advisers characterised their role as a filter between tools and their clients:

> *'We're a gatekeeper for a lot of these growers about data and tools as well and about technology' (Australia, Adviser 1).*

Another adviser described their role in facilitating the interest of their clients in use of specific tools, if they saw a clear benefit for them:

> *'I try to find the 10% changes [in farm production from use of tools/technologies]. I try to find the big ones [increases in productivity] and then … if they are [growers/clients] not interested, I'll start making them interested with, say, satellite imagery' (Australia, Adviser 3).*

6 Discussion

We discuss these results with respect to the research question: How is work changing for advisers in the UK and Australia when supporting farmers to implement SFTs?

6.1 Advisory roles in the use of smart farming technologies are evolving

The first main way in which work is changing for advisers working with SFTs is that their roles are evolving. Experienced former field-based advisers in private advisory services, farm consultancy or farm input suppliers/resellers, have adapted their professional practice to specialise in smart farming over their career, and as a result now have different forms of connection with farmers. This contrasts with suggestions that advisers are being replaced by new advisers from SFT companies without agronomic backgrounds (Ingram and Maye, 2020) or being replaced by digital technologies all together (Fielke et al., 2020). Advisers described their roles as having evolved with available technologies, such as variable rate technologies. These evolving roles were bifurcating, being to field or office-based roles, with remote advice provided either direct to farmers or to field staff who then worked directly with the farmer in face-to-face roles and specialising to either focus as a smart farming technology specialist or to considering the fit of SFTs to a whole farm context. While advisory roles in the 'front office' and 'back office' have previously been noted (Laurent and Labarthe, 2013; Eastwood et al., 2019; Rijswijk et al., 2019), our findings suggest that advisers are choosing different paths in their advisory work and this trend of adapting their consultancy services and business models is strengthening, particularly in the cropping/arable agriculture sectors. This is not to say that the replacement of advisers or the lack of agronomic knowledge will not be a problem in the future, particularly as experienced professionals retire, however currently our findings suggest diversification and specialisation in advisory work rather than replacement. We do note however the limitations of our study in that our sample of advisers did not involve advisers that may have lost jobs or work because of the smart farming transitions underway in agriculture.

We found many of the hypothesised roles for farm advisers in smart farming coming to fruition. These included roles in: digital data collection, organisation and interpretation; providing support to farmers in making technology investment choices; defining the value propositions that technology offers (Ayre et al., 2019); and, assisting farmers create value from technology (such as through agronomic and/or whole farm management advice) (Fielke et al., 2020). Further we identified roles of advisers in developing relationships with new partners, like technology companies, and through on-line platforms, thus altering communication patterns of advisers and others in the agriculture innovation system with farmers (Rijswijk et al., 2019). We conceptualise this bifurcation and specialisation in advisory roles and work in Figure 1. This is not to suggest that an advisor operates in one specified role, rather their roles operate across a spectrum whereby their work is evolving and may change in emphasis.

6.2 Expanded knowledge brokering and intermediation roles of advisers in the application of smart farming technologies

The second way in which the work of advisers is changing is that they are playing an expanded role in the agriculture knowledge system as knowledge brokers and intermediaries. We found agricultural consultants who are digi-specialists acting as knowledge brokers (Klerkx et al., 2019), and different advisers, work on different fronts in their knowledge brokering. Digital specialists, commonly based in commercial companies, were involved in knowledge brokering by supporting the learning needs of (field) agronomists or consultants providing advice to clients at a crop or field level. Other advisers, not only digi-specialists, worked on other knowledge brokering fronts involving: scanning for best fit in technologies (for both the advisory business and the farm decision contexts); providing 'help' (as identified by Charatsari et al., 2022, p6) related to the adoption of SFTs, and in supporting farmers in the transition of their farm practice; spending considerable time in understanding different digital technology options to help their clients evaluate the value of a particular digital technology; and interpreting digital data for farmers. These sense making tasks of advisers are essential in 'making Precision agriculture workable' for farmers, as suggested by Higgins et al., (2023, p. 8).

In addition to knowledge brokering, we found wide ranging intermediary work conducted by advisers at several interfaces. Drawing on Kivimaa et al.'s (2019) typology, we identified characteristics of *process intermediary* work, with advisers facilitating and supporting functions in projects and processes contributing to SFT transitions. In doing this advisers develop connections between other advisers and farmers, between farmers and technology companies and, as part of wider innovation networks, interactions with researchers. The work of *user intermediaries* was also identified. These advisers work with user support organisations often in trials of SFTs to help accelerate uptake by farmers of tools and technologies. They draw on their knowledge of farmers and their farming systems. These advisers were also called on to represent users at the interface with SFT developers to communicate user preferences to them. Aligned to Kivimaa et al. (2019) characterisation, we found that advisers in both these intermediary roles rarely have any explicit agency or agenda, but rather their SFT work practices are emergent as they respond to demands for information and support from farmers. We suggest these expanded roles in intermediary work represent a key change for advisers from SFT transitions, and the importance of these roles has not been recognised in the context of the agricultural advisory system to date (Fielke et al., 2020).

While double-mediating roles for advisers have been previously identified (Klerkx, 2020) our findings suggest triple, or quadruple mediating roles are becoming more prevalent. This includes adviser-to-specialist advisers, farmers, technology companies, and in some instances: to value chain actors, or public policy actors. The expansion in the number of relationships relates to different knowledge-flow

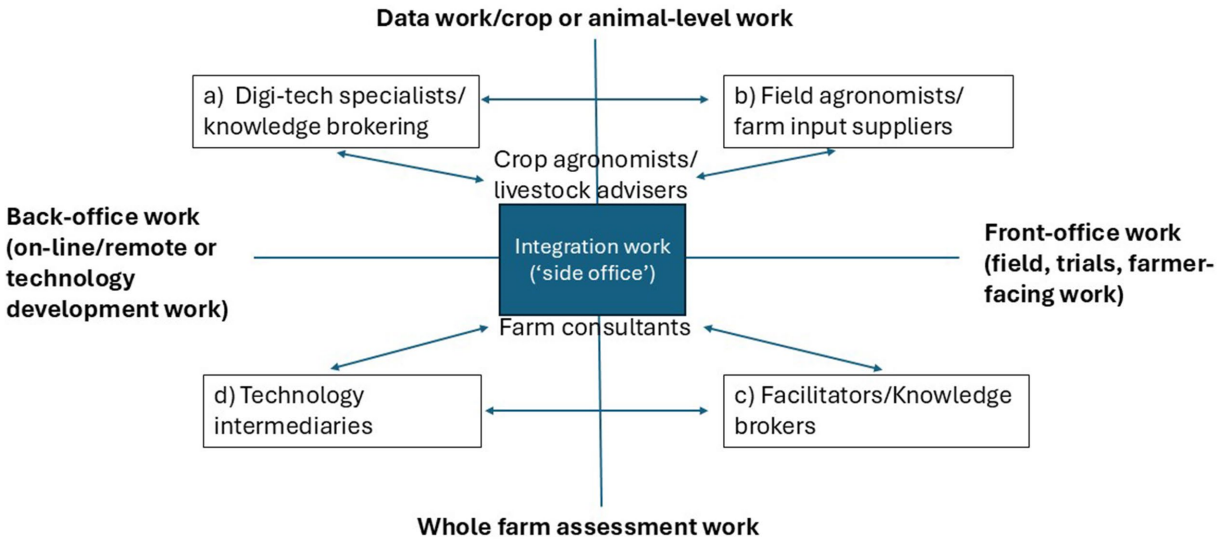

FIGURE 1
Bifurcation in farm advisory work to office or field (horizontal spectrum) or paddock/animal or whole farm (vertical spectrum) and specialisation as a smart farming technologist/specialist (quadrant a-d) or to the whole farm system (quadrant b-c).

fronts which, while offering possibilities for growing or sustaining advisory businesses on one hand, could also create discontinuities in professional lives or identities on the other (Klerkx, 2020; Charatsari et al., 2022). We were not able to precisely discern the weighting to either of these outcomes for advisers except that we found that advisers were looking at ways to curtail the number of technology intermediation roles they took on. Therefore, we suggest that the significance of the work implications of both knowledge brokering and intermediation roles with respect to agricultural advisers' time, capacity and developing new business models requires further investigation.

6.3 The emergence of digiwork in agricultural advising

A third way in which the work of advisers is changing is that advisers were needing to establish practices of integration, or 'digiware' (Ayre et al., 2019) to manage the new representations (i.e., ways of representing farm system dynamics in digital formats), materials (i.e., new digital instruments, equipment and hardware) and social relationships (i.e., as intermediaries and knowledge brokers; outlined in the previous section). These practices, which we term digiwork, are necessary for them to gain benefit from SFTs for their clients and their own businesses. This work involved learning about technologies and applications, building their own software /data analytic platforms, liaising with technology projects and technical specialists. This work also represented risk for advisers and their businesses, particularly when there is often not a clear value proposition for integrating a digital tool or service into their service delivery. We therefore identify integration work as a challenge and risk to advisers, a point also intimated in the integration work of advisers within the context of the agro-ecological transitions (Coquil et al., 2018). We found that the SFT integration work practices of advisers are characterised by two main dimensions: 1) they operate at distinct levels within the smart farming knowledge system; and 2) the increased time commitments (work duration) required and networking capacities for learning and coordination.

The distinct levels within the smart farming knowledge system relate to the integration work of individual advisers, the advisory business and the farming system (Ayre and Nettle, 2015). At each level, there are different sets of symbolic, social and material practices involved (Ayre et al., 2019). At the level of individual advisers for example, advisers were integrating software from different SFT companies and products to build unique and tailored digital platforms or datasets. At the level of the advisory businesses, advisory business owners and their staff were integrating digital data and tools at the interface between what others have identified as the 'front office' (extension activities) and 'back office' (research and development activities) (Laurent and Labarthe, 2013), hence our denotion of the 'side office'. We propose the metaphor of the 'side office' to connote the activities of advisers that include strategic and expert coordination of diverse materials (e.g., digital hardware), symbols (e.g., digital data representations and digital software) and social entities (e.g., people, organisations including technology developers, digital specialists and farmers. Here advisers perform integration practices of edge) (Koutsouris, 2014) and boundary spanning (Klerkx and Proctor, 2013), which are practices critical to 'social integration' dynamics in agricultural innovation (Stræte et al., 2023). We propose 'side-office' activities to be unique integration practices of advisers in smart farming and digital agriculture contexts. Side-office work also includes practices of mutual learning (through co-inquiry and collaboration) (Blackmore et al., 2018), as advisers and farmers together address the challenges of integrating new information of farm performance from digital tools and services into farm management decisions. This complements and extends the metaphors that have been used to describe complex dynamics in pluralistic extension and advisory

TABLE 4 Examples of digiwork—the advisory practices of integration in smart farming contexts.

Advisory practices of integration (the 'side office') in smart farming	Examples from this study
Social practices	- Communicating and interacting with different actors (clients, advisers, technology developers etc.) and organisations - Sensemaking with clients to assess the capacity of digital tools and technologies farmers had invested in and to understand how digital information can support farm decision making
Material practices	- Coordinating software, hardware, digital tools and equipment - Dealing with a lack of interoperability between platforms
Symbolic practices	- Generating, curating, interpreting and representing digital data in various formats

systems whereby 'extension' activities and 'research and development' capabilities are both important in providing support to farmers (Eastwood et al., 2017).

At all levels these new work practices had to be integrated with the more traditional advisory duties, as identified in the study of Charatsari, et al., (2022, p. 350). While the term 'digi-grasping' has been coined to describe how an adviser develops practices and knowledge in digital agriculture (Rijswijk et al., 2019; Fielke et al., 2021) we suggest 'digiwork' better represents the 'doing' of integration and the distinct dimensions of evolving advisory work. The digiwork of agricultural advisers involves routines and understandings that emerge from the relations between digital technologies and tools, people and groups (i.e., technology developers and their services, farmers, other advisers) and the sites and places in which they work and interact. The value for clients of digiwork is in the quality of the integration practices performed by advisers as they translate, coordinate and assemble different meanings and effects (Higgins et al., 2023; Sutherland and Calo, 2020), and, importantly, in how a value proposition for smart farming is formed (Ayre et al., 2019; Klerkx, 2021). We propose the concept of digiwork, as constituted by the key practices highlighted in this study (Table 4) as an important contribution to understanding the evolving advisory context in addition to that of professional identity (Charatsari et al., 2022) and competencies (Ingram and Maye, 2020).

Further, the required time commitments (work duration) and networking capacities for learning and coordination is an important and underrepresented aspect to advisory work in the smart farming transition. The practices of integration (above) are interconnected with work duration and the advisers' motivation to increase their own value to their clients. Developing new roles, working out new business models and learning new software programs takes time and such investment is a signal of commitment to the transition for their clients, however the work of developing business models, introduces risk. There were a range of adaptations being made, including from small changes (e.g., charging for the time spent) through to more substantial changes (e.g., developing and delivering add-on services or service packages or trialing contract services or licensing fees), and these new advisory business models are recognised as an important indicator for how digital agriculture is unfolding (Fielke et al., 2020; Birner et al., 2021). However, these changes and the integration work of advisers, has occurred mostly spontaneously, with the work duration burden resting almost entirely with the advisers and their businesses and with minimal support or coordination from formal institutions or programs. In the UK, the facilitation and intermediary roles were supported with dedicated government funding, which were less prevalent in Australia. Formal learning systems, such as through education and training programs, which would potentially reduce work duration for advisers, was largely ad-hoc or in-house, through the technology companies. While smart farming technology companies may embed farm advisory services in their offerings, such a technology-led, commercialised advisory service will not necessarily provide the capabilities for digiwork, nor support the level of ambition of the agriculture 4.0 transition, which requires strong public-private partnerships (Eastwood et al., 2017).

Table 5 summarises the key challenges that need to be addressed to improve the work situation of farm advisers in the era of Agriculture 4.0, and proposals to overcome them.

7 Conclusion

In this paper we have considered the implications of changes to advisory work in the context of the challenges and opportunities of the Agriculture 4.0 transition. We show that the work practices of advisers in supporting the implementation of SFTs represent a particular function and role for advisers, being that of knowledge integration. We suggest this is an important contribution to understanding the evolving advisory context in Agriculture 4.0, extending the work to date related to professional identities and competencies of agricultural advisers. Theorisation of advisory work as 'digiwork', or the symbolic, social and material practices of knowledge integration, and the metaphor of the side office, addresses a gap in current understanding of the advisory system with respect to SFTs. Our study also integrates and advances scholarship concerning work assessment frameworks, advisers' roles and professional competencies, and their skills and intermediation practices. We also raise the issue of the current response of advisers to Agriculture 4.0 challenges, which reflects the privatised 'laissez faire' approach of advisory systems of both Australia and the UK and the fragmented nature of support for SFT in these pluralistic settings. It raises questions about where the responsibility for responding to the many new demands on advisers' work lies. Building capacities and capabilities suited to the range of integration work needs is important, recognising that this requires social as well as software and analytical skills, and some balance of self-directed learning and formal training.

TABLE 5 Summary of challenges for advisory work and proposals for addressing the situation.

Challenges	Proposals to address the work situation
Bifurcation and specialisation of advisory roles fragments the advisory system.	Government or industry investment to improve coordination and enhance networking in the advisory system and address farmer needs.
Work duration in developing knowledge, learning and networking is a direct cost to independent advisers/small advisory businesses.	Subsidisation of adviser involvement in new technology developments and with pre-commercial start-up companies working with farmers.
Developing new business models, introduces more financial risk for independent advisers/small advisory businesses.	Formation of an advisory network for agriculture 4.0 learning, and incentives for involvement. Direct subsidisation of formal education/short course involvement of farm advisers.
Expanded knowledge brokering and process intermediation (e.g., triple or quadruple intermediation work) is time consuming and increases workload, with upper limits to the number of relationships to coordinate and maintain.	Investment in knowledge brokering, user and process intermediation by government or industry.
Integration work (digiwork) and side office activities are less visible to technology developers, government and industry. The work is unaccounted for in advisory fee-for-service structures (i.e., limited ability of advisers to charge for this work)	Collective assessment of the learning needs and educational demands related to these roles to develop and deliver targeted capability development. Cross-industry knowledge sharing and support for development of business models that accounts for integration work. Public and private funds to facilitate pre-competitive development of platforms to improve inter-operability between platforms

To support the integration and management of SFTs, digital management systems are required that enable communication amongst the farm management team (e.g., farm managers, farm workers, contractors, consultants, and smart farming specialists who may be engaged to manage and analyse data). Without such systems, the relevance and meaning of data to support on-farm decision making is not fully realised or can be compromised. Finding effective and efficient ways to engage advisers in the development of new tools and services would improve their integration with the farm management context and help realise benefits and reduce risks from investment on-farm and in their application to realise the value and benefits from engaging in smart farming. Fostering precompetitive development of platforms with public and private funds to allow more interoperability between platforms would save time and reduce risk for advisers, and lessen the integration work and responsibility that advisers have taken on as part of their digiwork.

Our findings suggest that government, technology companies and the agricultural sectors need to consider the inter-relationships between the different dimensions of advisory work in smart farming and the consequences of not supporting the farm advisory system in the Agriculture 4.0 context. In a rapidly evolving environment, including from the technological side, such as machine learning applications in advisory services and from the changing demands and needs of farmers, stronger and more cohesive strategies to support learning and communication are required. Given the critical role advisers play in facilitating on-farm change and the uncertainty regarding new roles and disruption to the advisory system there are important roles for government in acknowledging and supporting the digiwork and progress ways to avoid technology-centered education and advisory systems.

We note some limitations in our study being the self-selection process of advisers which has limited the range of potential advisory experiences canvassed, such as those advisers who may have lost jobs or work because of emerging technologies replacing advisory tasks such as Artificial Intelligence applications. Younger, less experienced advisers and advisers directly involved in selling agricultural technologies were also underrepresented in our study. We did not examine or compare changes to salaries, benefits or career progression among the advisers, and this is an important area for future research related to advisory work.

We recommend future research into the significance of the work implications of both knowledge brokering and intermediation roles with respect to agricultural advisers' time, capacity and developing new business models. Further research is also recommended into the governance of advisory systems in the context of smart farming, including who takes on the responsibility (and burden of work) for building advisory capacities/capabilities, particularly the differences in, or improvements in, support that may emerge in different countries. Furthermore, research is needed to better understand the specific learning needs and educational demands of advisers and investigate flexible, vocational and educational pathways for professional development in digiwork. While our study did not focus on the replacement of advisers, such as with machine learning systems, the emergence of new knowledge systems is a critical domain for understanding changes to work and where more research is warranted.

Data availability statement

The datasets presented in this article are not readily available because research participants have not provided consent for raw, anonymized data to be shared. Requests to access the datasets should be directed to ranettle@unimelb.edu.au.

Ethics statement

The studies involving humans were approved by Human ethics advisory committee (HEAG), University of Melbourne. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

RN: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Validation, Visualization, Writing – original draft, Writing – review & editing. JI: Conceptualization, Formal analysis, Investigation, Methodology, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing. MA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Validation, Writing – review & editing.

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Conflict of interest

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

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

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References

Agriculture Victoria (2024). Digital agriculture programs Available online at: https://agriculture.vic.gov.au/farm-management/agtech/digital-agriculture-programs (Accessed October 26, 2024).

AgriFutures (2024). Available online at: https://www.evokeag.com (Accessed October 26, 2024).

Agri-Tech Centre (2024). The future of UK Agri-tech. Understanding the aspirations of the UK agri-food sector and accelerating agri-tech ambitions. Available online at: https://ukagritechcentre.com/ (Accessed October 26, 2024).

Ayre, M., Mc Collum, V., Waters, W., Samson, P., Curro, A., Nettle, R., et al. (2019). Supporting and practicing digital innovation with advisers in smart farming. *NJAS Wageningen J. Life Sci.* 90-91:100302, 1–12. doi: 10.1016/j.njas.2019.05.001

Ayre, M., and Nettle, R. (2015). Doing integration in catchment management research: insights into a dynamic learning process. *Environ. Sci. Pol.* 47, 18–31. doi: 10.1016/j.envsci.2014.10.011

Balafoutis, A. T., Evert, F. K. V., and Fountas, S. (2020). Smart farming technology trends: economic and environmental effects, labor impact, and adoption readiness. *Agronomy* 10:743. doi: 10.3390/agronomy10050743

Birner, R., Daum, T., and Pray, C. (2021). Who drives the digital revolution in agriculture? A review of supply-side trends, players and challenges. *Appl. Econ. Perspect. Policy* 43, 1260–1285. doi: 10.1002/aepp.13145

Blackmore, C., Sriskandarajah, N., and Ison, R. (2018). Developing learning systems for addressing uncertainty in farming, food and environment: what has changed in recent times? *Int. J. Agric. Ext.* 6, 03–15.

Bryant, M., and Higgins, V. (2021). Securitising uncertainty: ontological security and cultural scripts in smart farming technology implementation. *J. Rural. Stud.* 81, 315–323. doi: 10.1016/j.jrurstud.2020.10.051

Business West (2024). Available online at: https://glostext.gloucestershire.gov.uk/documents/s104213/LSIP+Presentation+-+Glos+City+Region+Board+TBC+August+2024.pdf (Accessed October 26, 2024).

CHAP (2024). Available online at: https://chap-solutions.co.uk/ (Accessed October 26, 2024).

Charatsari, C., Lioutas, E. D., Papadaki-Klavdianou, A., Michailidis, A., and Partalidou, M. (2022). Farm advisers amid the transition to agriculture 4.0: professional identity, conceptions of the future and future-specific competencies. *Sociol. Rural.* 62, 335–362. doi: 10.1111/soru.12364

Charmaz, K. (2024). Constructing grounded theory. *3rd* Edn. Great Britain: Sage Publications.

Charmaz, K., and Thornberg, R. (2021). The pursuit of quality in grounded theory. *Qual. Res. Psychol.* 18, 305–327. doi: 10.1080/14780887.2020.1780357

Cook, S., Jackson, E. L., Fisher, M. J., Baker, D., and Diepeveen, D. (2022). Embedding digital agriculture into sustainable Australian food systems: pathways and pitfalls to value creation. *Int. J. Agric. Sustain.* 20, 346–367. doi: 10.1080/14735903.2021.1937881

Coquil, X., Cerf, M., Auricoste, C., Joannon, A., Barcellini, F., Cayre, P., et al. (2018). Questioning the work of farmers, advisers, teachers and researchers in agro-ecological transition. A review. *Agron. Sustain. Dev.* 38:47. doi: 10.1007/s13593-018-0524-4

Crop Consultants Australia (2024). https://cropconsultants.com.au/about/ (Accessed October 26, 2024)

Department of Agriculture, Water and the Environment (DAWE) (2022). Digital foundations for agriculture strategy: Driving the development and uptake of digital technologies in the Australian agriculture, fisheries and forestry industry, Department of Agriculture, water and the environment, Canberra, March

Dockès, A. C., Chauvat, S., Correa, P., Turlot, A., and Nettle, R. (2019). Advice and advisory roles about work on farms. A review. *Agron. Sustain. Dev.* 39, 1–14. doi: 10.1007/s13593-018-0547-x

Downing, E., Coe, S., and Audickas, L. (2018). Brexit: UK Agriculture Policy, Briefing Paper No. CBP 8218, London.

Eastwood, C., Ayre, M., Nettle, R., and Dela Rue, B. (2019). Making sense in the cloud: farm advisory services in a smart farming future. *NJAS Wageningen J. Life Sci.* 90-91:100298, 1–10. doi: 10.1016/j.njas.2019.04.004

Eastwood, C., Klerkx, L., and Nettle, R. (2017). 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. *J. Rural. Stud.* 49, 1–12. doi: 10.1016/j.jrurstud.2016.11.008

Fielke, S., Taylor, B., and Jakku, E. (2020). Digitalisation of agricultural knowledge and advice networks: a state-of-the-art review. *Agric. Syst.* 180, 1–11. doi: 10.1016/j.agsy.2019.102763

Fielke, S. J., Taylor, B. M., Jakku, E., Mooij, M., Stitzlein, C., Fleming, A., et al. (2021). Grasping at digitalisation: turning imagination into fact in the sugarcane farming community. *Sustain. Sci.* 16, 677–690. doi: 10.1007/s11625-020-00885-9

Fleming, A., Jakku, E., Fielke, S., Taylor, B. M., Lacey, L., Terhorst, A., et al. (2021). Foresighting Australian digital agricultural futures: applying responsible innovation thinking to anticipate research and development impact under different scenarios. *Agric. Syst.* 190:103120. doi: 10.1016/j.agsy.2021.103120

Gee, J. P. (2011). An Introduction to Discourse Analysis. Routledge, London.

Giua, C., Materia, V. C., and Camanzi, L. (2022). Smart farming technologies adoption: which factors play a role in the digital transition? *Technol. Soc.* 68:101869. doi: 10.1016/j.techsoc.2022.101869

Gosetti, G. (2017). Sustainable agriculture and quality of working life: analytical perspectives and confirmation from research. *Sustain. For.* 9:1749. doi: 10.3390/su9101749

Higgins, V., van der Velden, D., Bechtet, N., Bryant, M., Battersby, J., Belle, M., et al. (2023). Deliberative assembling: tinkering and farmer agency in precision agriculture implementation. *J. Rural. Stud.* 100:103023. doi: 10.1016/j.jrurstud.2023.103023

Ingram, J., and Maye, D. (2020). What are the implications of digitalisation for agricultural knowledge? *Front. Sustain. Food Syst.* 4:66. doi: 10.3389/fsufs.2020.00066

Ingram, J., and Maye, D. (2023). How can we?? The need to direct research in digital agriculture towards capacities. *J. Rural. Stud.* 100:103003. doi: 10.1016/j.jrurstud.2023.03.011

Ingram, J., Maye, D., Bailye, C., Barnes, A., Bear, C., Bell, M., et al. (2022b). What are the priority research questions for digital agriculture? *Land Use Policy* 114:105962. doi: 10.1016/j.landusepol.2021.105962

Ingram, J., Mills, J., Black, J. E., Chivers, C. A., Aznar-Sánchez, J. A., Elsen, A., et al. (2022a). Do agricultural advisory services in Europe have the capacity to support the transition to healthy soils? *Land* 11:599. doi: 10.3390/land11050599

Kivimaa, P., Boonc, W., Hyysalod, S., and Klerkx, L. (2019). Towards a typology of intermediaries in sustainability transitions: a systematic review and a research agenda. *Res. Policy* 48, 1062–1075. doi: 10.1016/j.respol.2018.10.006

Klerkx, L. (2020). Advisory services and transformation, plurality and disruption of agriculture and food systems: towards a new research agenda for agricultural education and extension studies. *J. Agric. Educ. Ext.* 26, 131–140. doi: 10.1080/1389224X.2020.1738046

Klerkx, L. (2021). Digital and virtual spaces as sites of extension and advisory services research: social media, gaming, and digitally integrated and augmented advice. *J. Agric. Educ. Ext.* 27, 277–286. doi: 10.1080/1389224X.2021.1934998

Klerkx, L., Jakku, E., and Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda. *NJAS Wageningen J. Life Sci.* 90:100315. doi: 10.1016/j.njas.2019.100315

Klerkx, L., and Leeuwis, C. (2008). Establishment and embedding of innovation brokers at different innovation system levels: insights from the Dutch agricultural sector. *Technol. Forecast. Soc. Change* 76, 849–860. doi: 10.1016/j.techfore.2008.10.001

Klerkx, L., and Proctor, A. (2013). Beyond fragmentation and disconnect: Networks for knowledge exchange in the English land management advisory system. *Land Use Policy*. 30, 13–24. doi: 10.1016/j.landusepol.2012.02.003

Klerkx, L., and Rose, D. (2020). Dealing with the game-changing technologies of agriculture 4.0: how do we manage diversity and responsibility in food system transition pathways? *Glob. Food Sec.* 24:100347. doi: 10.1016/j.gfs.2019.100347

Klerkx, L., Schut, M., Leeuwis, C., and Kilelu, C. (2012). Advances in knowledge brokering in the agricultural sector: towards innovation system facilitation. *Inst. Dev. Stud. Bullet.* 43, 53–60. doi: 10.1111/j.1759-5436.2012.00363.x

Koutsouris, A. (2014). Exploring the emerging intermediation roles (facilitation and brokerage) in agricultural extension education. *Int. J. Agric. Ext.*, 21–37.

KPMG (2019). Agricultural workforce digital capability framework. Available online at: https://www.crdc.com.au/sites/default/files/Agricultural%20workforce%20digital%20capability%20framework_Report_Final%20deliverable.pdf (Accessed October 27, 2024).

Laurent, C., and Labarthe, P. (2013). The importance of the Back-office for farm advisory services. *EuroChoices* 12, 21–26. doi: 10.1111/1746-692X.12015

Lioutas, E. D., and Charatsari, C. (2022). Innovating digitally: the new texture of practices in agriculture 4.0. *Sociol. Rural.* 62, 250–278. doi: 10.1111/soru.12356

Lioutas, E. D., Charatsari, C., La, E. D., Rocca, G., and De Rosa, M. (2019). Key questions on the use of big data in farming: an activity theory approach. *NJAS Wageningen J. Life Sci.* 90-91, 1–12. doi: 10.1016/j.njas.2019.04.003

Maffezzoli, F., Ardolino, M., Bacchetti, A., Perona, M., and Renga, F. (2022). Agriculture 4.0: a systematic literature review on the paradigm, technologies and benefits. *Futures* 142:102998. doi: 10.1016/j.futures.2022.102998

McCampbell, M., Schumann, C., and Klerkx, L. (2022). Good intentions in complex realities: challenges for designing responsibly in digital agriculture in low-income countries. *Sociol. Rural.* 62, 279–304. doi: 10.1111/soru.12359

Nettle, R., Crawford, A., and Brightling, P. (2018). How private-sector farm advisers change their practices: an Australian case study. *J. Rural. Stud.* 58, 20–27. doi: 10.1016/j.jrurstud.2017.12.027

Nettle, R., Morton, J. M., McDonald, N., Suryana, M., Birch, D., Nyengo, K., et al. (2021). Factors associated with farmers' use of fee-for-service advisers in a privatized agricultural extension system. *Land Use Policy* 104:105360. doi: 10.1016/j.landusepol.2021.105360

NFF, (2023). Australian farm data code - National Farmers' federation, edition 2 May 2023 (NFF-Australian-Farm-Data-Code-v2-May-2023.pdf) (Accessed October 26, 2024).

Parker, C., Scott, S., and Geddes, A. (2019). Snowball sampling: SAGE Research Methods Foundations.

Prager, K., and Thomson, K. (2014). AKIS and advisory services in the United Kingdom. Report for the AKIS inventory (WP3) of the PRO AKIS project. Available at: www.proakis.eu/publicationsandevents/pubs (Accessed October 4, 2025).

Prause, L. (2021). Digital agriculture and labor: a few challenges for social sustainability. *Sustain. For.* 13:5980. doi: 10.3390/su13115980

Reichelt, N., and Nettle, R. (2023). Practice insights for the responsible adoption of smart farming technologies using a participatory technology assessment approach: the case of virtual herding technology in Australia. *Agric. Syst.* 206:103592. doi: 10.1016/j.agsy.2022.103592

Renando, C. (2023). 2023 Australian Agritech sector report. Australia: Australian Agritech Association.

Rijswijk, K., Klerkx, L., and Turner, J. A. (2019). Digitalisation in the New Zealand agricultural knowledge and innovation system: initial understandings and emerging organisational responses to digital agriculture. *NJAS Wageningen J. Life Sci.* 90-91, 1–14. doi: 10.1016/j.njas.2019.100313

Rose, D. C., and Chilvers, J. (2018). Agriculture 4.0: broadening responsible innovation in an era of smart farming. *Front. Sustain. Food Syst.* 2:87. doi: 10.3389/fsufs.2018.00087

Rural R&D corporations, (2024). Available online at: https://www.ruralrdc.com.au/ (Accessed October 26, 2024).

Stræte, E. P., Hansen, B. G., Ystad, E., and Kvam, G. T. (2023). Social integration mechanisms to strengthen absorptive capacity in agricultural advisory service organisations. *J. Agric. Educ. Ext.* 29, 395–416. doi: 10.1080/1389224X.2022.2117214

Sutherland, L., and Calo, A. (2020). Assemblage and the 'good farmer': new entrants to crofting in Scotland. *J. Rural. Stud.* 80, 532–542. doi: 10.1016/j.jrurstud.2020.10.038

Tey, Y. S., and Brindal, M. (2022). A meta-analysis of factors driving the adoption of precision agriculture. *Precis. Agric.* 23, 353–372. doi: 10.1007/s11119-021-09840-9

UKRI (2023) Catalysing the transition to net zero food production. Projects from the transforming food production (TFP) challenge, A UK Research and Innovation (UKRI) Challenge Fund programme. UKRI. https://www.ukri.org/wp-content/uploads/2023/07/IUK-100723-CatalysingTransitionNetZeroFoodProductionProjectsFromTransformingFoodProductionChallenge.pdf (Accessed July 10, 2024).

Warhurst, C., and Knox, A. (2022). (2022) manifesto for a new quality of working life. *Hum. Relat.* 75, 304–321. doi: 10.1177/0018726720979348

Wolfert, S., Ge, L., Verdouw, C., and Bogaardt, M.-J. (2017). Big data in smart farming – a review. *Agric. Syst.* 153, 69–80. doi: 10.1016/j.agsy.2017.01.023

Appendix

*Link to public call for advisers to participate in the research.
https://docs.google.com/forms/d/e/1FAIpQLSfH8hdR5BzO44QYFwIywT2i9qyURZv1Dg5OHueZkivHHtXHuA/viewform