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Can a robot be an expert? The social meaning of skill and its expression through the prospect of autonomous AgTech

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Abstract
Artificial intelligence and robotics have increasingly been adopted in agri-food systems—from milking robots to self-driving tractors. New projects extend these technologies in an effort to automate skilled work that has previously been considered dependent on human expertise due to its complexity. In this paper, we draw on qualitative research carried out with farm managers on apple orchards and winegrape vineyards in Aotearoa New Zealand. We investigate how agricultural managers' perceptions of future agricultural automation relates to their approach to expertise, or the degree to which they think specialised skills and knowledge are required to perform agricultural work on their orchards and vineyards. Our research generates two insights: the perceived potential for work to be automated is related to the degree to which it is seen to require technical or embodied expertise, with technical expertise being more automatable; and, while embodied expertise is perceived to be more difficult to automate, it is sometimes attributed more exclusively to those in positions of power, such that embodied expertise can be highly valued while the majority of embodied work is viewed as non-expert and thus automatable. Our analysis illustrates that a robot can be an expert when expertise is technical. It also shows variability in the conceptualization of skilled or unskilled work, and that those conceptualizations can set the stage for the future effects of new technologies. This generates new insights into the conditions under which automation might reproduce existing inequalities in agriculture, and also raises new questions about responsibility in the context of automation.

Keywords Agricultural work · Agricultural labour · Digitalisation · Agriculture 4.0 · Robotics · Expertise

Introduction: what's new about AI robotics for agriculture?

New data-driven, digital technologies are being developed for agriculture that support, and sometimes perform, complex tasks. While there are a variety of technologies that are included in what is known as *agriculture 4.0* (Klerkx et al. 2019; Rose and Chilvers 2018) or *digital agriculture* (Keogh and Henry 2016; Shepherd et al. 2020; Rotz et al. 2019b), at their core is a novel use of sensors, data, and artificial intelligence (AI). This constellation of technologies and their ability to accurately measure and report on farm conditions is what leads to their characterisation as *smart farming technologies* (SFTs) or part of *precision agriculture*. Data is gathered about the farm via a range of sources—weather stations, satellite imagery, and sensors implanted on the farm. The application of this data to inform farm decisions, and even automate tasks when combined with robotics, is intended to ensure that activities on the farm will be performed more carefully and precisely to generate better outcomes. Yet, questions about the ecological appropriateness of these input-heavy strategies remain. From some perspectives, using smart farming can help overcome the ills of industrialisation by allowing technologies to be focused on reduced input use and higher efficiency (see Rose et al. 2021). In other cases, these technologies can be seen to potentially exacerbate the opaque and inequitable aspects of industrial food production, risking the loss of public trust (Stitzlein et al 2021) and reproducing the very environmental problems they aim to solve (Miles 2019).

The introduction of robotic AI technologies builds on a history of industrialisation in agriculture, and one where decision-making processes and labour structures on farms

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are continually shifting in response to the introduction of new technologies. For example, there has been considerable academic work suggesting that the industrialisation of agriculture reshapes the labour and landscape of the farm to increasingly resemble a factory (Fitzgerald 2008; Rotz et al. 2019a; Prause et al. 2020). This work is held up against a longer historical recognition that industrialisation in agriculture, and its incorporation into capitalist economic systems, is a particular challenge because of the environmental complexity of agriculture and resulting reliance on physical labour (Brooks 2021; Fraser 2021; Gardezi and Stock 2021; Gras and Cáceres 2020; Stock and Gardezi 2021). As technology in agriculture has developed, the basis for these claims about environmental complexity and the need for large amounts of human labour has also diminished. Fewer farmers can now operate over larger spaces with a highly efficient workforce, largely due to the simplification in the farm landscape, and the evolution of farm mechanics and chemicals (Rotz et al. 2019a; Prause 2021; Clapp and Ruder 2020). Given this history, our paper considers: how do existing labour relations and decision-making processes preface and even incentivise particular kinds of roboticisation for skilled work?

The digitalisation of agriculture has and will continue to reshape labour relations and agricultural work and, hence, will affect local economies and food production. For example, it may induce a further 'Taylorisation' of agricultural work with high levels of control and surveillance of agricultural workers, reinforcing precarity of rural employment (Rotz et al. 2019a; Reisman 2021). Additionally, it may lead to deskilling of both farm owners and managers (i.e., an owner operator of a family farm, and those permanently employed on a farm with decision-making power) and farm workers (i.e., those hired, often temporarily, to complete seasonal tasks). It may also affect how people define the meaning of work (Prause 2021; Rose et al., 2021; Ryan et al. 2021). Roboticisation may induce new risks related to occupational health, and there have already been many questions raised about the morality of robots and their liability for accidents (Sparrow and Howard, 2020; Ryan et al. 2021). The effects on migrant, seasonal, or low-wage workers—who are already often marginalised and disempowered in agricultural systems (e.g., Klocker et al. 2020)—is also a site of concern woven throughout this body of research. At an industry level, Brooks (2021) argues that digital technologies 'nudge' smallholder farmers into practices that increase their dependence on conventional food value chains, which also nudges them closer and closer to environmental and economic precarity. It can further concentrate the power of off-farm actors who control and aggregate data (Higgens and Bryant 2020; Fielke et al 2020). On the other hand, it has also been reported that digital technologies may encourage, or require, farmers and farm workers to develop new digital skills in order to navigate and interpret new sensory insights and information from smart technologies (Carolan 2017; Klauser and Pauschinger 2021; Prause 2021; Rose et al. 2021).

This paper extends this work by considering and exploring empirically how ideas from farm managers about farm labour, skills, and knowledge relate to attitudes towards automation. Here, we see farm managers both as owner-operators of farms (e.g., who are typically referred to as 'the farmer' in the case of family farms) and those that are hired to manage corporate farms or large family farms. In doing so, it focuses specifically on the impact of *intelligence in* technologies, or their ability to process information, calculate a possible course of action in response to that information, and potentially execute that action. This is an aspect of new agricultural technologies (AgTech) that could potentially distinguish agriculture 4.0 from previous periods of technological transformation.

The intended capacity of new AgTech to better inform farmers, support decisions, or make decisions, raises epistemic questions about the nature of farm work and the functioning of agricultural knowledge: the degree to which we can abstract knowledge about quite complex environmental systems from bodies and places into neural networks and algorithms. Although many remain skeptical of the possibility of full automation on farms (see Legun and Burch 2021; Fraser 2021), this decision-making capability could not only impact workers who do seasonal tasks but conceivably also replace managers and their expertise who are engaged with issues such as planning and finance of farms (see Duncan et al. 2022; Eastwood et al 2019). The potential to replace higher-level management positions with automation is premised on the assumption that decision-making is one of the primary responsibilities of people occupying these positions, and that those decisions could be made through the rational processing of collected data. This assumption underpins common understandings of expertise in farming systems, and particularly those associated with industrial agriculture (Clapp and Ruder 2020).

In horticulture, where crops are high value and production systems can be highly complex, the line between decision-making and physical labour is not easy to disentangle, as even basic tasks require levels of expertise—despite the introduction of techniques and technologies to reduce the level of expertise required. As such, it is a particularly useful case to investigate how the appreciation of embodied knowledge in farm work influences expectations around automation. As we elaborate in the following section, researchers have consistently found intuitive or embodied forms of expertise to also play important, albeit often implicit, roles in the everyday work of farming communities (Carolan 2011, 2015). When intuitive and embodied forms of expertise are considered, seemingly clear divisions between skilled work (i.e., work that requires some form of inalienable expertise) and unskilled work (i.e., work that relies on instructions and can be seen as quite monotonous), become blurry. This blurriness is perhaps most readily noticeable in the case of specialty crops where seemingly *basic,* labour-intensive tasks like harvesting, pruning and thinning (the removal of some fruit early on) require some degree of decision-making and can be classified as *skilled* tasks (Dedieu and Schiavi 2019; Pitt 2021; Klocker et al. 2020). In short, as we describe in more detail in the following section, we would expect that the introduction of AI in agriculture as an implicit champion of abstract knowledge to be complicated in farm environments where there is a strong social, cultural, and practical emphasis on embodied and intuitive knowledge.

In this research, we investigated three questions related to expertise and automation:

- Does an abstract approach to knowledge and emphasis on technical expertise translate to a more enthusiastic approach to automation?
- For those occupying a management position in agriculture, does a commitment to embodied knowledge and expertise translate to a greater ambivalence to automation?

  We would expect that both technical and embodied expertise would be operating within an orchard or vineyard, at different times for different tasks. As a result, the distribution of kinds of expertise (i.e., who has it) should, potentially, shape when automation is seen as possible and desirable, and whose work is replaceable. This led us to a third research question:
- Where total orchard or vineyard automation is not seen as feasible or desirable, do these approaches to knowledge and expertise influence whose work is seen to be automatable?

In answering these three questions, we investigate expertise as a multi-dimensional practice which emerges within the everyday operations of farming systems, and gain a fuller picture of the possible unique implications of AI and automation in the social history of agricultural technology. In particular, we can see the diverse expectations and interests agricultural actors may have in relation to the integration of AI robotics. These expectations can be shaped by a farm's current labour system, which in turn can shape the envisioned future labour trajectories of farm managers, and the institutional environment they view as necessary for a good agricultural future. Finally, we can also draw attention to the role of responsibility within the everyday operation of farms, and how responsibility and accountability are important social elements of expertise. This opens up further questions on the implications the prospective displacement of human experts might have on everyday agricultural work.

We answer our research questions drawing on work within a multi-university transdisciplinary collaborative design (co-design) project developing AI robotics and human-assist AgTech in Aotearoa New Zealand. We use qualitative interviews with orchard and vineyard managers participating in our co-design project to describe how expertise is expressed through labour relations on farms, which, in turn, shapes farmer expectations and interests in new autonomous robotics. We differentiate between technical and embodied expertise, which we describe in the following section, and illustrate how these different forms of expertise influence current labour practices and future labour preferences in the face of new autonomous robotics. We conclude by taking a closer look at the role of social responsibility in the future of farming. In this exploration, we highlight that while social responsibility is as an enduring and central feature of agricultural expertise, it is often articulated as a burden. We use these finding to shed light on shifting labour dynamics on the farm and their prospect for a more intensely AI-mediated farm environment.

Theoretical framework: what is an expert?

Programming expertise into AI

AI "expert systems" first emerged in the 1970s with the goal of translating expert knowledge into computer systems. While an interest in expert systems contributed to an AI-boom in the 1980s, the difficulty in accurately translating expert knowledge into computer logics—particularly when the knowledge was difficult to explain through 'if, then' rules—contributed to the onset of an AI winter (Noguchi et al. 2018). This winter began thawing with advances in machine learning, neural networks and deep learning methods, alongside an ability to produce, store and process enormous amounts of data (Noguchi et al. 2018; Taulli 2019). Agriculture 4.0 is emerging as a response to these new technological advances, again trying to translate complex forms of expert knowledge into AI systems, which will need to deploy this knowledge within existing social systems and complex, outdoor biological environments.

These new AI systems in agriculture must be programmed using expert agricultural knowledge. Exactly what kind of knowledge is necessary for which task, and how information can be gathered and used to achieve a particular outcome, is a source of considerable divergence within any agricultural industry. Within our own project, we have learned that programming AI requires gaining an understanding of how decisions are made on a particular orchard or vineyard from on-farm experts—those people who are skilled at completing the task being trained or replicated. Sometimes the calculative process can seem quite simple, following some kind of rule: if x and z, then y. For any given task across farms, there is considerable variation in the extent to which farm managers will rely on these rules, relating in part to the physical organisation of a particular orchard space, and the institutional/ownership structure of the orchard, as Legun and Burch (2021) found. In addition, the learning capabilities in AI can also only be calibrated through metrics which allow for evaluating an outcome. An AI-system could identify a good yield with the right specifications from a measured harvest. Overall, we could see AI as an objectivist epistemological process: given a particular desirable outcome, a particular set of parameters, and observations over time, it is conceivably possible for a machine to select the right course of action. Still, if an AI-system moves from rule-based decisions to machine-generated decisions, how and why a machine made a certain decision becomes almost impossible to discern, and these must potentially be re-calibrated to re-align with the human experts and their requirements.

Challenges with capturing different sorts of expertise within AI robotics

As highlighted by the boom and bust of the first emergence of expert systems, one of the major challenges with programming AI robotics is that it must be modelled after an existing human decision-making process, or provide a set of parameters for an AI system to reach an outcome on its own—which could lead to desired outcomes, or not, and raises a number of additional questions about on-farm responsibilities and whether or not that process achieves the task in the way farm managers and farm workers find most relevant and useful (see also Ryan et al., 2021). Therefore, if you want to build a robot that can harvest apples, you need to talk to people with some expertise about the best way to decide whether an apple is ready to be picked. This is further complicated by the reality that, for tasks involving high-value specialty products, it is quite possible that each orchard or vineyard (and even different experts within an orchard or vineyard) will have different ideas about how to make decisions. This includes different ideas about what information is necessary and how that information should be interpreted. On top of that, the decisions need to be made in complex outdoor biological systems where changes can be made to support AI-systems (e.g., transitioning to 2D growing structures), but where total standardisation can be difficult to achieve given landscape variation, and other factors of social, economic and institutional origin (Legun and Burch 2021). Introducing rule-based technologies into a farming system already using rule-based thinking would, in theory, be a much more seamless transition than introducing a rule-based technology into a farm using diverse forms of decision-making.

In other words, the prospective effects of new AI technologies on labour relations in agriculture is related to how epistemological processes currently operate, and how they map onto work and tasks, or the division of labour. If much of the farm work is governed by objectivist approaches that attempt to produce good outcomes through standardisations and control of a workforce according to a set of rules, we would expect robotics could replace the physical aspects of work and AI could easily replicate human decision-making and, indeed, improve it. This kind of knowledge system in agriculture is often associated with industrialisation processes, well documented in the USA by Fitzgerald (2008) in her work, *Every Farm a Factory*, and recently by Auderset (2021) in her research on efforts to rationalise agricultural work in Europe in the early twentieth century. In this research, industrialisation efforts often mobilised to make farming more productive or resilient to labour shortages met challenges associated with the embodied nature of agricultural work. Indeed, a large body of social research on farming and farmer identities has consistently emphasised that agriculture relies on embodied, intuitive, and experiential knowledge, particularly in decision-making (see Carolan 2008; Bell 2004; Nuthall 2012; Nuthall and Old 2018). While objectivist epistemologies may be part of those knowledge systems, there remains other knowledge processes deemed to be essential to the current operation of the farm, orchard or vineyard.

While embodied and technical knowledge may all be in operation to varying degrees on any given farm, how these knowledges are valued and translated into everyday farm work—and how this might shape the integration of technology within a farming system—is related to particular notions of expertise echoing industrialised ideals to greater or lesser extents. In their work on expertise and the democratisation of knowledge, Lowe et al. (2019) suggest that the recognition of vernacular knowledge is essential to democratising expertise. This kind of vernacular knowledge can create blurry forms of expertise, as it combines more technical knowledge with place-based, embodied knowledge. As Lowe et al. (2019) point out, this multi-dimensional knowledge is often easily dismissed in policy decisions and devalued by society (see also Ray 2001). This devaluation comes from a privileging of more abstract and professionalised forms of scientific knowledge, or what we refer to as technical knowledge and expertise, which can result in the disempowerment of people with more vernacular knowledge. This work highlights the ways that expertise is a cultural and social designation related to the valuation of different forms of knowledge. As we further elaborate in this paper, the possible effects of new precision technologies on a particular farming operation is dependent on how expertise is being valued in relation to work on a particular farm, and what kind of work allows a person to be classified as an expert. This also links to issues of power as we will discuss next.

Politics of agricultural epistemologies: embodied knowledge and power in the context of industrialisation

The politics of knowledge recognition has been an ongoing thread woven through the sociology of agriculture. In *Farming for Us All*, Bell (2004) describes how the 'Practical Farmers' of Iowa try to develop a community that celebrates embodied skill and sustainable strategies in opposition to the kinds of alienated communities linked to industrialisation. Others draw focus on the central and enduring role that more nuanced knowledge processes continue to play in farm management. In their review article, Nuthall and Old (2018) call for increasing attention to the legitimacy of intuition, with technical knowledge being a secondary support for successful decision-making (see also Nuthall 2012). Klocker et al. (2020) similarly emphasise that season agricultural workers are often colloquially categorised as unskilled, while farm managers and workers recognise that skills—the acquisition of experiential knowledge over time—is essential to the proper functioning of the farm (see also Dedieu and Schiavi 2019; Pitt 2021). Von Diest et al. (2020) similarly suggest that too much attention is paid to the role of technical knowledge, when intuition is more important for successful farm management. This body of work engages with the kinds of environmental alienation that is reproduced through the promotion of abstract, scientific knowledge over more embodied forms of knowledge, which cannot be disentangled from processes of farm rationalisation that challenge the social power of farmers.

These kinds of entanglements of power and definitions of knowledge have been elaborated in the context of environmental farm management. Riley (2008) finds that farmers draw on a complex set of experiential and embodied knowledge in making decisions, which often conflicts with conservation expertise developed by scientists. Burton et al. (2008) also found that conservation schemes prevented farmers from exercising their own forms of experiential expertise, leading to disengagement from these schemes. It is for these reasons that Legun and Sautier (2018) find that farmer governance of environmental management programmes in the New Zealand wine industry were successful, while Hale et al. (2020) find that the technical, rationalised dimensions of community-based water management schemes in Canterbury, New Zealand undermine collaboration.

What these bodies of work highlight is the ways that different forms of knowledge are woven together in practice, but may have tensions due to external power structures that privilege more abstract, rationalised knowledge for the sake of higher productivity, greater economic efficiency, or environmental conservation and reduced resource use. This is why embodied knowledge may not necessarily conflict with technical knowledge on the farm, but socially becomes mobilised as a symbol of irreplicable and inexplicable knowledge in an attempt to defend a farmer's autonomy (see Stock and Forney 2014). A desire to protect this kind of knowledge in an environment where science and agri-business can be allied and hostile toward the needs and desires of farmers is symbolically powerful for the defence of farmers. However, we also see this mobilisation of intuitive knowledge in defence of autonomy as complicated in an industrialised context where vast amounts of labour is often performed by temporary workers who are racialised and marginalised, and whose embodied knowledge may evade recognition and the power it wields (see Burch and Legun 2021; Keller 2019; Weiler 2018).

Agency, knowledge, power and technologies

Against this backdrop, we see a proliferation of new technologies in agriculture, as well as writing that engages with the changing character of the farmer within these new socio-technical landscapes. Much of this work (e.g., Comi 2020; Lioutas et al. 2019) stresses the ways that expertise in agriculture is composite, so that agricultural experts are operating at the nexus of various information sources and technical devices. Lowe et al. (2019) argue that current networked models of development build on expertise in place or vernacular expertise, which combines field/place- generated and field/place- focused knowledge nourished by outside sources and agents. It has been noted that the expertise of such 'outside agents' (e.g., advisors) are also undergoing reskilling in response to new digital technologies that partly replace their expert judgement or produce new sensory and analytical affordances (Ayre et al. 2019; Eastwood et al. 2019; Klerkx 2021; Pauschinger and Klauser 2021). Some of this work makes use of new theoretical approaches in science and technology studies (STS) that attempt to disturb conceptions of human agency as limited to human bodies, and instead emphasise the ways that agency is enabled by the various things and beings people relate with in their everyday lives (see, for example, Bennett 2010; Barry 2001; Callon 2008; Tsing 2015; Legun 2015). These approaches have been well elaborated in the context of agriculture.

Drawing from research on agronomists and seed sellers, Comi (2020) describes how the agency of farmers is *distributed* in the case of precision technologies. That is, the agency of the farmer is enacted through a set of relations with heterogeneous human and non-human elements. Likewise, Finstad et al. (2021) look at how precision dairy technology is ‘domesticated’ in interactions between the farmer, the technologies and the animals, whose relations are mediated by a broader range of experts such as advisors. As the farmer becomes increasingly distributed with the introductions of new technologies, it is becoming exceedingly important to better understand how farmers maintain social power within increasingly digitised farming operations. Central to our grappling with novel AI technologies, and related to the issues of what constitutes expertise, power and agency discussed above, is a question about the social, performative process of decision-making. In Carolan’s (2020) work on the effects of automation on labour and skill, he notes how new robotics for automation may reduce the need for migrant labour, but increase the reliance on highly skilled technical expertise to be able to interact with precision technologies (see also Rose et al. 2021; Prause 2021). From a historical perspective, we can see this “upskilling” as another step in a long line of technical transformations, along with de-skilling and other-skilling (see Prause 2021).

As these new AI technologies and discourses of automation enter into the lexicon of farming futures, we can see “upskilling” as a necessary element in the narration of a smooth and desirable transition to an automated agricultural future. At the same time, expanding emphasis on composite agency that includes humans and machines could complicate discussions on responsibility for farm activities—i.e., who is answerable if something goes wrong. As the everyday decision-making processes on the farm become increasingly eclipsed by autonomous technologies, the justification for the existence of experts on the farm (either local or external) becomes murky, just as the need for responsibility becomes more prescient in what have been referred to as ‘socio-cyber-physical systems’ (Lioutas et al. 2019; Rijswijk et al. 2021). This is because automation allows for decision-making processes to be pre-determined by technological developers or off-site experts, creating a situation where on-site personnel may have responsibility for a task to be completed, but little to no ability to direct how these tasks are done or to disagree with the expert system.

Many of the justifications for increasing AI robotics on the farm, like many other industries, relate to both the desire to reduce a dependence on physical labour and to be able to support more robust decision-making (Rose et al. 2021). The latter application of new AI technologies has come under considerable critique in non-agricultural contexts, such as criminal sentencing and mortgage brokering, where research has found that AI programmes can replicate and even amplify discrimination and inequality (i.e., AI systems learn biases from the humans that design them, and from uncritically drawing conclusions from data reflecting uneven power relations) (Tsamados et al. 2021; Završnik 2019). The risks of AI-systems perpetuating inequitable power relations have also been noted for the case of robots and AI in agriculture (Blok and Gremmen 2018; Fraser 2021; Klerkx et al. 2019; Rose et al. 2021; Sparrow and Howard 2020; Ryan et al., 2021). While bias may be tackled through new programming strategies, a substantial problem associated with new AI technologies is illuminated through discussions around systemic bias: the deflection and obfuscation of human agency through the introduction of AI. This is also a risk in agricultural environments, where a reduction of human error is a highly prized aim of technological development, as is the desire to reduce the burden of decision-making responsibility (see Pylianidis et al. 2021).

This paper furthers our understanding of prospective shifts in labour relations as a result of new AI robotics that are seen to perform tasks associated with expertise. As AI robotics enact forms of expertise on farms, we consider what features of expertise can be replaced by a robot, and how the prospect of automation, in turn, illuminates the knowledge and power relations that currently operate through different kinds of expertise. In particular, we consider whether the use and appreciation of abstract knowledge and technical expertise, commonly associated with heavily industrialised agriculture, can be considered a precursor to automation in agriculture, with the calculative processes of AI easily stepping in for humans. We investigate whether embodied knowledge and expertise presents a barrier to automation, and if so, how that barrier might be envisioned in practice: would farms that rely heavily on embodied forms of knowledge in how they operate be resistant to automation? How is the attitude towards automation mediated by perceptions of expertise? After a description of our case and methods, we detail our findings in sections on technical and embodied expertise, focusing particularly on narratives of replaceability. In our discussion, we consider how our participants’ orientations to technical and embodied expertise relate to current power and knowledge relationships and expectations for how they might be enacted in the future. The latter is linked to questions of social responsibility. We conclude by questioning whether the displacement of experts and de-emphasis on embodied expertise could obscure responsibility for decisions and suggest this possibility as a necessary site of attention for future research.

Co-designing AI robotics in Aotearoa New Zealand: case and methods

This research is part of a multi-university, transdisciplinary co-design project based in Aotearoa New Zealand. Over the course of five years, the project aims to develop human-assist and robotic technologies with AI capabilities to support and potentially automate tasks on blueberry orchards, apple orchards, and wine vineyards. While much of the project is dedicated to engineering and computer vision tasks

Table 1 Occupational roles of interviewees

Industry	Role	Number of people interviewed	Total for each industry
Apple	Orchard owner and manager	9	22
	Orchard manager	11	
	Industry representative	2	
Winegrape + Apple	Vineyard and orchard manager	1	1
Winegrape	Vineyard owner and manager	1	18
	Vineyard manager	8	
	Vineyard director	1	
	Contract grower and vineyard manager	4	
	Consultant	1	
	Industry representative	3	
Total interviewed			41

associated with developing physical technology, the project involves considerable input and participation from apple, winegrape, and blueberry growers, who guided the selection of technological goals at the outset of the project, and who are involved with field trials of the technologies. A significant part of the project is also dedicated to a social science team which aims to better understand the social implications of these technologies as they are being developed through the co-design process. This research is part of that effort, which also involves work on community technology adoption, the social and cultural dynamics of the co-design process, indigenous Māori business and community responses to the introduction of new agricultural technologies, as well as the potential impacts of the technologies the project is developing on industry partners, farmers and agricultural workers (see Burch et al. this special issue; Burch et al. 2022; Burch and Legun 2021; Legun and Burch 2021). Ethics approval for this research was secured through the University of Otago Human Ethics Committee.

As part of our research for this paper, we conducted 41 interviews in June, September, and December of 2019 and August and September of 2020. Our criteria for inclusion was that we interviewed people who had decision-making capacity regarding technology on orchards and vineyards, and tried to talk to those who managed or owned operations of varying sizes and ownership compositions. We also interviewed consultants and those who worked within the main industry bodies, who played a considerable role in advising orchards and vineyards about technology adoption, and supporting collective industry exchange around new technologies and labour policies. We primarily set up interviews with the support of project team members who are agricultural consultants. We asked for suggestions and introductions to a diverse range of producers, and also asked interviewees for referrals. Table 1 provides details about our interviewees, including the industries they worked in and their roles. In several cases, industry representatives and consultants were also managers or owners of orchards and vineyards, but we only listed these participants once in the industry or consultant category.

The interviews were open-ended, and involved asking interviewees a range of questions about their operation, changes in the industry overall, the technologies they used and expected to use in the future, and their relationships to those working on their orchard. We focused considerably in our probing questions about how things were done and why, but the interviews were conversational and largely led by participants, so we could get a sense of those topics that seemed most salient to understanding technology in agriculture. Interviews with managers and owners took place on orchards and vineyards, largely in offices on site or outside among the trees or vines. Interviews with consultants and representatives took place in offices. We asked interviewees about how they imagined farm work changing in the future with the introduction of new AI robotics, and these conversations generated much of the insights reported in this paper.

Our analysis of interviews was highly iterative with the analytic narrative starting to take shape during the interviews, but developing coherence and clarity through constantly revisiting the data and rethinking the interpretation. This process followed a grounded theory approach, where we entered the research process with background knowledge and expertise, but developed our explanatory theory through the research and from the resulting data (see Charmaz 2014).

The idea for this paper was initially inspired by observations during field visits, where the research team would have general discussions with agricultural research participants on their farms. These conversations centred on descriptions of tasks, and the discussions they would inspire between agricultural managers and engineers. These conversations remained in the back of our minds as we engaged with our interview data, and began to form more concrete insights into the social implications of task descriptions in agriculture, and locate those descriptions within a broader set of dynamics.

In this paper, we take a performative perspective to the descriptions of tasks and work on the orchard or vineyard. That is, we assume that the way that people explain how a decision is made or a task is completed is also an expression of identity—which has been shown to influence grower decisions about technology adoption (Gardezi and Bronson 2020). When managers are describing their work to scientists, be they social scientists or engineering scientists, they are both explaining the work and representing their own position within that work. This allows us to understand their explanations of tasks as not abstract or objective processes, but as being about their own expertise and its significance to the functioning of the farm.

Two aspects of expertise: technical and embodied

In line with the literature previously discussed, we found managers referred to two aspects of expertise grounded in two different kinds of epistemological systems, or ways of generating and exercising knowledge: technical and embodied. These often overlapped and could both be articulated by each of our interviewees, albeit to reference different aspects of farm management or tasks and to justify particular labour dynamics. Technical expertise is expertise that can be learned through training and can be associated with professionalisation, but is also quite abstract and follows a more objectivist epistemological paradigm. Some of our interviewees described much of this expertise as being performed by managers who exercised that expertise in offices. However, many also described technical knowledge and skill as valuable and necessary, but often lacking, in the workforce. This general technical expertise in the workforce could refer to highly transferable, abstracted skills in, for example, making calculations for chemical ratios. Embodied expertise is expertise that is associated with experiential, place-based knowledge held by a particular person. While that person can tell others *what to do*, they cannot tell other people *how to know what to do*, so decisions must be made by a person with expertise at the site of practice.

In our research, a commitment to embodied expertise on the orchard or vineyard did not necessarily conflict with the prospect of automation, but we found two different kinds of scenarios. In many of our interviews, managers suggested that embodied expertise is practiced by everyone working on the farm, and it was valued as necessary at all levels of farm work and for almost all tasks. In these contexts, any robotics incorporated into agriculture were seen to be appropriate only insofar as they incorporated considerable human oversight, and information intensive technologies described by Miller et al. (2021), rather than extensive automation, was seen as desireable. Others described a more exclusive distribution of embodied expertise, valorising the embodied practices of a few key decision-makers on the farm, but not necessarily seeing work associated with more everyday tasks (e.g., tasks often handled by a seasonal migrant workforce) as skilled or necessarily exercising embodied expertise. We elaborate on these below, and then describe the associated social definitions of expertise and the agricultural labour implications that emerged in our interviews.

Technical expertise: professional, transferable, and potentially automatable

The appeal of automation for some reflected the perception that technical knowledge and expertise is the foundation of good orchard and vineyard production. Take, for example, the motivation for automation in fertilizer applications and irrigation described by Chris,[1] a vineyard manager:

> Now, there's still a lot of variability within that hectare and all of those plants, but technology and managing fertilizer applications and water applications and things like that, it's hard for people to make those quantitative decisions, but it's easy for machines.

Similarly, Randy, a vineyard consultant, noted.

> I mean if you're pruning this vine here you'd leave that one, that one, that one and possibly that one. But if you're doing it by hand you can't even actually do it quick enough because of your thinking process.

For Chris and Randy, human cognitive functioning can't perform at the speed and agility of AI, because work is simply the processing of information for the execution of rule-based tasks.

Relatedly, some argued that moving the thinking skills of agriculture away from the physical orchard or vineyard would make it more enticing for younger generations *because* it would become seen as more professional and scientific (i.e., being less laborious and requiring more formal training). In some instances, this was tied directly to intergenerational continuity in farm families, as farm owners or managers would suggest that their children would be more likely to take over the farm if it was associated with corporate work and limitless career advancement, as opposed to the hard physical work associated with more traditional

[1] All names used are pseudonyms.

forms of farming. Flynn, a manager at a large family apple orchard, emphasised the need to change perceptions about horticultural work:

> You've got people who generally come out of school, drop out early, alcohol and drugs are problems, so it's a lower tier or lower class, without trying to put them in a box, and it's not culture based either so it doesn't matter if it's Pākehā,[2] Māori, Pacific Islander. That lower tier is the permanent workers; they're all in that same boat; all left school young; they've been pushed into horticulture because that's how the schooling systems see where they fit, but it's not the reality of what the industry needs. We need people who've got degrees. We need people who've got thinking capacity…. you can go and sell the sexiness of the industry, there are so many opportunities in this industry, not just on the paddock, but right through to sales. Again we still need accountants, lawyers, marketers, we need people who've got skills in terms of mechanics, engineers. I've gone along to careers evenings where you're trying to sell the industry and some of the kids get really excited, but then their parents say, no you're not going into horticulture. It's the perception that horticulture's for those that, without it being derogatory, are dumb. And there needs to be a whole culture shift.

For Flynn, robotics could be part of that culture shift. This would be partly achieved by replacing physically demanding jobs that could be categorised as 'menial labour' with professionalised work involving non-horticultural and vocational training, for example, in law and engineering—off-farm farm work. AI robotics could fully replace a "lower tier" of worker and make horticulture more appealing for those that have little horticultural experience. This quote reflects the ways that the rationalisation of agriculture associated with industrialisation processes are associated with social class, as preciously discussed, and suggests that this association may be reproduced or amplified by digitalisation and the prospect of automation.

In these cases, decision-making could happen at a distance and, given the focus on more abstract forms of knowledge, could potentially be automated altogether. For example, Fred, a corporate vineyard manager, suggested:

> Ultimately what I want to do, is I want to be able to lie in my bed, flick open a device, which could be a touch screen, probably quite a relatively big one, that will have all my things like my models; so it will have disease models, it will give me scanned pictures so I can determine where the stress is and whether it's nutritional stress or water stress or some other stress. It will have disease models, and it will have the weather forecast which will actually predict what's going to happen to the disease. Then it will come up with potential solutions about what I need to do to control those threats; and then also that's got to be linked to the financial software, so I can understand the financial decisions of putting product A versus product B, both in terms of an efficacy point of view, but also effect on the bottom line. I think one of the things I would like to see is sort of an integration of technology if that makes sense. I suppose ultimately I could lie in bed and just read the news and the machine could do it all for me.

Fred's quote brings up an interesting aspect of expert engagement in AI robotic co-design: participants who describe an operation run on technical expertise that could be fully automated are essentially describing the future obsolescence of their own labour. Take for example, Noam, a manager of a large vineyard, discussing how he standardised his own technical knowledge about grapevine pruning:

> So I think the specifications, and there are decisions that you make, you might be making them subconsciously. I've actually tried to follow my own eyes and verbalise what to look at and what decisions you must make and the order. And if I can do that, then potentially you can teach a machine to do that.

Noam was essentially talking about how he could replace his own work with a robotic technology. Paradoxically, while they narrate their work as automate-able, experts who engaged in these kinds of discussions also narrate their continued involvement in management. But what is management without decision-making? We grapple with this question further in our discussion section. As Hank summarised in our interview, "At a certain point you've got to look at technology versus humans, and then the question is, what do the humans do?" For some the answer is that the humans remain responsible for what happens on the orchard or vineyard, and this is the primary and irreplaceable role for humans. The inescapable variability of the environment and plants means that humans are going to be necessary to at least provide some oversight, even if this means watching activities while lying in bed, as Fred suggests. For others, this narrative of responsibility was absent, or technologies were seen to reduce variability and risk in ways that could also reduce the burden of responsibility away from farm owners and managers. We highlight the appeal of this potential aspect of AI robotics in agriculture, but also argue that this seductive draw of the responsible AI robot is one of the greatest sites of potential irresponsibility.

[2] Pākehā refers to New Zealanders of European descent.

Embodied expertise: broad embodied and stratified embodied expertise

Embodied expertise is a form of farm knowledge commonly discussed by social scientists as we elaborated in our earlier section, driven by intuition, developed through experience, and exercised in person and on site. Some of the sociological work on embodied knowledge engages with a sense that the need for embodied work provides an innate resistance to typical trajectories of mechanisation and deskilling associated with capitalist industrialisation. Our research nuances this perspective, by finding that embodied expertise can be expressed in two different ways: (1) embodied knowledge may be seen as essential to all agricultural work (broad embodied expertise), such that an orchard or vineyard's overall functioning is a reflection of expertise developing and being exercised by everyone working there; and (2) because embodied knowledge accumulates, is tied to place, and is non-transferable, embodied expertise may be highly stratified (stratified embodied expertise). In extreme cases, embodied knowledge may be valued amongst managers and decision-makers, but seen as almost entirely absent in day-to-day work. These two aspects likely emerge from the same beliefs in the value of embodied knowledge, but we suspect they may be the expression of different strategies used to align embodied knowledge systems with growing discourses of labour insecurity and precarity. Focus on retaining the same workers year after year, and spend considerable time on training, while the latter may divide labour tasks so that the decision-making associated with embodied knowledge is excavated from the performance of seasonal tasks, and concentrated amongst permanent staff—a trend consistent with observations around Taylorisation. Discussions of autonomous robotics and the future of agriculture clarified these distinctions and led us to speculate that they may be compounded by new AI robotics.

Below, we briefly describe our findings associated with those research participants whose perceptions aligned most closely with notions of broad embodied expertise. As one might expect, these participants saw all orchard or vineyard work as requiring direction from someone on site, so that technologies would primarily perform taxing manual tasks and basic calculations to support decisions. We then describe our findings related to more stratified forms of embodied expertise in more detail, and in particular, discuss associated narratives of future automation that emphasise the importance of people's embodied engagement in food systems, though these people would not be performing tasks, making decisions, or be physically present on the farm while engaging with it in real time.

Broad embodied expertise

Some of our interviewees described broad embodied knowledge or intuition being important for all work, and cultivated through ongoing physical embeddedness within farming environments. Doug, a manager at a large corporate winegrape vineyard, described the basis of agricultural decision-making where there may not be a right decision, but good decisions that people make based on some kind of embodied intuition.

> At the moment we've got people who are very good at making decisions based on their gut feel and their experience. But, I think in time a lot of risk will be taken out by a machine that's providing us with data to make quality decisions. But, then there might be an element of… it's like a good chef; you might have five chefs all given the same ingredients and they all make slightly different results. I think that's where that sort of human element comes in.

Here, Doug is describing how everyone on the farm needs to be able to make informed decisions based on their embodied perceptions. He suggested that this kind of embodied expertise was necessary for all tasks in order to have a well-functioning vineyard. Later in the interview, he described the difference between a tractor "steerer" and "operator," emphasising that he wanted to support the development of operators: "A steerer will just drive a tractor up and down a row. An operator will actually understand." He continued:

> What we try and do is involve them with the end product. We say, "This has worked, this has performed really, really well, and this is why it's performed well, or this hasn't gone so well and this is why it hasn't gone so well." So, that they can sort of see their role in the process. Some of that is with technology. I mean, we're constantly evaluating new equipment and new machinery, but also other things which are harder to evaluate, like sprays and nutrients and techniques like the sub-surface irrigation.

For Doug, robotic technologies doing work in the farm would require a lot of ongoing human engagement, and not so much replace human decision-making, but reduce risk or the burden on bodies, which was sometimes considered the same thing. Oliver, who manages a large family apple orchard, described the opportunities associated with using robotics for counting. "It's a real laborious job and it's not a particularly fun one as you can imagine." Oliver continued,

> If you add those two things together, it's not surprising it's often imperfect. The sooner we can get to the point where we've got that technology doing that for us, the more of it we can actually do from a data collection

> point of view, and the more accurate we will become… You still need the experience, growing experience, but it's all information and it all adds to the quality of the outcome... Like I'm saying, the machines aren't going to do the work. The work is always going to be there.

In both apple orchards and winegrape vineyards, counting fruit or buds was frequently described as a very sensorially demanding job with little reward. For Oliver, work and the experience of workers was irreplaceable, but a component of that work—fruit counting—was seen as being highly technical and could be replaced by a machine. Technology was seen to provide support for agricultural work and could be integrated throughout an orchard or vineyard, but the replacement of entire tasks or work positions was seen to be quite limited due to the need for the everyday exercise of more intuitive and embodied knowledge.

Stratified embodied expertise

In other cases, embodied expertise was less associated with everyday work, but attributed to specific people with power and experience, who would exercise expertise intentionally in discreet moments and this type of work was not automatable. Hank, part-owner and manager of a family-owned apple orchard, for example, said:

> There's nothing like going into the orchard. So what we do in our peak summer, one of dad's roles now is he just goes round the orchard once every three or four days with his ute and a picker on the back and he just goes under some apple trees and picks the ground and just feels the dirt and still you can't replace that.

In these expressions of embodied expertise, someone goes out into the agricultural space from indoors, specifically with the purpose of making managerial decisions that can then be communicated to a workforce. This type of expertise may be accumulated over years of making decisions in that agricultural space, but it is highly distinct from the everyday management of plants and landscapes, and for this reason, compatible with a highly automated landscape. Rather than passing along a decision to a manager or set of workers, that decision could be passed along to a programmer or directly to a robotic technology.

In these cases where embodied knowledge was valued but largely attributed to people who were not performing tasks physically on the orchard, the narratives about an automated future struggled to define the role of the human, even while insisting that a human presence was necessary. The physical participation of human bodies in farm systems was seen as essential, but these need not be engaging meaningfully in agricultural tasks. For example, Susan, who manages an apple orchard, was adamant that there would always be a need for people on the orchard and that full automation would never be possible, but also suggested that the physical aspects of all day-to-day tasks could be automated.

> Ideally you could spray through automation. You could spot disease and pests and manage for that through automation. Hopefully thin and harvest by automation. Hopefully, I mean in the end, this just leads down to pruning by automation doesn't it. ...they're the key tasks that happen in the orchard. Your harvesting, your thinning, your pruning, your spraying, your scouting for pest and disease. They're probably the key tasks that happen. So yeah, I mean in theory you could have a crack at everything, right?

When asked whether new employees with a higher skill set would need to be employed, she mentioned that the apps should be designed in such a way so as to be intuitive for those who need to keep track of the orchard from a distance. The need to have someone present was linked to ideas of oversight and responsibility, but these were somewhat disassociated from work. When describing his enthusiasm for new technologies, Dan, an Operations Manager at an apple orchard, described his appreciation of automated windmills. Windmills are used in orchards and vineyards to reduce frost damage by pushing warm air pockets from higher altitudes into the trees or vines. However, he emphasised that this automation did not displace responsibility from him and paired this desire for automation with a need to be constantly updated. He noted that technology can sometimes fail, and he remained responsible for its functioning. Here Dan is suggesting that once he has chosen an amount of fruit to leave on the trees to ripen in the spring, frost damage resulting from a failed automated wind system would derail his planning and be *his* responsibility:

> I don't like things jumping out at me around the corner, so the more I know the more I can avoid that. If I'm submitting fruit, I know once I've submitted it and it looks like this, and it's going to potentially be around that percentage of pack-out, and that's going to be my main defect because the windmill turned off.

In some cases, this need for continued responsibility for on-farm decisions was obvious in our interviews, and could be linked to concerns over maintaining some level of autonomy and the ability to exercise some control, even if it would be rarely actually needed. Comments from participants along these exemplify observations about embodied knowledge and autonomy in the face of industrialisation (Stock and Forney 2014).

Discussion: what kind of expert is a robot, and what kind of expert is required? Knowledge, power, and responsibility

Returning to our initial research questions, we firstly asked whether the use and appreciation of technical expertise made farm managers more likely to see automation as possible and positive. Technical expertise would rely on abstract forms of knowledge, which could be rule based and objective, and would be associated with a more industrialised ideal in agriculture (Fitzgerald 2008; Auderset 2021). In other words, we wondered whether a robot was, by design, a technical expert that could displace humans on the farm who were also performing this kind of work. Our research found this assumption to be reflected in our interviews. Some interviewees described how slowly and imperfectly the human mind could process information compared to AI, so that AI robotics would have the capacity to perform agricultural work better than people. This kind of approach to knowledge aligns with observations about industrialisation in farming systems: that the rationalisation of landscapes and more scientific approaches to farming practices can make tasks in agriculture more like piece work on a factory floor, and workers do not need to know about their tasks beyond the rules they are given to complete them. This also makes them easily replaceable by other workers and replaceable by robotics. In many cases, unlike previous periods of industrialisation, this replaceability also translated to decision-making and managerial work, and those we interviewed considered a future where they were absent from the orchard or vineyard space, or their job was completely obsolete. On the other hand, these interviewees saw new roles in agriculture for professional occupations like engineers and lawyers, and celebrated a form of agriculture that was more appealing to ambitious younger generations.

We also initially asked whether a reliance on embodied expertise on the farm translated to a sense that automation would not be possible. This built on research on farmer identity, and the importance of embodied work for autonomy (Stock and Forney 2014; Stock and Forney 2014) even in the face of new precision technologies (Carolan 2020). Consistent with this research, we found farm managers and owners who stressed the importance of embodied expertise for the functioning of the farm did emphasise the need for their presence and control over new robotics, supporting observations that there can be space for intuition in the use of AI robotics (Prause 2021) as long as people remain able to programme them. In these cases, more open and programmable technologies are emphasised as important—as opposed to technologies forcing their logics (and the logics of their developers and owners) onto farms and farmers. These findings echo the work of Ditzler and Driessen (2022), who link analogue and open design to a capacity for agroecological production. In some of our interviews, however, this presence and control seemed only necessary for those currently in a managerial position, as embodied knowledge and decision-making processes were not seen to be exercised by those performing physical tasks in orchards and vineyards. In this stratified context, full automation was not seen as possible, but automation could still be quite extensive, replacing many of the seasonal jobs which make-up a majority of on-farm labour.

Others saw embodied forms of knowledge as essential in more basic farm tasks, and expertise as something exercised by those performing seasonal work. In these cases, technologies would have to be more integrated into orchard or vineyard work, but these would largely include a human and AI robotic component. While robotics could perform activities like counting apples, much of the guidance around what would be happening would be performed by humans. This human activity was often a blend of needing the embodied knowledge to perform the task, but also included aspects of requiring observant bodies on the orchard or vineyard that could notice factors outside of the immediately relevant information for a task, or that could exercise the more intuitive aspects of performing a task. For example, Doug, the vineyard manager who we alluded to earlier in the section on embodied knowledge, described how a tractor operator, rather than a steerer, would be able to recognise and account for things out of place in the vineyard—work that was beyond the tasks they were engaged in. Doug also suggested that much of the work on the vineyard required behaving like a chef, something that could not be fully replicated by a machine.

Our work also extends findings on distributed or composite agency along the lines of what has been observed by Comi (2020), Lioutas et al. (2019), and Lowe et al. (2019), while adding to an understanding of 'socio-cyber-physical systems' (Lioutas et al. 2019; Rijswijk et al. 2021). Our work provides some insights into this line of research by thinking through possible human-technology networks, based on our observations, and considering how these might have very different configurations that develop out of a set of epistemological foundations:

(1) When managers and owners operated with a rationalised industrial ideal, they seemed to envision an autonomous future with the technology on the farm, and people largely off the farm. The farm space could be represented digitally and managed through AI, and much of the farm work would involve skills like engineering, legal expertise, and marketing, performed in other spaces off the farm. While we could see a lot of cognitive or intellectual integration with technologies

in this context, there would be less on-site physical integration of people and technologies.

(2) When more embodied form of expertise were described, our research participants saw AI technologies as integrated with human work in orchards and vineyards, but only for those whose embodied expertise is currently valued and used in decision-making. While it may be assumed that farm owners or managers retain the ability to exercise agency, our research finds that whether others on the farm would be afforded this kind of technological power depends on their current status. Where most tasks on the orchard or vineyards were seen to require embodied expertise, we would expect, as our interviewees noted, anticipation for a lot of what Prause (2021) described as "other-skilling," or the kinds of skills shift Rotz et al. (2019a, b) described in the improved conditions of dairy workers with autonomous milking systems, or what Ditzler and Driessen (2022) see as possible technological integration with agroecological farming styles. Robotics or decision-support AI would be fully integrated into everyday work on orchards and vineyards, but the degree to which these technologies would be truly autonomous and operating independently would be limited

In short, we can expect socio-technical networks to develop in the future and autonomous robotics can be seen to have a place in those networks. However, what those networks look like, in terms of technical integration into agricultural work, skills development, and the overall social transformation of agriculture, is quite variable, and likely to depend on the existing farming epistemologies and their influence on the division of labour and the distribution of power on farms. Our research teases out a few possible scenarios.

As described in our results section, there were times when participants described a need for human oversight, but it was unclear what those humans would actually be doing, apart from taking responsibility for what was happening on the farm. For some, like Dan, an Operations Manager at an apple orchard who was discussed in the last section, human engagement in an automated future meant being able to step in when something went wrong. We imagine that this role can help to fulfil a desire for control and autonomy in the face of roboticisation, and would generally reproduce existing power structures in agriculture.

Other times, the social role of enduring managers in imagined automated futures was quite opaque and it was difficult to see whether anyone would actually still be in charge, or whether responsibility was being offloaded onto the technologies themselves. For example, in the case of Chris, a vineyard manager we quoted in the previous section, irrigation and fertilizer calculations could be carried out entirely autonomously. These are activities that are somewhat sensitive in an environmental context, and it is unclear where responsibility would lie were those calculations found to be environmentally damaging. Moreover, many of our participants alluded to new AI technologies reducing risk, but this assumes that the information and processing of that information is always reliable, or that someone else would be liable should there be a mistake. In these cases, relations of responsibility would need to be clarified with the introduction of these technologies, and it may be necessary to rethink where legal responsibility for things like environmental outcomes would be located.

Conclusion

In this paper, we have questioned the social implications of new AI robotics, attending to their novelty in the history of agricultural industrialisation which lies in potential capacities to perform expert tasks. Their ability to perform expert tasks, and thus displace agricultural expertise, highly depends on the nature of agricultural expertise and the degree to which it is a calculative, objective process, or an exercise in more intuitive and embodied practices. Importantly, we found that the ways these different kinds of knowledge are used on the orchards and vineyards are highly variable. One significant source of variation lies in who is recognised as having embodied knowledge. While the requirement for embodied knowledge in agriculture is often seen to guard against increased mechanisation, this is only really the case if embodied knowledge is valued throughout the operation of the orchard or vineyard. Otherwise, the highly stratified form of embodied knowledge means that tasks could be automated in a way that aligns with existing functioning of the farm system—with decisions being made by experts with embodied knowledge, but tasks performed by AI robotics.

We also considered how the social dynamics in agriculture might change with the introduction of autonomous robotics, by considering how more technological mediation, might have varying effects on changing social dynamics of distributed agency (Comi 2020), composite agency (Lowe et al. 2019) and 'socio-cyber-physical systems' (Lioutas et al. 2019; Rijswijk et al. 2021), depending on the existing epistemologies at play in an agricultural system and their relationship to the division of labour. While our research is useful for thinking through possible future scenarios and the expectation of farmers, or their perceptions around future automation, it also sheds light on how we might expect automation to unfold.

The development of new autonomous technologies and their uptake reflects what people with power on the farm want, and what they view as possible. In this research, we have explored what people think is possible given different ways of orienting to agricultural knowledge, and linked that to what they want and anticipate in the future with robotics. Our research places this within a context of industrialisation, where there has been a historic push to rationalise the farm for greater productivity and reduced labour needs. Within that environment, there has been a continued commitment to embodied knowledge and expertise, and this has a politics in retaining farmer autonomy and supporting the cultural identity of farmers through their claims to specialised, place-specific knowledge. Our research shows how autonomous robotics exists within this context, and can further a more rationalised approach to agricultural landscapes, while creating new meanings attached to embodied expertise. Moreover, we suggest that the socio-technical physical systems we may see emerging relates to these industrialisation histories and is likely to shape the social dimensions of heterogeneous agricultural networks. Human integration with technologies can take multiple forms—from the facilitation of farm work occurring largely off farm, to everyday work being integrated with technologies. Critically attending to how farm managers and owners imagine the future of automation on their own farms can help to clarify why a particular set of conditions may develop in the future. It also provides a space to critically consider other possible futures, for instance, what we want our food production to look like from a social, environmental, and political perspective.

Through our analysis, we are left with lingering questions about the attribution of responsibility in this autonomous future. While much work has described the value of intuition in supporting sound decision-making, and there is much work on the value of embodied knowledge in navigating decision-making in complex ecological systems, one significant aspect of these performances of knowledge are that the attribution of responsibility is very clear. As our research participants noted their desire for the accurate reporting of data from sensors, or greater accuracy in the performance of tasks, or the combination of the two (i.e., more precise decisions and their autonomous performance), we were left wondering who would be responsible for any socially or environmentally undesirable outcomes. In some cases, our participants noted that their expert position would remain, but could be conducted at an increasing distance. In some cases, narratives around the reduction in risk seemed to skirt dangerously closely to a desire to shirk responsibility. When responsibility involves making yield and quality targets, this is one thing, but when it is about ongoing patterns of fertiliser or chemical applications, we take pause. Is it us, now, in projects like our own, who will have to take responsibility for the decisions and learning processes built into these machines? Or those who own the intellectual property and commercialise these technologies? Or are those who benefit financially from the reduced dependence on labour those who will be responsible? As humans and decision-making robotics become more entangled within agricultural settings, and the social and environmental pressure on good agricultural practices increases in the face of climate change, we need to be vigilant to ensure that those who should be responsible are aware of their responsibility and active in taking it.

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