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Embracing the social sciences, arts, and humanities in inter-disciplinary precision dairy research: opening-up conversations beyond adoption and techno-optimism

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Precision technologies in dairy farming are widely hailed as offering the opportunity to revolutionise modes of production, helping to create more with less. Promissory narratives of precision dairy technology continue to dominate, with an overwhelmingly positive view of technofixes in scientific, policy, and popular debates. When the social sciences and humanities are called on to play a role in nominally inter-disciplinary investigations of precision livestock technologies, many studies continue to focus on reasons for initial farmer adoption using superficial methodologies and appear tokenistically to involve social scientists from a narrow set of disciplines, late in the day. However, there is a growing wave of social science and creative arts-based studies focusing on precision livestock technologies, including in dairy systems, which offer something different. These studies do not focus purely on reasons for initial (non-) adoption of precision dairy technologies, which tend to miss critical debates around the opportunities and risks of change. Our arguments are based around three key concepts – *time, place, 'more-than-human'* – plus over-arching themes of *justice* and creative *inter-disciplinarity* – as a basis for encouraging precision dairy researchers to expand focus areas beyond adoption and techno-optimism. Inter-disciplinary and hybrid scholarship from across the animal sciences, social sciences, and humanities address different topics and offer innovative ways of including human and non-human stakeholders. We showcase and celebrate some of this work and call for its early and sustained integration in future inter-disciplinary collaborations.

KEYWORDS
digital livestock farming, precision agriculture (PA), precision dairy farming, precision dairy farming technology, social science & humanities

Social science and arts-based imagination: expanding disciplinary boundaries

Whilst the majority of peer-reviewed articles on precision technology in farming may reside firmly in natural science and engineering disciplines, there are studies that have incorporated social and behavioural approaches. However, a scoping review of over 200 studies by McGrath et al. (2023) found that social and behavioural approaches used in digital agriculture research tended to be narrowly focused on establishing reasons for farmer (non-) adoption of technologies. Despite the presence of a large number of studies that illustrate the complexity and non-linearity of farmer technology adoption (see Rose et al., 2023, Montes de Oca Munguia et al., 2021), belief in revolutionary change and rapid diffusion of innovation remains unchecked in some scientific, industry, and policy settings. Such a belief can direct attention towards the design of so-called 'game-changing' technologies (Klerkx and Rose, 2020), rather than the establishment of good systems for knowledge exchange, co-design, infrastructure upgrades, and skills development. In the context of precision dairy or livestock technology specifically, there have been many studies focused on factors affecting adoption or willingness to pay for technologies (e.g. de Assis Lage et al., 2024; Dell'Unto et al., 2025; Groher et al., 2020; Silvi et al., 2021), which all tend to reveal a similar set of reasons, such as cost, ease of use, interoperability, trust, and access inequalities. In addition, several studies have investigated rates of adoption of digital/precision dairy technologies like automated milking systems (AMS) or wearables (e.g. Bianchi et al., 2022; DairyNZ, 2023), but data on a global level may best be described as sporadic.

The overwhelming focus in using the social and behavioural sciences to investigate reasons why farmers do, or do not initially adopt technology misses many important questions and impacts that arise from encounters between technology, people, and animals on-farm (with impacts 'off' the farm too). Fielke et al. (2022) called for the expansion of disciplinary boundaries to integrate social science approaches into the critical examination of what digital and precision technologies 'do' on-farm. This call was inspired by interdisciplinary contributions to a special issue of *Sociologia Ruralis*, which acknowledged the opportunities and risks of precision technology and the need to ensure they do not further perpetuate current injustices.

In this paper, we draw attention to *justice* frameworks. Procedural, recognitional, and multi-species justice approaches, call for the inclusion of a wide range of human and non-human animal voices in determining the future of agri-food systems, helping to examine how benefits and risks are distributed (equally or unequally) (de Boon et al., 2023). There are good examples of research on what constitutes a 'just' transition in dairy systems. Social science research has indicated the potential for precision livestock technologies to have negative consequences, as well as benefits (e.g. Kopler et al., 2023; Neethirajan, 2025; Schillings et al., 2021; Hostiou et al., 2017). Bojović and McGregor (2025) explore sustainable and just dairy transition pathways in Aotearoa New Zealand, a country which is suffering socio-ecological challenges from dairy farming, as well as ongoing challenges with price volatility and productivity. Building on work done by the Ministry of Business, Innovation and Employment with stakeholders on a 'Guide to Just Transitions for communities…' (Just Transitions Aotearoa Group, 2023), Bojović and McGregor (2025) note that there could be several possible transition pathways, including diversification, de-intensification, or creating dairy alternatives. However, Bojovic (2024) recognises that different dairy farming futures have different consequences which may be unevenly spread across humans and non-human animals. The aim of including stakeholders (human and non-human) in anticipating the consequences of dairy transition pathways, including technology-based transitions, is to ensure that existing or new inequalities are not entrenched or created (Bojovic, 2024).

During the course of our arguments below, we highlight research from a number of disciplines from across the animal sciences, social sciences, and humanities, much of which is interdisciplinary and hybrid.

Since many of the contributions we highlight incorporate multiple disciplines and blur the boundaries between them, we stress the over-arching theme of *creative inter-disciplinarity*. Some of these collaborations, in the words of a Dutch project on establishing equitable ways of "living with non-human animals, plants, and technologies"[1] may appear 'unusual', but such innovativeness is key.

In this short perspective, we cannot do justice to the broad range of animal science, social science, and arts-based disciplines that have made, and will continue to make, valuable contributions to precision dairy research. Nor can we go far beyond a superficial account of each study. We selectively focus on approaches from some disciplines and further highlight only selective studies and authors within those disciplines. We urge readers to cast their nets wider and deeper.

Time

Rankin et al. (2017), remind us that technological change in dairy farming is nothing new, tracing a number of 'revolutionary advances' throughout the 20th Century. Historical accounts of innovation in dairy farming serve to contextualise current change or predictions of the future, with precision technologies widely heralded as revolutionary. Trapanese et al. (2025) review the last 50 years of so-called precision dairy farming, noting an exponential increase in material since 2000, and remind us that precision technologies constantly evolve over time. Bieleman (2005) traces technology change in Dutch dairy farming since 1850, highlighting how innovation responds to different economic, political, and social drivers over time, particularly the need to boost labour productivity. His account notes factors that contributed to rapid adoption of some technologies, particularly those that could be integrated quickly within existing farm infrastructure. He argues, however,

1 https://unusualcollaborations.ewuu.nl/unusual-collaborations/imagining-more-than-human-communities/. This project incorporates literary studies, philosophy, cultural geography, robotics, animal ethics, and cognitive science.

that the process of technology adoption and efficient use was not straightforward with various challenges, such as lack of farmer knowledge and resistance to new policies. Technology adoption also had a wider effect on the structure of the Dutch dairy industry and rural society.

We also highlight the work of historians and philosophers who captured the oral histories and experiences of farmers during the Green Revolution, which help to tell a more nuanced account of the opportunities and risks afforded by new technologies, which cuts through oversimplistic, positive accounts of technological silver bullets (Kumar et al., 2017; Pielke and Linnér, 2019; Shiva, 1991). Such work helps us to understand that technology in agriculture is not without its risks and benefits/costs may be unevenly spread across society, particularly when accounting for the influence of powerful actors.

By incorporating historical perspectives of change in dairy farming, it becomes clearer that contemporary debates around the opportunities and risks of precision technology, how they are distributed between human and farmed animals, and how human and animal stakeholders are or are not included in setting trajectories, are nothing new. For example, the ethical debates surrounding a more contemporary dairy technology, automated (or robotic) milking systems, are strikingly similar to controversies seen in the move away from hand to machine milking earlier in the twentieth century (Holloway and Bear, 2017). Holloway and Bear (2017) frame the technology as part of a long historical trajectory of change in milking practices in which previous technological advances have also affected human animal relationships and animal health/welfare. Similarly, Muñoz Sanz (2020) traced technological advancements in Dutch dairy farming, highlighting how farmers have tended to move away from treating cows as if they are members of the family and towards biological units embedded in technological systems. As technology has evolved, so has our ability to track their bodies, control their movements, and their lives.

These papers and the historical accounts mentioned above illustrate that some benefits have resulted from new technologies, such as enhanced efficiency and labour productivity, and in some cases have enhanced human and non-human wellbeing. However, they also show that dairy farmers did not always feel included in designing policy changes, were not necessarily helped with the infrastructure, skills, and other support needed to adopt, and some may have disagreed with the consequences of technical change on farming, rural society, and the health/welfare of animals. More contemporary studies rooted in approaches from disciplines like anthropology, geography, political economy, sociology, and STS, continue to highlight similar opportunities and risks.

The temporal element of change in precision farming, as well as the impacts of interactions between technology, people, and animals, is also noted in more contemporary studies. For example, Montes de Oca Munguia et al. (2021) illustrate that farmer adoption of technology has a temporal element, usually not picked up by a one-off quantitative survey or set of qualitative interviews which ask farmers why they did or did not adopt something. As Martin et al. (2022) show in the context of AMS, farmers may initially adopt the technology, and then either continue to use it or they may decide to dis-adopt for various reasons. Hansen et al. (2020) finds that farmers may initially struggle with AMS, but some find it easier over time as skills and workflows develop. Surveys or interviews that focus on the initial point of adoption, or at a single point in time, fail to capture what comes next and cannot answer several key questions, the answers to which are crucial to determine whether sustainability or justice was achieved – did the farmer continue to use the technology, and as intended, or differently? What ongoing support might the farmer need and how might the role of the advisor change? How does the technology change life on the farm, workflows, farmer/stocksperson identity, and human wellbeing? Does it actually lead to different or better decisions? How does it affect animal health and welfare? On the latter point, just because a farmer has adopted a technology designed to improve animal health and welfare does not automatically mean that it is being used as intended by the manufacturer, or that it is leading to decisions that result in an improvement. Rather, hybrid knowledge practices, integrating farmer and technological knowledge, tend to result (Barrett and Lansing, 2025) with data interpreted in the farm context within a farmers' belief systems and experiential knowledge. Indeed, some studies highlight unintended consequences of technofixes within livestock systems and that it can be harmful to animals (e.g. Boyle and Stevenson, 2025; Doidge et al., 2023; Schillings et al., 2021; Williams et al., 2024). Post-adoption studies following the farm technology journey are therefore needed, rather than looking at a single point in time.

Looking towards the future of precision dairy research, how else might we anticipate the benefits and costs of precision technologies? Several different social science and arts-based methodologies might be used to anticipate the consequences of precision dairy technologies (see e.g. Eastwood et al., 2019a), including outcomes for people, production, and animals/the environment, as well as to include a wider variety of stakeholders in designing dairy futures. Such approaches hold promise compared to more commonly used survey, interview, or econometric modelling methods that dominate the farmer technology adoption literature. They could include the use of Living Labs, which puts practitioners and the farm at the centre of research design and data collection, as used across several European countries to understand dairy farmer technology needs and experiences (Doidge et al., 2024). Citizen juries comprised of representatives across society, both from within and outside of the food production system (see Ayris et al., 2024), and finding ways to represent animals (encouraging people to look at things through the lens of animal perspective/experience), could facilitate a wider range of cultural beliefs and values to shape the future of dairy systems. User-centred technology design and development approaches, for example through design thinking to empathise with user needs before embarking on a process of co-design, could ensure precision technologies have more just outcomes (McGrath et al., 2025). Still too often social scientists might be involved late in the day once a precision dairy technology has been developed, acting as the de facto marketing department tasked with hopefully collecting

evidence that it is beneficial and wanted. Serious games or participatory workshops could enable different actors to consider the trade-offs associated with different transition pathways (Dernat et al., 2023; Kuhn et al., 2025), whilst arts-based approaches can help to generate narratives about the future and use associated stories, artwork, dance, poetry, etc. to engage stakeholders in a values-driven dialogue (Daum, 2021; Rose, 2026). We return to the valuable contribution of arts-based approaches several times in the remaining discussion.

Place

For several disciplines, place is everything (see e.g. Agnew, 2011). Whilst farms occupy spaces, being located on geographic co-ordinates on the Earth's surface, each one is a home and workplace to people and animals. This turns abstract spaces into meaningful places with each farm having a unique history and set of social relations, often formed over generations. As knowledge is situated (Haraway, 1988), it is important to recognise that on-farm interactions between people, animals, and technology are uniquely individual and the purposes, practicalities, and effects will be different in different places (Williamson and Hartley, 2024). In addition, research on precision dairying should account for the differing labour and advisory relationships on different farms, including both people making decisions on-farm (e.g. farm manager, workers) and off-farm (e.g. farm managers, advisors etc., Eastwood et al., 2019b; Nettle et al., 2025).

Many studies, for example, have taken an on-farm approach to studying the impact of precision livestock technologies on economic outcomes, farmer identity, workflows, advisory relationships, labour reconfiguration, wellbeing, and human-animal relationships (e.g. Holloway and Bear, 2019; Doidge et al., 2023; Driessen and Heutinck, 2015; Edwardes et al., 2024; Martin et al., 2022; Nettle et al., 2025; Schillings et al., 2021), which have identified benefits (e.g. lifestyle improvements, labour cost reduction, skills improvement) and risks (e.g. concerns over data overload and privacy, intensification or the dangers of surveillance, or loss of connection with animals), as well as highlighting how technologies are used within farmers' value and belief systems, or notions of 'care' for their animals (Lundström and Lindblom, 2021; Vaarst et al., 2024). It is only through understanding individual everyday technology journeys on a farm that we can begin to form judgements on the extent to which precision dairy technologies are affording benefits and costs to people and animals. Studies on the effects of robotic milking, some mentioned already, show the value of taking a place-based approach. For example, for some farmer adopters, the change to milking routines and lifestyles may be valued in a positive way, with the technology freeing up time to do other tasks or spend with family, and offering the opportunity for informed decision-making and development of skills. For others, the changes to work routines might not be as beneficial as first thought with the technostress of constant data alerts and the creation of new work (see Hansen et al., 2020; Martin et al., 2022). From the perspective of humans and non-humans, changes to the human-animal relationship as a result of changed milking routines could be positive (e.g. less disturbance to livestock) or result in a perceived or real negative change if stockspeople lose connection with livestock and traditional skills associated with spotting problems.

Ethnographic approaches (including visual ethnographies designed to focus on non-human animals, see next section) hold particular value in capturing the journey and effects of technology on-farm. Some good examples include Bear et al. (2017); Bellet and Morgan (2024); Cornips and van den Hengel (2021); Kramer and Bovenkerk (2024); Nyokabi et al. (2023), who use ethnographic approaches using methods such as field notes, observation of people and animals, photovoice, and videos, to explore human-animal relationships and how they are affected by precision technology, which raises important social and ethical questions. These approaches draw insights from Feminist Studies, Geography, Political Economy, Science and Technology Studies, Sociology, and Visual Culture (amongst others).

Ultimately, studies will need to be sensitive to place, as well as how places change over time. This will involve robust scientific testing of health, welfare, productivity, and environmental impacts across multiple different dairy farms, and the investigation of everyday interactions between farmers, workers, advisors, animals, and technology.

More-than-human

Taking a multi-species justice perspective, precision dairy research must ensure that animals' voices are included. As Coghlan et al. (2026) argue in the context of artificial intelligence, though their point holds for any type of precision dairy technology, animals are affected by technology in positive or negative ways. Humans have responsibility to protect animals from harm, both morally and because of legislation, and in the context of dairying, we have continued to restrict the agency of animals over time (Keulartz and Bovenkerk, 2021). Moreira et al. (2026) invite researchers to design future agricultural systems with non-humans and to conduct more research on what the most effective methods to include non-humans in participatory processes are. Several studies mentioned below, including those rooted in animal ethics and animal welfare science, act as bright spots to inspire a more inclusive approach to considering the role, if any, of precision technologies in the future of dairy systems, helping us to consider opportunities and risks, and on whom benefits and costs fall, from the perspective of animals.

Historically, non-human animal voices have been too readily dismissed because they cannot speak in the same way as humans (Cornips and van den Hengel, 2021). As Giersberg (2026) writes they may be 'seen but overlooked' in the deployment and use of digital technologies. This has meant that they have not been able to 'establish themselves as ethical, juridical and political subjects' in the same way as humans (Cornips and van den Hengel, 2021, 179).

Yet, non-human animals through various practices can clearly speak. For example, dairy cows, each of which has their own unique personality, that step back when approached by a farmer may clearly be saying 'do not approach us' (Cornips and van den Hengel, 2021).

Animal scientists have long used preference or motivation studies to allow animals to convey what they want and need (see e.g. Franks, 2019) and these experiments could be undertaken with a range of precision dairy technologies. However, they have limitations as they do not show how strongly an animal values a particular option or how important it is for welfare (Duncan, 2004), and preferences may reflect short-term rather than long-term needs (Dawkins, 1980). To address this, motivational approaches have been developed to measure the strength of preferences. Operant conditioning methods, in which animals work (e.g., lever-pressing or key-pecking) for access to a resource, demonstrate that the commodity is sufficiently rewarding to elicit an operant response (Fraser and Matthews, 1997), whilst consumer-demand approaches quantify how much an animal is willing to "pay" for access, indicating the resource's relative importance (Dawkins, 1990). However, whilst experiments have been undertaken in relation to motivation or preference, the degrees of choice afforded to animals may still be restricted (Heidenreich and Pedersen, 2025).

A further step would be to engage with and learn from nonhuman animals themselves to better understand their preferences, participation and agency. Within this paper, animal agency is understood as the capacity of animals to actively engage with and influence their physical and social environments through their behaviour, choices and interactions (Špinka and Wemelsfelder, 2011; Browning and Veit, 2025). Neethirajan (2025) poses interesting questions when considering whether technologies can support animal agency, rather than reducing them to points of data. He argues that technology design should prioritise freedom, choice, and individuality.

Various ethnographic studies, embracing multi-species ethnography, have tried to capture what dairy cows might think of technology and how it changes their lives (Bear et al., 2017; Bellet and Morgan, 2024, Cornips and van den Hengel, 2021, Kramer and Bovenkerk, 2024). Some of these studies try to move beyond taking field notes and human observations of cows and animals towards the use of visual methods as an attempt to try and decentralise the anthropocentric view of how non-human animals may be interacting with technology and to promote animals as 'active co-constituents of social relations' (Bear et al., 2017, 227). Holloway and Bear (2017) use interviews and observational research to capture personal histories of change on-farm and from the view of the milking robot supply chain. Kramer and Bovenkerk (2024) follow individual cows, people, and technologies to better understand interactions, which could include regimes of resistance from animals towards technology. They use their findings as a basis for considering how precision dairy technologies could be designed to take into account values of animal agency - to enhance animal choice, including possibilities for animals to resist. Cornips and van den Hengel (2021, 177) used an ethnographic fieldwork approach at intensive dairy farms to move 'beyond the assumptions of human exceptionalism', including audio and visual recordings to understand what they called the 'linguistic place-making of cows'.

On the use of creative arts- and humanities-based methods (some based in ethnographic fieldwork), including in emerging fields such as the veterinary humanities (Skipper et al., 2026), there are inspiring examples of how researchers are trying to stimulate values-based debates around precision livestock technology. For example, the Portable Cow project (Bellet et al., 2023) is a miniature exhibition combined with archival material, objects, photographs and field notes, designed to encourage publics to 'reflect on cow lives, farmers' experiences, and the human-cow bonds shaped by digital technologies'. Using the imagery of a farm that fits within a human hand, it invites debate over what it means to have engineered farmed animals to fit within human systems of control. A film called 'Routines' by Lagneaux and Becker (2022) illustrates the changes brought on farm by automation and how practices are changed from the perspective of cows, as well as humans, similarly to an exhibition by the affect lab[2]. Artwork, including 'Unleash Your Herd's Potential, by Szalai (2006) helps to show non-expert publics what the reality of precision technology looks like on-farm and to trigger conversations around the tracking and monitoring of animals from a surveillance capitalism perspective. Animals are tracked, behaviours are monitored and engineered, and environments are restricted (Szalai, 2006). In doing so, the artwork makes realities on-farm more visible to those who never visit a farm, offering an opportunity to democratise debates over the acceptability of precision dairy trajectories. Another possible approach to democratise conversations around precision dairy research is to embrace multi-species justice cinema as a way of centring the views of farmed animals[3].

Additionally, representational methods, building on social science approaches, have been used that allow humans to speak on behalf of animals (Moreira et al., 2026). Using livestock farmers as experienced individuals who could indicate what a cow's preferences might be, Mills et al. (2023) posed the question, "If you were a cow, what would you want?". Through a series of participatory workshops, farmers were encouraged to develop cow-centric farm designs, which considered environmental considerations and cow handling and care. Other relevant parties include respected animal advocacy organisations and animal welfare experts. Such organisations and experts already sit on official animal welfare standards making committees in some jurisdictions and could be consulted in both the development and implementation of precision dairy guidelines as suitable representatives of animal interests. There are also limitations with this approach though as humans cannot be expected to speak for animals without sometimes getting their needs wrong (Hughes and Black, 1973; Fraser and Matthews, 1997). This is why combining social science methods with animal welfare science and ethics is important.

Conclusion

If we are to pursue sustainable and just transitions in dairy systems, it is necessary to ensure that the opportunities and costs are

2 https://www.affectlab.org/waiting-for-cows

3 https://read.dukeupress.edu/the-minnesota-review/article-abstract/2024/103/103/393360/Attuning-to-the-PluriverseMultispecies-Cinema?redirectedFrom=fulltext

equally distributed and that benefits result for people, production, and non-human animals. Though precision dairy technologies make various promises, sustainable and just transitions will not be achieved purely by relying on faith, optimism, and linear notions of technology adoption and knowledge transfer. What matters more than if precision technologies are adopted is whether farm management decisions are improved, whether animal health, welfare and agency, productivity, and environmental outcomes are enhanced, and whether social and ethical impacts are considered to be favourable. None of these aspects can be investigated properly without user- and animal-centred, temporal, place-based, more-than-human, research. In other words, to ensure that dairy transitions are sustainable and just they must be shaped by those affected, which always includes farmers (and likely family members), advisors, workers/stockspersons, and non-human animals as key stakeholders, but arguably also involve everyone if we are to consider socio-ecological outcomes. We need to build on ways of including humans and non-human animals better in considering what the role of precision dairy technologies should have, if anything, in dairy futures, as well as following use journeys to articulate support needs and effects on farm over time. This requires creative and novel inter-disciplinary approaches, involving a range of social science and humanities disciplines, and we hope that some of the studies highlighted above provide inspiration in the forming of such collaborations so they become increasingly usual.

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