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Policy approaches for enhanced dairy sector innovation – a review of future pathways and policies for effective implementation of digital agriculture

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ABSTRACT

Innovation and technology are a feature of New Zealand's dairy sector. To overcome current challenges, dairy farmers require agile and multi-dimensional innovation, supported by forward-looking and integrated policy from both the sector and government. In this paper, we outline some of the current dairy sector challenges, and potential technologies to address these challenges. We focus on the future for digital agriculture innovation and discuss policy approaches to enable the sector to leverage digitalisation. These approaches include co-innovation, responsible innovation, multi-scale approaches, micro-innovation and poly-innovation and mission-oriented innovation. Digital agriculture and policy may interact in two ways: (1) policy may be used to enhance digital agriculture innovation and, (2) digitalisation itself may act to enhance agricultural policy design and delivery. Overall, innovation policy requires greater directionality, use of policy bundles and a focus on technology as a mediator of new dairy farming practices and institutional configurations.

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Poly-innovation; mission-orientated innovation; policy bundles; digital agriculture; data governance

1. Introduction – challenges for the New Zealand dairy sector in the next decade

Dairy farming is the largest export sector in New Zealand (NZ), with an expansion of the national herd over the past 30 years (Knook, Eastwood, & Pinxterhuis, 2022). The sector faces challenges, and significant policy uncertainty, related to water quality, greenhouse gas emissions, biosecurity, attracting and retaining farm employees, consumer expectations of increasing animal welfare standards and continuous improvement required for market access and the associated compliance/proof of practice (Romera *et al.*, 2020). The multifaceted nature of current, and future, sector challenges requires innovation processes and outcomes that are multi-dimensional, anticipatory and inclusive (Eastwood, Edwards, & Turner, 2021). The aim of this short paper is to outline future innovation in the dairy sector, and policies that would support such innovation. More specifically, we focus on digital agriculture as an example of future innovation relevant to the dairy sector tackling the current challenges.

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2. Innovation to address sector challenges

Development and application of technologies are one opportunity to address dairy sector challenges (Romera *et al.*, 2020). These include novel forage species and rumen-focused technologies to reduce greenhouse gas emissions, efficient fertiliser management to address water quality issues and automation and digital technologies to enable farm teams to work smarter and make dairy jobs easier. Many of these technologies face complex innovation environments that involve uncertainty not just around technology performance on-farm but also uncertainties related to political, regulatory, public/consumer perceptions, sources of advice, competitive behaviour and long-term impact on the dairy sector (Eastwood, Dela Rue, Edwards, & Jago, 2022). This highlights that successful agricultural innovation requires not just the creation of hardware/software but also institutional and policy settings that facilitate a systems-level approach to progress technology through the developmental process and to reduce barriers to adoption (Turner, Klerkx, Rijswijk, Williams, & Barnard, 2016).

Digital agriculture has been attracting international attention as a potentially transformational 'silver bullet' for increasing agricultural productivity while enhancing sustainability outcomes (Ehlers, Huber, & Finger, 2021; MacPherson *et al.*, 2022). However, this techno-optimism has also been contested (Eastwood *et al.*, 2021; Lajoie-O'Malley, Bronson, van der Burg, & Klerkx, 2020). One of the critiques of the hype that surrounds digital agriculture has been the technology-led approach, and the lack of a co-ordinated systems approach (Eastwood *et al.*, 2022).

In the NZ context, digital dairy technologies in use, or on the horizon, include wearable animal sensors, robotic milking (on new rotary platforms or retro-fitted), virtual fencing, in-shed automation, remote/robotic feed assessment, geo-location for nutrient and animal management, and advanced data analytics for decision support (e.g. digital twins, artificial intelligence); (Eastwood *et al.*, 2021). These technologies fit within categories of sensors for data capture, automation and robotics, internet of things (IoT) and connectivity, and cloud computing and data analytics (Table 1). Successful use of digital technologies could have benefits such as enhanced farm productivity, more efficient use of nutrients and water resources, improved dairy workplaces, transparency of practices to consumers and the public, enhanced animal care and better supply-chain integration (Ingram *et al.*, 2022; MacPherson *et al.*, 2022).

The path to the adoption of digital agriculture technologies is littered with unfulfilled hype and expectation (Ingram *et al.*, 2022). Recent survey data from AgritechNZ (see agritechnz.org.nz) highlight the uneven digital adoption across the dairy and wider primary sector. An enduring issue is a

Table 1. Examples of current and future digital innovations applicable to the NZ dairy sector (adapted from Eastwood *et al.* 2021).

Category	Current commercial applications in the dairy sector	Potential future application in the dairy sector
Sensors for data capture	Animal wearable sensors to measure activity, behaviour, rumination. Body condition score cameras and sensors.	Lameness sensors using imagery. Bio-metric sensors for animal health.
Automation and robotics	Robotic milking (using box-style robots or robotic rotaries), virtual fencing and herding. In-shed automation such as automated cluster removal, teat spraying, drafting, weighing and washing.	Retro-fitted robotic milking on existing milking platforms. Augmented and virtual reality for hands-free farm management and training.
Internet of things (IoT) and connectivity	Using low-bandwidth sensors connected to farm Wifi or LoRa IoT networks to measure milk temperature, milk flow, water usage, effluent application, soil moisture status, irrigation.	Fast data exchange using 5G or farm wifi networks, expanded use of high-resolution imagery for off-site computational analysis.
Cloud computing and data analytics	Data now being increasingly stored in cloud-based systems rather than farm-based hard drives. Enabling software as a service, rapid software updates and cloud-based analytics.	Future utilisation data at a farm and supply-chain level e.g. blockchain for efficiency and trust, digital twins, near-edge computing, and use of machine learning or AI for identifying complex patterns and novel solutions.

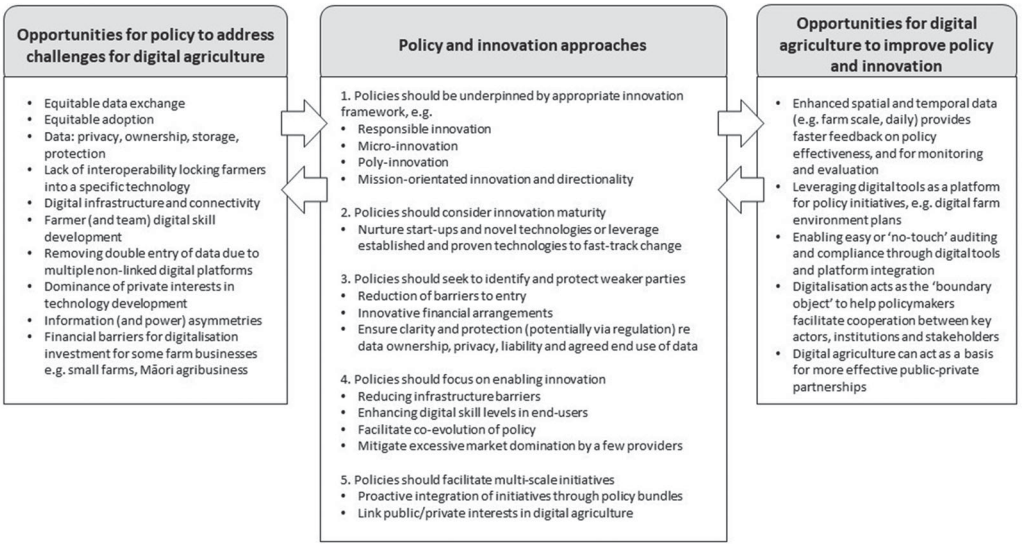

Figure 1. Policy and innovation approaches to enable digital agriculture in the NZ dairy sector (Key sources: Eastwood *et al.*, 2022, 2023; Ingram *et al.*, 2022; Kukk *et al.*, 2022).

myopic focus on technology development, without enough focus on co-innovation, which recognises a networked approach to innovation, involving a web of interactions among technology developers, industry, government and capability organisations, and aligned innovation policies as products or services are developed and successfully implemented on-farm (Klerkx, van Mierlo, & Leeuwis, 2012; Kukk, Põder, & Viira, 2022). The more successful technologies, for example, automated cup removers, have provided a clear return on investment for farmers based on saving time or improving workplace and animal productivity. However, many other technologies suffer from barriers to uptake related to uncertain return on investment, poor interoperability and high learning load required for farm teams (Figure 1).

3. Challenges for dairy sector innovation

The NZ agricultural innovation system suffers from significant fragmentation, which hinders a networked co-innovation approach (Turner *et al.*, 2016). For example, science knowledge and policy are not well connected with knowledge of farm system practices. Often, scientific experts conduct research independently of the farm advisors who work with farmers, and policy advisors who develop policies (Turner *et al.*, 2016), leading to a disconnect between public and private innovation. This is beginning to be addressed in innovation funds, such as Ministry for Primary Industries' Sustainable Food and Fibre Futures, that encourage participation of farmers, farm advisors, industry and science in programmes focused on delivering on-the ground change.

Uncertainty has a major impact on innovation and adoption (Charatsari, Lioutas, De Rosa, & Vecchio, 2022; Eastwood & Renwick, 2020; Lahnamäki-Kivelä, 2022). The current policy environment impacting agriculture presents significant uncertainty related to areas such as workforce (immigration policy), greenhouse gas emissions reduction, water quality, wetland management, intensive winter grazing, indigenous biodiversity and dairy cattle welfare. The scale and speed of change, together with uncertainty around the specifics of finalised regulations, can lead to a range of responses from farmers and innovators (Eastwood & Renwick, 2020; Knook *et al.*, 2022). In such a transformational

policy environment, it is vital that policy development is highly connected (e.g. policy bundles), co-developed with stakeholders to ensure effective policy and reflects the public–private good balance of costs and benefits.

Technological innovation needs to be broader than focussing on single technological fixes if the challenges facing the dairy sector are to be successfully tackled. These sector-level challenges have significant public benefit outcomes (e.g. water quality, climate change, amenity values), and sometimes relatively small private good drivers (e.g. profit, productivity, market access) for farmers. There is also the risk of unintended consequences for farmers as end-users. The public–private good imbalance, and the high costs of many digital technologies, will limit the digitalisation of the dairy sector (Eastwood, Klerkx, & Nettle, 2017). A multi-scale innovation approach is required to encompass technological opportunities, farmer-centred design, opportunities for new business models and merging of public and private roles in digital technology development (Eastwood *et al.*, 2022). The concept of co-innovation has been widely used to present a more holistic viewpoint of innovation compared to traditional linear concepts of technology-led innovation (Klerkx *et al.*, 2012). A range of other innovation approaches gaining attention internationally include responsible innovation (RI); (Espig *et al.*, 2022), multi-scale approaches (Klerkx *et al.*, 2012), micro-innovation and poly-innovation (Charatsari *et al.*, 2022) and mission-oriented innovation (Klerkx & Begemann, 2020).

4. Policy initiatives to enable innovation in the dairy sector

There are two main opportunities for future policy in NZ: (1) policy may be used to enhance digital agriculture innovation and, (2) digitalisation itself may act to enhance agricultural policy design and delivery – outlined below and in Figure 1.

4.1. Policy to enhance digital agriculture innovation

A recent review of opportunities for agrifood digitalisation identified roles for policy in both the protection of weaker parties and enabling innovation (Kukk *et al.*, 2022). There are several innovation frameworks that could enable effective innovation policy to enact these roles at a variety of levels (e.g. public/private R&D, farm-level), and these are discussed in the following sections.

4.1.1. RI (public R&D level)

In potentially game-changing contexts such as digital agriculture, the anticipation of unintended consequences and trajectories is vital (Charatsari *et al.*, 2022; Eastwood *et al.*, 2021). RI has been applied internationally, mostly at the public R&D level, in respect to agrifood innovation and digital technologies (Espig *et al.*, 2022). The concept provides researchers, technology developers and policy makers with a framework to guide innovation that is inclusive to a range of perspectives; forward-looking to anticipate both positive and negative consequences for not only users but a broader group of stakeholders; and agile and responsive when changes in trajectories are needed. However, the development of digital technologies occurs in the private market and a challenge exists to better engage private innovators and policy makers in the application of RI (Charatsari *et al.*, 2022; Espig *et al.*, 2022). For example, anticipation is required to explore the potential impacts of digital agriculture innovation related to shifts in core farming skills (among farm teams and farm advisors), the impact on types of tasks and roles on farm and in the wider sector, and potential inequality in adoption trajectories (Eastwood *et al.*, 2022). Further evidence is also required on the actual impact of technology on the farm system and business, as there is a lack of independent information available for use in investment decision-making and evaluation of on-farm performance (Ingram *et al.*, 2022).

Policy initiatives to facilitate greater adoption of the RI approach involve the inclusion of the RI factors of anticipation, inclusivity, reflexiveness and responsiveness in large publicly funded projects and agricultural policy. These factors can also be built into the design of national regulations, policy

statements and industry transformation plans. Government initiatives related to digital agriculture development and adoption must provide an exemplar for the inclusion of commercial interests but also participation of civil society, in technology co-design and anticipatory processes.

4.1.2. Micro-innovation (farmer-level innovation)

Digital agriculture technologies often require adaptation when integrating into the farm system, and result in adaptation of the farm system itself (Eastwood *et al.*, 2021). However, they are often designed with the average farmer in mind, rather than accounting for diversity. The inherent diversity of NZ dairy farms and farmers (e.g. size, feed system, ownership structure), means that future innovation policy initiatives must account for the biophysical, economic and social heterogeneity of the sector. This also applies to uncertain return on investment impacting on the ability of some farm businesses to access capital for digital investments. For example, financial barriers are compounded for Māori agribusiness (Rout, Reid, & Mika, 2020).

Micro-innovation, the design and adaptation of technologies via tinkering (Charatsari *et al.*, 2022), presents one approach to acknowledge the different contexts in which technologies will need to operate. Policy to facilitate micro-innovation would create initiatives to support a wide range of innovation platforms rather than a small number of large agri-tech entities. An example of micro-innovation is the Rural Innovation Lab (see: ruralinnovationlab.nz) where user-driven innovation can thrive.

4.1.3. Poly-innovation

It is tempting for policy makers to fall into a techno-centric approach to agrifood innovation. However, technologies like digital agriculture can be viewed as mediators of innovation, rather than the innovation itself (Klerkx & Begemann, 2020). The concept of poly-innovation (Charatsari *et al.*, 2022), a socially driven practice where business, organisational and social innovation is created through digitalisation, represents an opportunity to approach digital transformation from a broader perspective. Facilitation of poly-innovation in the dairy sector will require policy that seeks to lower the barriers to digitalisation across the low to high-tech scales. For example, ensuring equitable high-speed internet access for farmers to enable leveraging of e-commerce and cloud-based data analytics platforms.

4.1.4. Mission-orientated innovation (public policy level)

Policy should be forward-thinking and address the intersection of digital-based learning and extension. A major opportunity is skill development for farmers and support networks to leverage data at the farm-level. At the same time, we need to strengthen links between dairy extension and innovators to enable a need-driven approach to innovation. Taking a mission-oriented innovation approach would enable the identification of key barriers to digitalisation in the dairy sector (Klerkx & Begemann, 2020). Potential issues that require a cohesive approach include data governance and interoperability, updated codes of practice (e.g. acknowledge farmer rights and data ownership, straightforward language in agreements), rights to control and access data, streamlined compliance with functional feedback loops back to farms, and public/consumer engagement around digitalisation (Ingram *et al.*, 2022; Kukk *et al.*, 2022).

To make digital opportunities available and relevant to a wider range of farmers requires an improved policy for digital skills development at formal and informal training levels. Initiatives like Digital Boost (see: digitalboost.business.govt.nz) need refining for a farming audience. Extension and vocational training programmes need to be adapted to include skills relevant to a digital agriculture future, for example, technology investment analysis, digital skills and data interpretation. Training needs to match the changing learning modes of new generations, with visual, just-in-time and bite-sized knowledge. A sector-wide approach is required to build the 'back-office' skills in farmer knowledge networks (advisors, vets, extension agents) and this will require refined Tertiary training content in topics such as use of technology and data platforms, data analytics, systems thinking and communications. Finally, a long-term policy view is needed to move the narrative of a 'good

farmer' from the traditional productivist mindset (Knook *et al.*, 2022) to one of resilient and agile farm systems leveraging digital innovation (e.g. through NZ's food and fibre sector roadmap see: fitforabetterworld.org.nz).

Future policy needs to create the right space for effective change, by use of approaches such as co-ordinated policy bundles. For example, cross-cutting policies that connect training, innovation, environmental change and productivity. Such a bundled approach would align with the interconnected institutional logics that underpin dairy farmer values, beliefs and practices (Knook & Turner, 2020).

4.2. Digitalisation to enhance agricultural policy design and delivery

Digitalisation of the agricultural sector, and greater data collection, offer opportunities for improved agricultural policy design (Ehlers *et al.*, 2021; Kukk *et al.*, 2022). Highly integrated data platforms would provide information for policy that is timely, regional, at farm-scale and can show temporal change. For example, longitudinal data collected through remote sensing, regional sensor networks or farm-sourced sensor data can be used to measure the impact of nutrient or emissions policies. These data sources could also be integrated with policies that provide incentives or rebates to farmers for improved outcomes, particularly where there is a mix of private-public good.

Policy that links proactively with existing digital data and platforms or facilitates the uptake of data capture can enable faster and easier policy implementation. An example of this is the current Government's focus on farm environment plans (FEPs). Such approaches have existed in the dairy sector for over a decade, but current priorities now see a national approach to FEPs. This has intersected with greater capture of on-farm data (e.g. through milk company assurance processes) and pressure to minimise the practice of multiple data entry associated with compliance and audit requirements on-farm. A consequence of this is a renewed focus on the capture of digital data, integrated databases and digital FEPs. Digital data capture in near real-time offers a step change in associated monitoring and evaluation, and rapid refinement, of policies (Kukk *et al.*, 2022).

Conclusions

The NZ dairy sector faces several complex challenges. Digitalisation could underpin transformational change, but it requires effective innovation policy at national and sector levels. Policy to facilitate effective integration of digital agriculture needs to incorporate aspects of responsibility, micro-innovation and poly-innovation. Also required is directionality that focuses on technology as a mediator of new practices and institutional configurations, rather than technology adoption as an end in itself. Key questions for future policy are:

- How can policies protect public and farmer interests in a digital future?
- How can barriers to entry be reduced for small and large agricultural enterprises?
- What are the implications for future skill development in the agricultural sector due to digitalisation?
- How can policy prevent a broadening inequality gap between those with and without the capital and skills to adopt digital agriculture?
- Where can public policy foster innovation through a focus on world-leading digital infrastructure?
- How can digital agriculture data be leveraged to improve policy processes and outcomes?

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