4th International
Precision Dairy Farming Conference

3-5 Dec 2025 | Christchurch, NZ

Proceedings

Hosted by DairyNZ

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Foreword

The Fourth International Precision Dairy Farming Conference was held in Christchurch, New Zealand, from 3–5 December 2025. Following successful editions in The Netherlands (2016), the United States (2019), and Austria (2022), this was the first time the conference ventured into the Southern Hemisphere—and it was a privilege to welcome the global precision dairy community to New Zealand.

This conference sits at the intersection of scientific research and farming practice, with a strong focus on innovation, adoption, and real-world application of precision dairy technologies. In 2025, we brought together almost 400 researchers, farmers, advisors, and technology developers from 22 countries to explore advancements in automation, sensors, robotics, digital technologies, and data-driven insights that are shaping the future of dairy farming—while experiencing New Zealand's dairy industry, stunning landscapes, and warm hospitality.

The programme included field trips to see technology in action on commercial farms, seven world-class keynote speakers, and more than 110 presentations showcasing cutting-edge research, case studies, and insights from farmers, start-ups, and rural professionals. Two further highlights were the Emerging Scientists Session and Award, and a panel featuring New Zealand dairy farmers discussing the realities of on-farm adoption. Abstracts of all presentations are included in these proceedings. In addition, most authors were invited to submit a full manuscript to a special Research Topic in Frontiers in Animal Science (Precision Livestock Farming section).

DairyNZ was proud to host this conference alongside leading research and industry partners who engaged with a global audience, showcased innovation, and demonstrated their commitment to advancing our sector.

To all who attended, presented, supported, or travelled great distances to be part of this event—thank you. Your contributions made this conference a powerful space for collaboration, challenge, and discovery. I hope you leave with new ideas, new partnerships, and renewed optimism for the future of dairy.

Nicolas Lyons

Chair Organising Committee Fourth International Precision Dairy Farming Conference

Head of Science, DairyNZ

Organising committee members

Andrea Clayton, Brand Engagement and Partnership Manager, DairyNZ
Brian Dela Rue, Research Engineer, DairyNZ
Callum Eastwood, Senior Scientist, DairyNZ
Charlotte Reed, Scientist, DairyNZ
Jenny Jago, Science Partnerships and Impact Advisor, DairyNZ
Nicolas Lyons, Head of Science, DairyNZ
Paul Edwards, Senior Scientist, DairyNZ
Penny Timmer-Arends, Senior Animal Care Specialist, DairyNZ

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Conference Programme

Thursday 4 December

8.00am Registration and exhibition opens

9.00am **Mihi whakatau and welcome** AUDITORIUM

9.45am **Can artificial intelligence truly transform livestock and feed industries, or are we overpromising?** **Assistant Professor Joao Dorea** *University Wisconsin Madison, United States*

10.30am **MORNING TEA AMONGST THE EXHIBITORS** *Kindly sponsored by* BARENBRUG

Concurrent Session 1

	1A Technology adoption behaviour	1B Heat stress monitoring	1C Reproduction and genetics *Kindly sponsored by* CRV
	AUDITORIUM	CONWAY 1	BEALEY 4 AND 5
11.00am	Minimal Requirements for Data-Driven Applications: A Bio-Economic Modelling Perspective **Mariska van der Voort** *Wageningen University & Research, Netherlands*	Monitoring rumen temperatures in lactating dairy cows with focus on heat stress **Gundula Hoffmann** *Leibniz Institute for Agricultural Engineering and Bioeconomy (ATB), Germany*	The future contribution of precision dairy measurements to genetic gain in pasture based dairy industries **Peter Amer** *AbacusBio Limited, NZ*
11.15am		The association of calculated heat stress on rumination time in Holstein and Jersey cows **Francesca Pharo** *University of New Hampshire, US*	ICAR IDF initiative on sensor data for functional traits: Genetics and reference standards for rumination **Miel Hostens** *Cornell University, US*
11.30am	Profiling dairy farm worker daily fatigue and stress with digital technology **Lucy Hall** *DairyNZ, NZ*	Heat Stress in dairy cattle: comparison of novel sensor based metrics with production and physiological measures **Chenyu Zhang** *University of Reading, UK*	Variation in heifer rumination before breeding, and the relationships with fertility **Susanne Meier** *DairyNZ, NZ*
11.45am	Student Perceptions of Sensor Technologies in Dairy Farming: Insights for Veterinary and Agricultural Education **Michael Iwersen** *Centre for Systems Transformation and Sustainability, University of Veterinary Medicine Vienna, Austria, Austria*	Combining wearable data to create cow behaviour profiles that provide insight on individual differences in response to heat stress **Charlotte Reed** *DairyNZ, NZ*	Enhancing Estrus Detection in Dairy Cows Through Multi-Sensor Integration and Cycle-Specific Labeling Approaches **Pongsanun Khamta** *Faculty of Veterinary Science, Chulalongkorn University, Thailand*
12.00pm	Artificial Intelligence for New Zealand Dairy Farmers **Rachel Durie** *Perrin Ag, NZ*	Impact of Temperature-Humidity Index Zones on Freestall Barn Air Quality Metrics Assessed Using Continuous Monitoring Technology **Jeffrey Bewley** *Holstein Association USA, US*	The Curious Cow: Using Precision Technology to Link Personality Traits with Behavior and Milk Yield **Heather W. Neave** *Purdue University, US*
12.05pm		Using wearable sensor data from collars and ear tags to quantify animals' behavioral responses to weather variability **Regina Eckhardt** *Technical University of Munich, Germany*	Activity-based first estrus detection in grazing heifers and first-lactation dairy cows **Simon Woodward** *DairyNZ, NZ*
12.10pm	Evaluating the impacts of milking management technologies on the labour efficiency, productivity and profitability of Irish dairy farms **Bernadette O'Brien** *Teagasc, Ireland*	Unraveling cows' response to weather through respiration rate and drooling **Kirsty Verhoek** *DairyNZ, NZ*	Investigating the Association Between Herd-i Lameness Scores and Reproductive Outcomes on a Dairy Farm **Winston Mason** *Epivets, NZ*
12.15pm		Exploring sensor technologies for assessing cow response to heat stress events **Kirsty Verhoek** *DairyNZ, NZ*	Daily rumination time in early lactation dairy cows with divergent genetic merit for fertility **Charlotte Reed** *DairyNZ, NZ*
12.20pm	Exploring on-animal sensor data use for decision-making in pasture-based dairy systems: a qualitative study of farmers and advisors **Stacey Hendriks** *DairyNZ, NZ*	Physiological and behavioural responses to environmental heat load in lactating dairy cows fed pasture with variable proportions of Plantago lanceolata **Roshean Woods** *DairyNZ, NZ*	Evaluation of early reproductive success machine learning prediction in commercial us dairies **Marcia Endres** *University of Minnesota, US*
12.25pm	Unlocking the potential of AI Chatbots: A case study with New Zealand dairy farmers **Mos Sharif** *AgResearch, NZ*	Association between three phenotypic indicators of heat stress in dairy cattle **Alice Shirley** *University of Sydney, AUS*	

12.30pm **LUNCH AMONGST THE EXHIBITORS** *Kindly sponsored by* AGRICOM

Concurrent Session 2

	2A Animal behaviour and welfare	2B Robotics and computer vision	2C Milk quality, animal health and calves
	AUDITORIUM	CONWAY 1	BEALEY 4 AND 5
1.30pm	Multi-Sensor Modeling for Individual Dairy Cow Behavior Classification Using Accelerometer and Gyroscope Data **Pongsanun Khamta** *Faculty of Veterinary Science, Chulalongkorn University, Thailand*	Preparing Cows for Automation: Training Strategies to Improve Adaptation and Voluntary Milking Behavior **Trevor DeVries** *University of Guelph, Canada*	Utility of an in-line somatic cell count sensor for selecting cows for dry-cow therapy **Rob Orchard** *MSD Animal Health, NZ*
1.45pm	Measuring and modelling shade use by grazing dairy cows **Simon Woodward** *DairyNZ, NZ*	Designing Farm Intelligence: Five insights from multi-system practice **Line Ferriman** *CowSmart, NZ*	Uterine health is associated with detection of estrus by automated activity monitors and subsequent fertility **Lucio Campora** *University of Guelph, Canada*
2.00pm	Computer vision classification of ear postures as a preliminary scalable approach to automated on-farm detection of emotional state in dairy cows **Kevan Cote** *Moose Data Limited, NZ*	A Vision-Based Cattle Management System for Automated Monitoring of Jersey Cattle Brush Usage **Li Lyu** *City University of Hong Kong, Hong Kong*	Precision Livestock Management: Tailoring Management Practices for Dairy Cattle Based on Individual Variability and Characteristics **Joao Costa** *University of Vermont – Burlington, US*
2.15pm	Investigating Circadian Rhythms' Impact on Animal Welfare in Precision Dairy Research for Lactating Cattle **Rielle Perttu** *University of Minnesota, US*	A Foundational Framework for Animal Behavior Analysis Using Computer Vision **Miel Hostens** *Cornell University, US*	Cost-effectiveness of somatic cell count monitoring systems in smallholder dairy farms **Achmad Fadillah** *IPB University, Indonesia*
2.30pm	A preliminary study on virtual fencing **Bernadette O'Brien** *Teagasc, Ireland*	Associations between milk persistency, cow behaviour, and feed efficiency **Fernando Masia** *Lely International N.V. Netherlands*	Impact of early or late age at group housing on health and behavior of suckling dairy calves **Matt Buckley** *MSD Animal Health, NZ*
2.35pm	Using RFID ear tags to measure resource use behaviour in dairy cattle as a possible indicator of positive mental state **Laura Hunter** *Agresearch Ltd, NZ*	Barn layouts and factors associated with Behaviour, Udder Health and Herd Performance in Automatic Milking Systems in a Mega Robotic Dairy Cow Farm **Enrique Bombal** *DeLaval, Chile*	Transition period rumination time and its association with milk production in new zealand dairy cows **Matt Buckley** *MSD Animal Health, NZ*
2.40pm	Use of on-animal sensors to describe voluntary use of a wooded area by pastured dairy cows **Paul Edwards** *DairyNZ, NZ*	Monitoring Animal Welfare in AMS Dairy Farms: Insights from Different Production Systems in Argentina **Enrique Bombal** *DeLaval, Chile*	Factors influencing the value of automated mastitis detection technology in seasonal calving systems **Callum Eastwood** *DairyNZ, NZ*
2.45pm	An investigation of the impact of various calf-feeding systems on growth, first-lactation performance and emissions intensity **Magdalena Bremer** *Dairy Trust Taranaki, NZ*	AI for cattle tracking and behaviour identification from video footage **Anna Chlingaryan** *The University of Sydney, AUS*	Variation in calf drinking behaviour on an automatic milk feeder **Racheal Bryant** *Lincoln University, NZ*
2.50pm	Behavioural and Physiological Cow Variability Through Precision Dairy Technologies: A Comprehensive Analysis **Joao Costa** *University of Vermont – Burlington, US*	Cow flow matters: grazing behaviour and milk yield in a subtropical pasture-based automatic milking system **Lucia Del Carmen Betancor** *Inia, Uruguay*	Artificial Intelligence for dairy calf management: Current trends, and visions for the future **Melissa Cantor** *Penn State University, US*
2.55pm		Integrating Smartphone Vision and AI for On-Farm Pasture Measurement and Grazing Decision Support **Jeremy Bryant** *Aimer Farming, NZ*	

3.00pm **AFTERNOON TEA AMONGST THE EXHIBITORS** *Kindly sponsored by* PRIMARY PURPOSE

3.30pm

Boosting the Precision Dairy Farming domain through Data Science

Dr Claudia Kamphuis *Wageningen University, The Netherlands*

4.00pm

Emerging Scientists Session and Award

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AUDITORIUM

Behavioural and environmental needs of grazing dairy cows: a systematic review of technology-enabled indicators
Stacey Hendriks *DairyNZ, NZ*

Dairy farmers' willingness to share digital animal welfare-related data
Henrike Grotsch *Kiel University of Applied Sciences, Germany*

High-throughput sensor technologies for identifying early indicators of pasture persistence risk
Chinthaka Jayasinghe *Agriculture Victoria Research, Australia*

Developing a calf feeding behavior alert to classify training success using automated milk feeder data
Breanna Bone *The Pennsylvania State University, US*

Precision Dairy Farming Modelling: Seeing what averages can't show **Duy Tran** *AgResearch, NZ*

4.30pm

Challenges and opportunities - Robot technology transfer from horticulture to dairy farms

Professor Mike Duke *University of Waikato, New Zealand*

5.10pm Day two concludes

7.00pm **Conference Dinner** *Kindly sponsored by* RAVENSDOWN

Friday 5 December

8.30am Welcome to Day Two

8.40am **What have the social scientists ever done for us? Opening up inter-disciplinary precision dairy research beyond techno-optimism and adoption**
Professor David Rose *Harper Adams University, United Kingdom*

9.20am **Dairy Farmer Panel Discussion**
Facilitator: **Tony Finch** *DairyNZ*
Peter Morgan *Dairy Farmer, Waikato*, **Sharn Roskam** *Dairy Farmer, Southland*, **Stuart Taylor** *Craigmore Sustainables NZ*

10.00am **The Halter story of innovation and disruption** **Craig Piggott** *Founder and CEO, Halter, New Zealand*

AUDITORIUM

10.30am **MORNING TEA AMONGST THE EXHIBITORS** *Kindly sponsored by* PIONEER BRAND PRODUCTS

Concurrent Session 3

3A Cow monitoring and management

3B Environment and greenhouse gases *Kindly sponsored by* ON FARM SUPPORT

3C Milking and milking standards

	3A AUDITORIUM	3B CONWAY 1	3C BEALEY 4 AND 5
11.00am	Practice learnings from 12 months of engaging farmers in wearable focus groups **David Hawkins** *Franklin Vets, NZ*	Use of drone based remote sensing to determine the spatial distribution of cattle dung under conventional and regenerative management **Zach Dewhurst** *Landcare Research, NZ*	Precision control of vacuum and pulsation in conventional milking systems **Douglas J. Reinemann** *University of Wisconsin - Madison, US*
11.15am	Precision with purpose: Integrating data and rural professional insight to transform on-farm decision making **Krispin Kannan** *Veterinaryfirst Te Awamutu, NZ*	Agscent GHG Methane Measurement Solution for On-Farm Decision Making in Dairy Systems **Darren Price** *Agscent Pty Ltd, AUS*	Assessment of low-cost Near InfraRed sensor for detection of milk de novo fatty acids **Marlon Reis** *Agresearch, NZ*
11.30am	Practical use of wearable data – Sensehub collar fertility reports **Ryan Luckman** *Veterinary Centre Waimate, NZ*	Feed conversion efficiency prediction based on measured CO2 production from lactating dairy cows **Aj Jonker** *Agresearch Ltd. NZ*	Enhancing Efficiency, Traceability, and Sustainability in Dairy Farming through Precision Agriculture Technologies **Harry Jassal** *Vantage New Zealand, NZ*
11.45am	Utilising CowManager Data Insights to Optimise Reproductive Performance in Seasonal, Pasture-Based Dairy Systems **Kyle Kannan** *Vetplus, NZ*	Using daily milk meter and walk-over scale data to improve the prediction of dairy cow-level enteric methane emissions **Juan Rocha** *Massey University, NZ*	Standardisation Enables Digitisation Enables interoperability Enables Optimisation **Kenneth Irons** *Iso Standards Tc347, NZ*
12.00pm	Mastering mastitis - our milk quality journey **Holly Jackson** *Jackson Partnership Ltd, NZ*	A prototype milk-based indicator tool for farmers to manage herd dietary nitrogen surplus and reduce nitrogen loss risk in pasture-based dairy systems **Roshean Woods** *DairyNZ, NZ*	Precision control of automatic milking systems **Douglas J. Reinemann** *University of Wisconsin - Madison, US*
12.05pm	Improper backing gate use within cowsheds leads to increases in milking times and lameness **Richard Appleby** *Livestock Visibility Solutions, NZ*	A Soil Health Dashboard for New Zealand Pastoral Soils **Nicole Schon** *Agresearch NZ Ltd, NZ*	Revision of ISO standards for milking machines for cows, water buffaloes, sheep and goats - ISO 21355 **John Baines** *Milking Equipment Association (UK), UK*
12.10pm	Who? What? Wearable!: Lessons from Vet-Led Farmer Panels on Precision Dairy Adoption **Kirsty Ashcroft** *Anexa Veterinary Services, NZ*	Improving Management of Dairy Farm Effluent Using IoT Technologies **Ross Aimer** *Farm Water Management, NZ*	Effect of different vacuum settings on cow comfort **Douglas J. Reinemann** *University of Wisconsin, US*
12.15pm	In-vivo monitoring: Unmatched precision via Bolus Sensors **Jeff Hill** *smaXtec, NZ*	Water - more than a commodity... **J Legg** *MHV Water Ltd, NZ*	Utilising machine vision to reduce labour by automating teat spraying on pastoral farms **Ben Morris** *Gea Farm Technologies (NZ) Ltd, NZ*
12.20pm	On-farm use of virtual fencing in grazed dairy farm systems **Brian Dela Rue** *DairyNZ, NZ*	The use of environmental DNA (eDNA) data in life cycle assessment (LCA) for estimating the impact of farming on biodiversity **Tim Driver** *AgResearch, NZ*	Identification of Detrimental Milk Flow Patterns in Dairy Cows Using Machine Learning: Implications for Milk Yield **Maria Belen Ugarte** *University of Florida, US*
12.25pm			Validation of a computer-vision artificial intelligence milking parlour monitoring system **Trevor DeVries** *University of Guelph, Canada*

12.30pm **LUNCH AMONGST THE EXHIBITORS** *Kindly sponsored by* EAGLE DIRECT

Concurrent Session 4

	4A Applications and decision support tools	4B Forage and feeding	4C Data connectivity and insights
	AUDITORIUM	CONWAY 1	BEALEY 4 AND 5
1.30pm	Farm-level needs for improved data and analytics in decision making **Callum Eastwood** *DairyNZ, NZ*	Comparison of Rumination and Eating Time Measurements of Multiple Wearable Technologies **Jeffrey Bewley** *Holstein Association USA, US*	Data management in dairy research **Elizabeth Morse-McNabb** *Agriculture Victoria Research, AUS*
1.45pm	Beyond the Brochure: A Dealer's Perspective on Precision Dairy Technology Adoption in the Real World **Thomas Allison** *Gareth Howells Livestock & Dairy Technology Limited, Ireland*	Employing collar-based algorithm to predict dry-matter intake for evaluating and improving feed efficiency in dairy-cows **Roni Yair** *Afimilk, Israel*	The use and impacts of precision livestock farming technologies on dairy farms: a post-adoption study **Joanne Sharpe** *Harper Adams University, UK*
2.00pm	What 'smart' technologies are Irish dairy farmers using and why? Drivers and barriers to technology adoption in a pasture-based system **Lisa Parce** *Teagasc, Ireland*	A rapid approach to cross-calibration between two sensors for pasture biomass estimation **Anna Thomson** *Agriculture Victoria Research, AUS*	Application of PID control to support dairy heifer planning **Albert De Vries** *University of Florida, US*
2.15pm	Redefining excellence in agribusiness advisory: the role of the rural advisor in the modern world **James Allen** *AgFirst, NZ*	Potential of advanced geospatial technologies and machine learning in precision mapping of land and pasture resources on dairy farms **Duy Tran** *Agresearch Ltd, AUS*	Enhancing global interoperability in livestock data **Andrew Cooke** *Map of Agriculture, NZ*
2.30pm	Using a step-by-step visual training App (Knowby) to upskill farm teams, increase autonomy, performance, and job satisfaction **Grant Rogers** *Knowby, NZ*	In search of the Holy Grail: Will technology help us measure Pasture Performance? **Mark Neal** *DairyNZ, NZ*	Technological change, milking-related practices, and the features of highly efficient milking in pasture-based systems **Brian Dela Rue** *Dairy NZ, NZ*
2.35pm	Perception of Chilean dairy farmers regarding an App for an early warning and monitoring system for heat stress **Rodrigo Aria,** *Universidad Austral De Chile, Chile*	Integrating APSIM and remote sensing to predict maize silage biomass **Anna Chlingaryan** *University of Sydney, AUS*	Data focussed projects for dairy systems viewed through a national lens **John Penry** *Dairy Australia, AUS*
2.40pm	B+LNZ Dairy Beef Progeny Test **Jim Inglis** *B+LNZ, NZ*	A library of dairy forage spectra for the future **Elizabeth Morse-McNabb** *Agriculture Victoria Research, AUS*	Utilising animal behaviour data to enhance farm performance **Ben McArthur** *Halter, NZ*
2.45pm	Use of the CLEANED tool as a precision feeding strategy for feeding agro-industrial by-products to dairy cows in the Peruvian Amazon **Eduardo Fuentes** *Universidad Nacional Agraria La Molina, Peru*	The use of image analysis to quantify plantain content in mixed swards **Lisa Box** *Agresearch, NZ*	The impact of expanding data connectivity in Australian herds **Erika Oakes** *Datagene Limited, AUS*
2.50pm	Augmented reality in dairy farming: improving productivity and training efficiency **Abdolabbas Jafari** *Lincoln Agritech Ltd, NZ*	Managing pasture with precision **Toby Hurley** *Halter, NZ*	Dairy data, science and reporting using a Modern Science Workflow **Mark Neal and Paul Edwards** *DairyNZ, NZ*
3.00pm	**AFTERNOON TEA AMONGST THE EXHIBITORS** *Kindly sponsored by* EAGLE TECHNOLOGY		

3.30pm **Getting more from our cows – making sense of the innovation shaping farming and society?** **Dr Mark Fisher** *Kotare Bioethics, New Zealand*

4.00pm **Unlocking the Potential of Technology in New Zealand's Unique Dairy Landscape** **Dr Jenny Jago** *DairyNZ, New Zealand*

AUDITORIUM

4.30 - 4.45pm Closing remarks

Keynote Speakers

Dr Joao Dorea

Dr. Joao Dorea is an Associate Professor specializing in Precision Agriculture in the Department of Animal and Dairy Sciences at the University of Wisconsin–Madison. He also holds affiliate positions in the Department of Biological Systems Engineering and the UW Data Science Institute. Dr. Dorea's research focuses on using AI and sensing technologies to uncover complex biological interactions in farm animals, driving advancements in agricultural practices. He has developed and deployed large-scale computer vision systems for monitoring thousands of animals. His lab leverages AI and remote sensing (drones and satellites) to study animal nutrition, health, and welfare, and to enhance farm management decisions. Most recently, he has employed Large Language Models to leverage publicly available text for building smart farm systems, as well as to generate relevant inputs for predictive analytics in farm management.

Claudia Kamphuis

Claudia Kamphuis received her MSc Animal Scientist from Wageningen in 2004, and her PhD at Utrecht University in 2010. After her PhD she worked at DairyNZ as a researcher focusing on automation and information technologies to reduce labor and improve farm profitability and productivity. Since 2016, she works as researcher at Wageningen Livestock Research, and she is the coordinator of the Expertise Team Data Science since 2024. Her work involves the use of high-dimensional longitudinal sensor data and time-series analysis to tackle the challenges within the dairy cattle domain, using tools and methodologies to retrieve new information related to animal health, and ICT methods to store, collect, and access these data, sometimes even real-time.

Prof Mike Duke

Professor Mike Duke is the Dean of Engineering at the University of Waikato. He is a founding member of the Waikato Robotics Automation and Sensing (WaiRAS) research group. Mike's group works with growers and robot manufacturers undertaking research into automating horticultural processes. His research includes human assist technologies as an intermediate step towards full automation, electric and hybrid autonomous orchard vehicles, specialist robotic hardware for horticultural tasks and smart automation to replace obsolete horticultural machinery.
He was the lead academic on the hardware development of the MBIE Horticultural Robotics project and led the hardware research on the MBIE MaaraTech: Data informed decision making and automation in orchards and vineyards.

Prof David Christian Rose

David is the Elizabeth Creak Chair in Sustainable Agricultural Change at Harper Adams University (UK), one of the leading specialist institutions for agriculture and land management.
He is the Director of the Centre for Social Science and Lead of the Engaging for Change research group, which explores how to include human and non-human stakeholders better in the co-design of change. With a Bachelors, Masters, and PhD in Geography from the University of Cambridge, David has published over 80 papers in his ten-year career to date and undertook a Fulbright scholarship to Cornell University in 2023.
He has written background reports and reviews for the OECD, FAO, UK Government, and other bodies on issues related to technology adoption, behaviour change, responsible innovation, skills, and mental wellbeing. He is one of the handling editors at The Journal of Agricultural Education and Extension and at the Journal of Agromedicine.

Craig Piggott

Halter Founder and CEO Craig Piggott grew up on his family's Waikato dairy farm. In 2016, after completing his Mechanical Engineering degree from the University of Auckland, he took a role at the satellite launch company, Rocket Lab. Inspired by the innovation and investment into New Zealand's space industry, Craig founded Halter with a vision to revolutionise the dairy industry. Now serving dairy and beef farms and ranches in New Zealand, Australia and the US, Halter's mission is to empower farmers and ranchers to run more productive and sustainable operations while caring for their animals and the environment.
Halter's smart collars and app guide cattle around the farm, enable farmers to set virtual fences, precisely manage their pasture and monitor cows' health and behaviour 24/7.
Craig now leads a team of 180 people across three markets. In 2024, the Deloitte Fast 50 Index named Halter the fastest growing company in New Zealand, and in the same year, Craig won the Tech & Emerging Industries category for EY's Entrepreneur of the Year Award programme.

Mark Fisher

Mark grew up on a sheep and beef cattle farm on the East Coast of the North Island of New Zealand. He started his career in animal science with AgResearch, studying reproductive physiology of red deer at a time deer were still being live captured for farming from the wild and domestication was a real-time experiment. His work extends beyond specific species, exploring the broader philosophical and ethical considerations of animal welfare. Mark has served on the NZ National Animal Welfare Advisory Committee, the Australian and New Zealand Council for the Care of Animals in Research and Teaching, and the Bioethics Council, and was a president of the NZ Society of Animal Production. He's the author of two books, including the seminal text Animal Welfare Science, Husbandry and Ethics and has a private consultancy firm, Kotare Bioethics, specialising in ethical evaluations in science and farming.

Jenny Jago

Jenny has built a distinguished career at DairyNZ where she has collaborated with multiple internal and external partners to deliver numerous programmes. She has held senior leadership roles, including spending seven years in the DairyNZ Strategy and Investment team contributing to sector strategy development and has recently been appointed as Science Partnerships & Impact Advisor to help shape DairyNZ's science direction, support strategic partnerships, and ensure research continues to deliver meaningful, on-the-ground impact for dairy farmers. She has served on the International Dairy Federation standing committees for farm management and animal health and welfare. Jenny is highly respected nationally and internationally for her scientific expertise in farm systems, milking efficiency, animal welfare, the application of digital technology to animal management, and workplace productivity. She has expertise in pastoral automatic milking systems and the learning ability of dairy cattle, and developed milking routines to shorten milking times in conventional dairies.

Farmer Panel

Tony Finch

Facilitator

Tony has been involved within the New Zealand Primary sector for over thirty years, primarily across & within the Dairy sector.

He has been involved in many aspects of farming on both sides of the farm gate. He has worked within the finance industry, as the General Manager of a large-scale corporate dairy farming business and within the Dairy industry good organisation, DairyNZ. At DairyNZ he has led large teams, managed projects, led the extension teams across the South Island, and is now the national key relationship manager.

After completing a Bachelor of Agricultural Science (majoring in farm management and valuation) at Massey University, Tony spent two years within Corporate Mergers and Acquisitions for Credit Suisse First Boston in London. On his return to New Zealand, he spent ten years in rural banking finance, and a further seven years managing a start-up large scale dairy farming business encompassing 5,000 hectare's or 8,000 cows in Missouri, USA. He has held numerous governance roles including directorships with NZIPIM, Southland Demonstration Hub (SDH Limited), South Island Dairy Event (SIDE) and farming entities both in NZ and abroad.

Pete Morgan

With over 35 years' farming experience, 26 as an owner-operator, Pete Morgan brings deep expertise and practical insight to New Zealand dairying. He and his wife, Ann Bouma, farm 265 hectares southwest of Te Awamutu, milking around 620 cows and 210,000 kgMS annually. Their farming philosophy is centred on a dynamic and efficient pasture focus, supported by innovative tools such as Halter, which they adopted in 2022 to improve feed utilisation, staff progression, and environmental outcomes. In recognition of their leadership, Pete and Ann were named Fonterra Responsible Dairy Award winners in 2021. Alongside farming, Pete holds a Master's in Agricultural Science and a Diploma in Agribusiness, and through DairyNZ's Dairy Training he teaches a range of farm and environmental management courses, using education and an open farm, to both share and sharpen his passion for continuous improvement in dairying.

Stuart Taylor

Stuart Taylor is a fifth-generation dairy farmer, with an 800-cow farm in mid-Canterbury and currently serves as General Manager of Farming at Craigmore Sustainables NZ, which manages over 20 dairy properties and 16,000 cows across Canterbury and North Otago. Stuart's approach, as a modern farming leader, combines strong foundational farming skills with people-focused leadership and a forward-looking commitment to sustainability. He encourages mastering basics before adopting new technologies, relying on peer learning, and being a "fast follower" of proven innovations. Environmental goals include a 1% annual reduction in greenhouse gas emissions per kilogram milk solids, aiming for a 35% reduction in CO_2 intensity by 2035, and targeting net-zero on operations. Stuart is involved with the Dairy Environmental Leaders Network, AgriZeroNZ Farmer Focus Group, and Safer Farms organisations, to name a few.

Sharn Roskam

Sharn Roskam farms in Winton, Southland. Together with husband Billy and their 4 children aged 8-14 years old they milk 600 crossbreed cows on a 280ha self-contained system utilizing a grass and baleage system over winter. They've been early adopters of technology and currently use Halter. Sharn has a background in extension, working for DairyNZ after she graduated from Massey University in 2003. She is incredibly passionate about the dairy industry and enjoys sharing the knowledge she has with others to see them pursue successful careers in agriculture.

Meet our MC

Dr Scott Champion

Chief Executive Officer
Foundation for Arable Research (FAR)

Dr Scott Champion is an experienced leader, strategist, facilitator and executive. He has worked across tertiary education, innovative organisations in the private sector and industry service delivery and advocacy for almost 30 years. Scott is currently the Chief Executive Officer of the Foundation for Arable Research (FAR), commencing in the role on 1 July 2025. FAR is New Zealand's 'industry good' applied research, development and extension organisation for arable growers.

Scott has significant experience in strategy development, facilitation, the securing of investment, and governance, across diverse areas such as product marketing, sector development, international trade, and research and development.

From 2016 to 2025 Scott consulted across food, agriculture and natural resources, co-founding the specialist consulting practice Primary Purpose. Primary Purpose worked broadly across food and fibre sectors including horticulture, sheep and beef, dairy, arable, fisheries and aquaculture and forestry. This work spanned an array of areas including strategy development and review, research needs identification and prioritisation, service design, extension, community engagement and policy. Primary Purpose's client base extended across commercial agribusiness and the broader agri service sector, industry good organisations and trade associations, and government.

During this time Scott also held a number of governance and technical advisory roles in the primary sector, not for profit and community organisations, with a particular focus on innovation programme governance. Scott was also the Programme Director for the Kellogg Rural Leadership Programme, New Zealand's premiere agri leadership developing programme that has been developing leaders for the rural and agri-food sector since 1979. In April 2016, Scott completed a decade working for the national sheep and beef industry body, Beef + Lamb New Zealand, the last 7.5 years as Chief Executive Officer. He was also concurrently Chief Executive Officer of the New Zealand Meat Board for this period.

Scott is passionate about the primary sector, and identifying, creating and connecting strongly with 'communities of interest' and farmers, growers and their customers/clients to build effective products and services that make a difference.

Abstracts

Keynote speakers

CAN AI TRULY TRANSFORM LIVESTOCK AND FEED INDUSTRIES, OR ARE WE OVERPROMISING?

J.R.R. Dorea

Department of Animal and Dairy Sciences, University of Wisconsin-Madison, Madison, Wisconsin, USA

The advance of AI systems in different fields of science has created incredible opportunities for the new generation of students and scientists to answer research questions that would not have been possible before the recent progress toward more intelligent systems. Core technologies such as computer vision, natural language processing, and robotics, now underpin everyday applications such as facial recognition, speech-to-text, and autonomous systems, and are increasingly being adapted for agriculture. The agricultural sector has leveraged AI advancements from other scientific domains, and livestock systems are increasingly integrating modern solutions to address critical challenges related to animal health and welfare monitoring, greenhouse gas emissions, animal traceability, and labor shortages. Driven by the growing availability of digital sensors and data, multimodal machine-learning frameworks have become essential for integrating wearables, imaging, unstructured text, and genomics to improve predictive accuracy and inform management decisions.

In this talk, we will explore key AI technologies, including computer vision and natural language processing, that can positively impact dairy farming and the industry in the coming decades, and discuss how these innovations align with real-world challenges for farmers, industry stakeholders, and the scientific community.

BOOSTING THE PRECISION DAIRY FARMING DOMAIN THROUGH DATA SCIENCE

C. Kamphuis

Wageningen Livestock Research, Wageningen University & Research, Wageningen, the Netherlands

For decades, our dairy domain has become increasingly tech-savvy with a wide variety of (automation) technologies and sensors being commercially available. All of these technologies have potential to aid in precision dairy farming as they measure automatically, continuously and sometimes non-invasively physiological, behavioral, and production indicators on individual animals or fields. These indicators are there to ultimately improve management strategies and thus animal and farm performance. These technologies also share the fact that they generate large volumes of data at a high velocity, often with a variety in dimensions and structure. These three Vs (volume, velocity, and variety) describe the challenges that we have to tackle before utilizing and valorizing Big Data and, therefore, PDF technologies. Challenges can be solved by new data infrastructures and tools to collect, curate, store and fuse (real-time) data, and other traditional data analytics (AI, machine learning) to transform these data in information, knowledge and actions. Data science is at the intersection of ICT, data analytics and our precision dairy farming domain and it will boost the maturing and impact of our precision dairy farming domain. This boost is felt at different levels.

For example, the necessity to reduce methane emissions is evident. There are several ways to do so, and breeding for lower methane emitting dairy cows is one of them. However, for breeding we needed data on many individual dairy cows but a infrastructure that allowed collection of high-quality data in real-time was lacking. A new infrastructure was developed that allowed collection and real-time data quality control of cow-individual methane data on >100 Dutch farms. This dataset was used by Wageningen researchers and pushed the launching of a new breeding value for methane emissions in a relatively short period of time. The boost of data science is also impacted by the opportunities offered by computer vision. At Wageningen, we are researching computer vision to track individual dairy cows through time and space in a multi-camera system, and investigating how to use this to assess and monitor (new) behavior of individuals. Finally, data science plays an essential role in the development of digital twins. Digital twins are tools that could impact our domain by helping farmers to simulate (high-risk) management decisions and see the impact of that decision, e.g., on their farms' nitrogen status. At Wageningen, we are developing a digital twin of a dairy farm that uses real-time farm and field specific data to feed a model framework and that uses data assimilation to bring model output and reality in-synch. The aforementioned examples demonstrate how data science boosts our precision dairy farming research at different levels, allowing precision dairy farming to mature and as such impact the future of farming.

CHALLENGES AND OPPORTUNITIES – ROBOT TECHNOLOGY TRANSFER FROM HORTICULTURE TO DAIRY FARMS?

M. Duke

School of Engineering, University of Waikato, Hamilton, Waikato, New Zealand

Over the past decade, rapid advancements in technologies such as machine learning (ML), computer vision, sensing systems, and automation hardware have opened up transformative possibilities for the horticulture industry. These innovations are already being deployed in pack-houses for tasks like fruit sorting, but the growing labour shortage is driving a shift toward in-orchard automation.

Forward-thinking growers are responding by redesigning orchard structures from traditional 3D layouts to more automation friendly 2D configurations. This structural evolution enables more effective deployment of technologies such as image-based data collection for yield estimation and disease detection, powered by ML. Beyond data analytics, we are seeing the emergence of robotic systems including autonomous vehicles and prototype harvesting machines, some of which are now entering production.

Importantly, the industry is recognising the value of lower-tech solutions such as human-assist machines, and the need for a System of Systems approach, integrating multiple technologies and workflows to create scalable, adaptable solutions. Emerging tools like narrow AI and augmented reality also present exciting opportunities to embed expert level decision-making into critical tasks such as vine pruning. This could enable robots and semi-skilled workers to perform with the precision of top experts, potentially revolutionising horticultural labour. Despite these promising developments, adoption has been slow. However, the trajectory is clear: these technologies are shaping the future of horticulture.

In contrast, the New Zealand dairy industry has long been a leader in technology adoption, particularly in areas such as herd management, decision support systems, and milking automation. This raises an important question: Are there synergies between horticulture and dairy? Can the innovations emerging in horticulture, such as robotic platforms, expert decision systems, and integrated automation be adapted to dairy farming? Could these technologies enhance pasture management, animal health monitoring, or even robotic handling in dairy sheds?

This talk will explore the latest research in New Zealand horticulture and examine how it might be transferred to the dairy sector. By identifying cross-sector opportunities, we aim to spark new thinking around how robotics and intelligent systems can support the future of dairy farming.

WHAT HAVE THE SOCIAL SCIENTISTS EVER DONE FOR US? OPENING UP INTER-DISCIPLINARY PRECISION DAIRY RESEARCH BEYOND TECHNO-OPTIMISM AND ADOPTION

D. Rose, J. Sharpe and G. Charlton

Agriculture and Environment Department, Harper Adams University, Newport, Shropshire, United Kingdom

The aim of this keynote is to take stock of how the social sciences can inspire inter-disciplinary efforts to foster sustainable and just precision transitions in dairy systems. It reviews old and nascent literature on robotic milking and digitalisation to show how the social sciences (and arts/humanities), including quantitative, qualitative, and creative methodologies, can help us to critically evaluate the effects of precision dairy technologies on humans and non-humans. The effects of precision dairy technologies - for example, the extent to which they enable tangible improvements in animal health, welfare, and productivity - depend on how they influence management decisions on-farm. Rather than simply shedding light on factors affecting farmer adoption or public acceptability, early and substantive involvement of social science disciplines presents the opportunity to capture everyday experiences of how technologies are (or aren't) used, and to pursue key aspects of distributional, recognitional, and multi-species justice. It can help us (1) to embrace post-adoption perspectives, exploring how precision dairy technologies change life on the farm for people and animals, and consider how benefits and costs are distributed; (2) to include human and non-human stakeholders in the co-design of user- and animal-centred precision technology, helping to account for diverse cultural, religious, multi-species and ethical perspectives; (3) to recognise the knowledge brokering activities across agricultural knowledge and innovation systems and identify emergent forms of labour organisation, 'digi-work', and advisory structures with the rise of artificial intelligence, and (4) to move beyond techno-optimistic narratives and consider the question of what precision dairy technologies should do, if anything. Ultimately, the perspective/keynote recommends multi-disciplinary collaboration to investigate the purposes, practicalities, and effects of precision dairy technologies, considering impacts on people and animals in ways that neither social scientists nor animal scientists could address alone.

THE HALTER STORY OF INNOVATION AND DISRUPTION

C. Piggott

Halter, Auckland, New Zealand

Halter's journey began with a simple, foundational truth: a farmer's greatest levers are how they manage their land and their animals. This presentation, delivered by Halter's founder Craig Piggott, traces its evolution from a first-principles idea to a product that is transforming global agriculture. Piggott applied an engineer's mindset from his work at Rocket Lab to his dairy farming roots, sparking a mission to solve universal farming challenges. The story starts humbly on a single New Zealand farm and has grown into a technology managing hundreds of thousands of cattle worldwide.

At its core, Halter is an operating system for farming, designed to create a virtuous loop of data-driven decision-making. This system is enabled by a solar-powered smart collar and an intuitive app, which together provide the tools for precise farm management. By replacing traditional fences with dynamic virtual boundaries and guiding cows with gentle, learned sound and vibration cues, farmers can execute herd movements and manage grazing with unprecedented flexibility and control directly from their phone. This powerful execution capability is seamlessly combined with the platform's deep insights into animal health, behaviour, and pasture management, allowing farmers to make better-informed decisions. This synergy between insight and execution means farmers can act precisely, enhancing the productivity and sustainability of their farming operations.

Bringing this technology to market was a journey of perseverance. The path from concept to reality involved years of intensive research, solving complex technical challenges, and building a world-class team. Success required a deep understanding of technology and animal behaviour, a firm commitment to user-centric design, and the vision to reimagine modern agriculture. Halter's story demonstrates the potential of agritech to optimise farm operations and fundamentally enhance the way we farm.

This presentation will share key milestones, lessons learned, and the forward-looking vision that has propelled Halter from a New Zealand start-up to a global player. It is a modern chapter in New Zealand's history of pioneering, reflecting a spirit that empowers farmers, not replaces them. Attendees will gain insight into the future of dairy, where technology enhances productivity, improves animal welfare, and promotes environmental sustainability. It is a story of how a fresh perspective and a passion for solving real-world problems can create a more productive and sustainable industry for generations to come.

GETTING MORE FROM OUR COWS – MAKING SENSE OF THE INNOVATION SHAPING FARMING AND SOCIETY

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Precision farming, such as the use of data, sensors, and automated systems to optimise production, continues the trend of technology changing farming. To the likes of artificial breeding techniques, bST and automated milking systems, might be added acoustic technologies to assess animal health and behaviour, and responses to environmental conditions; monitoring of individual animals through biometric facial recognition; and optimising milk yield and economic benefits in challenging climatic conditions. However, while technologies from learning to utilise novel information to inform management, to artificial intelligence and machine learning, have the potential to make farming more efficient and effective, it is also the social, political and cultural context in which those innovations are developed and used, which determines their impact. Consideration is, then, given to exploring some of costs and benefits of precision farming, to animals, farmers, and society, and who should be responsible for leading and thus shaping their acceptance.

The impact on animals, whether they are fit, happy or feeling good, have what they want, and can live naturally, is a key determinant for many. As well as optimising production, many technologies have the potential to improve individual and herd health and welfare, perhaps even providing a transparent means of assuring others of their status. The risks to farming systems, and farmers, may include an increased dependency on technology and associated professionals, altering the ideals of animal husbandry and the human-animal relationship. While some of these benefits and costs are speculative, data-limited, or require economic evaluation, others are seemingly proven. Some issues, such as the continuing trend towards larger herds and industrial-like farms, may be beyond the capacity of those directly involved to address, requiring societal leadership and support.

Since animals and producers serve society's wider needs, and are constrained by society's concerns and perceptions, it is suggested that developments in precision farming are guided by the broader goals of agriculture (profitable, sustainable and environmentally safe production satisfying human needs in a fair and just manner); are informed by considering the perspectives of interested parties, especially those cognisant of animal husbandry; and their consequences monitored. A further consideration is whether such developments are in keeping with the future of the relationship between humans and animals. Such nuanced and complex interdependencies require sophisticated conversations and leadership to overcome the 'shrill and dramatic articulations' that tend to demand attention, as well as those seeking personal and corporate gain at the expense of those who entrust them.

Farmers must choose and combine the various inputs and develop the most advantageous production systems dependent on the constraints of the land, climate, animals, financial and personal circumstances and the threats and promises of markets and society. It is suggested that those engaged in developing precision farming technologies help them by openly describing the issues, providing relevant information and involving people, as many individuals and institutions already do, thereby ensuring farming and society are responsibly shaped.

UNLOCKING THE POTENTIAL OF TECHNOLOGY IN NEW ZEALAND'S UNIQUE DAIRY LANDSCAPE

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New Zealand aims to double the value of primary sector exports by 2034, with dairy currently contributing around 45% of total export revenue. While the sector has grown significantly since the early 2000s, productivity has plateaued over the past decade. Past innovations that met farmers' needs have largely been adopted, while others remain unused. This raises a critical question: what role can technology play in driving the next wave of productivity growth?

New Zealand's dairy systems are predominantly pastoral, with cows grazing outdoors year-round. Technologies must therefore be robust, suited to low-cost, highly efficient systems that prioritise efficiency over intensification. Environmental stewardship is essential, as sustainability underpins both market value and social license. The strong co-operative model and culture of knowledge sharing creates opportunities for rapid adoption and product testing, while the free-market environment demands that technologies deliver clear economic returns. With all products destined for export, customer expectations also shape innovation priorities.

The sector's competitiveness rests on three pillars: a pasture-based feed system (cost focus), farming in harmony with nature (customer focus), and farmer-centric decision-making. These must remain central when pursuing productivity gains aligned with sustainability credentials. Advances in artificial intelligence highlight the growing importance of data and information. To leverage emerging technologies, the sector must become "data-ready," with better-organised, higher-quality, and accessible data. Aligning data-driven innovations with the fundamentals of New Zealand's dairy systems and unique innovation environment will be key to unlocking future productivity potential.

Concurrent session 1

December 4, 2025, 11:00 am – 12:30 pm

1A | Technology adoption behaviour

MINIMAL REQUIREMENTS FOR DATA-DRIVEN APPLICATIONS: A BIO-ECONOMIC MODELLING PERSPECTIVE

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Data-driven applications, particularly sensors, offer promising solutions that address the detrimental economic and animal health impacts of animal health disorders. There is a need for a comprehensive understanding of how these applications can be leveraged at the farm-level to improve animal health and economic outcomes. The value of data-driven applications for producers lies in the information they generate and the decisions they lead to. The usefulness or profitability of that information is expressed as utility. The value of information, therefore, is measured by the difference in utility with and without that information. This seems to be a straightforward analysis, but in practice the proven value of sensors is lacking in literature. Ex-post analyses are ideal to study the value of farm implemented data-driven applications. However, such studies are expensive and complicated which means that the value of these applications is often not visible. The objective of our research is to improve understanding the value of data-driven application to justify research efforts and provide guidance on the requirements for (new) data-driven applications.

To deal with issues in ex-post analysis, ex-ante bio-economic simulation studies become of interest when questioning the added information value. Such studies can remove the variation between farms, and possible correlation between diseases and farm decisions. For ready to perform sensor systems, of which we know the performance, we can study the value of management actions to determine which actions in which farm situations are of economic interest. But it is also of interest to study 'concept' sensor systems, those systems that are under development, and of which we do not yet know the performance. We have carried such ex-ante analyses regarding the use of sensors to detect suboptimal locomotion (SOM) in dairy cattle.

Previous economic research shows that classifying SOM as a binary problem in sensor-based management has little to no economic value while non-binary SOM classification may be more economically beneficial. We assessed whether economic gains can be achieved by using 3-class SOM classifiers (i.e., sensors) for sensor-based SOM management compared with the current no-sensor SOM management. With respect to mobility scores 1–5, three SOM classes (K1 = non-SOM, K2 = SOM, and K3 = severe-SOM) along with two management scenarios, with four different classifiers each, were defined. Mobility scores 1–5 were grouped into one of three SOM classes depending on the classifier. For each of the eight classifiers (i.e., 4 classifiers per management scenario) 600 classification outcomes were defined.

Among the tested classifiers, all showed economic gains on average. Classifiers with larger separations between non-SOM and SOM classes showed the highest economic gains. Economic gains were sensitive to trade-offs in classification outcomes. This study provides valuable insights on designing appropriate 3-class SOM classifiers to be used in practice that could also be beneficial when designing classifiers for health disorders other than SOM. Ultimately, this study, and the results within, can further support farmer decision making apropos the economic implications of different classification outcomes that best fit their sensor-based SOM management preferences.

PROFILING DAIRY FARM WORKER DAILY FATIGUE AND STRESS WITH DIGITAL TECHNOLOGY

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Dairy farmers are struggling to recruit and retain farm workers. One of the unappealing aspects of dairy farm work is stress and fatigue, which can be created by an increased workload over calving on farms that block-calve their cows, such as in seasonal dairy systems in New Zealand. Previous studies have indicated that different work tasks over calving may affect dairy farmers' sleep and therefore may be drivers of fatigue and stress. There are currently very few studies that use quantitative measures of stress and fatigue in the dairy sector, with previous studies mostly focused on sleep.

This novel study aimed to identify tasks around calving that elevate exertion and stress metrics throughout the working day. Results will enable farmers with workers that are assigned to these tasks, and therefore may reach fatigue or high stress more quickly, to manage this via task assignment, work breaks, and rostering. This study used digital technologies to investigate the relationship between calving tasks and stress and exertion measures over calving.

Ten dairy farm workers on 5 farms across New Zealand wore Garmin Instinct smartwatches over the calving period (August and September) in 2024. The watch calculates hourly averages for metrics including heart rate, respiration rate, calories burnt, stress score and metabolic equivalent (met) score, which can indicate exertion and physical and mental stress. For two consecutive working days at 3 to 4 weeks past the planned start of calving date they recorded the tasks undertaken, the timing within the day, and total time taken on each task to create a daily timeline over these two days. For analysis, these tasks were grouped into milking tasks, animal-based tasks, feed-based tasks, and work breaks. The watch data was aligned with the task data and analysed in R studio.

At the time of submission the analysis was being completed and results will be available in time for the conference.

STUDENT PERCEPTIONS OF SENSOR TECHNOLOGIES IN DAIRY FARMING: INSIGHTS FOR VETERINARY AND AGRICULTURAL EDUCATION

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Digital technologies are increasingly reshaping dairy farming, offering advanced tools to monitor and manage animal health, welfare, and productivity. As the dairy sector transitions toward data-driven management, veterinarians and agricultural professionals will be expected to leverage these technologies effectively. This study aimed to explore how students in veterinary medicine (VetMed) and agricultural sciences (AgriSci) perceive sensor technologies on dairy farms and how well their academic training prepares them for this digital transformation.

An online survey was distributed via student bodies and administrative offices across universities in Austria, Germany, and Switzerland. A total of 428 completed questionnaires were analyzed, 295 from VetMed students and 133 from AgriSci students. The survey included closed and open-ended questions about demographics, familiarity with dairy farming, views on sensor use, emotional associations with images of digitalized barns, and self-evaluated preparedness for future digital roles.

Overall, students demonstrated a high level of acceptance toward sensor-equipped cows, with more than 96% expressing approval under the condition that it benefits animal health. AgriSci students were notably more positive, with 69.2% agreeing that sensors offer benefits for both animals and workers, compared to 44.2% of VetMed students. However, skepticism was also evident, particularly among VetMed students, who expressed discomfort with practices like automated calf feeding and early cow-calf separation. A significant portion of respondents, especially from VetMed, feared that increasing automation could undermine the human-animal bond central to their professional identity.

Only 20.7% of VetMed students reported feeling well prepared for the digital shift in dairy farming, versus 37.6% of AgriSci students. Qualitative analysis of image-based associations revealed terms like 'modern' and 'efficient' alongside 'unnatural' and 'impersonal', highlighting a perceived trade-off between technological efficiency and animal contact. Students emphasized animal welfare as the most important motivation for adopting digital tools, followed by reducing pharmaceutical use and improving farmers' work-life balance.

The findings underscore a clear educational gap in preparing students for digital integration in livestock farming. Veterinary education, in particular, may benefit from earlier exposure to data analysis, herd health management procedures, and interdisciplinary collaboration. The study suggests that joint educational formats, such as shared farm visits, project-based learning, or discussions involving both VetMed and AgriSci students, could foster a more comprehensive understanding of digital transformation in agriculture.

In conclusion, while future professionals recognize the potential of digital technologies to enhance dairy farming, concerns about reduced animal interaction and inadequate training must be addressed. Curricula that bridge technical knowledge with ethical and practical concerns are essential to ensure graduates are both competent and confident in navigating the evolving landscape of dairy production.

ARTIFICIAL INTELLIGENCE FOR NEW ZEALAND DAIRY FARMERS

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Current adoption of Generative AI (GenAI) amongst the dairy farming community appears to be low, with many farmers unaware of how GenAI can be used or the benefits it can provide. For farmers that are aware of the GenAI tools available, many have not yet engaged with them in a meaningful way. There is often concern around the accuracy of outputs, difficulty in seeing how GenAI can integrate within their existing systems or a feeling that their traditional methods are working adequately, and so their motivation to change is low.

In contrast, farmers that are engaging with GenAI are doing so in a variety of ways, noting the ability to make better, more informed and faster decisions; reduce time spent on repetitive tasks; empower team knowledge and improve communication. Observed use cases could be placed into three categories: decision support (knowledge access, contextual reasoning, predictive modelling), task enhancement, and communication support. Decision support is by far the most common application of GenAI, with most uses focusing on either general knowledge access or contextual analysis.

Areas of the farm business that are most frequently used in contextual analysis applications reflect those with high data availability (e.g., animal health, reproduction, and feed). This suggests that wider application of GenAI in the future will rely on increasing technology and data collection opportunities.

Novel use cases identified through this project included the creation of farm-tailored chatbots, large-language model (LLM)-powered digital twins, customised GenAI-driven breeding tools and the integration of farm or industry-specific data for tailored outputs. Diffusion of these currently advanced and novel applications is limited to the innovator and early adopter farmers who actively seek new opportunities, are willing to experiment and take risks, and can see potential early on. By contrast, use cases that have diffused beyond these groups of farmers are those that are more basic, but have proven value, including the use of GenAI to help draft documents, record or transcribe meetings, or perform basic question and answering (knowledge gathering).

Building on the adoption insights uncovered in the exploration phase of this project, a conservative and aspirational future pathway for GenAI adoption was developed considering limitations of the technology and the challenges of pasture-based dairy farming in New Zealand.

The conservative pathway illustrates a future where GenAI acts as a digital assistant/adviser supporting and accelerating farmer decision-making. Data integration remains a key limitation under this pathway and, as such, contextual understanding is limited to the data and information manually provided by the farmer. Accordingly, farmers interact with GenAI through standalone, and often customised, LLMs or through GenAI functionality embedded in web portals or software programmes that are easy to use, have high trust and provide seamless integration. Agentic capabilities are limited to low-level, rules-based tasks that remain firmly human-directed.

In contrast, the aspirational pathway illustrates a future where GenAI acts as an integrated digital partner operating within a connected technology and AI ecosystem. Data interoperability is no longer a constraint, enabling real-time data analysis, insights, contextual awareness, adaptive learning and more proactive decision-making. Mid-level agentic capabilities exist and can co-ordinate or adjust operations within farmer-defined boundaries and learn from outcomes to continuously refine future recommendations. A high level of on-farm technology and data capture devices maximise the value of GenAI.

EVALUATING THE IMPACTS OF MILKING MANAGEMENT TECHNOLOGIES ON LABOUR EFFICIENCY, PRODUCTIVITY AND PROFITABILITY OF PASTURE-BASED DAIRY FARMS

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The use of automation technologies has been increasingly promoted on dairy farms to reduce labour requirements and to improve the management of dairy herds. They have the potential of either reducing pressure on labour or improving labour efficiency by helping to perform tasks previously undertaken manually by farm operators. By reducing labour costs, they are expected to improve profitability. Moreover, the adoption of milking management technologies could increase milk yields and milk solids due to an improvement in parlour management (better feed allocation and better hygiene of the milking equipment), which could also increase profitability. From the wide range of technologies available for dairy farms, automation technologies that are used in the milking parlour (milking management technologies) are particularly important because the milking process and its associated tasks account for approximately one third of the total annual farm labour in Irish pasture-based dairy farms.

Despite the potential benefits derived from the use of milking management technologies, there is a lack of evidence of the causal effect of these technologies on dairy farm performance. The present study aims to fill this knowledge gap by using national farm-level data from Ireland (Teagasc National Farm Survey) and a Propensity Score Matching (PSM) approach to empirically assess the impacts of adopting three milking management technologies (automatic parlour feeders, automatic cluster removers and automatic washers) on the labour efficiency, productivity and profitability of Irish dairy farms.

The results of the research (Table 1) show that although those farms that adopted milking management technologies (adopter farms) were initially more labour efficient than non-adopter farms, there was no significant effect of milking management technologies on labour efficiency (total labour hours per cow) when self-selection bias was controlled (PSM). The results did show, however, that milking management technologies had a positive impact on milk yield and milk solids which translated into increased gross output and in turn gross margin per ha. However, once the fixed costs associated with technology were incorporated (including depreciation), milking management technologies did not significantly increase net profit.

Outcome variable	Differences between users and non-user means	Differences between users and non-user means, after PSM
Sample sizes		
Treated units	41	41
Control units	232	48 (matched)
Productivity		
Milk yield (kg of FPCM/ha)	3,646.8***	1,650.5**
	(642.9)	(699.8)
Milk solids (kg/ha)	274.7***	119.7**
	(46.8)	(50.7)
Labour efficiency		
Total labour (hours/cow)	-18.3***	2.4
	(5.34)	(3.1)
Profitability		
Gross output (€ per ha)	1294.9***	647.1**
	(232.1)	(272.5)
Gross margin (€ per ha)	692.2***	415.0**
	(151.8)	(169.4)
Net margin (€ per ha)	266.1	178.4
	(136.1)	(162.8)

Table 1. Estimation of the effects of using milking management technologies on productivity, labour efficiency and profitability, 2018. Standard error in parenthesis.

Source: 2018 Teagasc NFS

*** *P*<0.01

EXPLORING ON-ANIMAL SENSOR DATA USE FOR DECISION-MAKING IN PASTURE-BASED DAIRY SYSTEMS: A QUALITATIVE STUDY OF FARMERS AND ADVISORS

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On-animal sensors (wearables) and rumen boluses are increasingly being adopted by farmers in seasonal-calving, pasture-based dairy systems. Data from a 2023 DairyNZ survey indicates that more than 18% of New Zealand dairy farmers use some form of cow wearable. Wearables monitor a range of cow behaviours including, but not limited to, lying, rumination, and activity, and provide health and heat alerts. These technologies may offer improvements in herd management, animal welfare, and productivity through real-time data. To date, most research in grazing dairy cows has focused on validating the technical accuracy of these devices for intended applications such as heat detection, health alerts, and, more recently, virtual fencing. However, anecdotal evidence suggests farmers are leveraging wearable data in innovative ways to support herd-level decisions, improve work-life balance, and maximise their investment in this technology. Understanding how farmers and advisors (e.g. veterinarians, rural consultants) use wearable data is critical for identifying current practices, knowledge gaps, and opportunities to integrate this information into on-farm decision-making. While these devices are marketed as decision-support tools, little is known about how this process plays out in practice on New Zealand dairy farms.

This study aims to explore how wearable-derived data is being used in pasture-based systems for day-to-day decision making on farm. Using a qualitative online focus group approach, we will engage with a group of 7 farmers and 7 advisors to understand how they interpret and act upon wearable data at key decision points throughout the season (e.g. calving, pre-mating, mating). Thematic analysis will be used to identify common patterns in data use, perceived benefits and limitations, and the practical challenges faced by users. We will also investigate broader implications of sensor adoption, including confidence in alerts, standardisation of tasks, reliance on advisors, and unintended consequences arising from user error or technical issues. By capturing the experiences and insights of those actively using wearable technology, this research will provide an improved understanding of how sensor data supports decision-making in pasture-based dairy systems. The findings will inform future research, industry extension, and support farmers to maximise the value of their investment in sensor technologies.

UNLOCKING THE POTENTIAL OF AI CHATBOTS: A CASE STUDY WITH NEW ZEALAND DAIRY FARMERS

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This abstract details the experiences of New Zealand dairy farmers using data-driven applications for daily operations and introduces a potential AI-driven solution. Through semi-structured interviews and participant-led discussions with Southland dairy farmers, we analysed their engagement patterns, decision-making processes across various tasks, transitions between applications, and the factors hindering effective action. Our findings indicate that farm managers routinely monitor between 4-7 different applications related to weather forecasting, soil moisture levels, pasture management, and livestock tracking. This fragmentation often results in cognitive burden and delayed decision-making. While farmers can successfully interpret task-specific data patterns, they experience significant difficulty synthesising cross-application insights.

With the recent advancement of large language models (LLMs) demonstrating remarkable competence in terms of reasoning, multimodality, and performance, agricultural AI has received less attention than other applications of LLMs despite its effectiveness and promising future. To better understand the system and discover potential pathways for these technologies in this sector, we developed an innovative AI-powered chatbot prototype capable of processing agricultural data, including PDF documents. This prototype allows farmers immediate information accessibility, eliminating the need to open manuals and reducing the effort needed to find and retrieve information when needed. We showcased this system as a preliminary case study at the Thriving Southland 2025 Southern AgriTech and Innovation Day, gathering direct feedback from primary industry stakeholders.

Farmer feedback from the showcase revealed strong interest in the chatbot's potential, highlighting five key desired capabilities: 1) context-aware AI systems that can effectively bridge information silos, 2) accessing historical farm-specific data through natural language queries, 3) automated compliance report generation, 4) proactive anomaly detection across multiple data streams, and 5) adaptive interaction styles aligned with individual farmer preferences.

Farmers particularly showed interest in the chatbot's capability to integrate multiple data sources, such as production data, livestock information, weather forecasts, and pasture data, providing timely insights when conditions change. For example, the potential to alert farmers when milk production falls below district averages and suggest potential causes. This capability addresses a significant gap in current agricultural technology: the disconnect between data availability and actionable insights. Participants emphasised the value of AI chatbots providing context-specific, personalised farm data, recalling historical events, and generating compliance reports, thereby significantly reducing administrative burden. The findings demonstrate the potential for AI chatbots to fundamentally transform data accessibility in farming systems, supporting more timely and informed management practices and accelerating the adoption of digital technologies in the primary sector.

1B | Heat stress monitoring

MONITORING RUMEN TEMPERATURES IN LACTATING DAIRY COWS WITH FOCUS ON HEAT STRESS

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With predicted climate change, the impact of heat stress on dairy cow welfare is becoming increasingly important, even under moderate climate conditions. In order to maintain cow welfare and performance, it is important to know when heat stress affects physiological parameters such as body temperature.

The aim of the present study was to analyse the rumen temperature of lactating dairy cows during the summer months in relation to the ambient temperature (AT) and the temperature-humidity index (THI) in the barn.

The study was conducted in a naturally ventilated dairy barn with cubicle loose housing system in Brandenburg, Germany, as part of the DigiMuh project. The herd in the experimental barn consisted of 160 Holstein Friesian dairy cows (2nd to 7th lactation, average daily milk yield: 41.52 ± 5.22 kg), milked two times per day in an external rotary milking parlour (DeLaval PR2100, Tumba, Schweden). Data from June to September were analysed for this study. Only healthy cows that were in the herd during the entire experimental period were included for analysis. This resulted in a sample size of n=40. The rumen temperatures of the cows were measured every 10 min individually with a rumen temperature bolus (smaXtec, Graz, Austria; accuracy: ±0.01°C) placed in the reticulorumen. During drink cycles recorded temperature data were corrected. Time periods of milking were also excluded from the statistical analysis. Ambient temperature (AT, accuracy: ±0.01°C) and relative humidity (RH, accuracy: ±3%) of the air were recorded every 10 min (Climate Sensor SX.2, smaXtec, Graz, Austria) inside the building. The temperature-humidity index (THI) was calculated as follows:

$$THI = (1.8 \times AT + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times AT - 26), \qquad (1)$$

where AT is the ambient temperature in °C, and RH is the relative humidity in %.

The THI was used to define the heat load the cows were exposed to.

Statistical analysis was performed using JMP 16 (SAS Institute, USA). The correlations (Pearson's correlation coefficient, *r*) between body temperature and barn climate were analysed and a broken stick model was performed for each individual cow, taking into account the animal individuality.

Only a weak positive correlation ($P<0.001$) was found between rumen temperatures and AT (r=0.11, mean summer temperature: 21.2°C) and THI (r=0.12, mean THI of that summer: 68.1). This indicates that even at high ATs, cows are able to maintain their core body temperature relatively constant. The broken stick model showed that the median break point for the cows was an AT of 22.56 °C and a THI of 72.41.

A reaction in rumen temperature seems to be a late indicator of heat stress regarding the whole herd. Further analysis of data is necessary for an individual consideration of dairy cows' heat load reactions.

The project was supported by funds from the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support program.

THE ASSOCIATION OF CALCULATED HEAT STRESS ON RUMINATION TIME IN HOLSTEIN AND JERSEY COWS

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Heat stress (HS) is a growing concern within the dairy industry, especially as temperatures increase worldwide, negatively affecting dairying regions previously unthreatened by extreme heat. Heat stress has been shown to negatively impact health and production as well as rumination time (RT) in dairy cows. In part because of the association with dry matter intake, RT is a useful metric of overall cow health and well-being.

The objective of this research was to assess the effects of calculated heat stress on RT and analyze differences between Holstein, Jersey, and Jersey-x cows. A dataset with rumination data (SCR Heatime) from June 1 to October 1, 2024, from one New Hampshire dairy herd was obtained and checked for completeness. Cows with more than 3 consecutive days of missed rumination data were excluded from analysis. Daily temperature humidity index (THI) for the entire study period was calculated. Each day was then categorized into 1 of 4 HS categories: no HS (NHS; THI < 68; n = 15 d), mild HS (MHS; 68 ≤ THI < 71.9; n = 19 d), moderate HS (MOHS; 72 ≤ THI < 79.9; n = 57 d), or severe HS (SHS; THI ≥ 80; n = 31 d). Linear models were built in R (version 4.4.1) and included HS category, parity (1, 2, or ≥3), breed (Jersey, Jersey-x, or Holstein), and their respective interactions. Cow ID was included as a random effect. Three models were fit: 1) wherein all cows were included (n = 132) and the effect of breed was tested, 2) Holstein only model (n = 111), and 3) Jersey and Jersey-x (n = 21). Models including only Holsteins or Jerseys and Jersey-x excluded the effect of breed. When all breeds were analyzed together, there was a significant effect of HS, parity, and breed on RT (all $P < 0.001$). For the all-breed model, the mean RT in the NHS, MHS, MOHS were significantly greater than the SHS days (588 [95% confidence interval: 574, 586] min/d, 589 [577, 587] min/d, 588 [578, 584] min/d, vs 572 [557, 565] min/d, respectively). In the Jersey model, the HS category negatively impacted RT with SHS resulting in a significantly lower RT compared to NHS (567 [555, 575] min/d; P = 0.047), MHS (570 [562, 580] min/d; P = 0.001), or MOHS (568 [566, 577] min/d; $P < 0.001$). The Holstein model showed significant effects of HS and parity, where SHS significantly decreased the RT compared to the other HS categories ($P < 0.001$). There was a tendency for an interaction between HS and parity, wherein parity 1 cows experienced greater reductions in RT with increasing severity of HS.

Our results suggest that resilience to HS differs between breeds and across parities. Further investigations are needed to explore these differences more thoroughly, as well as more targeted strategies to minimize HS. These findings stress the importance of HS abatement techniques within farms, especially with rising global temperatures and more days spent with SHS.

HEAT STRESS IN DAIRY CATTLE: COMPARISON OF NOVEL SENSOR BASED METRICS WITH PRODUCTION AND PHYSIOLOGICAL MEASURES

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In response to heat challenges, dairy cows exhibit physiological, behavioural, and production-related adaptations to restore thermal balance. Although these responses have been widely studied, they are often examined in isolation, with limited attention to their temporal dynamics. Consequently, their relative sensitivity and responsiveness to heat load remain unclear.

This study aimed to compare the relative sensitivity of various physiological, behavioural and production indicators of heat stress and identify potential sensor-based measures capable of automating heat stress detection. The study spanned 10 days, with the temperature-humidity index (THI) exceeding 68 on days 1 to 5, a threshold previously shown to elicit heat stress responses in cattle, before declining thereafter. In the six days before the study THI remained around 65, rising to 69.5 the day before observations began. Daily mean values of temperature, relative humidity, and THI (Table 1) were calculated from a network of 23 wireless sensors (RuuviTag, Ruuvi Innovations Ltd., Riihimäki, Finland) distributed throughout a cubicle yard, housing approximately 110 high-yielding lactating cows. Thirty of these cows, in early to mid-lactation, were selected for monitoring. The positions of cows were tracked using a neck-mounted local positioning system (S500, Omnisense Ltd., Cambridgeshire, UK) and range size measured as the number of 4 m^2 virtual cells that each cow occupied per day. Ear surface temperature was recorded using ear-mounted sensors equipped with infrared thermometers (SmartBell Ltd., Cambridgeshire, UK). Respiration rate and panting score were visually assessed three times daily (08:00, 12:00, and 16:00) on days 1 to 6 and day 10. Milk samples were collected during each milking on the same days for analysis of cortisol concentration using an enzyme immunoassay kit (EA65, Oxford Biomedical Research Inc., MI, USA), and for compositional analysis using infrared spectra (National Milk Laboratories, Wolverhampton, UK). Milk yield was automatically recorded at every milking session (2 times daily) using an in-parlour recording system (Swiftflo Endurance, Dairymaster Ltd., Worcestershire, UK). Data were analysed using Linear Mixed Models (lmerTest) or Cumulative Link Mixed Models (ordinal) with Tukey post-hoc comparisons (emmeans) in the statistical computing language R.

Significant day-to-day variation was observed in most indicators (Table 1). Ear temperature, respiration rate, and panting score showed immediate and significant reductions with decreasing THI, indicating high responsiveness to environmental conditions. Cortisol levels peaked numerically on day 4 and showed a non-significant trend toward reduction by days 6 and 10, suggesting a delayed response. Among milk composition variables, urea concentration declined significantly over days 1 to 4, but there were no other significant changes in milk concentration of protein (Table 1) or other components (data not shown). Milk yield remained stable during days 1 to 6 but declined slightly during days 7 to 9 before recovering on day 10. Range size varied across the study period but the pattern was inconsistent. Other space use metrics are still to be tested and may be beneficial in exploring longer term behavioural trends. Individual animal-worn sensors, such as those measuring ear temperature, have potential for real-time monitoring of heat stress and may support responsive automated management strategies.

Table 1. Daily means of temperature, relative humidity and temperature-humidity index (THI), and least square means (±SE) of physiological, behavioural, and production indicators in dairy cows over the 10-day testing period (Days 1–10).

Indicators	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10
Temperature (°C)	24.8	24.6	22.7	22.6	21.3	18.6	20.3	19.5	18.1	18.3
Relative humidity (%)	62.3	59.7	71.0	71.2	67.5	68.8	74.8	76.6	71.4	82.6
THI[1]	72.7	72.2	70.4	70.4	68.1	64.2	67.1	66.0	63.5	64.3
Ear temperature (°C)	36.3 ± 0.2[a]	36.0 ± 0.2[a]	35.5 ± 0.2[b]	35.5 ± 0.2[b]	35.1 ± 0.2[c]	34.5 ± 0.2[de]	34.8 ± 0.2[cd]	34.5 ± 0.2[de]	34.4 ± 0.2[de]	34.3 ± 0.2[e]
Respiration rate (per min)	68.9 ± 1.7[a]	64.0 ± 1.7[ab]	58.8 ± 1.7[bc]	55.8 ± 1.7[c]	50.1 ± 1.7[d]	43.0 ± 1.7[e]	--	--	--	40.8 ± 1.7[e]
Relative panting tendency[2]	1.3 ± 0.4[a]	0.5 ± 0.4[a]	0.1 ± 0.4[ab]	0.2 ± 0.4[ab]	-1.1 ± 0.4[bc]	-2.5 ± 0.4[cd]	--	--	--	-2.8 ± 0.4[d]
Milk yield (kg)	46.3 ± 1.2[ab]	45.6 ± 1.2[ab]	47.8 ± 1.2[a]	45.9 ± 1.2[ab]	NA	45.5 ± 1.2[ab]	44.0 ± 1.2[b]	44.4 ± 1.2[ab]	43.9 ± 1.2[b]	45.6 ± 1.2[ab]
Milk cortisol concentration (ng/ml)	0.82 ± 0.08	0.85 ± 0.08	0.88 ± 0.09	1.11 ± 0.08	NA	0.81 ± 0.08	--	--	--	0.82 ± 0.08
Milk urea concentration (mg/dl)	20.4 ± 6.8[a]	19.5 ± 6.7[ab]	17.7 ± 7.1[b]	13.9 ± 6.8[c]	NA	NA	--	--	--	14.9 ± 7.1[c]
Milk protein (%)	2.94 ± 0.04	2.97 ± 0.04	2.95 ± 0.04	2.92 ± 0.04	NA	NA	--	--	--	3.01 ± 0.04
Full-range[3]	86.4 ± 4.5[a]	80.9 ± 4.4[abc]	69.4 ± 4.1[bc]	79.8 ± 4.3[abc]	71.4 ± 4.1[abc]	83.1 ± 4.4[ab]	74.3 ± 4.2[abc]	78.4 ± 4.3[abc]	85.0 ± 4.5[ab]	67.0 ± 4.0[c]

[1] The THI was computed using the formula $THI = (1.8 \times T + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T + 32 - 58)$ where T signifies the temperature in Celsius and RH represents relative humidity.

[2] Relative panting tendency refers to the panting levels of cows, scored based on various behavioural indicators, with higher scores representing more severe panting.

[3] Full range refers to the number of 4 m² grid cells each cow occupied per day, representing 95% of her total location data within the yard.

[a, b, c, d, e] Different superscript letters indicate statistically significant differences among testing days ($p \leq 0.05$).

-- Data not collected on these days as per the experimental design.

NA. Data unavailable due to technical issues.

COMBINING WEARABLE DATA TO CREATE BEHAVIOUR AND ENVIRONMENTAL PROFILES THAT PROVIDE INSIGHT ON INDIVIDUAL DIFFERENCES IN RESPONSE TO HEAT STRESS

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New Zealand dairy farmers are investing in cow wearable technology. Cow behaviours generally do not change in isolation, thus combining automatically collected data can promote the development of holistic wellbeing metrics. One area of opportunity is integrating environmental and animal data to understand the risk of, and manage the response to, heat stress.

We combined cow behaviour and environmental measures into profiles and related these to an indirect indicator of heat stress (rumen temperature). Commercial farms in Canterbury (Farm 1) and Waikato (Farm 2) were equipped with devices (both farms: Davis weather stations, AfiPedometer, SmaXtec; Farm 1: Herd-i and CowManager; Farm 2: AfiCollar). Behavioural (rumination, panting, grazing, resting, drinking, milking order, Herd-I lameness score) and environment (ambient air temperature, relative humidity, wind speed, rainfall, solar radiation) measures collected between December 2023 and February 2024 were analysed using principal component analysis with varimax rotation and z-score standardised variables (R software version 4.2.1). High loading variables (≥ ± 0.62) were used to make a biological interpretation of each component, hereinafter referred to as 'profiles'. A regression method was used to obtain the score for each cow on a continuum for each profile.

To determine if profiles could explain variation in an individual's heat stress response, a 14 day high heat stress risk period was identified for each farm using the grazing heat load index. A repeated measures linear mixed effects model was run (rumen temperature = dependent variable; profile scores = independent variables; cow = random factor). Squared terms accounted for potential nonlinear associations with rumen temperature.

Two profiles were consistent on both farms: 1) long and frequent resting, and 2) high and frequent drinking volumes. Farm-specific profiles were as follows: Farm 1 – 1) hot windy days, 2) high rumination, and 3) low mobility with high grazing; Farm 2 – 1) hot low rainfall days with panting, 2) dry windy sunny days, and 3) high activity. All profiles affected rumen temperature, except 'long and frequent resting' on Farm 1 (Table 1).

On Farm 1, the 'hot windy days' profile had a quadratic relationship with rumen temperature, suggesting wind provided a cooling effect until ambient temperatures became too high. The 'high rumination' and 'low mobility and high grazing time' profiles were associated with higher rumen temperatures. The 'high and frequent drinking volumes' profile predicted rumen temperature in opposite directions, highlighting the need to consider behaviour changes within the farm context. On Farm 1, increased drinking had a cooling effect, suggesting cows were managing their thermal load, whereas on Farm 2 the positive relationship between drinking and rumen temperature suggested a reactive response to existing heat stress. Two quadratic relationships predicted increased rumen temperature on Farm 2. The 'long and frequent resting' profile suggested that cows had an optimal resting zone; the 'hot low rainfall days with panting ' profile highlighted that while high heat load increases panting and rumen temperature, rainfall's evaporative cooling moderates this. Additionally, the 'dry windy sunny days' profile was negatively associated with rumen temperature, likely due to the mitigating effect of wind. Finally, the 'high activity' profile was associated with greater rumen temperature.

These findings highlight the importance of integrating behavioural and environmental data to understand the heat stress response. These profiles could be developed as novel metrics to provide a more holistic view of wellbeing, above what can be deduced with discrete behaviour measures, and ultimately be used to support management.

Table 1. Estimates for the model predicting rumen temperature. To account for the potential of nonlinearity, all terms were also squared and those that improved model fit were left in the model.

Predictor	**Estimate**	**SE**	**t-value**	***P*-value**
Farm 1 (n=53 cows)				
(Intercept)	39.6	0.034	1165.0	<0.001
High drinking intake and bouts	-0.033	0.012	-2.84	0.005
Hot windy days	-0.215	0.027	-0.79	0.431
Hot windy days^2	0.063	0.016	3.93	<0.001
High rumination time	0.085	0.013	6.56	<0.001
Low mobility & high grazing time	0.048	0.014	3.50	<0.001
Farm 2 (n=40 cows)				
(Intercept)	39.4	0.062	637.0	<0.001
High temperature and panting time, low rainfall	0.092	0.062	1.27	0.203
High temperature and panting time, low rainfall^2	0.073	0.022	3.39	<0.001
High resting time and bouts	0.014	0.022	0.66	0.511
High resting time and bouts^2	0.045	0.013	3.54	<0.001
Dry windy sunny days	-0.141	0.033	-4.30	<0.001
High drinking intake and bouts	0.040	0.017	2.40	0.020
High activity	0.064	0.024	2.72	0.006

IMPACT OF TEMPERATURE-HUMIDITY INDEX ZONES ON FREESTALL BARN AIR QUALITY METRICS ASSESSED USING CONTINUOUS MONITORING TECHNOLOGY

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Air quality within dairy freestall barns has important implications for cow health, productivity, and welfare. This study investigated the influence of temperature-humidity index (THI) categories on key air quality metrics using two years of continuous environmental data collected at the Western Kentucky University SmartHolstein Lab (Bowling Green, KY). Environmental variables, including ammonia (NH_3), carbon dioxide (CO_2), methane (CH_4), hydrogen sulfide (H_2S), and total volatile organic compounds (TVOCs), were monitored using the Cynomys® Livestock System (Cynomys Srl, Italy), which integrates multi-gas sensors and cloud-based data transmission for real-time environmental management.

Observations were categorized into three biologically relevant THI zones:
- Ideal Zone (THI 17.1–58.0; mean 43.5; n = 226 observations)
- Moderate Zone (THI 58.0–68.0; mean 63.2; n = 118 observations)
- Heat Stress Zone (THI 68.1–84.6; mean 74.7; n = 264 observations)

Statistical analysis using mixed models with repeated measures revealed highly significant ($P < 0.05$) increases in air quality metrics as THI increased.
- Ammonia (NH_3): Concentrations increased from 0.93 ppm (Ideal) to 1.02 ppm (Moderate) and to 1.27 ppm (Heat Stress), a 37% increase from Ideal to Heat Stress ($P < 0.01$).
- Carbon dioxide (CO_2): Levels rose from 412.6 ppm (Ideal) to 577.9 ppm (Moderate) and reached 732.1 ppm (Heat Stress), an overall increase of 77% ($P < 0.05$).
- Hydrogen sulfide (H_2S): Concentrations, though low, rose progressively from 0.037 ppm (Moderate) to 0.0418 ppm (Heat Stress) and 0.0465 ppm (Ideal), with a 26% increase overall ($P < 0.05$).
- TVOCs: Concentrations increased from 0.93 ppm (Ideal) to 1.02 ppm (Moderate) and peaked at 1.27 ppm (Heat Stress), also representing a 37% increase ($P < 0.001$).
- Methane (CH_4): Followed similar increasing patterns, with detailed values available in the full dataset.

Air quality indicators consistently and significantly increased with each THI zone transition, underscoring a clear relationship between environmental heat load and declining barn air quality. From Ideal to Heat Stress conditions metrics increased by 26% to 77% highlighting critical thresholds where heat abatement and ventilation strategies become essential.

These results emphasize that elevated THI is strongly associated with declining barn air quality, which may adversely affect cow health, productivity, and welfare. The Cynomys® system proved to be an effective tool for continuous, automated assessment of barn air conditions, providing essential data to support precision dairy management decisions.

USING WEARABLE SENSOR DATA FROM COLLARS AND EAR TAGS TO QUANTIFY ANIMALS' BEHAVIORAL RESPONSES TO WEATHER VARIABILITY

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Heat stress is a significant concern in both dairy and beef production, especially in pasture-based systems where animals are directly exposed to ambient conditions and may have limited access to shade or other means of ameliorating heat stress. Production consequences from prolonged exposure to solar radiation and warm weather have also been documented in temperate regions, highlighting the prevalence of the issue. Dairy cattle are particularly susceptible due to their elevated metabolic heat production, which adversely affects both milk yield and reproductive performance.

To better understand how cattle respond to environmental temperature fluctuations, we used sensor-equipped collars alongside local weather data to monitor cattle behaviour and environmental conditions in real time, aiming to identify behavioural patterns and potential traits linked to heat stress resilience. Although the study focused on beef cattle, the methods and findings are relevant to precision dairy systems facing similar climatic challenges.

The study was conducted in Queensland, Australia, using Brahman and Droughtmaster cattle. Cattle were fitted with collars containing accelerometers and GNSS modules. Accelerometer data was processed using an embedded behaviour classification model to detect activities such as grazing, resting, and walking. GNSS data, aggregated over 10-minute intervals, was overlaid with satellite imagery to determine time spent in shaded versus open areas. Weather data was used to compute the Comprehensive Climate Index (CCI) as an indicator of heat load. This data was integrated with animal-level information, including weight gain and *Bos indicus* genetic proportion, to explore associations between behaviour, environmental conditions, and performance.

Results suggest that individual differences in shade-use behaviour may reflect underlying resilience to heat stress. Notably, some animals continued grazing in open areas despite high CCI conditions and tended to exhibit higher weight gains.

These findings demonstrate the potential of sensor technologies to detect subtle, behaviour-based traits that contribute to thermal resilience. Such traits may inform future breeding and management strategies aimed at improving livestock adaptation to a changing climate.

UNRAVELING COWS' RESPONSE TO WEATHER THROUGH RESPIRATION RATE AND DROOLING

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Outdoor farming systems expose cows to variable weather, necessitating accurate predictive indices to manage heat stress effectively. Heat load indices, such as the Temperature Humidity Index (THI - combines ambient air and relative humidity), and the most recent (2024) Grazing Heat Load Index (GHLI - incorporates temperature, solar radiation and wind speed), could be used for predicting and managing heat stress by combining weather variables to assess thermal load. We investigated the impact of weather variables on dairy cow respiration rate (RR) and drooling, using data from 483 cows across 7 pasture-based farms located throughout New Zealand between January and March. On each farm, there were 2 consecutive 5-day data collection periods. RR and drooling were observed up to six times per cow daily across three periods (0900-1100h, 1200-1400h, 1700-1900h) and matched to the nearest 15 minute weather data. Fourteen weather-related variables, including air temperature, humidity, wind speed, solar radiation and cumulative solar radiation (during the hour matching the behaviour, and shifted to the previous hour to account for potential behavioural response delay), and THI and GHLI were used to model RR and drooling. Analyses initially used data from 0900–1800h, reflecting daytime summer conditions. The final analysis used 1200-1500h as it aligned with peak heat load and gave better predictive accuracy.

Pearson correlations suggested that RR was moderately ($p<0.001$) related to temperature (r = 0.50), THI (r = 0.50), and GHLI (r = 0.54). Generalized additive mixed models (GAMMs) revealed nonlinear relationships ($p<0.001$) between RR and weather variables, with temperature, solar radiation, and wind speed being critical; this model explained 65.4% of RR variation. RR remained stable up to 19.5°C, began increasing, and then increased sharply above 22.8°C (Figure 1a), while solar radiation increased RR up to 2.9 MJ/m² (Figure 1b), and wind speed had a mitigating effect up to 4 m/s (after this, our data was sparse; Figure 1c). The inclusion of interaction terms between weather variables provided a more comprehensive understanding of the factors affecting RR, increasing the amount of total variation explained to 68.6%. The GHLI explained 59.8% of the variance in RR while the THI explained 58.7%. This highlights the limitations of variables based on linear models, particularly for predicting RR at higher temperatures, and throughout the entire day. Similar to separate weather variable models, THI (Figure 1d) and GLHI (Figure 1e) models highlighted that an RR of approximately 60 breaths/min is likely an important threshold for cows. Aligning the GHLI model with drooling provided an additional assessment of heat load severity, with about 40% of cows drooling at a GHLI of 70. The nonlinear relationship between RR and drooling probability ($p<0.001$) illustrates the interrelatedness of cow physiological responses to heat stress. The probability of drooling increased sharply above a GHLI of 55 (Figure 1f), highlighting a threshold where mitigation strategies become important.

Heat load indices can be helpful for farmers to indirectly predict and mitigate heat stress, thus promoting cow wellbeing and productivity. Future research should focus on refining these predictive models and validating them across different climatic regions, farming systems, and types of animal.

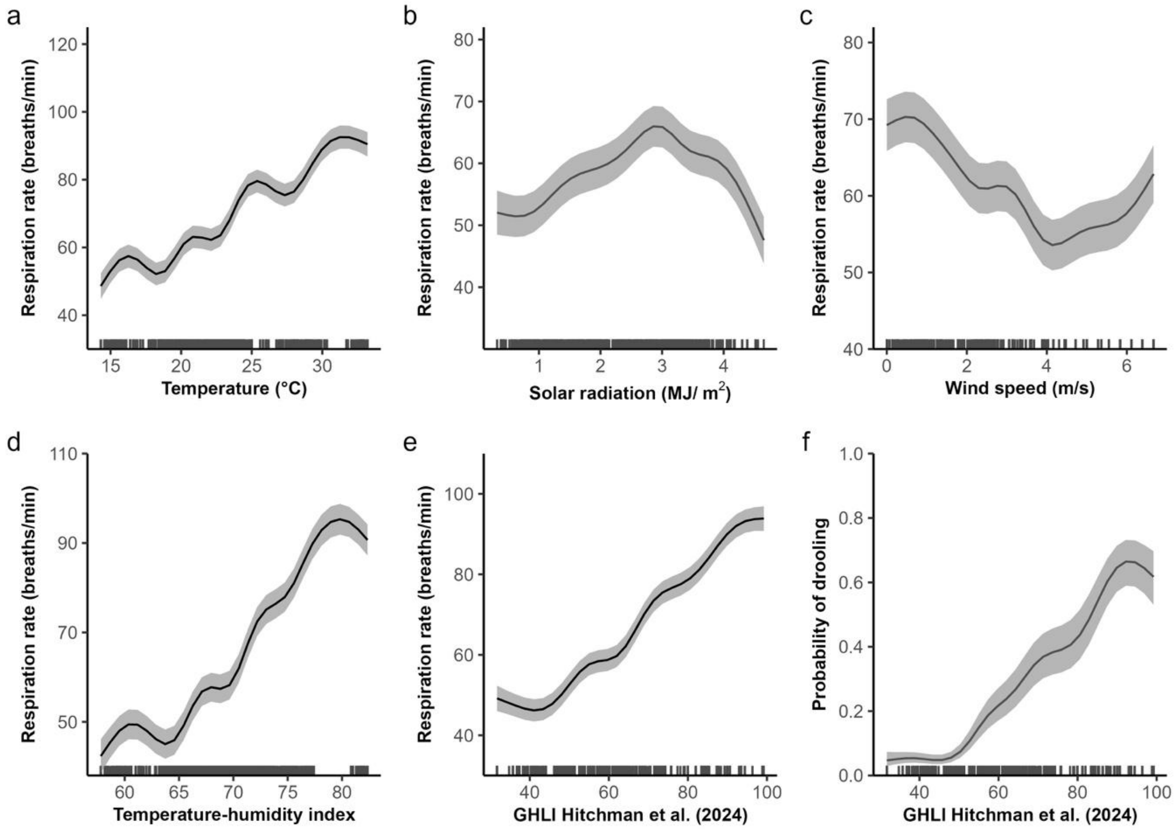

Figure 1. Predicted respiration rate (RR) with 95% confidence intervals by their associated significant weather predictors (a – c) and by THI and GHLI (d, e). Predicted probability of drooling with 95% confidence intervals by GHLI (f). The rug plots represented at the bottom of each plot show the frequency of the predictors of each smooth.

EXPLORING SENSOR TECHNOLOGIES FOR ASSESSING COW RESPONSE TO HEAT STRESS EVENTS

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Heat stress is a global problem in the dairy industry, including in pasture-based systems. Respiration rate (RR) is routinely used in research as a heat stress indicator; however, collecting RR data is typically manual and labour intensive. Sensor technologies have the potential to monitor heat stress-related variables; thus, the aim of this study was to examine the relationships between RR and two variables from commercially available on-cow devices: rumen temperature (RT – using boluses (SmaXtec Animal Care GmbH, Graz, Austria) validated for RT) and panting time (PT – using collars (Afimilk, Kibbutz, Afikim, Israel)), followed by modelling the effect of weather data on these two variables. Behaviour of 483 dairy cows and weather data were collected from 7 commercial pasture-based New Zealand farms between January and March. On each farm, there were 2 consecutive 5-day data collection periods. Device data was recorded 24 h/d and RR was observed up to six times per cow daily across three periods (0900-1100h, 1200-1400h, 1700-1900h).

Analyses initially used data from 0900–1800h, reflecting daytime summer conditions. Final analyses used the 1200–1500h window as it aligned with peak heat load and gave better predictive accuracy. RR observations were matched to the nearest 15 minute weather data. Weather variables were included in two ways: 1) aligned with the hour in which the behaviour occurred and 2) shifted to the previous hour to account for the potential of a delayed behavioural response. Solar radiation was also included as a cumulative value of the past 24 h. Pearson correlation coefficients were calculated between RR and RT and PT, while generalized additive mixed models (GAMMs) provided insights into the nonlinear relationships between the weather and device-based variables.

The estimated RR increased from as low as approx. 25 breaths/min at 0700h to a peak rate (approx. 70 breaths/min) at 1400h. Moderate positive relationships ($p<0.001$) existed between RR and RT ($r=0.45$), and PT ($r=0.42$). Temperature, cumulative solar radiation, wind speed in the previous hour and their relevant interactions explained 46.7% of the total variation in RT. The relationships were nonlinear ($p<0.001$), with a predicted increase in RT when previous hour air temperature exceeded 19.2°C (Figure 1a) and cumulative solar radiation surpassed 22.2 MJ/m^2 (Figure 1b). RT was predicted to sharply increase when previous hour air temperature was above 29°C. Previous hour wind speed had a mitigating effect (Figure 1c). Air temperature, solar radiation, and wind speed in the same hour as the behaviour explained 40.2% of the total variation in PT (nonlinear $p<0.001$). As air temperature surpassed 22°C (Figure 1d) and solar radiation exceeded 1.8 $MJ/m^2/h$ (Figure 1e), predicted PT increased steeply. The highest PT occurred when wind speed was <2 m/s (Figure 1f).

Weather variables can be used to predict high heat load events. The key weather thresholds predicted to change RT and PT were like those reported previously for RR (i.e. grazing heat load index). The current results suggest that RT and PT could be used on-farm to help farmers identify times to use suitable mitigations for managing heat stress.

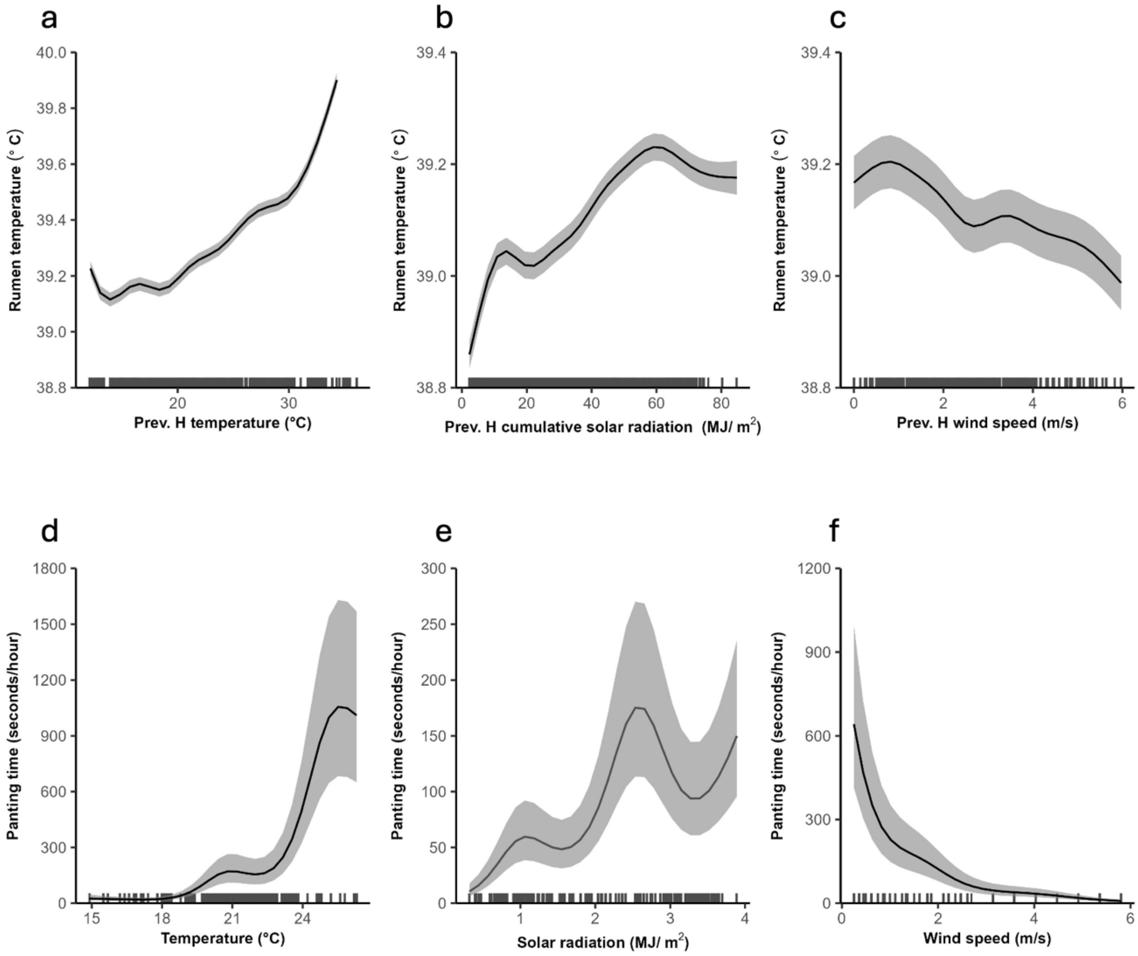

Figure 1. Predicted rumen temperature (RT) and panting time (PT) with 95% confidence intervals by their associated significant weather predictors using Gaussian GAMMs. The rug plots represented at the bottom of each plot show the frequency of the predictors of each smooth. Prev. H refers to the weather variable being recorded in the hour previous relative to the rumen temperature value.

PHYSIOLOGICAL AND BEHAVIOURAL RESPONSES TO ENVIRONMENTAL HEAT LOAD IN LACTATING DAIRY COWS FED PASTURE WITH VARIABLE PROPORTIONS OF *PLANTAGO LANCEOLATA*

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Dairy cows grazing outdoors are exposed to a variable climate, including conditions that could cause heat stress. Cows experience heat stress when they are unable to dissipate excess body heat effectively. This can result in reduced feed intake and milk production, and negatively impact their overall welfare. The use of shade and sprinklers are proven options to help mitigate heat stress; however, nutritional strategies which result in lower metabolic heat production during fermentation may provide additional benefits and may be a useful alternative approach on some farms. Examples include reducing dietary fibre, increasing concentrates with slow fermenting starch, and using feed additives. Thus, the inclusion of plantain (*Plantago lanceolata*), which has comparatively high water and low fibre content, into perennial ryegrass and white clover swards could help mitigate responses to increasing heat load.

Data from an existing farm systems experiment in Canterbury, New Zealand, were used to understand the associations between physiological and behavioural responses to increasing environmental heat load in lactating dairy cows grazing pastures with variable proportions of plantain (0-33%).

The study consisted of 10 observation days in summer between 20 February and 9 March 2023, focusing on the period 1200-1459 h each day. Cows were rotationally grazed and supplemented with pasture baleage during pasture deficits (mean of 3.8 kg DM/cow/d (SD =2.3)). Mean hourly weather data were obtained from the onsite weather station (Standard Agricultural, Scott Technical Instruments Ltd, New Zealand). Measurements from 77 cows included individual cow respiration rate (manual observations), rumen temperature (1300-1559 h to allow for a 1-hour lag, smaXtec Animal Care GmbH, Graz, Austria), daily total lying time (IceRobotics, Edinburgh, Scotland) and afternoon milk yield (DeLaval, Tumba, Sweden). Relationships between these measures and cow, diet (proportion of plantain in the diet, supplement allocation), and weather variables were explored using partial least squares (PLS) modelling including linear and quadratic terms.

PLS modelling showed that air temperature as a quadratic term and as an interaction with solar radiation and evapotranspiration, plus relative humidity explained 60% of the variation in respiration rate (Table 1). Air temperature as linear and quadratic terms and as an interaction with solar radiation, wind speed and relative humidity, plus wind speed as a quadratic term explained 42% of the variation in rumen temperature. PLS models were only able to explain 23% and 20% of variation for lying time and afternoon milk yield, respectively.

Under the conditions of our study, the proportion of plantain in the diet was found to be non-significant in the PLS models for respiration rate, rumen temperature, lying time and afternoon milk yield. However, the dataset had several limitations: there were only four of the 10 observation days where cows were exposed to high heat load conditions (grazing heat load index > 62; a linear function of air temperature, solar radiation and wind speed), use of supplementary feed may have confounded the results, and the proportion of plantain in the diet did not exceed 33%. This study leveraged milk metering data and cow wearable technology to monitor physiological and behavioural responses to environmental heat load, complementing traditional manual observations. Future research conducted under more controlled conditions – over a longer time period, with higher plantain inclusion, and without supplementary feed – would more effectively determine the impact of plantain on cow responses to increasing heat load.

Table 1. Partial least squared regression model equations (raw coefficients) for predicting respiration rate (breaths/min), rumen temperature (°C), lying time (h/d), and afternoon milk yield (kg/cow/d). The most parsimonious models are presented, i.e. greatest proportion of variation explained with the smallest number of predictors.

	Respiration rate	**Rumen temperature**	**Lying time**	**Afternoon milk yield**
R^2 of the model (%)	60	42	23	20
Intercept	55.74	39.19587	12.61	2.52
Evapotranspiration × Air temperature	0.979			
Air temperature × Air temperature	0.024	0.00044		
Solar radiation × Air temperature	0.195	0.00427		
Relative humidity	-0.527			
Air temperature		0.01735	-0.134	
Air temperature × Wind speed		-0.00040		
Wind speed × Wind speed		-0.00046		
Relative humidity × Air temperature		-0.00059		
Supplement allocation × Wind speed			-0.021	
Age			-0.206	1.201
Age × Age				-0.108

ASSOCIATION BETWEEN THREE PHENOTYPIC INDICATORS OF HEAT STRESS IN DAIRY CATTLE

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Climate-smart strategy development remains a priority across global dairy systems as a consequence of heat stress (HS) on dairy cattle. Effective monitoring of individual animal responses to HS can provide valuable insights for management decisions. Phenotypes of core body temperature, milk yield, and drinking behaviour each have established relationships with changes in thermal conditions, but their interrelationships and potential utility in commercial applications remain underexplored.

This study aimed to assess the suitability of these traits to serve as effective proxies for HS within the context of climate-smart management. Time series decomposition and mixed model analysis of historical animal data – reticulorumen temperature, drinking frequency, and milk yield – alongside corresponding climate data were conducted. To evaluate temporal relationships and lagged responses to heat stress, cross-correlation analysis was applied to trait deviations relative to climate indices. Mixed effects models were fitted using ASReml, incorporating fixed effects, random intercepts and slopes for individual animals, and spline terms to capture nonlinear responses. Wald tests assessed fixed effect significance, and variance components were used to evaluate individual variability. Trait-specific linear trends were derived for each animal as a composite phenotype measure. Results confirmed significant effects of temperature humidity index (THI) for all traits (Figure 1). All traits revealed individual animal diversity in response to deviations in both THI and reticulorumen temperature. Analysis of trait-specific response slopes revealed meaningful multi-trait associations, suggesting that certain traits – particularly drinking behaviour – may serve as indicators or proxies for others in the context of heat stress adaptation. These insights contribute to the development of more responsive and adaptive livestock management strategies under changing climatic conditions.

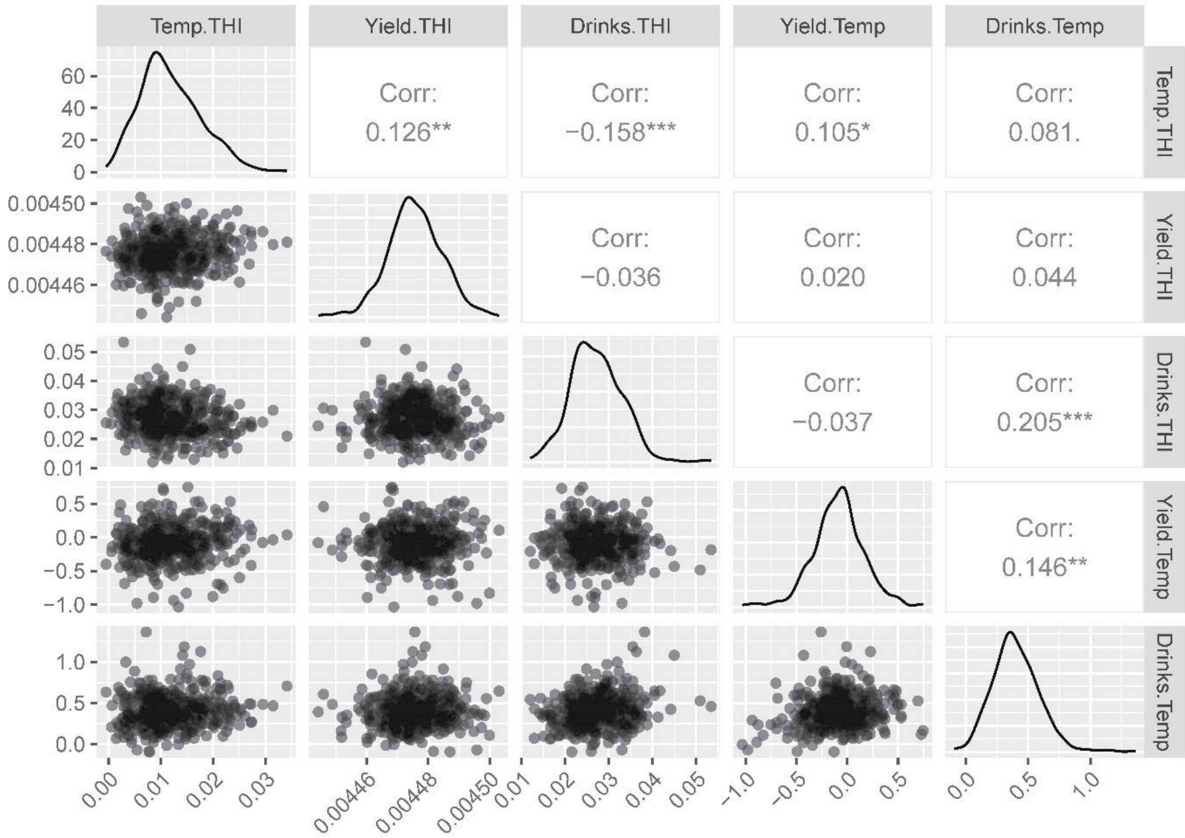

Figure 1. Generalised pairs plot revealing the association between slopes of $Temp_{dev}$ per change in THI_{max_dev} (Temp.THI), $Yield_{dev}$ per change in THI_{max_dev} (Yield.THI), $ndrink_{dev}$ per change in THI_{max_dev} (Drinks.THI), $Yield_{dev}$ per change in $Temp_{dev}$ (Yield.Temp), and $ndrink_{dev}$ per change in $Temp_{dev}$ (Drinks.Temp) for each individual.

1C | Reproduction and genetics

THE FUTURE CONTRIBUTION OF PRECISION DAIRY MEASUREMENTS TO GENETIC GAIN IN PASTURE BASED DAIRY INDUSTRIES

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Genetic improvement in pasture-based dairy systems has historically relied on conventional farmer recording and herd testing information to provide the data that drives genetic evaluations. As individual animal precision recording measures proliferate as tools to enable more effective farm management, there will be opportunities to enrich the quantity and quality of data for genetic evaluation. The opportunities include more cows with records of sufficient quality to include in genetic evaluations, more precise phenotypes with less error, the introduction of novel traits with higher heritability, and more cost-effective recording. However, integration challenges with existing national database and genetic evaluation system infrastructure, establishment of data sharing agreements, and concerns over data quality and efficacy are barriers that are still a long way from being overcome.

This talk will identify and discuss the most likely opportunities for effective use of precision measurement technologies to drive genetic gain, and the research gaps and investment required to realise the potential benefits. Examples will include automated mastitis detection through inline milk sensors, wearable devices for measuring puberty and strength of oestrous, automated body condition score measures, and walk-over weighing systems. In particular, Body Condition Score can be measured by camera, laser, wearable devices and CT scan. This raises questions about who should be the independent 3rd party validator of these technologies? What methods of validation should be used? Are farmers happy to participate in this type of programme, i.e. measure the same cow twice using different devices? Effective integration of these technologies into future breeding strategies incorporating high quality genotyping and phenotyping of cows within coordinated information herds will be considered.

ICAR IDF INITIATIVE ON SENSOR DATA FOR FUNCTIONAL TRAITS: GENETICS AND REFERENCE STANDARDS FOR RUMINATION

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While sensor technology offers many possibilities for genetics or quality assurance systems, it is primarily used for on farm level decision-making. Using data from these technologies across farms and along the dairy value chain offers new opportunities for genetic evaluations, welfare assurance, and improved transparency and sustainability in general. The overall aim of the joint ICAR IDF initiative is to develop guidelines to support the adoption of novel technologies and use of sensor data for improving animal health and welfare. During a workshop at the ICAR Conference 2024, the joint initiative discussed motivation and topics of interest for collaboration of different actors, including different stakeholder groups, scientists and manufacturers. A survey among participating manufacturers identified mutual interests and priority areas:

- Establishing a common agreement on definitions and terminology for health conditions and behaviors measured with sensor systems.
- Developing standards to facilitate exchange of data and information across different farms and sensor technologies in accordance and collaboration with other ICAR standards and working groups.
- Making guidelines based on best practices for data collection, handling and analysis for different use, e.g. genetics, health and welfare monitoring.
- Generating recommendations and protocols for testing the performance of sensor systems.

Sensor-based rumination data was selected as the first use case. Preliminary results and recommendations on use of rumination data for genetic evaluation, sensor key performance indicators and preferred reference standards will be presented. Close collaboration between ICAR/IDF with relevant stakeholders and manufacturers of sensor systems enables better understanding of needs and potential of commonly agreed on guidelines, which will improve global adoption of the guidelines to promote use of sensor data in herd management, animal welfare assessment and genetic improvement.

VARIATION IN HEIFER RUMINATION BEFORE BREEDING, AND THE RELATIONSHIPS WITH FERTILITY

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New Zealand dairy farmers have been increasing their investment in and use of cow wearables. Initially used to support heat detection, data related to rumination outputs increasingly support health management decisions. However, there is a lack of information regarding the variation in rumination time in heifers and the impact on heifer productivity is not well understood. This retrospective analysis investigated the rumination patterns of heifers in the four weeks before mating start date.

Our aims were to: 1) report the variation in rumination in grazing heifers, 2) explore factors that may contribute to the variation in daily rumination, and 3) evaluate differences in rumination time and reproductive outcomes.

The datasets were collected from a study evaluating the reproductive performance of Holstein-Friesian heifers divergent in genetic merit for fertility, extensively grazed in one location in four management mobs, with detailed reproductive data. Heifers were bred naturally with Jersey bulls for 98 days (ratio 1:20 heifers). We focused on the daily rumination for the four weeks before the bulls were added, and the post-mating reproductive results. Following data cleaning, the two-hour rumination data (SCR, SenseHub) available for analysis comprised 12,469 animal days (representing 526 heifers across 25 days from Sep to Oct). Of these, 4.1% of the animal days were categorised as having an oestrus event by the system ('System Heats'). This varied from 2.9% to 4.9% across the four management mobs of >130 heifers per mob (based on age at weaning).

The rumination data were combined with static data that included management mobs (the mobs formed when the heifers were transported between rearing facilities post-weaning), genetic merit for fertility (High and Low), day of System Heat pre-mating (Heat, NoHeat), and whether animals conceived in the first 3-weeks of breeding (Yes, No).

Categorical variables were analysed using chi-squared test of independence, while continuous variables were subjected to analysis of variance followed by Tukey t-test for pairwise comparisons. All data processing and statistical analyses were performed with the R statistical computing software (version 4.4.1; R Core Team 2024).

Daily rumination across the 12,469 animal days varied from 290 to 484 min/d. There was significant variation (P<0.001; Figure 1) between mobs, with the youngest mob (Blue) ruminating significantly longer than the any of the older mobs (Green, Purple, Orange). Unsurprisingly, rumination declined on days when the heifers were on heat (P<0.001; Heat 333 (327-338) min/d, NoHeat 409 (404-414) min/d), and genetic merit for fertility was associated with daily rumination time (P=0.03; High 374 (369-379) min/d, Low 368 (362-373) min/d). There was no association between rumination time and conception status after 3 weeks of breeding (P=0.89; Yes 371 (367-376) min/d, No 370 (364-377) min/d).

Utilising large datasets retrospectively enabled us to describe the variation in rumination time in heifers and evaluate how management mobs and heat events affected rumination in heifers, and whether reproductive outcomes were associated with rumination. Future research will evaluate how to expand these analyses to fill knowledge gaps and support future research to support the effective use of these technologies.

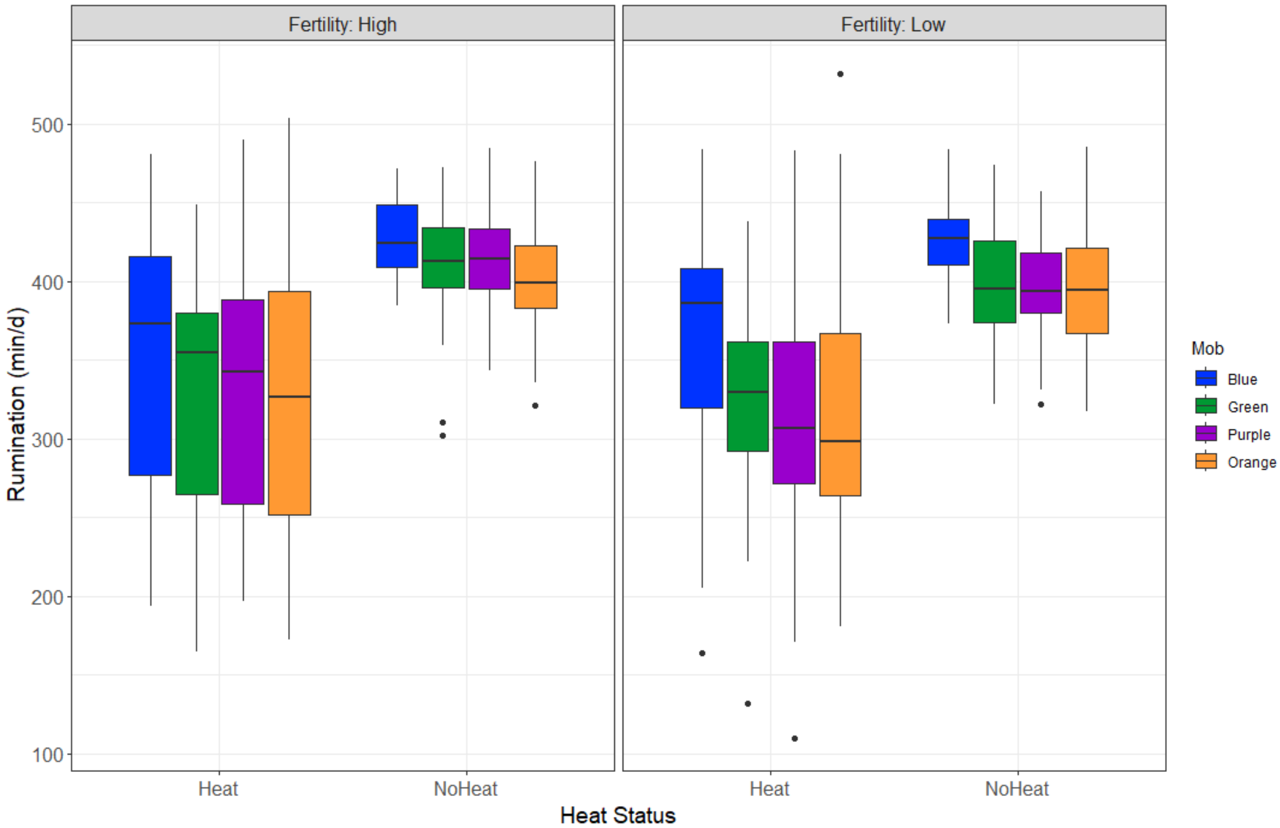

Figure 1. Variation in average daily rumination (min/d) within each management mob (P<0.001), Heat status (P<0.001; Heat days 4%, NoHeat days 96%) and genetic merit for fertility (P=0.03; High vs Low).

ENHANCING ESTRUS DETECTION IN DAIRY COWS THROUGH MULTI-SENSOR INTEGRATION AND CYCLE-SPECIFIC LABELING APPROACHES

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Accurate estrus detection is essential for effective reproductive management in dairy farming, especially in tropical climates where heat stress can mask behavioral signs. Although accelerometers are widely used to monitor estrus-related activity, their performance varies across animals and environments. Gyroscopes, which measure rotational movement, may offer complementary information, but their application in estrus detection remains limited. Additionally, the combined effect of sensor integration and estrus labeling strategies, particularly in natural versus synchronized cycles, has been insufficiently explored.

This study aimed to (i) evaluate the performance of estrus detection models using accelerometer, gyroscope, and combined sensor inputs; (ii) assess the effect of including the proestrus period in estrus labeling; and (iii) compare detection efficacy between natural and synchronized estrous cycles.

Eight Holstein-Friesian heifers were monitored for 90 days using neck-mounted prototype activity meters containing a tri-axial accelerometer and gyroscope (MPU-6050), microcontroller, LoRa transmitter, 3,700 mAh battery, and Wi-Fi antenna enclosed in a 3D-printed case. A total of 1,220,754 data instances were recorded, including 699,588 from naturally cycling cows (Cows 1–5) and 521,166 from synchronized cows (Cows 6–8). Data were segmented into 10-second windows, and 79 statistical features were extracted. Behavioral annotations were manually labeled from synchronized CCTV footage. Proestrus was identified by behavioral signs such as restlessness, sniffing, mounting attempts, and vocalization, with an estrous score >15 at two consecutive time points. Estrus was defined by the first occurrence of standing heat, confirmed by an estrous score >100 at two successive observations. This phase continued until ovulation, confirmed by transrectal ultrasonography every six hours and serum progesterone sampling every three days. Synchronized cows were treated using a CIDR-Ovsynch protocol. Individual Random Forest models were trained for each cow using Recursive Feature Elimination and evaluated via stratified cross-validation.

Models combining accelerometer and gyroscope data consistently yielded the highest performance, achieving F1-scores and accuracy up to 88.14% and 95.4%, respectively (Figure 1). Incorporating proestrus in the positive class label enhanced sensitivity and F1-score in several individuals, notably synchronized cows such as Cow 8, while Cow 2 and Cow 7 showed minimal gains. In specific cases (e.g., Cow 1, Cow 3, Cow 6), gyroscope-only models offered comparable precision but lower sensitivity and F1-scores. Performance trends varied by individual, with Cows 2 and 7 maintaining high metrics across all configurations, while Cows 4 and 5 showed moderate sensitivity. Superscript annotations in Figure 1 indicate statistically significant differences ($p < 0.05$) among sensor types and labeling strategies.

Integrating linear and rotational movement data improved estrus detection accuracy, with enhanced sensitivity observed when proestrus was included in labeling, particularly in synchronized cows. Although responses varied among individuals, synchronized cows demonstrated more consistent signal patterns. Despite limitations in sample size and setting, the results support the application of multi-sensor, individualized detection models and underscore the potential of incorporating proestrus and estrus type information to refine model performance.

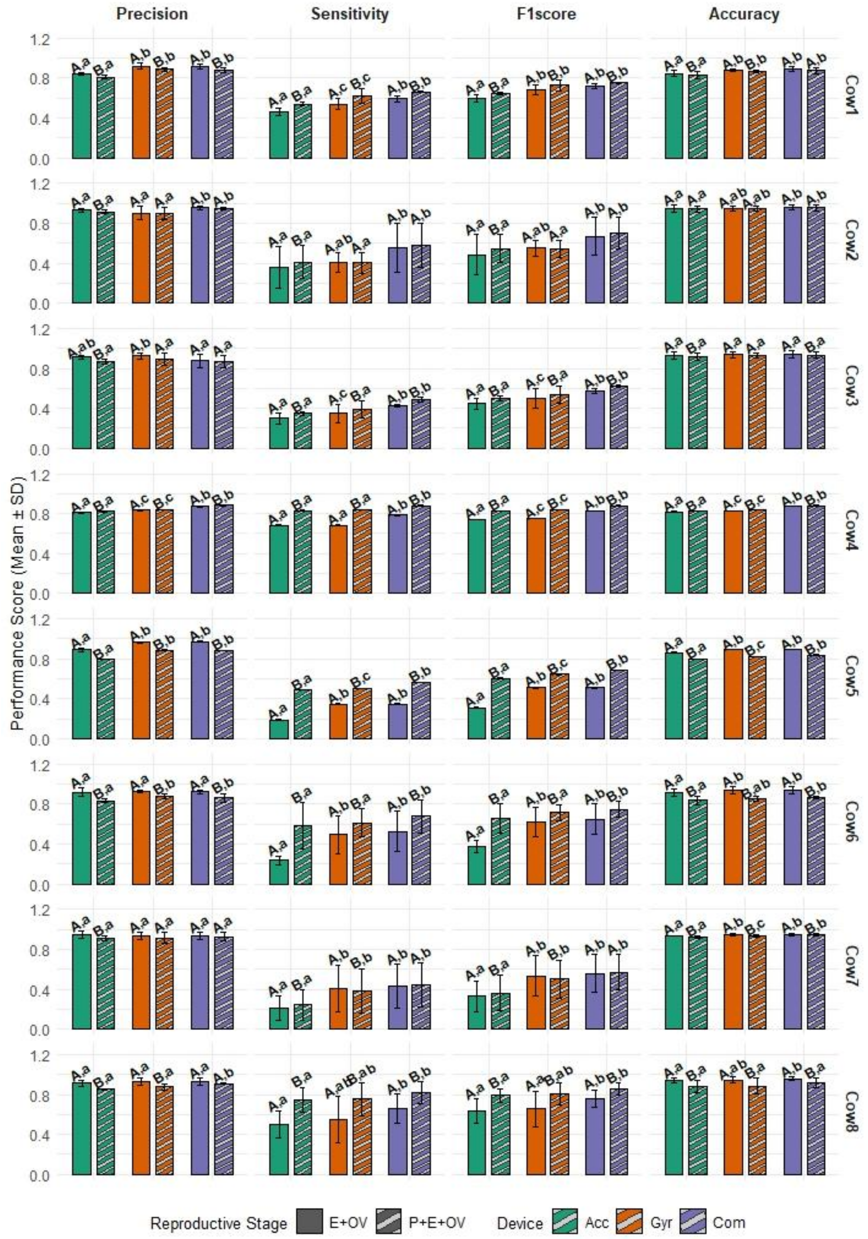

Figure 1. Classification performance of estrus detection models using accelerometer (Acc), gyroscope (Gyr), and combined (Com) sensors under estrus and integration of proestrus labeling in natural estrus cows (Cows 1–5) and synchronized cows (Cows 6–8).

Note: E+OV (estrus with ovulation) indicates that class 1 was assigned exclusively to data within the estrus and ovulation period, while all other data were labeled as class 0. P+E+OV (proestrus, estrus, and ovulation) indicates that class 1 included all three phases, with the remaining data labeled as class 0. Superscript uppercase letters indicate statistically significant differences ($p < 0.05$) between estrus labeling strategies (E+OV and P+E+OV) within each sensor type. Subscript lowercase letters indicate statistically significant differences ($p < 0.05$) among the sensor types, including accelerometer (Acc), gyroscope (Gyr), and the combined sensor configuration (Com), within each estrus labeling condition. Statistical comparisons were conducted separately for each performance metric and individual cow.

THE CURIOUS COW: USING PRECISION TECHNOLOGY TO LINK PERSONALITY TRAITS WITH BEHAVIOR AND MILK YIELD

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Personality, defined as consistent individual differences in behavior across time and contexts, reveals how dairy cows respond to their environment. Traits (e.g. curiosity, sociability, fearfulness) have been associated with differences in feeding behavior, stress resilience, and productivity outcomes. New precision livestock technologies enable continuous, individual-level behavior monitoring, allowing integration of personality assessments into management strategies. Characterizing cow personality traits could inform individualized management decisions that would enhance welfare and productivity on dairy farms. The primary aim of this study examined how personality traits, scored using wearable precision technologies, influence milk yield and behaviors of grazing dairy cows. A secondary aim examined how management practices influence these outcomes.

Commercial dairy farms across New Zealand were enrolled (n = 27). Over a 2- to 3-week period, grazing, ruminating and lying behaviors of 30 to 40 focal cows per farm were monitored with ear- and leg-based accelerometers. A subset of 10 cows per farm were also fitted with GPS collars to record time off-paddock and walking distance during milking hours. Cows (n = 788) were scored for personality traits using 3 standardized tests: (1) avoidance distance in the paddock (trait = tolerance to humans), (2) response to a novel object during return from milking (traits = curiosity and reactivity to novelty), and (3) reactivity during cluster attachment (trait = milking reactivity). Additional recorded variables included cow characteristics (body condition, lameness, age, breed, days in milk), farm characteristics (herd size, location, topography), weather (daily rainfall and temperature loggers, or satellite information), and management practices (farmer self-reported in a survey). Associations between personality traits and behavioral or productivity outcomes were analyzed using mixed regression models at the level of day, cow, or farm, with relevant covariates included.

Cow personality traits were associated with behavior and milk yield. More "curious" cows (approached to investigate the novel object) had greater milk yield (1.8±0.67 L/d; P<0.01), greater milk solids (0.12±0.05 kg/d; P=0.03) and protein (0.08±0.02 kg/d; P<0.01) and had greater grazing (0.52±0.26 h/d; P=0.04) and lying times (0.20±0.1 h/d; P=0.04). More "tolerant" cows (less fearful of approaching humans) tended to have greater milk yield (0.89±0.47 L/d; P=0.07) and greater ruminating time (0.15±0.09 h/d; P=0.09). Milking reactivity trait was not associated with behavior or yield. Increased time off-paddock was associated with reduced lying time (P<0.001), while longer walking distances to/from the milking parlour were associated with increased lying time (P=0.04). Farms that consciously adjusted management to reduce walking distances tended to have cows with greater grazing time (P=0.09). Farms providing more than one trough per paddock showed higher milk yield (P=0.01), and those offering more diverse feedstuffs had cows with greater ruminating and lying times (P=0.01). Farms that offered staff more days off per week had cows with greater lying and ruminating times (P=0.01), but tended to have less grazing time (P=0.09).

Our results show consistent individual differences in dairy cow behavior and performance related to their personality. There is potential for wearable technologies to guide tailored management practices that meet the needs of individual cows of different personalities.

Figure 1. Three standardized personality tests performed on total 788 grazing dairy cows across 27 commercial dairies.

ACTIVITY-BASED FIRST ESTRUS DETECTION IN GRAZING HEIFERS AND FIRST-LACTATION DAIRY COWS

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Lifetime reproductive performance of dairy cows is correlated with early age at first estrus and shorter days to first estrus after first calving. However, these traits are difficult to measure at scale using conventional methods. Wearable animal sensors that measure walking or lying activity provide an opportunity to automate estrus detection, since estrus events are usually accompanied by higher activity metrics. This approach is likely scalable to monitoring large numbers of animals across many herds with high temporal resolution. Therefore, it could be a valuable tool for generating accurate estrus-based traits for evaluating genetic merit for fertility and ultimately accelerating the rate of genetic gain. In this proof-of-concept study, we investigated an approach to generate novel earlier-in-life fertility phenotypes using wearable sensors across large numbers of grazing dairy heifers and primiparous cows managed in pasture-based, seasonal calving dairy herds.

Tri-axial accelerometer data (IceQube; Peacock Technology, Stirling, UK) were collected from 18 herds of peripubertal heifers in 2019 and 17 herds of primiparous cows in 2020, located in the Waikato and Taranaki regions of New Zealand. Herds were selected as having a high proportion of Holstein-Friesian genetics. From the accelerometer data, 24-hour moving averages of step counts and non-lying time were calculated, the mean herd value at each point in time subtracted, and the resulting deviations standardised for each animal. Comparing this signal processing algorithm with the visual and clinical observation data, estrus events were most accurately identified when a heifer or cow's activity deviation exceeded 2.2 for at least 12 hours.

Significant between-herd variation was observed in the distribution of age at first estrus in heifers, despite large proportions of left- and right-censored values (Figure 1a). Mean detected age at first estrus was 334 days (SD 17 days). Substantial herd differences in the distribution of days to first estrus after calving were also identified for the cows (Figure 1b). Mean days to first calving after estrus was 49 (SD 23 days). These results are consistent with industry norms.

Overall, we demonstrated a scalable approach for measuring earlier-in-life reproductive phenotypes in dairy cattle, which is increasingly transferrable to other wearable devices as technology advances. These novel phenotypes may create opportunities for more accurate genetic evaluation of fertility traits.

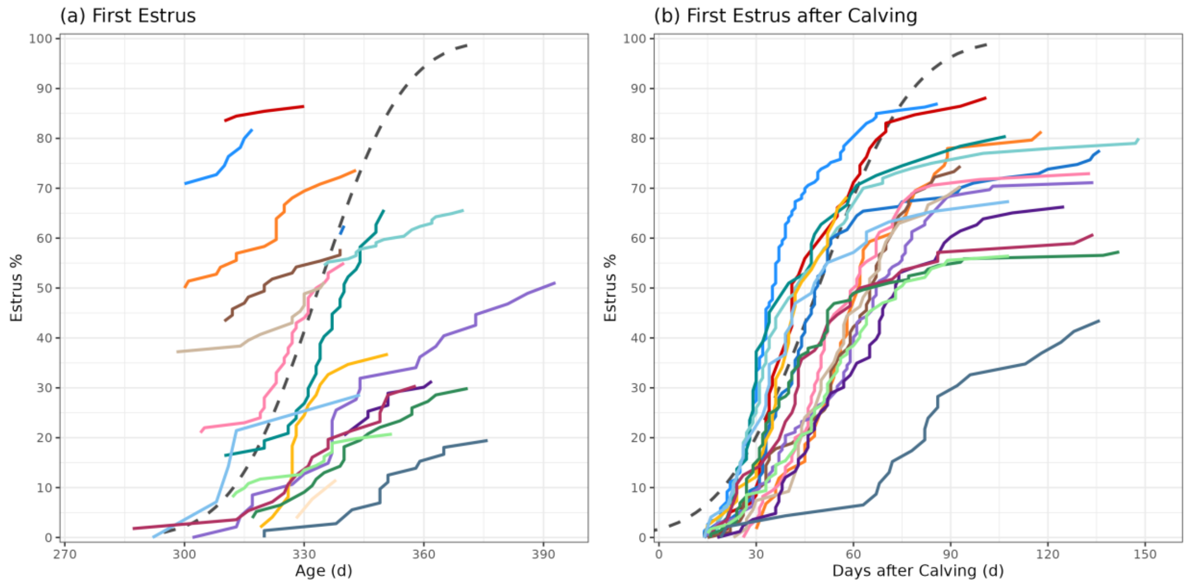

Figure 1. Herd differences in distribution of (a) age at first estrus and (b) days to first estrus after calving. Left- or right-truncated curves indicate left- or right-censored data, respectively, i.e., the proportion of animals whose first estrus occurred before or after the monitoring period. Dotted curves show the mean distributions: 334 ± 17 (SD) days old and 49 ± 23 days post calving, respectively.

INVESTIGATING THE ASSOCIATION BETWEEN HERD-I LAMENESS SCORES AND REPRODUCTIVE OUTCOMES ON A DAIRY FARM

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Lameness is a well-recognised animal welfare issue and a production-limiting condition in dairy cattle. While its negative effects on fertility are well documented, poor detection and recording practices on many farms mean that the real-world impact of lameness often goes unnoticed. This study aimed to evaluate how lameness, as detected by an automated lameness monitoring system (Herd-i), affected reproductive performance and associated financial losses on a South Island dairy farm.

Data were collected for 549 cows over a single calving and mating season (June 2023 to February 2024), including 125,304 Herd-i lameness scores. These scores were generated using a model trained on the DairyNZ-adopted 0–3 lameness scoring system, in which cows with a score of ≥2 were classified as lame. These values were post-processed to provide weighted smoothed trend scores at each scoring event. Records detailing lameness treatments, calving dates, and pregnancy outcomes were also collected. Each cow was assigned to one of three lameness categories based on their maximum Herd-i lameness trend score (LS < 1.25, LS 1.25–1.5, LS > 1.5). Reproductive performance was assessed by calculating the 6-week in-calf rate and final pregnancy rate for each group, key reproductive measures of success in the New Zealand seasonal-calving dairy system. Financial losses were estimated using the DairyNZ InCalf assumptions based on the observed differences in reproductive performance. Cows were also grouped by whether they had been identified as lame by Herd-i and/or treated by farm staff, to compare alignment between detection systems and reproductive performance.

Cows with higher lameness scores had poorer reproductive outcomes. The 6-week in-calf rate declined from 64% in non-lame cows (LS < 1.25) to 50% in cows with scores above 1.5. A similar pattern was observed in final pregnancy rates, which fell from 84% in non-lame cows to 69% in the animals with maximum LS > 1.5. Cows with a maximum lameness score between 1.25 and 1.5 had reproductive outcomes between the other two categories. The financial impact was substantial: estimated per-cow reproductive losses were $108 for cows with scores of 1.25–1.5 and $204 for cows with scores >1.5, amounting to a total unadjusted farm-level cost of $21,276. While 79% of treated cows had Herd-i scores ≥1.25, only 22% of Herd-i lame cows were treated, indicating limited alignment between system-detected and farm-treated cases. However, untreated Herd-i lame cows still exhibited reduced fertility.

This case study demonstrates that elevated Herd-i lameness scores are associated with poorer reproductive outcomes and notable economic losses, even in a well-managed herd with low lameness prevalence. The lameness score thresholds linked to reproductive impacts were lower than previously reported, suggesting that even mild increases in lameness may negatively affect dairy cow health. These findings highlight the potential for automated detection systems to support early lameness identification and management, ultimately improving fertility and profitability. While broader studies are needed to confirm these results across herds, Herd-i may offer farmers a valuable tool to detect lameness early and reduce its impact on reproduction.

DAILY RUMINATION TIME IN EARLY LACTATION DAIRY COWS WITH DIVERGENT GENETIC MERIT FOR FERTILITY

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This retrospective study compared daily rumination time in early lactation between cows with divergent genetic merit for fertility traits. An automated monitoring system was used to capture rumination time from Holstein Friesian cows with positive (POS) or negative genetic merit for fertility traits (NEG) across two lactations. Data was collected between −2 weeks and 7 weeks around calving. POS refers to cows with a positive (+5.0 average) fertility breeding value (n = 257 in lactation 1 and n = 209 in lactation 2). NEG refers to cows with a negative (−5.1 on average) fertility breeding value (n = 225 in lactation 1 and n = 123 in lactation 2). Rumination time was summarised to produce a daily rumination time, and this was averaged for 1-week periods beginning −2 weeks pre-calving to 7 weeks post-calving. A repeated measures ANOVA was used to explore associations between daily rumination time and fertility groups (POS or NEG), week relative to calving, and the interaction between week and fertility group. In lactation 1, rumination time was greater in the POS group than the NEG group from weeks 2 to 7 post-calving (Figure 1). In lactation 2, rumination time was greater in the POS group than the NEG group in weeks -1 and -2 and between weeks 2 to 5 post-calving (Figure 1). Genetic merit for fertility traits is associated with higher rumination time in early lactation. Further analyses evaluating the relationship between rumination in early lactation with reproductive outcomes (e.g. cycling before mating, time to submission and conception) are areas of interest for future analyses.

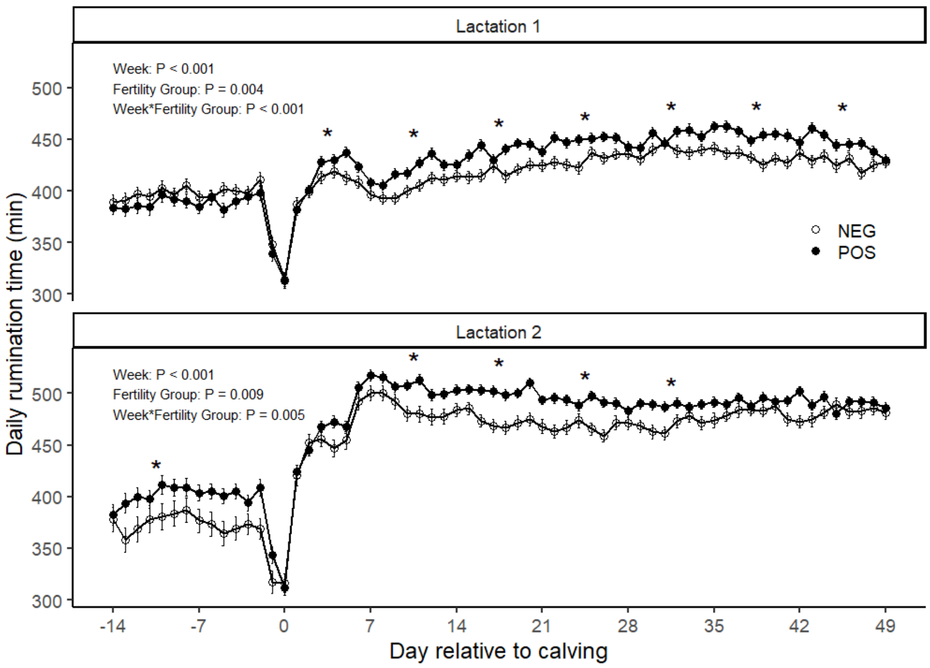

Figure 1. Daily rumination time (mean ± SE; min/d) between -14 d to + 49 d relative to calving for primiparous (lactation 1) or multiparous (lactation 2) dairy cows with positive (POS; closed circles) or negative (NEG; open circles) genetic merit for fertility traits. Asterisks denote time points where the POS and NEG groups differ. Daily rumination time has been back-transformed to the original scale to aid interpretation.

EVALUATION OF EARLY REPRODUCTIVE SUCCESS MACHINE LEARNING PREDICTION IN COMMERCIAL US DAIRIES

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Reproductive performance impacts the profitability of a dairy farm. Culling risk, replacement heifer supply, and genetic progress are a few of the components of a dairy farm it impacts. The ability to understand the reproductive capabilities of individual animals and use of targeted reproductive management could optimize cow reproductive performance and herd profitability. To address this need, early reproductive success prediction was developed using a light gradient-boosting machine (LightGBM) algorithm including herd level reproduction data, weather data, Genomic Predicted Transmitting Ability (GPTAs), individual animal parity, milk production, health events, and previous lactation performance data. The early reproductive success algorithm predicts the probability of pregnancy by 110 days in milk (DIM).

This retrospective study was conducted to demonstrate the ability, prior to the end of the voluntary waiting period, of the early reproductive success prediction to predict pregnancy probability by 110 DIM in addition to other reproductive performance metrics. The study included 19,433 Holstein and Jersey multiparous cows that calved in 2022 from seven US commercial herds. Animals were ranked by their prediction within herd and then assigned to deciles based upon this ranking. Animals' performance data were collected for 18 months following calving from on-farm management software. Statistical analysis was performed using generalized linear mixed models with prediction decile as a fixed effect and herd and semen type as a random effect.

Results showed that early reproductive success prediction deciles were different ($P<0.001$) for pregnancy at first insemination (25.3% vs. 44.2%, for worst 10 compared to best 10), proportion pregnant at 110 DIM (35.6% vs. 64.8%), and proportion of cows that gave birth to a live calf to initiate the following lactation, referred to as successful calf (49.1% vs.77.8%), with percentage improvements in performance of 75%, 82%, and 58% respectively. Early reproductive success prediction deciles were different ($P<0.001$) for abortion incidence (20.9% vs. 6.8%) and sold in enrolment lactation (43.8% vs. 17.2%), with percentage improvements in performance of 67% and 61%. Figure 1 shows the proportion successful calf when animals were ranked by the prediction.

This study demonstrated that the Early Reproductive Success prediction presents an opportunity for dairy producers to identify the reproductive capabilities of individual animals and make informed management decisions.

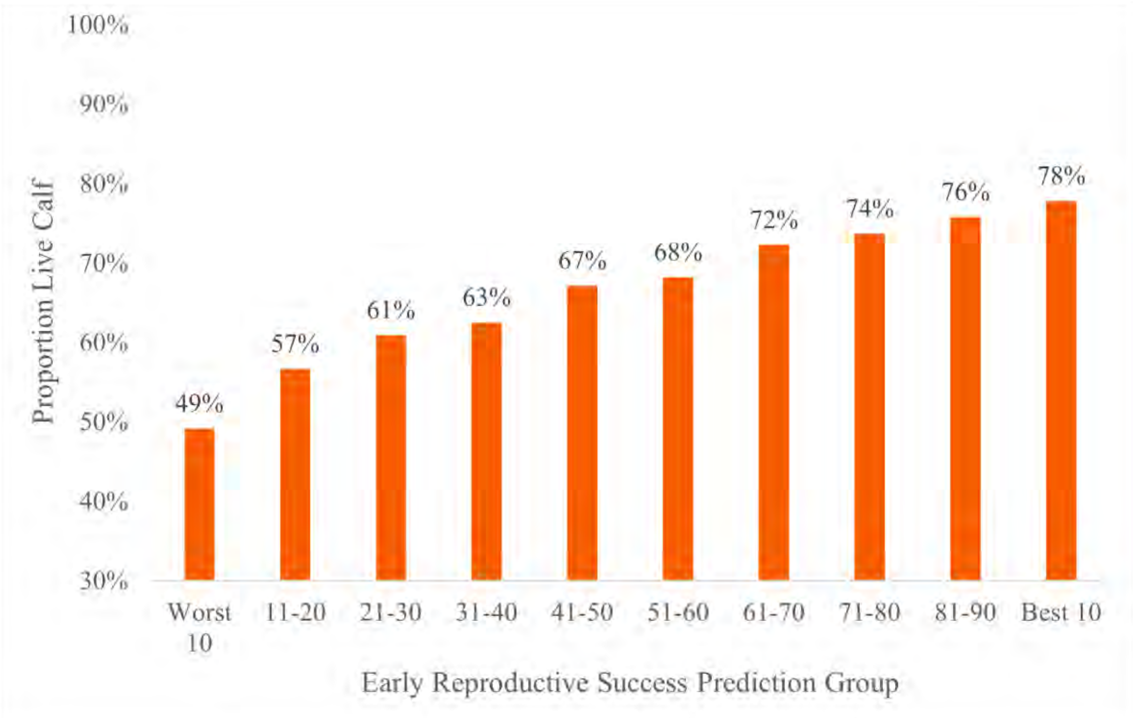

Figure 1. Proportion successful calf when animals are ranked by the Early Reproductive Success prediction. The proportion success calf was different by prediction group ($P < 0.01$) with a 58% improvement performance between the best and worst decile prediction groups.

Concurrent session 2

December 4, 2025, 1:30 pm – 3:00 pm

MULTI-SENSOR MODELING FOR INDIVIDUAL DAIRY COW BEHAVIOR CLASSIFICATION USING ACCELEROMETER AND GYROSCOPE DATA

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Monitoring livestock behavior is a critical component of precision dairy farming, enhancing early detection of health issues, improving animal welfare, and optimizing productivity. While accelerometers have proven effective in capturing linear motion associated with behaviors such as lying and walking, they are less sensitive to rotational movements, which are critical for distinguishing more nuanced activities. Gyroscopes, which measure angular velocity, provide complementary rotational data; however, their integration with accelerometers for individual-level behavior classification remains underexplored.

This study aimed to evaluate the behavior classification performance of three sensor configurations: accelerometer only, gyroscope only, and combined sensor models for identifying four key behaviors (lying, standing, eating, and walking) in individual dairy cows.

Seven Holstein-Friesian heifers were monitored continuously for 90 days using a custom-designed activity meter mounted on the neck. The prototype comprised a tri-axial accelerometer and gyroscope (MPU-6050), microcontroller, LoRa-based wireless module, 3,700 mAh battery, and Wi-Fi antenna, housed in a 3D-printed casing. Behavioral annotations were obtained from synchronized CCTV footage and manually labeled by trained observers ($\kappa = 0.84$). Sensor data were segmented into 10-second windows, and 79 statistical features were extracted. These features included axis-wise statistics and magnitude-based measures such as Signal Vector Magnitude (SVM). SVM_acc represents the magnitude of translational movement computed from the three axes of the accelerometer, while SVM_gyro captures the magnitude of rotational movement based on the three axes of the gyroscope. Random Forest classifiers were trained individually for each cow, with feature selection performed using Recursive Feature Elimination and evaluation conducted through stratified cross-validation.

Results showed over 780,000 labeled observations. Distinct signal patterns were observed across behaviors: lying was characterized by low Z-axis values, while walking exhibited high peaks in the accelerometer X-axis and gyroscope X- and Y-axes. SVM_gyro values were significantly higher for eating and walking than for lying and standing ($p < 0.05$), revealing the role of gyroscopes in capturing rotational intensity during dynamic behaviors. Combined-sensor models consistently outperformed single-sensor approaches across all metrics, particularly for static behaviors such as lying and standing. Sensor fusion improved sensitivity for dynamic behaviors (eating and walking) and enhanced classification stability across individual cows (Table 1).

The discussion emphasized that accelerometer-only models are insufficient for comprehensive behavior recognition, especially for complex or rotational movements. The integration of gyroscopic data provides essential angular velocity information, enabling the detection of subtle behavior transitions. This fusion strategy is especially beneficial at the individual cow level, capturing cow-specific locomotion patterns and improving model robustness.

In conclusion, integrating accelerometer and gyroscope data significantly improves the robustness and accuracy of cow behavior classification. This study establishes a foundational approach for scalable and individualized behavioral monitoring using multi-sensor systems in precision livestock farming.

Table 1. Classification performance metrics (Precision, Sensitivity, F1-score, and Overall Accuracy) of random forest models using accelerometer(Acc), gyroscope(Gyr), and combined(Com) features across four behaviors.

Behavior	Device		Precision		Sensitivity		F1-score		Overall Accuracy	
		N	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max	Mean ± SE	Min-Max
Lying	Acc	70	**93.33±2.45^{ab}**	90.75-96.87	**94.52±1.6^{a}**	92.01-96.51	**93.91±1.93^{a}**	91.55-96.69	89.44±3.5^{a}	86.26-94.15
	Gyr	70	**92.93±2.07^{b}**	90.39-96.87	**94.5±1.91^{a}**	91.9-96.94	**93.71±1.88^{a}**	91.14-96.91	88.35±3.63^{a}	83.46-93.56
	Com	70	**95.94±1.66^{a}**	94.02-98.21	**96.81±1.25^{b}**	94.8-98.37	**96.37±1.34^{b}**	94.81-98.29	92.74±2.68^{b}	89.99-96.77
Standing	Acc	70	85.44±4.99^{a}	80.04-92.71	90.28±4.33^{a}	84.51-95.56	87.78±4.57^{a}	82.68-93.93	89.44±3.5^{a}	86.26-94.15
	Gyr	70	83.63±5.66^{a}	75.52-92.2	90.81±2.81^{a}	87.76-95.87	87.03±4.11^{a}	81.33-92.44	88.35±3.63^{a}	83.46-93.56
	Com	70	89.63±3.9^{a}	84.4-95.91	93.67±3.02^{a}	89.72-97.61	91.59±3.34^{a}	88.21-96.75	92.74±2.68^{b}	89.99-96.77
Eating	Acc	70	83.61±5.93^{a}	77.67-94.17	**65.65±10.75^{a}**	54.05-84.54	**73.29±8.3^{a}**	63.75-89.1	89.44±3.5^{a}	86.26-94.15
	Gyr	70	82.65±7.83^{a}	74.57-96.15	**42.44±13.78^{b}**	30.23-71.92	**55.4±12.59^{b}**	44.83-82.29	88.35±3.63^{a}	83.46-93.56
	Com	70	86.29±4.53^{a}	83.64-95.95	**72.46±8.44^{a}**	62.16-87.32	**78.65±6.57^{a}**	71.32-91.44	92.74±2.68^{b}	89.99-96.77
Walking	Acc	70	90.65±7.35^{a}	82.06-100	31.78±17.23^{a}	5.34-59.18	44.65±20.3^{a}	10.15-74.22	89.44±3.5^{a}	86.26-94.15
	Gyr	70	91.33±9.77^{a}	75.56-99.76	34.34±16.8^{a}	15-62.76	47.62±17.33^{a}	26.01-77.05	88.35±3.63^{a}	83.46-93.56
	Com	70	93.26±5.96^{a}	83.64-100	46.76±16.22^{a}	20.34-65.52	60.61±15.8^{a}	33.67-78.89	92.74±2.68^{b}	89.99-96.77

Note: Different lowercase superscript letters (a–d) indicate significant differences ($p < 0.05$) of mean classification performance among device types (accelerometer, gyroscope, combination), based on 70 data points (10 iterations per cow × 7 cows). Bolded values represent the highest means for each performance metric across device types (accelerometer, gyroscope, and combination) within each behavioral classification.

MEASURING AND MODELLING SHADE USE BY GRAZING DAIRY COWS

S.J.R. Woodward[AC], C.R. Burke[A], L.J. Farrell[A], and J.P. Edwards[B]

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Recent advancements in animal welfare have emphasized the importance of offering animals opportunities to make choices that promote their physiological well-being and psychological comfort. To this end, the current study sought to understand voluntary use of shade by dairy cows grazing on pasture in summer conditions with the potential for heat stress.

Cow location was continuously recorded on four farms (at Matamata, Te Awamutu, Te Puke and Wellsford) in the upper North Island of New Zealand for the month of February 2024, using the Halter® cow management system, which incorporates approximately 5-minute GPS locations with virtual fencing-based grazing. From existing LiDAR imagery of the farms, shade availability during each 15-minute interval of each day was calculated (assuming clear skies) using a bespoke software program (www.shadeapp.com) which also identified whether each cow location was potentially shaded or not. The percentage of cows in shade (CIS) above what would be expected from independent random walking was calculated for each 15-minute interval and analysed in relation to break area available, shade area available, air temperature, relative humidity, solar radiation and wind speed.

Using a decision tree model (Figure 1), the percentage of cows in shade (CIS) was most strongly associated with solar radiation (SOL_MJH ≥ 2 MJ/m^2/h). Under these conditions, the highest percentage of cows in shade (CIS = 26 %) was predicted when SHADEC ≥ 3.6 m^2/cow of shade was available, air temperature (AIR_C) was above 24°C and wind speed (WIND_MPS) was below 4.2 m/s. This suggests that cows do not only stand or lie in shade during the hottest part of the day but also continue to spend time grazing. High shade use (CIS = 19 %) was also predicted under lower solar radiation conditions (SOL_MJH < 2 MJ/m2/h) when wind speed was high (WIND_MPS ≥ 6 m/s) suggesting that cows were also using trees for shelter. Such high shade-use conditions occurred on 59%, 55%, 45% and 57% of days for the Matamata, Te Awamutu, Te Puke and Wellsford farms, respectively, in the February 2024 period.

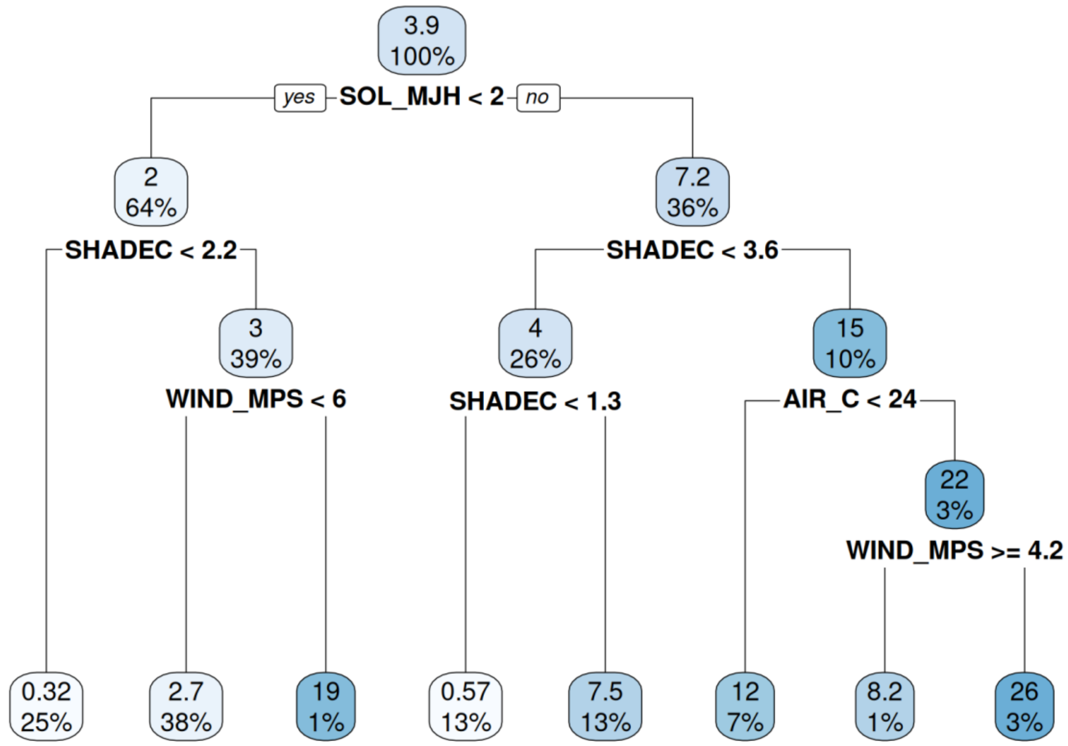

Figure 1. Regression tree model to predict CIS, the percentage of cows in shade above what would be expected by random chance. At each node the blue ovals show the average CIS percentage (e.g., 3.9) and the proportion of data included (e.g., 100%). The eight bottom nodes represent the optimal partitioning of the data.

Provision of daily solar radiation estimates could therefore be a valuable meteorological service, allowing farmers to make decisions around the optimal use of shade resources, given they are often balancing multiple goals. Guidelines around shade use could also inform farmers on cost-effective investment in infrastructure to increase the availability of shade.

COMPUTER VISION CLASSIFICATION OF EAR POSTURES AS A PRELIMINARY SCALABLE APPROACH TO AUTOMATED ON-FARM DETECTION OF EMOTIONAL STATE IN DAIRY COWS

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Improving our ability to recognise indicators of positive and negative emotional states in dairy cattle has important implications for animal welfare assessment. Recording ear postures at frequent, regular intervals may provide dynamic insight into emotional states reflective of welfare; however, manual scoring is time-consuming and limits scalability for on-farm use. Therefore, the objective of this study was to develop a preliminary computer vision approach to automate detection of key ear postures associated with emotional state.

Video was selected from 8 animals in a study where recently calved indoor-housed Holstein cows experienced negative and positive emotional situations (i.e., separation from, and reunion with, their calf). Frames were extracted from a CCTV recording at every other minute using a python script over a 90-min period. After excluding frames where cows' heads were not visible, 1344 images (approximately 90/cow) were manually scored by trained observers for ear positions: Forward (in line with or in front of frontal plane), Up (behind frontal plane, above line of neck), Backward (behind frontal plane, held in line with neck), Hanging (falls loosely downwards, perpendicular to head). Observers relied on facial landmarks (nose, eyes, ear tip, neckline) to aid in position identification. Scored images were split into two datasets: 1) training (300 images), and 2) comparison (1044 images).

Training dataset images were manually masked to identify cows' faces, and used to train a deep learning masking model (maskRCNN V2.1) to locate and crop cow faces. Next, the cropped images were manually annotated for key landmarks (left/right ear tip, left/right eye, nose tip) and used to train the deep learning pose recognition model (DeepLabCut 3.0.0). Mean average precision (mAP) and root mean squared error (RMSE) were calculated to assess the difference between the predicted (model) and actual (annotated) pixel locations of facial landmarks. Finally, both models were applied to the comparison dataset, and angles between facial landmarks calculated. These angles were compared to the manually scored images to obtain a relationship between scored ear posture and computed angle.

The pose recognition model performed well (mAP = 0.91; RMSE = 8.37 pixels across detected points). Mixed modelling revealed no difference between left/right ear angles ($p = 0.87$), and differences ($p < 0.0001$) between ear positions (mean ± SE; forward: 157° ± 0.5; up: 172° ± 0.69; backward: 168° ± 1.1; hanging: 156° ± 1.3). All pairwise comparisons were different ($p < 0.0001$) except forward and hanging ears ($p = 0.96$). While overlap exists, particularly with the smaller angles (Figure 1), video collection methods were artificially distorting the angle (e.g., non-frontal head positioning) or resulting in a mislabeled facial landmark (e.g., black ear tip against a black coat misdetection). Follow-up work should pair these models with a deep learning classification model to optimise camera angles that minimise variation and improve detection accuracy.

Our previous work demonstrated that dairy cow ear postures differ during expected positive and negative emotional situations (e.g., hanging ears associated with low-arousal positive states); thus, there is merit in exploring ear posture monitoring as a practical, repeated welfare metric. Our preliminary results demonstrate the feasibility of automated ear posture detection as a foundation for scalable emotional state monitoring.

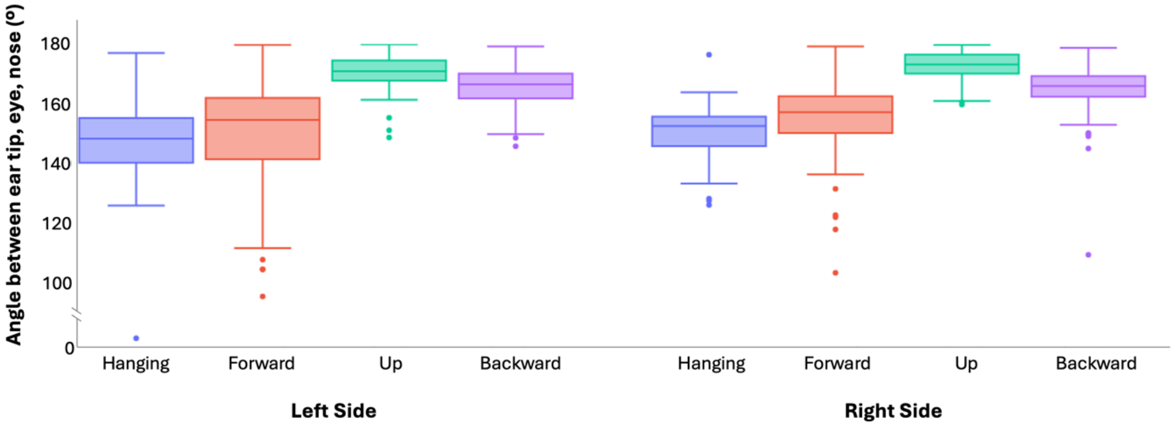

Figure 1. Boxplot illustrating the raw values of angles across 4 ear postures for left and right side of the cow.

INVESTIGATING CIRCADIAN RHYTHMS' IMPACT ON ANIMAL WELFARE IN PRECISION DAIRY RESEARCH FOR LACTATING CATTLE

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The objective of this study was to evaluate the influence of circadian rhythms on behavioral patterns associated with welfare in lactating dairy cattle using precision sensor technologies. Lactating Holstein and crossbred cows of the Holstein, Jersey, Montbeliarde, Normande, and Viking Red breeds (n = 1,468) were monitored at the University of Minnesota's West Central Research and Outreach Center (Morris, MN), a pasture-based grazing dairy, using CowManager SensOor ear-tag accelerometers (Agis Automatisering BV, Harmelen, the Netherlands). These sensors classified behavior at sixty-minute intervals into five categories: rumination, eating, not active, active, and high active. Behavioral data were collected continuously across multiple months, providing a longitudinal dataset to evaluate how daily time budgets shift with seasonal or environmental cues.

To explore the potential influence of circadian or seasonal patterns, linear models were used to assess the effect of calendar month on each behavior. Month was treated as a continuous variable to identify general trends across time. Results indicated that rumination decreased by approximately 3 minutes with each successive month ($P < 0.001$), while eating declined by nearly 12 minutes per month ($P < 0.001$). In contrast, not active time increased by about 10 minutes per month ($P < 0.001$), and high activity also varied significantly across months ($P < 0.001$). These results suggest that behavior shifted over the course of the year in a consistent, time-linked pattern, supporting the hypothesis that seasonal or circadian rhythms influence behavioral time budgets in grazing dairy cattle.

These preliminary findings highlight the utility of continuous behavioral monitoring in identifying biologically meaningful patterns over time. The results support the hypothesis that shifts in circadian alignment affect core behavioral indicators of welfare. Integrating circadian-aware management strategies into precision dairy farming may enhance the ability to promote natural behavior expression, support physiological regulation, and improve long-term animal well-being.

A PRELIMINARY STUDY ON VIRTUAL FENCING

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Virtual fencing (VF) enables animal containment within or exclusion from land areas without physical fences. This technology uses GPS-enabled collars on the animal which produce an audio cue when the animal approaches the boundary. If the animal breaches the boundary it receives an electric pulse from the collar. The animal can avoid the electric pulse by learning to stop or turn away from the virtual boundary when the audio cue is emitted. VF allows new opportunities in reducing the labour associated with fencing and can increase the flexibility of herd and pasture management; it can prevent over-grazing or allow time-limited access to a specific herbage, e.g. clover. However, it is important to investigate the operation of this technology with dairy herds within different farm infrastructures. The focus of this preliminary study was to examine the operation of the VF collars on a cow herd in an Irish pasture-based system.

One hundred and sixty-eight pluri-parous, spring-calved Holstein-Friesian dairy cows were assembled (average 154 days in milk). Animals were balanced for calving date, milk yield, parity and bodyweight, and randomly assigned to one of two treatments. Cows in treatments 1 and 2 were managed by a conventional electric fence and by VF collars, respectively. Cows in treatment 1 had 22-h (full-time) access to pasture (24 h minus 2 h for morning and evening milkings) with an allocation of 18 kg DM/cow per day. Treatment 2 cows received the equivalent grass allocation over 22 h but with this allocation given in three portions over the 22 h (this increased the challenge to the virtual fence to contain the cow herd in smaller grazing areas). Forty five percent of the 22 h allocation was given after morning milking (08:00 – 12:00); 10 % until evening milking (12:00 – 15:00); and 45 % until the following morning milking (16:00 – 07:00). Training of the cows to the VF equipment took place prior to the experimental period. Treatments were imposed over 4 weeks from 22nd July. A t-test was used to determine differences between treatments in terms of milk yield and composition, pre-grazing grass cover and post-grazing height measurements.

Virtual fence data, grass measurements and milk yield and composition data from cow herds with and without VF collars are shown in Table 1. Average number of audio cues/cow/day and average number of electric pulses/cow/day were in line with those observed in other studies. The audio cues outnumbered electrical stimuli, indicating cows generally responded to the benign audio cues alone, and avoided receiving electric pulses. Grass cover and post-grazing height were similar for the two treatments. Likewise, cow performance (milk yield and composition) was similar for cows contained by the VF and by the conventional electric fence.

In summary, this preliminary study showed that the VF retained cows in the areas specified without apparent negative implications for cow behaviour or welfare. However, further work is required to interpret the potential for and implications of combining grass measurements with VF collar data to create a decision support tool that could optimise grassland management and grazing efficiency while optimising animal performance and welfare, with minimum labour requirement.

Table 1. Virtual fence data (audio cues and electric pulses), grass measurements and milk yield and composition data from cow herds with and without virtual fence collars and receiving 1 or 3 grazing allocations per day.

	Treatment 1[1]	**Treatment 2**[1]	
		Week 1	**Week 4**
Average number of audio cues/cow per day	-	7.3	10.9
Average number of electric pulses/cow per day	-	0.3	0.3
Grass cover pre-grazing (kg dry matter/ha, above 4 cm)	1,344	1,308	
Post grazing height (mm)	50	52	
Milk yield/cow per day (kg)	16.7	16.6	
Milk solids/cow per day (kg)	1.55	1.50	

[1]Treatment 1: herd managed with a conventional electric fence and receiving one grass allocation per day; Treatment 2: cows wearing virtual fence collars and receiving three grass allocations per day.

USING RFID EAR TAGS TO MEASURE RESOURCE USE BEHAVIOUR IN DAIRY CATTLE AS A POSSIBLE INDICATOR OF POSITIVE MENTAL STATE

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Accurately measuring an animal's behaviour and interactions with resources in their environment can help us understand their experiences which is integral to their welfare. Traditionally, this involves manual observation or reviewing video footage, which is labour intensive. Even with potential future applications of computer vision, assessing behaviour in outdoor environments with limited connectivity and numerous similar-looking cows is challenging.

This proof-of-concept project aimed to compare two radio frequency identification (RFID) technologies, ultra-high frequency (UHF) and industry established low frequency (LF) tags (e.g., NAIT tags), for measuring frequency and duration of individual animal interactions with a stationary resource, specifically a scratching brush. Previous research has suggested that cows are motivated to use a brush for grooming and that this resource may be linked to positive experiences. UHF RFID readers have a longer detection range and can detect the signal strength of the tag, and thus the distance of an individual animal from a resource. LF RFID readers have a shorter range and provide a binary detection of presence within the reader's range and could be used to record close range behavioural interactions.

Two UHF tags were attached to existing ear tags on each ear of 14 mixed-age Holstein-Friesian x cows at Ruakura Research Centre. Tags were correlated to the cows' visual IDs and an individual paint identifier. Data were collected over four days with different configurations of UHF and LF antennae, however LF data were only collected on day 4 on five cattle. Each day the cattle were moved into a paddock with access to a stationary scratching brush mounted on a post with cameras positioned around and above the post to record behaviour. A 1 m radius ring was painted on the ground to estimate the cattle's distance from the brush. RFID antennas were placed directly behind the brush on the post and at the top and bottom of the post on the other side of the fence. Cattle behaviour was scored from live observation and video, including animal ID, proximity to brush, contact with brush, part of body making contact (e.g., head, neck, shoulders), and the duration of the interaction.

Data from the RFID antennas were analysed for both LF and UHF tags. LF RFID results performed better than anticipated, capturing 71% of interactions, though failed to capture the entire duration due to limited range. UHF RFID results generated large volumes of data, making analysis challenging. The UHF system could not provide simple and accurate positioning of tags and did not reliably identify a cow's position within a 1 m radius of the brush.

With further refinement, LF RFID tags could be used to record resource use and duration of behavioural interactions with stationary resources, such as a scratching brush, in dairy cattle. General applications, less dependent on the spatial resolution of less than 1 m, should consider UHF RFID applications. This opens many opportunities to automatically collect individual resource use behaviour information in the future, potentially unlocking metrics that could help understand animals' mental states and overall wellbeing.

USE OF ON-ANIMAL SENSORS TO DESCRIBE VOLUNTARY USE OF A WOODED AREA BY PASTURED DAIRY COWS

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New Zealand's pasture-based dairy systems are valued by consumers for their ability to promote natural behaviours; however, evolving expectations now mean that consumers are wanting proof that cows are living a good life. An important aspect of providing resources to support a good life is that cows can exercise choice over how they spend some of their time. Opportunities for self-led and goal motivated behaviour allows cows to consistently and predictably make choices that have rewarding experiences.

Providing cows access to a stand of trees as part of their daily routine potentially has numerous positive outcomes. These areas align well with public perceptions of 'natural' systems cows require. Access to trees could improve thermal comfort for cows; trees are anticipated to provide scratching and foraging opportunities, as well as social and sensory benefits. We hypothesized that cows would exercise choice and voluntarily exit their grazing break and walk (range 21 to 426 m) to a stand of trees (wooded area).

Following a standardised personality test to use as a blocking factor alongside age, 60 Friesian-cross cows were randomly allocated across 2 treatments (2 farmlets/treatment): Wooded groups (contiguous paddocks and one area of trees within a single block) and Reference groups (contiguous paddocks).

Measuring cow responses relied heavily on the use of wearable sensors. Each was fitted with a Halter collar, IceQube pedometer, and smaXtec bolus. The study ran from November 2024 to March 2025. Prior to study commencement, wooded groups were habituated to their wooded area as follows: Days 1 - 3: cows spent 2 - 3 h in new paddock after AM milking, then moved to wooded area (gate closed) until PM milking, after PM milking, cows had free choice between wooded area and paddock; Days 4 - 9: same process, except gates remained open. Observation periods included: twice daily milking (TAD, 23 d), once daily milking without supplement (OAD1, 15 d) and with supplement (OAD2, 15 d), and after that, treatment groups were mixed together (resulting in 1 Wooded group and 1 Reference group) and fed supplement (MIXED, 15 d).

Based on visualisation of the transformed cow-GPS data, visits were defined as 80% of the herd being present in the woods. Across all observation periods, the proportion of days which the two Wooded groups visited was 61 ± 27% (range: 13 - 93% of days/period) (mean, SD, range). On these days, cows visited 1.5 ± 0.22 times/d. Most visits ranged between 10 - 179 min (72% of visits). Remaining visits were either transient (less than 10 min; 10%), extended (180 - 599 min; 8%) or prolonged (600+ min; 10%). However, when cows were mixed as one group, all visits were 10 - 179 min. Visits appeared to occur primarily in the late afternoon and evening, with some early morning visits prior to milking.

Analysis is ongoing and includes examining daily and diurnal behavioural changes according to wooded area use, weather, shade availability and walking distance, descriptive comparisons to the Reference groups, as well as social dynamics and clustering of individuals within groups. On-animal sensors have provided a rich suite of data for investigating behavioural responses in a pasture-based, dairy cow environment.

AN INVESTIGATION OF THE IMPACT OF VARIOUS CALF-FEEDING SYSTEMS ON GROWTH, FIRST-LACTATION PERFORMANCE AND EMISSIONS INTENSITY

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The dairy sector faces increasing pressure to reduce greenhouse gas emissions while sustaining productivity and profitability. In New Zealand, where dairy farming is a cornerstone of the economy, achieving net-zero emissions is both a challenge and an opportunity. In response to the global imperative to reduce greenhouse gas emissions, Fonterra and Nestlé have partnered with Dairy Trust Taranaki to establish a ten-year trial on Kavanagh farm aimed at developing a commercially viable net-zero carbon dairy system. Among the various components of this initiative, calf-rearing practices represent an area with the potential to influence lifetime productivity and emissions intensity. Research suggests that calves raised on automated feeding systems – particularly those with higher milk allowances – exhibit superior growth and increased first-lactation milk yield compared to conventionally reared calves. Improved early-life performance can improve first-lactation milk yield, reduce replacement rates, and enhance overall herd efficiency – critical steps toward lowering emissions per litre of milk.

The objective of this study is to evaluate the effects of three calf-rearing systems on growth, weaning performance, and subsequent first-lactation productivity. Treatments include: (1) conventional hand-rearing, (2) a basic automated system (Heatwave) that heats and dispenses milk, and (3) a fully automated system (Förster-Technik®) incorporating individual calf identification, milk allocation, and real-time monitoring. Key metrics include growth rates to weaning, transition success post-weaning, and first-lactation milk yield.

This research will validate and refine existing findings which highlight the influence of milk intake and feeding technology on calf growth and future milk production. This study will inform the relationship between rearing system, lifetime emissions efficiency, and herd sustainability, and aims to provide actionable insights for farmers seeking to reduce emissions while maintaining profitability. Ultimately, optimising calf-rearing systems represents a practical pathway toward achieving net-zero emissions in dairy farming.

BEHAVIORAL AND PHYSIOLOGICAL COW VARIABILITY THROUGH PRECISION DAIRY TECHNOLOGIES: A COMPREHENSIVE ANALYSIS

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Understanding individual cow variations in behavioral and physiological patterns can help farmers to make more informed decisions and promote greater cow health and welfare at a cow level. Therefore, our study aimed to investigate individual variations in rumination, locomotion and feeding activity, inactivity, and panting time (h/d) in dairy cows, utilizing a dataset from 298 Brazilian dairy farms (90% confined and 10% pasture systems). Individual data were gathered from 12,851 dairy cows (n = 3,902,551 records) using behavior monitoring collars. To assess animal variability, we applied the Wood model to each cow data. The Wood model was selected after visual evaluation of the average curve for each response variable across lactation. We defined cow variability as the residual standard deviation derived from each adjusted model. The average rumination time variability was 0.766 h/d (min = 0.199, first quartile (Q1) = 0.658; third quartile (Q3) = 0.845; max = 1.763). The average locomotion and feeding activity time variability was 0.827 h/d (min = 0.172, Q1 = 0.677; Q3 = 0.933; max = 2.648). The average inactivity time variability was 0.935 h/d (min = 0.063, Q1 = 0.789; Q3 = 1.040; max = 2.479). The average panting time variability was 0.326 h/d (min = 0.128, Q1 = 0.275; Q3 = 0.358; max = 0.754). Our results display the variability of dairy cow behaviors and physiological parameters, providing insights that can enable early on-farm interventions for improved animal health and management.

2B | Robotics and computer vision

PREPARING COWS FOR AUTOMATION: TRAINING STRATEGIES TO IMPROVE ADAPTATION AND VOLUNTARY MILKING BEHAVIOR

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The success of automated (robotic) milking systems (AMS) relies heavily on how well cows adapt to the system, particularly their willingness to visit the robot without human intervention. Key factors influencing AMS adaptation include parity, individual behavioral traits, and pre-calving training strategies. Primiparous cows typically adapt faster than multiparous cows, but inherent behavioral and personality differences, such as boldness, sociability, and stress-coping ability, also affect how readily cows embrace AMS.

We have demonstrated that these differences can be mitigated through structured training before AMS introduction. Both active and passive training methods can reduce fetching, improve milking frequency, and increase milk yield. Active training, which involves repeated, hands-on exposure to the AMS environment, mechanics, and feed, has demonstrated the greatest improvements in milk yield and voluntary visits. In recent work, we have demonstrated that first lactation cows trained to both the mechanical aspects (noise and arm movement) and positive elements (feed reward) of AMS produced up to 7% more milk, required fewer fetches, and exhibited better milk letdown during early lactation than untrained cows. These results suggest that effective active training requires not only positive reinforcement but also habituation to potentially aversive stimuli. Alternatively, training can also be passive; simply exposing heifers to the AMS environment without milking, may bring familiarity and adaptation benefits. Ultimately, integrating some form of pre-milking training, tailored to farm resources and herd demographics, will enhance adaptation and maximize AMS efficiency, thus contributing to improvements in system performance, profitability, and the overall success of precision dairy operations.

DESIGNING FARM INTELLIGENCE: FIVE INSIGHTS FROM MULTI-SYSTEM PRACTICE

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While most farmers operate within few vendor ecosystems, veterinary practitioners work across many - each with its own settings, sensitivities, and vocabulary. The emerging challenge is fluency: advisors must understand the nuances of every system, recognise their characteristics, and help farmers interpret information with confidence. Precision outcomes reflect both technological capability and the human capacity to connect information across systems and apply it where it matters.

This paper explores what multi-system practice reveals about the evolution of precision dairy farming and the changing role of veterinarians and advisors within it. The goal is to distil practical experience into insights that help maintain biological integrity, confidence, and coherence as farms move toward increasingly integrated, intelligent ecosystems.

The analysis draws on field work through CowSmart, a veterinary-led reporting and advisory service integrating multiple wearable, milk, and herd-management data systems across commercial New Zealand dairy herds. Insights were derived from day-to-day advisory practice and comparative review of multiple commercial platforms - observing where systems align, where they diverge, and how advisory teams adapt to keep information clinically relevant and biologically grounded.

Five recurring insights were identified:

1. Data speaks different languages - creating a need for cross-platform fluency.
   Each platform expresses the same cow differently. Developing cross-platform "data fluency" enables advisors to align messages so that farmers receive consistent interpretations regardless of vendor. This fluency is built through experience - comparing how systems define metrics, thresholds, and alerts, and translating algorithmic language back into biology. The need for cross-platform understanding is recognised globally, with ongoing ICAR and IDF work exploring data-standardisation frameworks to support this. Fluency is both a local skill and a global ambition - the foundation for a genuinely connected, interpretable precision-dairy ecosystem.
2. Transparency builds confidence.
   When advisors cannot see how a system defines and weights its alerts, confidence in the resulting insight can falter. Much of the current learning still happens the hard way - through experience, cross-checking, and dialogue that uncovers how different platforms frame their data. In practice, this has meant acting as a translator between systems and people - facilitating conversations that clarify settings, align expectations, and strengthen understanding. These experiences highlight that transparency is not a technical feature but a relationship feature. It determines how quickly information is trusted, how confidently it is acted on, and how effectively people work together around it. Where assumptions are visible and shared, data become easier to interpret and more valuable to everyone who relies on them.
3. Precision depends on recording accuracy.
   User entry is currently a critical feature. Calving dates, mating records, and management events remain the scaffolding that keeps integrated analytics aligned with time and biology. Improving recording precision - through workflow design, training, and shared expectations - directly improves the precision of the analytics themselves.
4. Cross-checking for coherence.
   Integrated data gain value when they align with physiology and season. Treating outputs as hypotheses and cross-checking them against the biological context keeps interpretation realistic and defensible. Staying curious about this alignment ensures that technology continues to build confidence in the system and the advice it generates.

5. The next evolution of precision.
   The next stage of precision dairy will be defined by systems that reason, learn, and adjust within their own ecosystems. Decision-making support will become less about transferring advice and more about curating system learning. Advisors may act as facilitators within an adaptive network - interpreting feedback, mediating between algorithmic outputs and farm priorities, and refining the parameters that shape decision frameworks.

Integration is advancing rapidly, and continuous improvements will soon address many of today's limitations. These insights reflect an optimistic stage of maturity for precision dairy: one in which technology, advisors, and farmers are co-evolving toward *farm intelligence* - a system that is not only connected but also contextually aware and biologically aligned.

At present, achieving true precision still relies on people who can connect information across systems, check coherence, and translate meaning into practice. Understanding how different influences interact - biological, environmental, and digital - reminds us that precision is achieved through interpretation as a critical step in turning data into outcomes.

A VISION-BASED CATTLE MANAGEMENT SYSTEM FOR AUTOMATED MONITORING OF JERSEY CATTLE BRUSH USAGE

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Modern dairy farming faces significant challenges due to labour shortages, rising operational expenses, and the increasing demand for better animal welfare. Precision dairy farming aims to tackle these issues by implementing scalable, affordable, and non-intrusive technologies for monitoring livestock.

This study presents a novel computer vision system to observe the behaviours of Jersey cattle, with a particular focus on automated brush usage, which is a key indicator of cattle well-being and health. To facilitate automated tracking of brush usage, the system used a computer vision framework, utilising existing fixed-angle CCTV cameras (Hikvision DS-2CD2383G2-IU) and network video recorders (NVR, Hikvision DS-7732NI-I4/24P) for data collecting and storage. This method avoids the need for RFID tags, wearable sensors, or physical restraints, ensuring minimal interference with natural cattle behaviour while significantly lowering the financial and technical challenges associated with traditional monitoring systems. Data were collected at CityUHK dairy farm. The farm is equipped with two automatic cow brushes (Agriprom) in free stall barns of about 20 meters by 11.5 meters, which accommodate 20 Jersey cows. The recorded videos during the inter-milking period (7:00 AM to 4:00 PM) were processed into 8 FPS, 1,280*720-pixel segments, and each second of the video was manually labelled as '0 - no brush using' or '1 - brush using'. To gather detailed information on brush interaction frequency, usage duration, and patterns, a dataset including 38,762 clips from two cameras was built, and a SlowFast network was trained on an Nvidia GTX 3090. The SlowFast network included two pathways, slow and fast, learning features with different frame rates and temporal resolutions, and achieved an accuracy of 98.16% in classifying brush interaction behaviours.

By using low-cost, fixed-angle CCTV cameras, the system removes the need for specialised hardware, achieves automated behaviour measurement without intrusive devices, which makes it practical in real-world environments and easy to implement across an entire farm, allowing for accurate measurement of cattle activity and providing valuable insights into animal welfare. This work, validated on real-world data, demonstrates its robustness, illustrating how advanced technologies can overcome critical limitations of current livestock management strategies. It not only offers a sustainable and efficient solution to the challenges the agricultural sector faces, aligning with the broader objectives of precision dairy farming, but also can be used as a tool for animal science and welfare researchers to conduct research on topics such as social structure and hierarchy within cattle herds.

A FOUNDATIONAL FRAMEWORK FOR ANIMAL BEHAVIOR ANALYSIS USING COMPUTER VISION

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Animal behavior analysis serves as a crucial indicator of welfare, health, and productivity in modern agricultural practices. Traditional manual observation methods are labor-intensive, subjective, and limited in scalability. This study presents a comprehensive foundational framework that leverages state-of-the-art computer vision techniques to automate behavior analysis in complex farm environments.

Agricultural settings present unique challenges including complex barn layouts, severe occlusions, variable lighting conditions, and frequent animal interactions in group housing scenarios. Our framework addresses these challenges through a modular pipeline that integrates multiple components: (1) optimized video decoding with configurable frame sampling, (2) zero-shot object detection using YOLOv12 for initial animal localization, (3) motion-aware segmentation and tracking with SAMURAI for continuous individual monitoring through occlusions, (4) automated object cropping for isolating individual animals, (5) feature extraction using DINOv2 or CLIP for robust representation learning, and (6) flexible classification architectures for behavior recognition. YOLOv12's area attention mechanism reduces computational complexity while maintaining global context awareness, and SAMURAI's Kalman filter-based motion modeling with selective memory mechanisms ensures tracking stability. We evaluated our framework on the CBVD-5 dataset comprising 25,324 annotated dairy cow samples across seven surveillance cameras. The system achieved 98% accuracy in binary classification (standing vs. lying) using simple MLP classifiers with both DINOv2 and CLIP embeddings. t-SNE visualizations demonstrate clear behavior clustering, with DINOv2 showing slightly superior discriminative power.

The framework is currently deployed across 12 European farms to detect play behavior in dairy calves. Despite high performance, limitations include tracking instability with white-colored animals, performance degradation in overcrowded scenes, reduced accuracy in low-light conditions, and challenges with out-of-view tracking. Mitigation strategies include enhanced training data, optimized camera placement, and algorithmic improvements. Our modular approach enables adaptation across species and research objectives, providing a scalable solution for real-time behavior monitoring. This foundational framework advances precision livestock farming by enabling continuous, objective behavior analysis critical for animal welfare and farm management optimization.

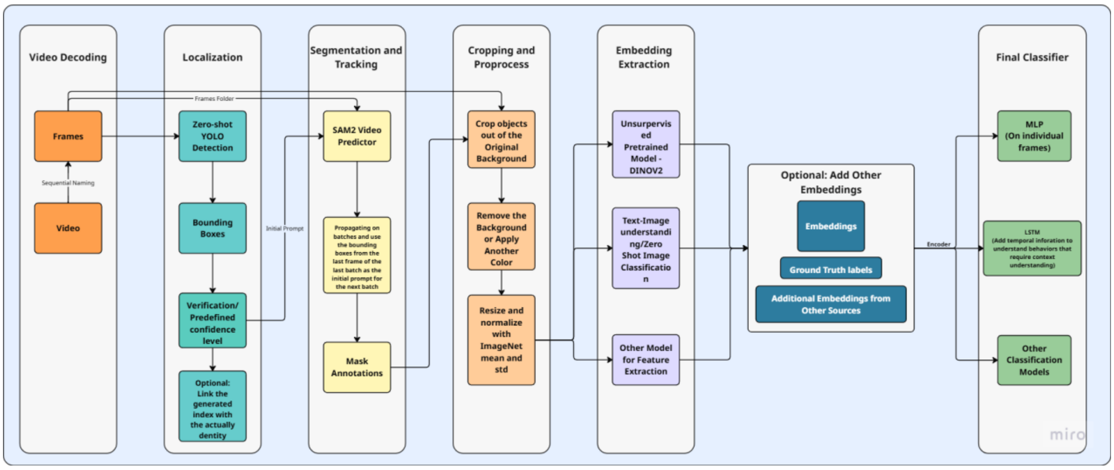

Figure 1. Workflow overview.

ASSOCIATIONS BETWEEN MILK PERSISTENCY, COW BEHAVIOUR, AND FEED EFFICIENCY

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Improving the sustainability and resilience of dairy production systems requires a deeper understanding of cow-level factors associated with productive longevity and adaptability. Lactation persistency, defined as the ability of a cow to maintain milk production after peak yield, is a recognized indicator of resilience, yet its behavioural and nutritional associations remain insufficiently described, particularly during late lactation. This study investigated associations between lactation persistency and cow behaviour, specifically rumination and eating time, concentrate allocation, and milk production outcomes.

Data were collected from two commercial dairy farms and included cows with complete sensor and production records during late lactation. Cows in their second lactation or greater were included. Lactation curves were fitted using the MilkBot model, and a parameter associated with persistency was derived for each cow. Within each farm, cows were classified as high or low persistency based on the 33rd and 66th percentiles of the persistency estimation distribution. The dataset comprised 845 unique lactations. Linear mixed-effects models assessed differences in average rumination time and concentrate allocation per 100 kilograms of milk, adjusting for lactation number and eating time, with animal nested within farm as a random effect. Estimated cumulative milk yield over 305 days was calculated using standardized adjustment models and compared using Welch's t-test. Cows with high persistency produced significantly more milk over 305 days compared to cows with low persistency (13,416 versus 12,498 kilograms; $p < 0.001$), indicating a clear production advantage. These cows also ruminated approximately 22 minutes more per day on average ($p = 0.0076$), independent of eating time. Rumination time was modestly higher in cows in their second lactation compared to older cows, with an average difference of 16.92 minutes per day ($p = 0.0371$). Cows with low persistency received more concentrate per 100 kilograms of milk (1.21 kilograms; $p < 0.001$). Although concentrate allocation in the automatic milking system was based on milk production, their lower cumulative yield resulted in less favourable concentrate use efficiency. No significant interaction effects were observed between persistency and lactation number for behavioural or nutritional traits, suggesting these associations were consistent across parities.

These findings indicate that cows with high persistency are not only more productive but also exhibit behavioural patterns consistent with greater physiological stability, including more consistent rumination. Minimal differences in eating time and the absence of interaction effects imply that the observed differences reflect intrinsic variation in metabolic and digestive efficiency rather than intake behaviour or parity alone. Reduced rumination in low-persistency cows may result from higher substitution of roughage with concentrate feeds, which could compromise rumen function and long-term resilience despite potential short-term yield benefits. In conclusion, lactation persistency is positively associated with key indicators of performance and resilience during late lactation. Cows with high persistency produce more milk with more efficient use of concentrate and more stable rumination behaviour. These results support including behavioural data from previous lactations in predictive models of persistency and inform management strategies to enhance long-term productivity and welfare.

BARN LAYOUTS AND FACTORS ASSOCIATED WITH BEHAVIOUR, UDDER HEALTH AND HERD PERFORMANCE IN AUTOMATIC MILKING SYSTEMS IN A MEGA ROBOTIC DAIRY COW FARM

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Automatic Milking Systems (AMS) are becoming more common in large dairy cow farms. However, facility design studies - especially those addressing the optimal number of AMS units/pen - are scarce and this remains a topic of ongoing discussion in the industry.

The objective was to compare behaviour, udder health and performance in 3 AMS facility design. Three treatments (AMS1 = 66 ± 1.53 cows and 1 milking robot (MR); AMS2 = 124 ± 0.58 cows and 2 MR and AMS3 = 186 ± 0.58 cows and 3 MR), were evaluated between January and March 2021. Data was collected over the 3 month study period using automatic records from the MR software (Delpro®, DeLaval, Sweden). For each treatment, data were analysed for daily milk yield/cow, milk yield/milking visit/cow, milking interval (h), milking duration (min), incomplete milkings (%), kick-off occurrences (%) and Mastitis Detection Index (MDi) which is mathematically generated considering milk electrical conductivity and blood presence (both measured at quarter level) as well as milking interval. Three udder health risk ranges were established, MDI < 1.4 low, ≥ 1.4 medium and ≥ 2.0 high. The effect of the treatment was analysed by GLIMMIX procedure (SAS v.9.41). Daily milk yield was affected by treatment and parity. Cows in AMS1 and AMS2 produced similar daily milk yields, both higher than those in AMS3 (49.94, 49.04 and 47.74 kg/d, respectively). Milk yield per milking visit was affected by treatment and parity. Milk yield per milking visit was similar between AMS1 and the other systems, while AMS 2 produced more than AMS 3. Milking interval was affected by treatment and parity. The milking interval was shorter in cows in AMS1 than in those in AMS2 and AMS3, which had similar intervals (7.97, 8.50 and 8.45 h, respectively). Multiparous cows (Mult) produced more daily milk, more milk per milking visit and had shorter milking intervals than primiparous cows (Prim). Milking duration was affected by treatment but not by parity. Milking duration was longer in AMS2 than in AMS1 and AMS3, with AMS1 and AMS3 having similar durations. The percentage of cows with incomplete milking and kick-off occurrence were affected by treatment*parity interaction. Among cows in AMS1 and AMS3, Prim had a higher percentage of incomplete milking than Mult. Prim in AMS3 had a higher percentage of incomplete milking than those in AMS2, while Mult in AMS2 had more incomplete milking than those in AMS1 and AMS3 (1.23, 0.43, 0.65 %, respectively). Prim had more kick-offs in AMS1 than in AMS2 and AMS3, and more in AMS3 than in AMS2. In AMS1, Prim had a higher kick-off occurrence than Mult, but this difference was not observed in AMS2 or AMS3. MDI was affected by treatment*parity interaction. In AMS3, Mult had a higher MDI than Prim. Mult in AMS3 had a higher MDI than those in AMS1 and AMS2.

These findings indicate that the number of robots per pen is a factor that should be considered when designing and building new barns or retrofitting existing facilities to implement AMS.

MONITORING ANIMAL WELFARE IN AMS DAIRY FARMS: INSIGHTS FROM DIFFERENT PRODUCTION SYSTEMS IN ARGENTINA

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There is a global trend towards the automation of farms, including the introduction of automatic milking systems (AMS) in the dairy industry. In Argentina, AMS adoption has been increasing in recent years driven by the benefits for farmers, improving productivity, profitability and competitiveness, and one of the benefits perceived by farmers has been improved animal welfare (AW). However, facility design and management practices effects on AW studies are scarce and comparisons of different production systems with AMS almost non-existent.

The goal of this study was to compare the behaviour and welfare of cows in AMS dairy farms with different production systems, which served as the basis for creating a new monitoring platform that allows tracking AW measurement taken on farm with AMS. The study was conducted in fifteen AMS dairy farms, located in Argentina's main dairy areas, which were grouped into five production systems (free-stall (FS; n = 5), compost barn (CB; n = 4), cold bed (CBe; n = 1), dry-lot (DL; n = 2) and grassland (GL; n = 3) systems. The average size of farms measured as the number of productive cows per farm was 224 ± 140. AW and management practices data were collected over the years 2023 and 2024. An on-farm welfare assessment based on the Welfare Quality® assessment protocol for cattle (WQ) was used single for each farm. Observations were carried out by direct visual observation and by the same trained person. This study was analyzed by R software using lineal and generalized lineal models.

Overall, on-farm welfare assessment was similar between production system for the variables referred to good feeding such as, body condition score, cleaning, water flow and operation of the drinkers and also for other parameters such as lameness indicators. About good housing CBe system cows showed the minor udder dirtiness compared with the other system. Respecting good health and the evaluation of clinical indicators, a higher percentage of cows with tarsal injuries was observed in FS (8%) compared with the other systems (0%). A minor percentage of nasal discharge was observed in FS (1.35%) compared with CB, CBe and GL (in all > 10% of cows). In relation to appropriate behaviour, FS cows showed minor avoidance distance than CB (93 and 125 cm, respectively), probably due to the fact that the daily handling and movement of cows between systems are different. Cows in FS showed minor avoidance distance per activation time than CB and GL (-0.46, 1.96 and 1.27 cm, respectively). The five production systems have shown more than 50% cows with 1 meter of avoidance distance and more than 75% cows without touching them.

Although the AMS farm dimensions and building characteristics of the dairy systems in this study are according to requirements of good dairy practices, these findings indicate that in AMS farms in Argentina the five systems could improve animal-human relationships and herd management related to good housing and good health. The next challenges include continuing field measurements with AMS farms and integrating new sensors and technologies into the platform created, allowing for the automatic capture of different data that can generate continuous monitoring for AW.

AI FOR CATTLE TRACKING AND BEHAVIOUR IDENTIFICATION FROM VIDEO FOOTAGE

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Cattle exhibit behaviours such as tail flicks, flat ears and abnormal resting behaviour in response to pain from invasive husbandry procedures such as disbudding. Effective monitoring and analysis of these behaviours is essential for identifying pain, and for determining the impact of pain alleviation treatments. Direct visual observation of behaviours presents challenges as it is time-consuming, therefore methods that reduce the frequency of observations are often used in scientific studies of behaviour. This can limit the quality and interpretation of results. Current approaches to automated cattle behaviour monitoring from video footage often rely on combinations of computer vision and machine learning techniques, which can be time-consuming due to the need for extensive data labelling.

This study aims to develop an advanced AI-driven methodology for automated cattle tracking and behaviour identification from video footage in agricultural settings. By utilising recent advances in AI, the primary objective is to reduce the reliance on manual data annotation by leveraging large vision-language models and prompts.

A video recording of 5 six-month old Holstein calves in an indoor pen was used for the methodology development. Calves were part of a larger study evaluating novel pain mitigation for cautery disbudding at the University of Sydney's Corstorphine Dairy Farm. The calves had undergone disbudding by the University veterinarians using a cautery iron and had been treated with a lignocaine cornual block and 1 mg/kg oral meloxicam prior to surgery. Video recordings commenced 1 hour following disbudding.

The methodology (Figure 1) utilises the Segment Anything Model 2 (SAM2) to accurately identify, segment, and continuously track each animal, including during interactions with other calves, feeding systems, and fences. For each behaviour of interest - flat ears, lying down, and tails flicks - a prompt was engineered using a few manually selected video frames indicative of these behaviours. The integrated large vision-language model, QWEN2 VL, was then applied to each masked video frame using the engineered prompts to obtain a textual description of the behaviour in that frame. Following the automated analysis of the QWEN2 VL responses for each video frame, the behaviours were assigned accordingly.

Manual visual inspection of the proposed methodology's performance demonstrated that behaviours involving animal large body parts are easier to identify robustly. For example, the methodology achieved 100% accuracy in identifying whether an animal was standing or lying down. In contrast, for smaller body movements such as flat ears, accuracy depended on their clear visibility in the video footage. However, this limitation can be overcome by zooming into the area of interest before sending the video frames to the large vision-language model for behaviour identification.

The proposed methodology demonstrated performance close to human levels, with the advantage of being fully autonomous and overcoming the prohibitive manual labour required for animal behaviour identification in long video footages. Ongoing work aims to extend the proposed methodology making it a robust super-human-level identifier for a wider range of behaviours of interest.

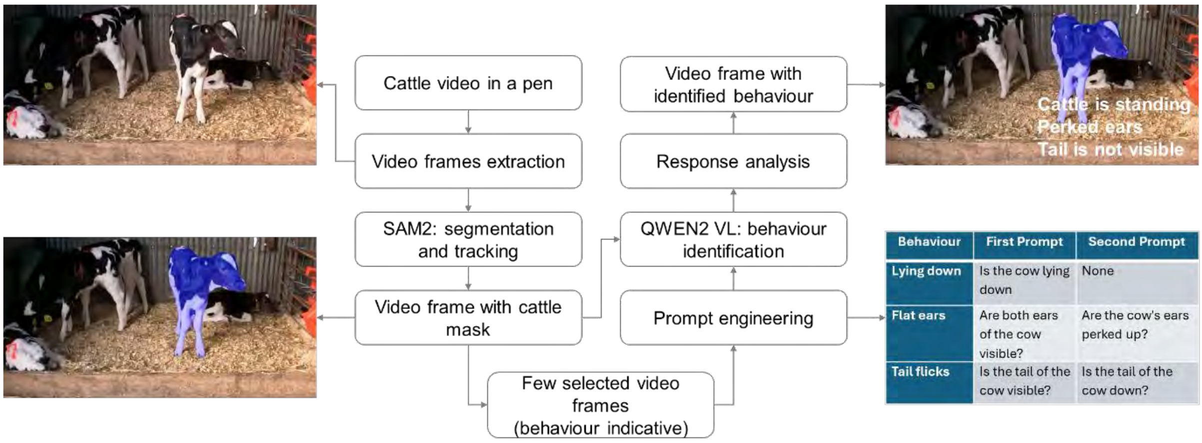

Figure 1. Flowchart of the proposed AI-driven methodology for automated cattle tracking and behaviour identification from video footage.

COW FLOW MATTERS: GRAZING BEHAVIOUR AND MILK YIELD IN A SUBTROPICAL PASTURE-BASED AUTOMATIC MILKING SYSTEM

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Automatic milking systems (AMS) are often integrated into pasture-based systems with rotational grazing and voluntary cow movement. However, relationships between milking frequency (MF), grazing behaviour, and milk production remain insufficiently understood, particularly under subtropical conditions. We hypothesised that voluntary cow flow would enhance individual milk yield by improving grazing performance and increasing MF, compared to conventional forced flow systems.

This study compared a conventional milking system with forced cow flow (CMS-FF) and an AMS with voluntary flow (AMS-VF) under identical pasture-based conditions at INIA's experimental dairy farm in Colonia, Uruguay (34° 20´ 23.72" S, 57° 41' 39.48" W). Each system included 100 Holstein Friesian cows at peak lactation, grazing on 45 ha of land with homogeneous soil fertility, similar pasture – crop sequence, and consistent supplementation and grazing management. A subgroup of 30 cows per system was matched for parity, genetic merit, production level, and days in milk. These cows were individually monitored over two 15-day spring periods, during which they had full access to pasture and received concentrate during milking. Studied variables included fat-corrected milk (FCM, kg/cow/day), MF (milkings/cow/day), sward height (SH, cm), harvested pasture quality [neutral detergent fiber (NDF), acid detergent fiber (ADF), and crude protein (CP)], at 0, 2, and 6 hours after the first cow entered the strip, grazing time (GT, min/cow/day), and pasture entry delay (PED, the sum of the average daily delay in minutes per cow to access the paddock). Linear mixed models and regressions assessed treatment effects and variable relationships. Effects were considered significant at $P \leq 0.05$.

Cows in AMS-VF showed higher FCM yield and MF compared to CMS-FF ($P = 0.001$). The slope of SH reduction in early grazing was steeper in CMS-FF (-9.4 vs. -6.1 cm/hour), indicating faster and more uniform pasture depletion. Pasture harvested in AMS-VF had higher CP ($P < 0.001$) and lower fibre content (NDF and ADF; $P < 0.001$), particularly at 2- and 6-hours post-allocation, suggesting improved access to higher-quality herbage. Cows in the AMS-VF system had longer and more variable GT (median = 516 min/day; range = 252 – 726 min) than those in CMS-FF (median = 474 min/day; range= 372 – 612 min), indicating more flexible grazing behaviour. Regression analysis showed that milk yield increased with MF ($R^2 = 0.59$), while MF decreased with increasing PED ($R^2 = 0.67$), highlighting the importance of voluntary movement and timely paddock access for optimising performance in AMS systems.

Under subtropical grazing conditions in spring, AMS with voluntary cow movement improved individual cow performance compared to CMS-FF systems. Cows in AMS-VF achieved higher FCM yield, supported by the access to higher quality and quantity herbage and MF. The dispersion observed in individual milk yield and MF within the AMS-VF group suggests significant potential for further improvement through targeted management strategies.

	CMS-FF[1]	AMS-VF[2]	SD	Significance[3]
Fat-corrected milk (3.5%) (kg/cow/day)	30.9	31.5	0.1	0.001
Milking frequency (# milkings/cow/day)	2.0	2.2	0.1	0.001
Grazing time (min/cow/day)	474	509	10.8	0.001
Sward height (cm)				
0 hours[4]	29.3	31.5	1.5	0.136
2 hours[5]	10.5	19.3	1.6	<0.001
6 hours[6]	6.1	11.0	1.0	<0.001
NDF (% DM)				
0 hours[4]	38.1	36.9	2.6	0.664
2 hours[5]	56.4	49.4	2.1	0.002
6 hours[6]	58.9	53.3	1.4	<0.001
ADF (% DM)				
0 hours[4]	20.5	19.2	1.4	0.349
2 hours[5]	33.3	27.6	1.2	<0.001
6 hours[6]	34.9	30.6	0.9	<0.001
CP (% DM)				
0 hours[4]	24.3	27.2	1.2	0.025
2 hours[5]	15.6	20.8	1.2	<0.001
6 hours[6]	12.6	17.0	1.0	<0.001

[1]Conventional milking systems – forced flow.
[2]Automated milking system – voluntary flow.
[3] $P \leq 0.05$ = significant, $0.05 < P \leq 0.10$ = trend.
[4-6]Sward height 0, 2, 6 hours after the first cow entered the grazing strip.

INTEGRATING SMARTPHONE VISION AND AI FOR ON-FARM PASTURE MEASUREMENT AND GRAZING DECISION SUPPORT

J. Bryant, N. Bhatia, P. Maguire, D. Willcock, L. Thresher, C. Benson, A. Hearfield, I. Campbell, J. Kerslake, and K. Macdonald

Pasture-based livestock systems rely heavily on the efficient utilisation of home-grown forage. Empirical benchmarking analyses have shown that for every additional tonne of dry matter (DM) consumed per hectare, farm operating profit increases by approximately $300/ha. Despite this, the adoption of regular pasture measurement remains limited due to barriers around cost, need for hardware, high labour requirements, and ease of use. High frequency, accurate measurement is essential for implementing precision pasture management practices, yet tools that are accessible, low-cost, and capable of estimating pasture mass accurately remain scarce.

This study presents the development and evaluation of AIMER Vision, a smartphone-based pasture mass estimation tool, and the AIMER digital assistant, an AI-powered decision support platform. The objective was to (1) evaluate the feasibility of using consumer-grade smartphone hardware to estimate pasture mass accurately, (2) develop models capable of estimating paddock pasture mass from partial measurements, and (3) deliver grazing management recommendations based on real-time analysis of pasture supply and demand.

To train and validate the AIMER Vision system, pasture data was collected from 12 commercial dairy farms across New Zealand. The summer/autumn dataset comprised over 2,000 annotated paddock-level samples, including short video sequences (~5 seconds per sample) captured under varied seasonal and lighting conditions, paired with pasture mass estimated using a plate meter or C-Dax Pasture Meter. Machine learning algorithms were trained using 70% of this data. Model evaluation on held-out test sets (30% of data) achieved a root mean square error (RMSE) of 5-10%, equivalent to 90% of estimated Vision covers within ± 250 kg DM/ha of measured values. Predictions were delivered on-device in 2–10 seconds, with full offline capability.

In addition to mass estimation, proprietary algorithms were developed to analyse feed wedges and detect over 40 distinct pasture supply scenarios (e.g., surplus, deficit, declining cover trends). The system generated specific recommendations aimed at optimising conservation decisions, nitrogen usage, and supplementary feeding decisions. Furthermore, a proprietary learning algorithm was implemented to learn relative paddock growth rates as well as a proprietary algorithm to automatically generate dynamic grazing plans at the mob level. These are provided to users via a web and mobile application.

Results indicate that smartphone-based vision models can deliver pasture mass estimates with an accuracy comparable to industry-accepted tools, while significantly lowering the barrier to regular measurement. The feed analysis and recommendation engine demonstrated strong agreement with expert assessments in on-farm trials, suggesting potential for real-time decision support.

In conclusion, the integration of smartphone vision, machine learning, and decision support algorithms offers a scalable and practical approach to pasture measurement and management. The AIMER system has demonstrated potential to support more frequent and precise pasture-based decision-making, thereby enabling improved utilisation and contributing to the economic and environmental performance of pastoral farming systems.

UTILITY OF AN IN-LINE SOMATIC CELL COUNT SENSOR FOR SELECTING COWS FOR DRY-COW THERAPY

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Minimizing the use of antimicrobials at the end of lactation (dry cow therapy, DCT) requires categorization of cows as likely infected or uninfected. While microbiology is the gold standard, indirect tests such as somatic cell count (SCC) are commonly used in the dairy industry. An in-line SCC sensor (SenseHub™ In Line Somatic Cell Count, in-line SCC) is commercially available but its utility to differentiate cows eligible for dry cow therapy has not been assessed. This study tested the utility of in-line SCC to select cows for different dry-off treatments, using cow-composite milk samples submitted for conventional microbiology as the gold standard. A secondary objective was to compare the utility of in-line SCC with the maximum (max HT SCC) or last (last HT SCC) SCC results from monthly herd tests by an independent laboratory.

Cows (n = 1,544) from four New Zealand herds had cow-composite milk samples collected using aseptic methods at the final milking of lactation and submitted for microbiology testing by an independent laboratory. Microbiology data from approximately half the cows (n = 770; training dataset) were used to determine the optimal predictor for indicating intramammary infection (IMI) from the in-line SCC data, which was the bounded 12-week geometric mean of the in-line SCC results (in-line 12wSCC). Using the data from the remaining cows (test dataset), the area under receiver-operator curve (AUC) for max and last HT SCC were compared with that of the in-line 12wSCC (see Figure 1).

The cow-level prevalence of minor and major IMI was 50.6% and 14.2%, respectively. The in-line 12wSCC sensitivity (Se) and specificity (Sp) for any IMI were 0.68 and 0.71, respectively, and 0.89 and 0.51, respectively, for major IMI, using a threshold of 150,000 cells/mL. For the last HT SCC, Se and Sp for any IMI were 0.68 and 0.68, respectively, and 0.91 and 0.50, respectively, for major IMI at the same threshold. Max HT SCC Se and Sp were 0.82 and 0.52, respectively, for any IMI, and 0.99 and 0.35, respectively, for major IMI.

No significant difference in AUC for detecting major IMI was found between the in-line 12wSCC (0.824), last HT SCC (0.816), or maximum HT SCC (0.836) ($P = 0.50$). The in-line 12wSCC was noninferior to both maximum and last HT SCC for major IMI (both $P < 0.001$). For predicting any IMI at drying off, the AUC using in-line 12wSCC (0.776) was higher than last HT SCC (0.737) or max HT SCC (0.735) (both $P = 0.03$).

The four herds enrolled in the study were representative of New Zealand's dairying regions and mastitis levels. The observed IMI prevalence and pathogens, and the Se and Sp of SCC predictors, were consistent with previous New Zealand studies, suggesting strong external validity for the New Zealand context.

It is concluded that the in-line 12wSCC is equivalent and noninferior to the use of HT SCC from the entire lactation (maximum or last SCC). Hence, in-line SCC has utility for selecting cows for either antimicrobial or internal teat sealant treatment at the end of lactation.

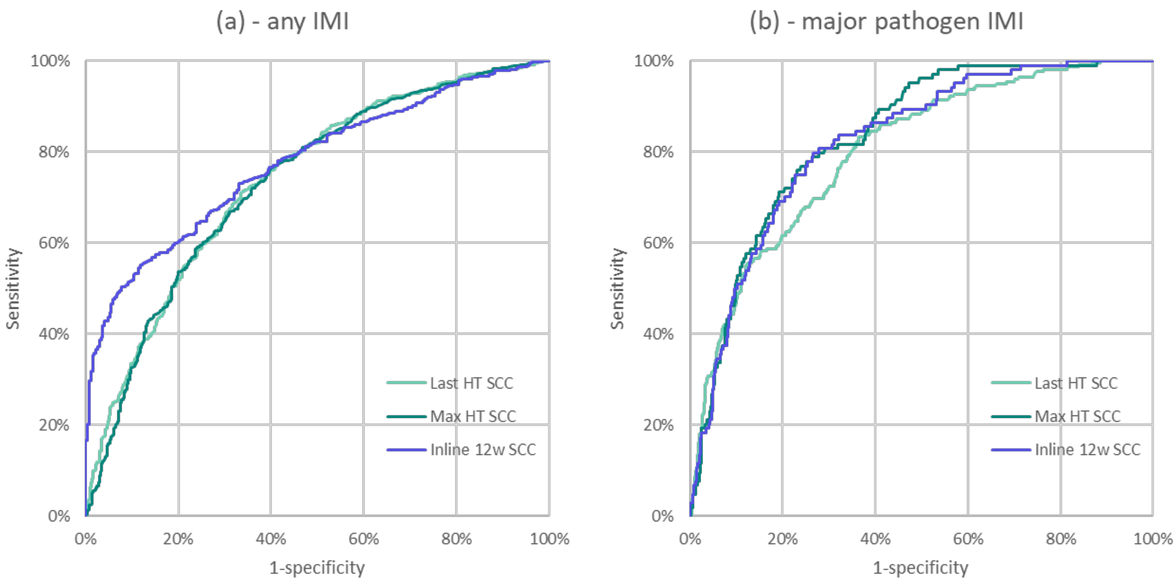

Figure 2. Receiver operator curves for the presence of (a) any intramammary infection or (b) a major pathogen at drying off.

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UTERINE HEALTH IS ASSOCIATED WITH DETECTION OF ESTRUS BY AUTOMATED ACTIVITY MONITORS AND SUBSEQUENT FERTILITY

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The objective of this prospective observational study was to assess the factors associated with estrus detection by automated activity monitors (AAM) and pregnancy at first artificial insemination (P/1st AI). Holstein cows (n = 846) from 10 herds in Ontario, Canada using automated activity monitors as the primary reproductive management tool, were enrolled after calving. Body condition score change (ΔBCS) between weeks 1 and 8 was categorized as ≤ – 0.5, – 0.25, or ≥ 0. Hyperketonemia (HYK) was defined as blood BHB ≥ 1.2 mmol/L at week 1 or 2. Metritis was diagnosed when fetid discharge was observed at week 1 or 2. Purulent vaginal discharge (PVD; > 50% pus) was diagnosed at weeks 4, 6, and 8, while endometritis (ENDO; > 5% PMN in uterine cytology) was diagnosed at week 4. Serum progesterone concentration < 1 ng/mL in blood samples collected at weeks 4, 6, and 8 defined anovular cows (ANOV).

A multivariable logistic regression model was built in R to predict the probability of being inseminated based on estrus detected by AAM (IDE) between 50 and 120 days in milk. Variables with P ≤ 0.10 were retained in the model, and least squares means (LSM) with their 95% confidence intervals (CI) are reported. Overall, IDE was 65% (56 – 73%). Parity, ENDO, and ANOV were associated with IDE, but accounting for these, ΔBCS, HYK, metritis, and PVD were not. First-lactation cows were more likely to be IDE (68%, 58 – 77%) than ≥ 3rd parity (65%, 55 – 73%) or second-parity cows (61%, 50 – 71%). Cows with ENDO had a 61% (51 – 71%) probability of IDE compared to cows without (67%, 57 – 75%). ANOV cows were less likely to be IDE (48%, 33 – 62%) than cyclic cows (66%, 57 – 74%).

Another multivariable logistic regression assessed P/1st AI. Here, ENDO and PVD were combined into a four-level variable representing their possible combinations. The overall P/1st AI was 41% (36 – 45%). Primiparous cows were more likely to be pregnant (49%, 42 – 56%) than second parity cows (41%, 34 – 48%) or ≥ 3rd parity cows (35%, 30 – 41%). The probability of P/1st AI was 44% (39 – 50%) for cows classified as Non-PVD-Non-ENDO, 43% (34 – 52%) for ENDO only, 42% (34 – 50%) for PVD only, and 29% (22 – 37%) for BOTH.

Exploring univariable herd-level associations, P/1st AI tended to be different among farms (P = 0.07) ranging from 33% to 56%. The proportion of cows AI after estrus detected by AAM ranged from 45% to 86% (P < 0.01). The prevalence of ANOV was not different among farms (5 – 11%, P = 0.7), whereas PVD (24 – 41%), and ENDO (25 – 52%) differed among farms (P < 0.01). Uterine health at 4 to 8 weeks postpartum is associated with IDE and P/1st AI and varies substantially among farms.

PRECISION LIVESTOCK MANAGEMENT: TAILORING MANAGEMENT PRACTICES FOR DAIRY CATTLE BASED ON INDIVIDUAL VARIABILITY AND CHARACTERISTICS

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Understanding individual variability and personality traits in dairy cattle offers new opportunities to enhance animal welfare and productivity through tailored management strategies. Personality traits – defined as consistent behavioral differences between individuals across time and contexts – can influence how animals perceive and respond to environmental and management stressors. This scientific review and experimental testing project integrate a broad literature review of the literature and findings from a series of studies evaluating the relationship between individual behavioral patterns and animal personality traits across various ages, breeds, and production contexts of dairy cattle. Using Precision Livestock Farming (PLF) tools, such as automated feeders, rumination monitors, and activity sensors, researchers have identified consistent individual differences in feeding behavior, locomotion, rumination, and responses to thermal stress. These behaviors were linked to performance outcomes (e.g., days open, services per pregnancy) and health indicators (e.g., disease bouts, behavioral signs of discomfort) in a myriad of studies.

In dairy calves, personality traits influenced solid feed intake development and moderated responses to stressors such as weaning and disease events. In adult cows, large-scale behavioral datasets revealed associations between daily activity patterns and key reproductive and health metrics. Two tailored interventions were tested: a weaning protocol based on solid feed intake behavior and a voluntary cooling system informed by individual thermal responses. Both approaches demonstrated significant inter-individual variability in resource use and positive implications for animal health and efficiency. Collectively, the reviewed studies support the integration of PLF tools with behavioral profiling to implement individualized management. This approach represents a promising pathway for improving the welfare, resilience, and productivity of dairy cattle in commercial settings.

COST-EFFECTIVENESS OF SOMATIC CELL COUNT MONITORING SYSTEMS IN SMALLHOLDER DAIRY FARMS

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Improving milk quality enhances the profitability and sustainability of dairy farms, which can be achieved through effective udder health management. Somatic cell count (SCC) monitoring provides critical insights for the early detection of subclinical infections, enabling timely intervention to prevent udder health deterioration. However, its adoption remains limited in low- and middle-income countries, particularly in production systems dominated by smallholder farmers, due to cost and accessibility barriers. This study used a stochastic Monte Carlo bio-economic simulation model to evaluate the cost-effectiveness of various SCC monitoring systems for smallholder dairy farms in Indonesia.

The model simulated SCC dynamics in individual cows across 100 farms within a single milk collection point (MCP) and assessed the diagnostic performance and economic viability of various SCC monitoring systems. Modelled events and alerts were defined using monitoring frequencies (weekly, biweekly, monthly) and different algorithms. The first algorithm flagged all SCC levels exceeding 400,000 cells/mL (Indonesian national standard), the second algorithm identified first-time SCC increases above the threshold, and the third algorithm detected chronic SCC elevation over consecutive measurements. By comparing the modelled events with the alerts, the performance of SCC monitoring systems could be evaluated. The SCC monitoring systems demonstrated varying abilities to detect modelled SCC events. A visualization of modelled SCC events across different algorithms for weekly measurements is shown in Figure 1.

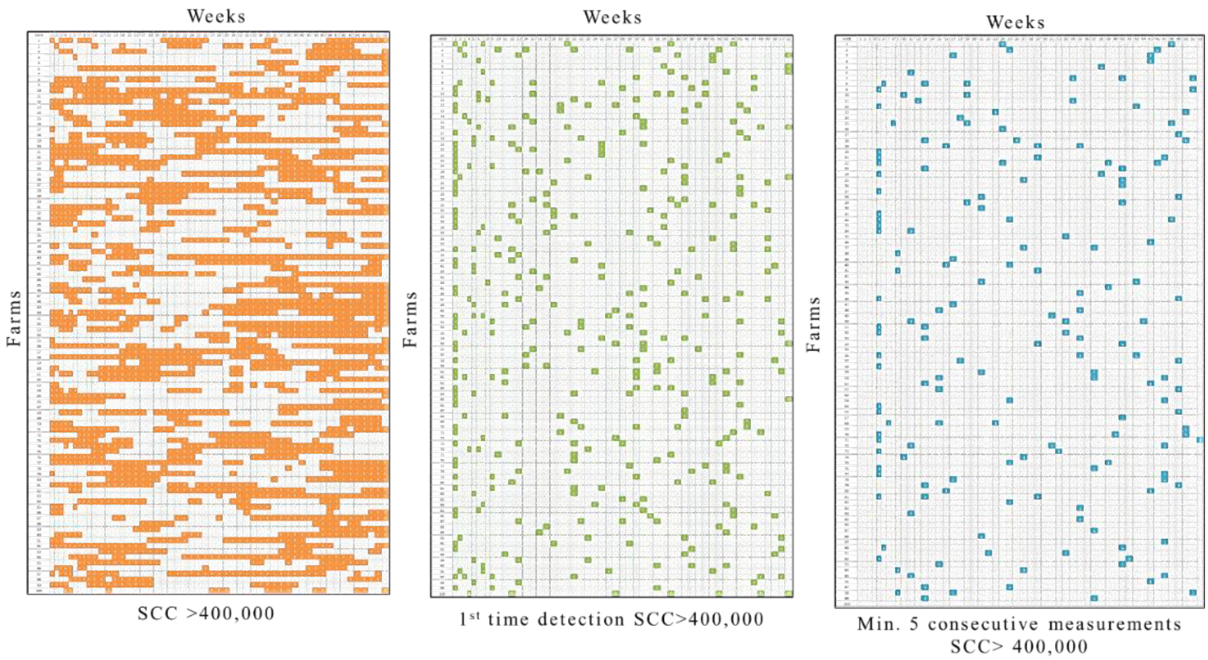

Figure 1. The visualization of modelled weekly SCC events according to three algorithms. Orange indicates SCC > 400,000, green represents first-time detection of SCC > 400,000, and blue shows events where SCC > 400,000 for five consecutive measurements.

An economic analysis was carried out to calculate the total annual costs at the MCP level. These costs were then used to calculate the mean cost-effectiveness ratio (MCER) based on the total number of modelled SCC events detected by each SCC monitoring system. The SCC monitoring systems consisted of a measuring device, either the DeLaval cell counter (DCC) or a hypothetical diagnostic equipment (HDE), combined with three alert algorithms and measuring frequencies. The cost-effectiveness analysis revealed significant variation in sensitivity and economic feasibility among SCC monitoring systems. The DCC-based weekly system incurred the highest average annual cost of €11,533 per farm, whereas the HDE-based weekly system significantly reduced average costs to €1,026 per farm. Among all strategies, the HDE-based system with weekly monitoring using the first alert algorithm emerged as the most cost-effective, achieving the lowest MCER of 0.5. Additionally, the HDE-based biweekly system and HDE-based weekly system with the second algorithm ranked as the next most cost-effective solutions, with MCER values of 0.9 and 1.0, respectively.

These findings highlight the importance of balancing diagnostic accuracy and affordability in SCC monitoring systems for smallholder dairy systems. While the DCC is widely recognized as a reliable on-farm option, the development of an affordable and scalable SCC monitoring solution could drive broader adoption. This study recommends that dairy cooperatives and policymakers should consider implementing an HDE-based SCC monitoring system with optimised alert algorithms and measurement frequencies to enhance milk quality, farm productivity, and economic viability in smallholder dairy settings.

IMPACT OF EARLY OR LATE AGE AT GROUP HOUSING ON HEALTH AND BEHAVIOR OF SUCKLING DAIRY CALVES

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Rearing suckling dairy calves in hutches facilitates biocontainment and health assessment compared to group housing. However, hutch rearing raises welfare concerns and might have a negative effect on growth performance.

Our study examined the effect of early (EGH) or late (LGH) transition to group housing on health and behaviour changes in three Israeli dairy farms. The trial was conducted during the winter (farms A and B) or summer (farm C). In each farm heifers were classified, using the median age at first day of group housing as a cut-point (range between 21 to 25 days), to either EGH (n=42) or LGH (n=37). To achieve continuous and standardized health evaluation, all heifers received a behaviour monitoring sensor (SenseHub Dairy Youngstock™ provided by MSD Animal Health) within the first five days of life and were monitored up to weaning at 60 days of age. The monitoring system recorded the heifer's behaviour minute by minute and calculated a health index (HI) value every hour (range between 40 to 100) according to behaviour changes. Health index values below 86 represented heifers that were considered potentially sick and required attention by farm personnel. The monitoring period was divided into sub-periods, coinciding with trial stages and housing types, according to age in days: 1 - 15 (P1), 16 - 30 (P2), 31 - 45 (P3), and 46 - 60 (P4). Age at first day of group housing was on average 19.5 ± 3.5 and 33.3 ± 9.0 days for EGH and LGH, respectively. Rumination, eating, resting, activity, suckling, and non-nutritive oral behaviours did not differ between EGH and LGH heifers. A linear mixed model with time at group housing, age, and farm as fixed effects and individual repeated measurements as random effects was specified to evaluate effect on HI values and risk of being sick (generalized model). During P1 a negative effect on daily HI values was detected for farm C compared to farm A (+ 3.48; $P < 0.01$) and farm B (+ 1.68; $P < 0.05$). Accordingly, the proportion of potentially sick heifers in P1 was larger for farm C compared to farm A (-13.3%; $P < 0.01$) and B (-8.3%; $P < 0.05$). During P4 a negative effect on daily HI values was detected for farm B compared to farm A (+3.06; $P<0.01$) and farm C (+1.26; $P<0.05$). During P2 a negative effect on daily HI values was detected for EGH compared to LGH heifers (+ 1.71; $P < 0.01$). Accordingly, in period P2 the daily proportion of potentially sick heifers was higher for EGH compared to LGH (8.6 vs 3.4%; $P < 0.01$). The current study shows increased risk for morbidity at 15-30 days of age following an early move to group housing. To maximize the benefit of group housing advantages at an early stage, it is suggested to increase health assessment capabilities to mitigate the increased health risk. Behavior monitoring solutions can facilitate better calf management.

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TRANSITION PERIOD RUMINATION TIME AND ITS ASSOCIATION WITH MILK PRODUCTION IN DAIRY COWS

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Maximising the seasonal performance of dairy cows is dependent on a positive transition into lactation. This study explores how daily rumination time (RT), obtained through automated monitoring devices, can help farmers gain insights into peripartum management practices which impact cow dry matter intake, health and production. The association between mean transition period RT and milk production has not been assessed in pasture-based systems. Therefore, the objective of this study was to create linear mixed effect models to investigate the association between mean peripartum RT with seasonal herd-test-predicted milk solids (kg MS), and first 30 days in milk cumulative milk yield (MY30). A second objective was to describe the relationship between peripartum RT, parity and breed in pasture-based dairy systems.

Data was retrospectively collected from cows (n = 5947) across twelve New Zealand dairy herds, utilising individual cow milk meters (SenseHub™ Milk Sensor, MSD Animal Health) and behaviour monitoring neck tags (SenseHub™ Monitoring Neck Tag, MSD Animal Health). Farms were well distributed across New Zealand, with 4 farms containing > 1000 cows and 5 farms < 450 cows. All farms included in the study population milked through rotary milking sheds. Cows were categorised by parity number into parity 1 (P1, n = 1355), parity 2 (P2, n = 1149) and parity 3+ (P3+, n = 3443). The cow breeds were Friesian (n = 2135), Jersey (n = 413), Kiwi Cross (n = 2830) and other (n = 569). Lactation curves were derived using a Wilmink equation, and the area under the curve values for the first 30 days in milk was used to derive MY30 (Wilmink, 1987). Disease incidence data was sourced from farm records.

Arithmetic mean RT for the week relative to parturition included: week one prepartum (PrP1, 460.0 min/d), week one postpartum (PoP1, 441.3 min/d), and week two postpartum (PoP2, 483.4 min/d), with production and RT data for parity categories shown in Table 1. Peripartum RT relationships between parity and breed are displayed in Figure 1. Model analysis revealed that for P3+ cows, RT of 200 - 300min during PoP1 resulted in a decrease of 46.5 kg MS, while RT of 300-400 min during PoP2 indicated a reduction of 29.4 kg MS compared to the reference group of 400-500 min/d RT. No increase in kg MS was observed for RT above 500 min. In terms of MY30, P3+ cows showed a 3.5 - 9.1% increase per 100 min difference in RT from 300 - 600min/d in postpartum models. Overall, the study indicates positive correlations between transition period RT and milk production, particularly in P3+ cows during the first two weeks postpartum, highlighting the advantages of real-time monitoring and improved management practices.

Table 1. Parity group summary of key variables from an observational study.

Parity	RT 1st week prepartum (min/day)	RT 1st week postpartum (min/day)	RT 2nd week postpartum (min/day)	Seasonal Milk solids (kg)	First 30d cumulative milk yield (L)
1	410.8 ± 80.3 (n =5 92, missing = 846)	409.7 ± 60.9 (n = 929, missing = 509)	442.1 ± 52.7 (n = 1198, missing = 240)	397.3 ± 99.4 (n = 1424, missing = 14)	449.4 ± 127.5 (n = 1374, missing = 64)
2	471.3 ± 70.8 (n = 852, missing = 359)	453.4 ± 62.6 (n = 1093, missing = 118)	492.6 ± 54.2 (n = 1116, missing = 95)	468.9 ± 109.2 (n = 1205, missing = 6)	609.6 ± 140.0 (n = 1166, missing = 45)
3+	467.2 ± 65.1 (n = 2605, missing = 1167)	446.2 ± 64.7 (n = 3270, missing = 502)	495.0 ± 60.4 (n = 3401, missing = 371)	486.9 ± 140.4 (n = 3687, missing = 85)	667.5 ± 160.3 (n = 3502, missing = 270)

Measurements are given as mean +/- 1 standard deviation.
Parity: 1 = first parity, 2 = second parity, 3+ = third and greater parity. RT = rumination time.

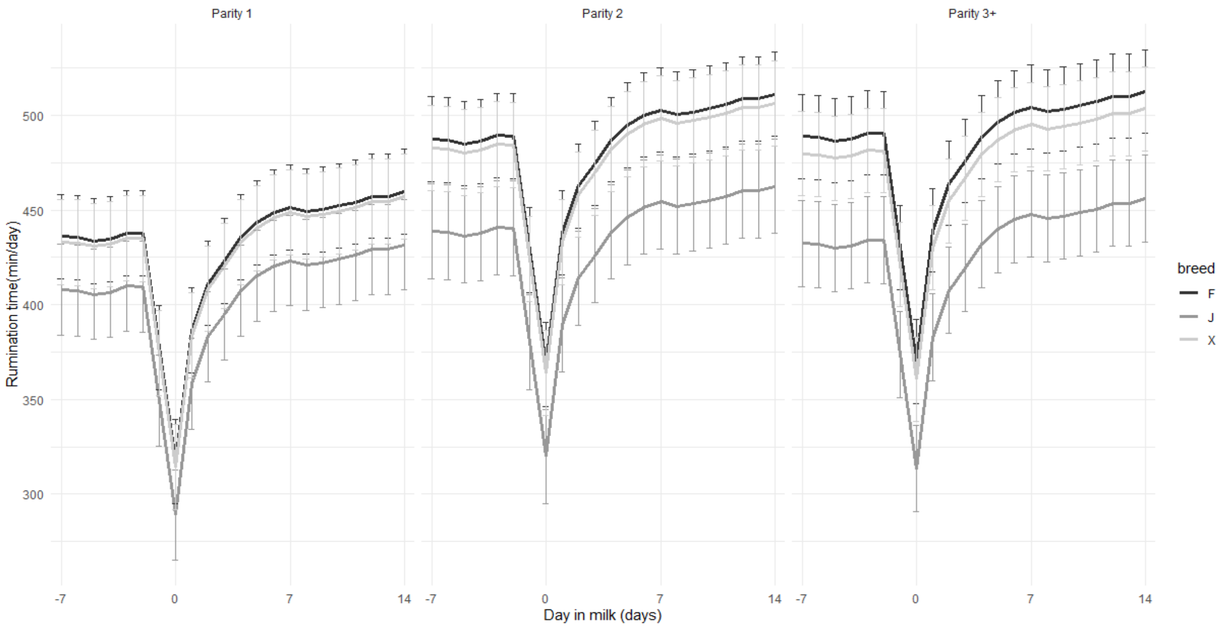

Figure 1. Least squares means of rumination time (RT) by day in milk (DIM), parity, and breed from a linear mixed effects model, including interactions for breed:parity, farm as a random effect, and DIM as a repeated measure.

Breed: Holstein-Friesian (F), Jersey (J), Holstein-Friesian x Jersey (X).
Parity: 1 = first parity, 2 = second parity, 3+ = third and greater parity.

FACTORS INFLUENCING THE VALUE OF AUTOMATED MASTITIS DETECTION TECHNOLOGY IN SEASONAL CALVING SYSTEMS

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Technologies for the automated detection of mastitis are increasingly available for use on dairy farms. While many farmers can see the potential of such automated detection, adoption remains minimal in New Zealand (NZ), partly due to a lack of information on the return on investment. Adoption of inline mastitis detection sensors in New Zealand is currently around 6% of farms. An important barrier to technology investment is the lack of independent return on investment assessments or calculators.

The aim of this work was to test a model that could highlight the factors influencing the value of automated mastitis detection technology. We updated a 2015 model with up-to-date data and used a stochastic modelling approach to compare electrical conductivity-based automated mastitis detection (AMD) with visual detection for return on investment. The model was based on an average NZ pasture-based dairy farm with 440 cows, producing 400 kilograms of milksolids (i.e. milk fat and protein) per cow per year, a lactation length of 276 days, four milk production recordings per season and an assumed clinical mastitis incidence of 14.8% per year. Modelling outcomes indicated that the optimal sensitivity for quarter-level electrical conductivity sensors was 88%. This resulted in detection of 90.2% of all clinical mastitis episodes at an average delay of 2.3 milkings from the start of the clinical mastitis episode until treatment, compared with 46.1% detection and treatment at a delay of 8.8 milkings using visual detection.

Results from the modelling showed that the profitability of investing in AMD depends greatly on the initial investment cost, for example a net present value (NPV) of NZD -$7,800 when individual sensors cost NZD $1,000 compared with an NPV of NZD $4,400 when sensors cost NZD $500 each. The model output indicated that where mastitis detection technology worked well, it raised the average expenditure on treating clinical mastitis cases compared to poorer performing visual inspection. This was driven by the greater identification of mastitis leading to a higher use of antibiotics. Limited information was available on transmission rates of pathogens, per cow costs of clinical and subclinical mastitis, the impact of early treatment on milk production losses and reduced use of antibiotics. This highlighted the need for further research on these factors before a more accurate value could be estimated for such technology. The model developed in this study could be adapted for use in different seasonal-calving dairying systems by altering relevant input factors and could be updated if more accurate information becomes available.

VARIATION IN CALF DRINKING BEHAVIOUR ON AN AUTOMATIC MILK FEEDER

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Automatic calf milk feeders (ACF) offer an opportunity to individually manage calf nutrition during the pre-weaning period to improve growth outcomes and manage transition weaning. Users of ACF are able to assign calves to feeding plans with predetermined milk feeding limits, weaning transition periods and milk entitlement ranges when calves enter the feeder. Consequently, milk allocation budgets can easily be set in order to determine rearing costs associated with milk requirements. However, changes in calf behaviour on ACF often mean that calves do not drink their full entitlement and the variation in drinking behaviour of calves impacts their growth rate pre weaning. The purpose of this research was to explore the drinking behaviour of calves reared using ACF when offered a high or moderate milk entitlement.

A study was carried out at Ashley Dene Research Development Station in Canterbury, New Zealand, between July and September 2024. Forty Holstein Friesian x Jersey heifer calves between 7 and 35 days of age and with similar breeding worth were randomly assigned to one of three feeding plans using an ACF (Lely Calm, Smart™, Lely, Canterbury, New Zealand). (1) Moderate daily milk entitlement with moderate milk allocation per feed (MoMo, 6 L/day, 3 L/feed, days 1 to 35), (2) high daily milk entitlement, moderate milk allocation per feed (HiMo, 10 L/day, 3 L/feed from 7 to 14 days of age, then 5 L/feed from 15 to 35 days), (3) high daily milk entitlement, high milk allocation per feed (HiHi, 10 L/day, 5 L/feed day 7 to 35). Calves on the high milk entitlement were transitioned to their full entitlement between day 1 and 7 of age, while calves on the low milk entitlement had no transition. Milk feeding consisted of 50% bulk milk colostrum and 50% calf milk replacer (CMR, Ancalf ™). From 7 days of age calves had *ad lib* access to starter meal (Calf Max® 20% Muesli, Seales Winslow) and pasture. Calf drinking behaviour at 2 weeks (7 to 14 days of age) and 5 weeks (28 and 34 days of age) was extracted. Repeated measures analysis of variance in Genstat (v 22 VSN International) was used to compare means of each age group.

Milk consumption was lower ($P < 0.05$) for the moderate (MoMo) compared to the high daily entitlement groups (HiMo, HiHi) both at 2 weeks (5.74, 7.37, and 7.82 ± 0.24 mean ± SEM L/calf/day) and 5 weeks of age (5.65, 7.05 and 7.47 ± 0.18). We were unable to statistically detect a 6% increase in milk consumption by calves in the HiHi compared to HiMo groups. Calves which were entitled to less milk consumed a greater proportion of their entitlement compared with calves entitled to more milk (Figure 1). An interaction between feeding regime and calf age showed that at lower daily milk entitlement calves maintained high consumption of milk entitlement (95%) while calves on the high daily milk entitlement improved consumption from 76% to 89% between 2 weeks and 5 weeks of age. Users of automatic feeders should account for lower milk consumption than target when using ACF if achieving target growth rates based on milk consumption is expected.

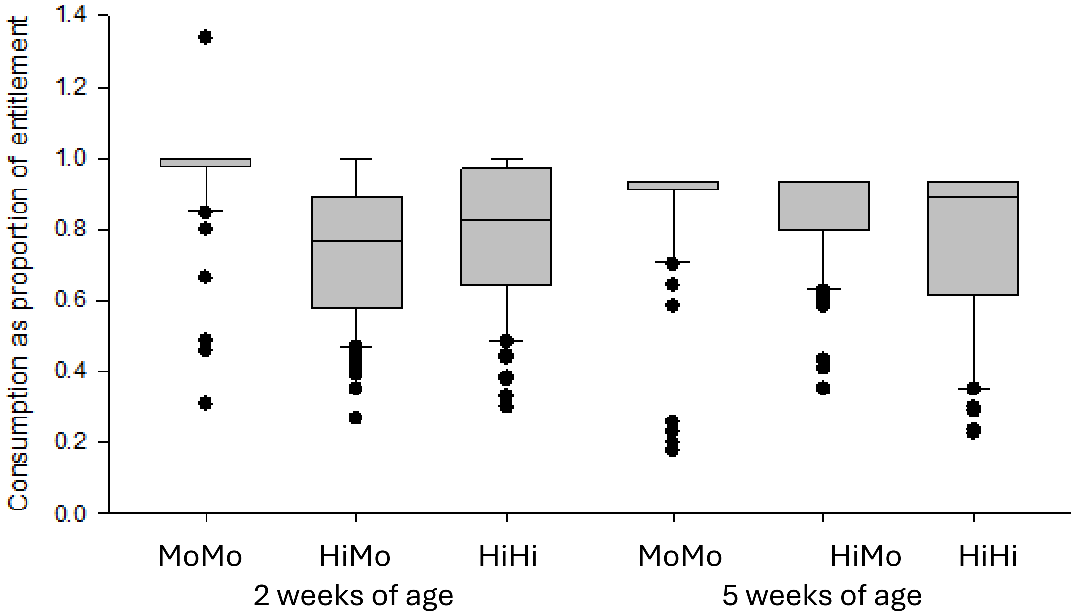

Figure 1. Box and whisker plots showing variation in the proportion of milk consumed relative to entitlement for calves on a moderate daily milk entitlement of 6L/day at up to 3L/feed (MoMo) versus high milk entitlement (10 L/day) at either moderate (HiMo, 3L/feed at 7 days then 5L/feed at 14 days old) or high (HiHi, 5L/feed) allocation per feed.

ARTIFICIAL INTELLIGENCE FOR DAIRY CALF MANAGEMENT: CURRENT TRENDS, AND VISIONS FOR THE FUTURE

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Group housing offers major welfare benefits for dairy calves, but it also makes disease detection more complex. The objective of this research was to use artificial intelligence to detect sickness behavior in calves with automated feeders and wearable technologies (n=140), and to design algorithms that classified calves with neonatal calf diarrhea (NCD) before they were clinically sick (n=300). Calves wore accelerometers that tracked activity behavior daily (total steps, activity index, lying time, and lying bouts) and used robotic feeders that tracked feeding behavior (milk intake, drinking speed, rewarded visits, and grain intake). Researchers conducted health exams for clinical NCD (loose or watery fecal consistency) and Bovine Respiratory Disease (BRD) status (i.e., according to the Wisconsin Scoring System, plus thoracic ultrasound exams). Calves had pneumonia when lung consolidation was consolidated ≥ 3 cm2, and they had positive outward signs of disease. We used logistic regression modeling to develop an algorithm that classified calves with NCD up to 24 hours before disease onset using relative changes in a calf's baseline drinking speed and milk intake by 60%. However, for pneumonia classification, more complex machine learning techniques were required. For example, a KNN nearest neighbor algorithm classified calves with pre-clinical pneumonia up to 6 days before disease onset using sickness behavior (activity and feeding behavior) at 96% accuracy. A limitation to this work was that most farms cannot afford a pedometer system and automated feeding system to manage their calves, and this system only explored data from one farm. With future refinement, it was observed that an AI algorithm CALF could constrain a farm's start up budget to allow only one PLF technology and still improve the detection accuracy of chronic calf pneumonia from 70 to 90% compared to veterinarian observation. This work suggests that AI can detect calf disease using changes in sickness behaviors. Future work needs to refine algorithms to classify BRD in calves before the onset of pneumonia to improve their welfare, and explore the possibility of other PLF technologies to classify sickness behaviors in calves.

Emerging scientists session and award

December 4, 2025, 4:00 pm - 4:30 pm

BEHAVIOURAL AND ENVIRONMENTAL NEEDS OF GRAZING DAIRY COWS: A REVIEW OF TECHNOLOGY-ENABLED INDICATORS

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Animal welfare assurance is becoming increasingly important to consumers, industry, and regulators. Many existing welfare assurance frameworks capture a range of health and welfare measures through periodic on-farm assessments; however, one-off visits may not reflect the animal's lived experience across time. The seasonally concentrated calving period and the outdoor nature of pasture-based dairy systems pose challenges throughout different times of the year for cows (Hendriks et al., 2025), which cannot be captured through one-off visits. Therefore, continuous monitoring could better reflect a cow's quality of life than traditional inspections; this could be achieved through technology. Animal-based measures are the gold standard and are a more direct measure of welfare than resource- and management-based measures, allowing an animal's interaction with their environment to be captured.

A review of 19 European welfare assurance schemes for dairy cattle and pigs reported that only 26% of schemes (n = 5/19) used predominantly animal-based measures, and one scheme in dairy cows utilised accelerometer technologies to provide information on animal welfare. Further, only 11% of dairy schemes (n = 1/9) applied at least 50% of animal-based measures within the appropriate behaviour area (Stygar et al., 2022). In a review of suitable welfare indicators for New Zealand dairy farms, Sapkota et al. (2020) reported only two feasible animal-based measures for application in pasture-based dairy cows addressing whether their environmental needs were met, despite this area having the most indicators overall (n = 13). Therefore, there is an opportunity to use technology aligned with cows' behavioural and environmental needs to support continuous monitoring and to provide more animal-based indicators that could capture key welfare risks within grazing systems.

This review identified animal-based welfare indicators of behavioural expression and environmental interaction that can be captured through technology. We consolidated evidence around what to measure, how to measure it, and the suitability of different indicators for continuous monitoring. Promising indicators that can be captured using commercially available accelerometers include lying time, rumination, grazing, and activity to understand cow time budgets. Emerging indicators such as behavioural synchrony (i.e. lying down with herd mates) may offer insights into positive welfare states but require further research. This review provides a foundation for the development of technology-supported welfare monitoring tailored to pasture-based dairy farms. Our insights will support the selection of meaningful, feasible indicators that can be integrated into welfare assessment tools to help farmers monitor and enhance welfare outcomes over time in grazing systems and provide quality assurance.

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Sapkota et al. 2020. Animal welfare assessment: Can we develop a practical, time-limited assessment protocol for pasture-based dairy cows in New Zealand? Animals 10:1918.

Stygar et al. 2022. How far are we from data-driven and animal-based welfare assessment? A critical analysis of European quality schemes. Front. Anim. Sci. 3:874260.

DAIRY FARMERS' WILLINGNESS TO SHARE DIGITAL ANIMAL WELFARE-RELATED DATA

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With growing consumer awareness of animal welfare in livestock farming (Winkel et al. 2020), dairy farmers face increasing pressure to document compliance with animal welfare standards and certification schemes. This presents challenges for farmers, primarily due to the extensive and time-consuming documentation required, as noted by Winkel et al. (2020) and Schukat et al. (2019). Precision livestock farming (PLF) technologies offer the potential to automate the collection of animal-based welfare indicators and reduce the need for manual documentation. According to Buller et al. (2020), PLF-based welfare monitoring has the potential to be integrated into both quality assurance systems and the wider agri-food value chain. Further, on-farm sensors enable real-time monitoring and may reduce inspection needs (Stygar et al. 2022; Krampe et al. 2024).

This study explores the factors influencing dairy farmers' behavioral intention (BI) to share digital animal welfare-related data. A standardized online survey was conducted among 269 dairy farmers in Germany between June and September 2024. The theoretical framework is based on an extended unified theory of acceptance and use of technology (UTAUT) model. To validate the model, partial least squares structural equation modeling (PLS-SEM) was applied.

The results (see Figure 1) show that trust in fair and secure data handling, along with perceived farm-level benefits, are the strongest drivers of farmers' BI. These factors not only influence farmers' intention directly but also shape their general attitude toward data sharing. In contrast, the perceived effort involved in using digital systems has a modest negative effect. External expectations, such as those from consumers or other stakeholders, play only a minor role, suggesting that farmers are primarily motivated by clear on-farm advantages rather than external pressure.

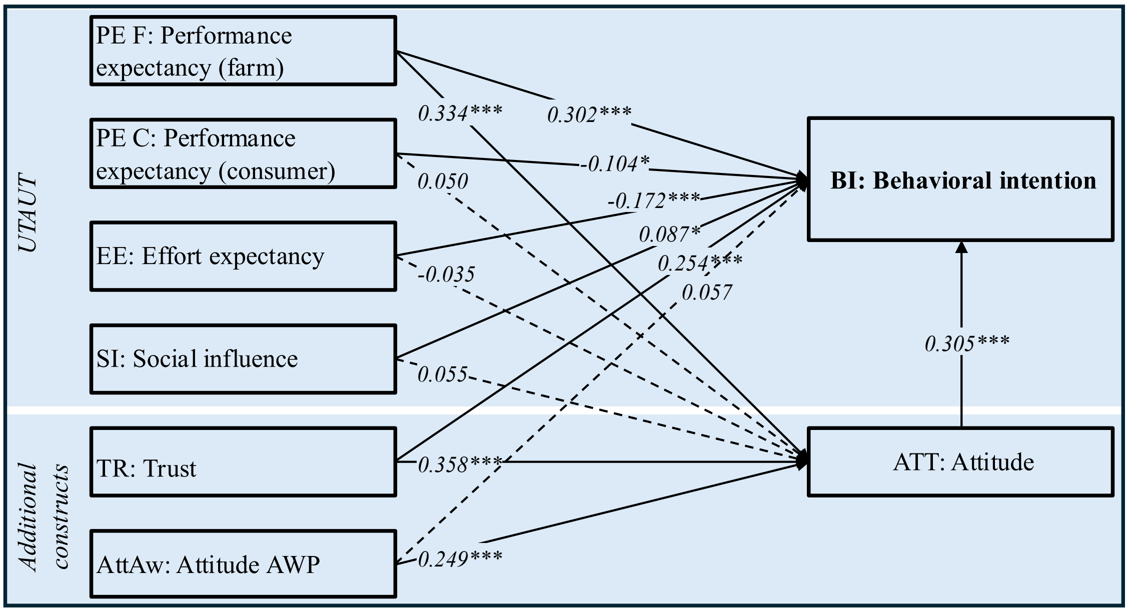

Figure 1: PLS-SEM analysis results – direct path coefficients from independent variables to mediator and dependent variable.

Notes: The sample size is 269.

Descriptive results indicate that, overall, farmers show a greater willingness to share data with private initiatives than with governmental bodies. Among the various data types, farmers are most willing to share productivity and housing data. Perceived benefits, such as market opportunities, benchmarking, and increased consumer acceptance, positively influence farmers' BI, while concerns about data security, surveillance, and the risk of wrong data interpretation reduce it.

To support data sharing in the context of animal welfare certification, digital systems must be perceived as trustworthy and beneficial at the farm level. Future research should prioritize the participatory development of such systems in collaboration with farmers and stakeholders along the value chain to ensure sustainable implementation.

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Winkel, Carolin; Schukat, Sirkka; Heise, Heinke (2020): Importance and Feasibility of Animal Welfare Measures from a Consumer Perspective in Germany. In: Food ethics 5 (1-2), S. 1–16. DOI: 10.1007/s41055-020-00076-3.

HIGH-THROUGHPUT SENSOR TECHNOLOGIES FOR IDENTIFYING EARLY INDICATORS OF PASTURE PERSISTENCE RISK

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Identifying early indicators of declining pasture persistence may enable livestock farmers to implement timely management strategies, such as adjusting grazing patterns, optimising fertiliser application, or improving pasture species selection, to increase the productive lifetime of their swards. Persistence assessments have traditionally relied on manual pasture measurements, that are subjective or labour-intensive, limiting their usefulness for tactical decision-making. With the rapid development of sensors and image processing algorithms, remote sensing platforms offer promising opportunities to accelerate the identification of early indicators of pasture decline. For instance, in recent studies, spectral sensors have been used to monitor pasture biomass, grazing patterns, variability in pasture growth, and plant physiological traits.

This study aimed to test the feasibility of multi and hyperspectral sensors for capturing early indicators (early summer plant height, pasture greenness, pasture dormancy, and pasture senescence) of pasture persistence risk at the paddock scale.

The study was conducted at the Hamilton SmartFarm (VIC, Australia), across 4.5 hectares of existing perennial ryegrass (PRG) paddocks. Ground-truth sampling (portable chlorophyll meter reading, ruler pasture height, and manually measured pasture dead and green biomass fraction) was taken between November and December 2024 at five locations within each paddock, using a 35 cm × 70 cm quadrat placed along a transect. The location of each sampling point was recorded with a RTK GPS. Spectral data were collected before and after ground-truth sampling using an airborne multispectral sensor (model: Altum-PT camera, www.micasense.com; Washington, USA) at 50 m elevation and a ground-based hyperspectral sensor (model: Specim IQ; Oulu, Finland). Data extraction and analysis were undertaken using multiple software platforms, including Pix4D 4.9.0 (www.pix4d.com;Switzerland), R 4.5.0 (https://www.r-project.org/) and QGIS 3.42.2 (https://qgis.org/).

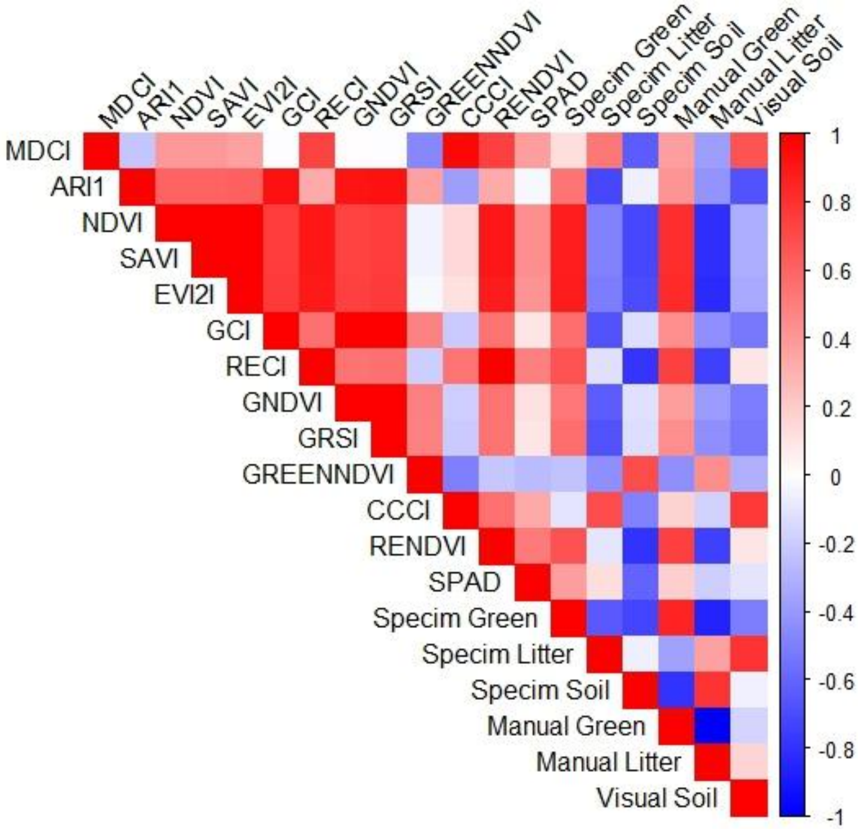

Figure 1. Pearson correlation matrix of multispectral vegetation indices, hyperspectral sensor-derived fractional ground cover, and manual observations related to pasture fractional ground cover, where red indicates a positive correlation and blue indicates a negative correlation.

There was a strong positive correlation between manually measured senescent dry matter proportion and the hyperspectral sensor-derived senescent ground cover, suggesting that the sensor-based approach reliably captured variations in senescence within perennial ryegrass swards (R^2 = 0.69). Moreover, a strong positive correlation was observed between visual ground cover and hyperspectral sensor-derived senescent plus green ground cover fraction (R^2 = 0.84). Strong positive correlations were found between multispectral vegetation indices such as NDVI, SAVI, EVI2, and GCI, and manually measured green pasture dry matter (Figure 1).

Hyperspectral data from the Specim IQ camera was able to accurately estimate green and senescent pasture ground cover during summer, while multispectral imaging at 50 m altitude provided sufficient resolution to differentiate green ground cover from bare ground and senescent pasture at a broader scale. The potential of UAV-derived vegetation indices, such as NDVI and RECI to estimate the chlorophyll content of standing pasture further supports the use of remote sensing platforms for monitoring long-term pasture longevity

DEVELOPING A CALF FEEDING BEHAVIOR ALERT TO CLASSIFY TRAINING SUCCESS USING AUTOMATED MILK FEEDER DATA

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Data collected from automated milk feeders (AMFs) may support the early prediction of calf training success on the feeder. The objective of this study was to evaluate whether AMF-collected feeding behaviors could be used to predict calf training success by day 4 on the feeder. Training success was defined as a calf visiting the feeder more than twice and consuming over 6 liters of milk in a single day by day 4. Calves that required more than 4 days to meet this training threshold were classified as unsuccessful. AMF-collected feeding behaviors analyzed included milk intake, drinking speed, rewarded visits, and unrewarded visits (e.g. when milk is not allotted). Additionally, relative changes in milk intake, drinking speed, and rewarded visits were calculated and analyzed. For the relative change calculations, day 4 was the 100% reference level for each behavior, with relative change calculated by the calf's daily behavior (day 1 to day 4) minus the day 4 behavior and then dividing by day 4 behavior. The dataset included 463 Angus × Holstein calves from a calf raiser in England. The calves had an average training duration of 3.46 ± 3.57 (mean ± SD) days, hence why day 4 was selected as the training threshold. Calves were offered near *ad libitum* milk from the AMF. Mixed-effects logistic regression models and receiver operating characteristic (ROC) curve analyses were used to evaluate predictors of calf training success. The fixed effects tested included milk intake, drinking speed, rewarded and unrewarded visits, relative changes in milk intake, relative changes in drinking speed, relative changes in rewarded visits, relative changes in unrewarded visits, sex, calf age of training, farm arrival weight, and various farm level factors (i.e. source farm, batch, pen, shed, and feeder). The best-performing model included the fixed effects of milk intake, rewarded visits, relative change in rewarded visits, and sex, with a random effect of source farm. The model (Figure 1) showed good discrimination with the ROC area under the curve (AUC) = 0.82, with high sensitivity (85%), moderate specificity (68%), moderate accuracy (72%), and poor precision (51%). The maximum Youden's index was 0.53 at a probability threshold of 0.26. These results suggest that feeding behavior captured by AMFs may be used to predict early calf training success. Future work should prioritize increasing model precision to reduce false positives.

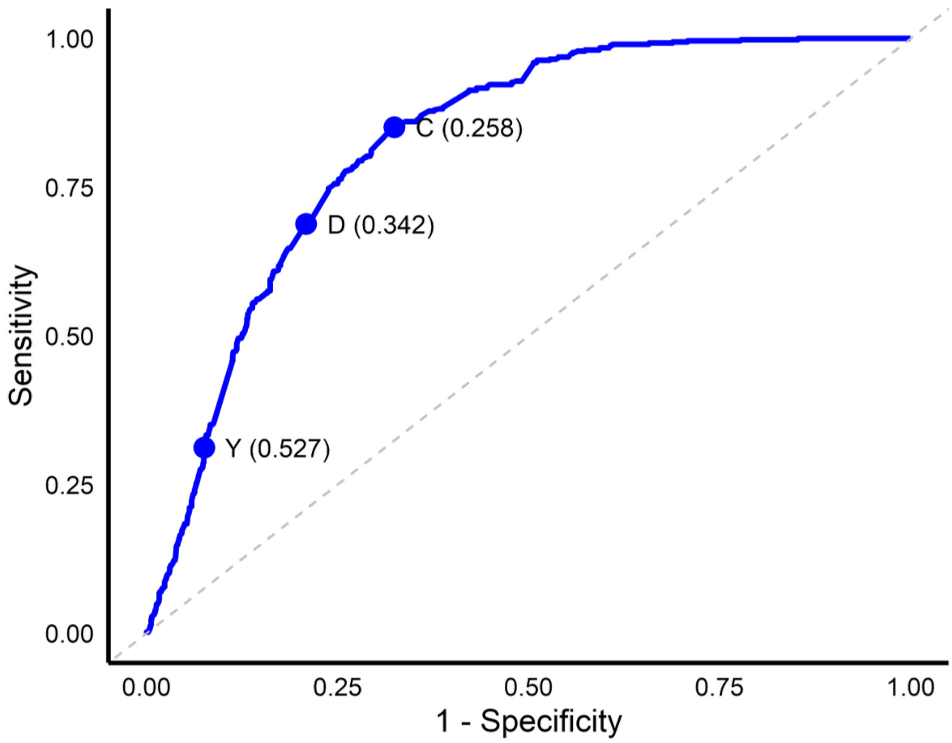

Figure 1. Receiver operating characteristic (ROC) curve plot from a mixed-effects logistic regression model with Youden's index probability threshold (Y), the optimal classification cutoff (C), and the maximum Euclidean distance (D) for classifying early calf training success by day 4 on an automated milk feeder (AMF). Fixed effects included milk intake, rewarded visits, relative change in rewarded visits, and sex, with a random effect of source farm. Calves (n = 463) were offered near ad libitum milk replacer from an AMF and were raised at a calf raiser in England. Model performance included an area under the curve (AUC) of 0.82, with sensitivity of 85%, specificity of 68%, accuracy of 72%, and precision of 51%.

PRECISION DAIRY FARM MODELLING: SEEING WHAT AVERAGES CAN'T SHOW

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The integration of trees into intensive dairy pastoral systems has the potential to improve the overall delivery of ecosystem services. Trees strongly influence understorey pasture production, soil conditions, microclimate, and animal welfare, yet their impacts vary widely with species, canopy morphology, height, and whether they are evergreen or deciduous. These differences create highly complex patterns of shade and solar insolation across farmed landscapes. Traditional non-geospatial models use average tree canopy cover or green crown length per unit of land area (such as a paddock) as an input, but this coarse metric overlooks the substantial within-paddock variability. As a result, estimates of tree–pasture interactions and their impacts are often inaccurate or incomplete. We demonstrate the potential of a pixel-based geospatial approach that maps tree influences at fine spatial resolution. By integrating canopy characteristics with high-resolution solar radiation and LiDAR vegetation metrics, and land surface data, our method captures detailed spatiotemporal patterns in shade and insolation. The resulting maps provide a more precise and comprehensive representation of tree impacts, supporting improved dairy farm management and landscape design to optimise both animal welfare and farm profitability.

Concurrent session 3

December 5, 2025, 11:00 am – 12:30 pm

3A | Cow monitoring and management

PRACTICE LEARNINGS FROM 12 MONTHS OF ENGAGING FARMERS IN WEARABLE FOCUS GROUPS

D.T.P. Hawkins

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The uptake of wearable technology for cows has progressed rapidly in the Waikato since 2021. There is a need to help farmers turn information into actions that drive improvements in animal well-being, herd productivity and team efficiency. Our team sought to:

- understand what systems are being used locally,
- why farmers are engaging with wearable technology, and
- determine the value of a charged wearable farm focus group.

In 2023, each clinic team compiled lists of clients' farms having wearable technology.

In May 2024, an online survey was sent to clients in the South Auckland/North Waikato using Allflex® collar technology. The survey posed 16 statements requesting agreement or disagreement and two open questions pertaining to why clients invested in wearable technology and to invite general feedback. Farms were personally contacted after the survey to discuss responses.

From September 2024, we began quarterly 4 hour wearable farm focus groups which 14 farms subscribed to. Participating farms provided access to their data through the Data Live® online portal. Each group followed a similar format with participant KPI sharing, specific diet analysis of the host farm, season specific topics and an extension or guest topic. Active client retention within the group beyond 12 months was considered a success.

In 2023, 20% of cows under our care were on farms using wearable technology and this has increased since. Systems represented included Allflex® collars (61.7%), Halter® collars (19.1%), Cow Manager® ear tags (16.0%), Afimilk® collars (1.7%) and Dairy Master® collars (1.6%).

Clients in the north part of the practice (representing 52.7% of cows with wearable tech) using the Allflex® collars responded (n=21) to the online survey. Clients were attracted to wearable technology for the following reasons: to create groups and manage drafting, improve heat detection efficiency and to identify sick animals. Clients were supportive of engaging their vet with wearable technology.

Clients felt varying degrees of confidence with the use of wearable technology in different areas (Table 1). Two thirds or more were confident the technology was delivering in the desired areas.

Table 1. Areas where clients felt greater or lesser degrees of confidence with the use of wearable technology.

Area		(n)		% Agreement	
1.	I have confidence using collars to draft groups	2.	14/21	3.	66.7
4.	I use collars to monitor pre-mating heats	5.	19/21	6.	90.5
7.	With collars, cows are mated at the correct time	8.	18/21	9.	85.7
10.	I understand why cows appear on health alerts	11.	13/21	12.	61.9
13.	I know what to do with cows appearing on health alerts	14.	16/21	15.	76.2
16.	I completely trust the collar's pregnancy diagnosis	17.	5/21	18.	23.8
19.	Collar technology is helping me make more milk	20.	9/21	21.	42.9
22.	I want my vet to access my collar data through an online portal subscription	23.	15/21	24.	71.4
25.	I will engage with a charged farm focus group	26.	11/21	27.	52.4

Of the farms that subscribed to the focus groups, 92.9% (13/14) farms will continue into the next subscription cycle.

SCR collar technologies are the most encountered technologies in our practice area. Drivers for investing in these technologies primarily revolve around making management easier and to reduce the demand on key staff over mating, rather than driving cow performance.

Secondarily, farmers are interested in managing sick cows with collar data. However, the ability of systems to update sufficiently fast enough to identify cows in acute distress, such as when calving, limits farmers' abilities to respond in a timely manner. Large numbers of health alerts in clinically normal cows can limit farmer perception of value. Providing support to help clients understand what alert patterns mean and how to respond maintains client perception of value in this area. Flowcharts are useful for farm teams to deal with health alerts.

Specific clients were approached for the formation of the focus group with the intention of attracting a group that would drive value from the group rather than waiting to receive it. Farmers within the group have shaped the direction of content and identified areas of interest for pursuit. Heat stress is an example. Patterns of heat stress have been compared to farm and environmental factors known within the group to identify farm specific risk factors. Accumulating baseline knowledge in areas such as this provides farm-specific insight into how we might mitigate risks in the future.

The challenge for this format is to remain relevant as familiarity with the technology grows.

We report that farmer investment in wearable technology is driven by making the management of cows and mating easier. There is opportunity for vets to work alongside farmers to add value to wearable technology. Farm focus groups can be used to enable farmers and practitioners to develop in this space.

PRECISION WITH PURPOSE: INTEGRATING DATA AND RURAL PROFESSIONAL INSIGHT TO TRANSFORM ON-FARM DECISION MAKING

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The rapid growth of data from wearable technologies on dairy farms presents an enormous opportunity - but also the risk of overwhelming rather than empowering farmers. Without clear interpretation, data remain abstract and underutilised. To fully realise the promise of precision dairy farming, data must be translated into meaningful, real-time insights by skilled rural professionals who act as critical connectors between data complexity and practical, on-farm action.

At Farmfirst Veterinary, we currently support over 100 wearable-enabled dairy farms across New Zealand, actively partnering with both farmers and technology providers to fully understand and maximise the potential of wearable farm data. Through a veterinary-driven initiative, we have created tailored, on-the-ground engagement designed specifically to enhance farmer confidence and simplify decision-making processes. This hands-on approach delivers measurable returns on investment and improved animal health. Our ongoing collaborations with technology companies help ensure insights remain cutting-edge, relevant, and directly aligned with our farmers' unique goals and operational challenges.

This oral presentation explores how rural professionals working at the grassroots partner closely with farmers to transform continuous data streams from wearable technologies such as CowManager, Allflex, Halter, Datamars, Herd-i, SmaXtec and numerous other technologies into actionable insights. By embracing this collaborative partnership model, rural professionals work alongside farmers to proactively utilise data at critical farming periods, including drying-off, calving, mating, and transition stages.

Farms and farmers that actively participate, embrace partnership, and champion technology stewardship consistently experience remarkable results. Improvements in reproductive outcomes include significantly higher six-week in-calf rates and substantially lower empty rates. Animal health is also noticeably enhanced, characterised by reduced incidence of diseases (such as non-cyclers, milk fever, and ketosis) and improved nutritional management strategies. These outcomes directly reflect deeper farmer engagement, confidence, and skilled application of precision technology.

Ultimately, precision dairy technology alone cannot deliver transformative outcomes. It is through skilled interpretation and the collaborative effort of dedicated rural professionals – veterinarians, consultants, nutritionists, and advisors – that data becomes truly valuable. By bridging the gap between technology and practical application, rural professionals empower farmers to harness data's full potential, creating sustainable, resilient, and profitable dairy systems for the future.

PRACTICAL USE OF WEARABLE DATA – SENSEHUB COLLAR FERTILITY REPORTS

R. Luckman

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Wearable data has provided a wealth of information for farmers and their advisors to use – with daily rumination, eating, and activity data, highly sensitive health alerts, heat stress warnings, and remote heat monitoring (to name a few!) the opportunities are endless, but can also be overwhelming. The question we set out to answer for this project was – could we turn this wealth of data into an easily digestible report, with summaries that are easily understood by vets and their farm clients, and with tangible actions that can be implemented on farm.

One of the key foundations for this project is the use of "Rasta Plot" benchmarking. Because we currently don't have scientifically validated targets for collar performance in New Zealand, these graphs report current farm level performance compared to what is being achieved across all other SenseHub farms in New Zealand. Each colour represents 25% of all farms (i.e. red is the lowest quartile of performers, green is the top 25%). This gives an idea of what levels are achievable within systems in New Zealand, and anecdotally they seem to motivate farmers to make changes far more than targets (regardless of their current quartile) because it is data from their farming peers. It should be noted that with the wide range of farm systems, feeding strategies, and breeds involved throughout New Zealand, vet involvement with interpreting the appropriate targets for a farm adds immense value.

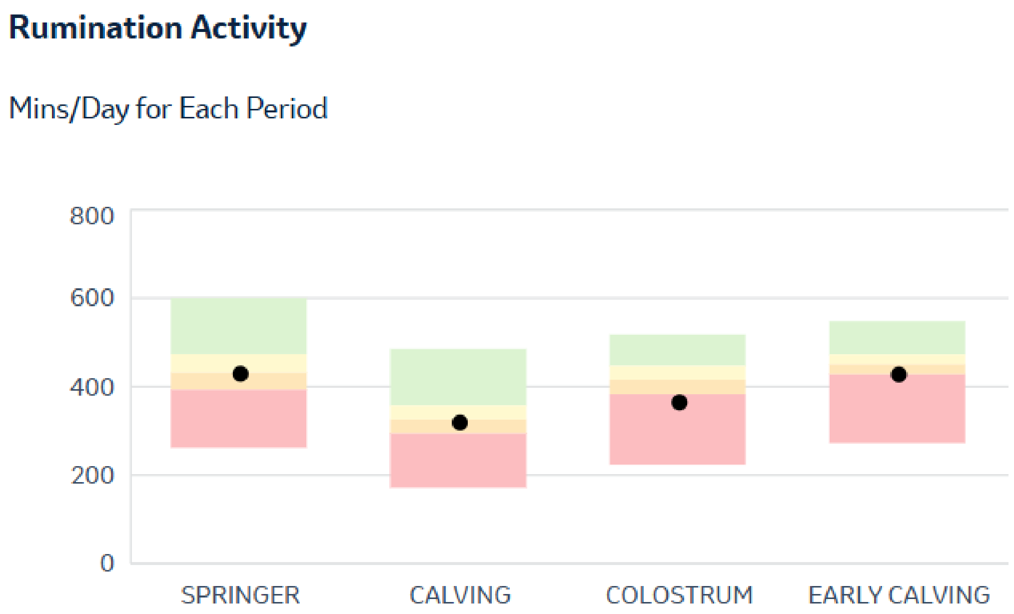

Figure 1. Example of "Rasta Plot" Benchmarking for rumination minutes in the transition calving period (10 days pre-calving to 10 days post-calving).

The SenseHub Collar Fertility Report includes the following 10 areas, covering the full-season period from calving through to end of mating:

1. average days in milk,
2. in-calf rate (by round of mating),
3. 9-week NICR (by age group),
4. transition rumination (peri-calving),
5. transition health alerts (by age group),

6. pre-mating cycling rates,
7. proportion of later calvers in the herd,
8. weekly submission rate (by age group) of non-pregnant animals,
9. weekly conception rate (by age group),
10. breakdown of not in calf cows (phantom rates, missed matings, never mated etc).

These reports have now been built into SensHub's "Datalive" platform, which is available to veterinary practices in New Zealand. They offer a good access point to be able to get collar data in a format that is easily interpreted (and doesn't require data handling skills). Alongside the fertility reports are other more detailed transition and pre-mating cycling reports, as well as a suite of other KPIs and graphs (such as rumination variability and consistency, health levels, heat stress etc) that can be assessed over specific time periods (e.g. mating) improving your understanding of how a SenseHub farm is tracking.

UTILISING COWMANAGER DATA INSIGHTS TO OPTIMISE REPRODUCTIVE PERFORMANCE IN SEASONAL, PASTURE-BASED DAIRY SYSTEMS

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Seasonal, pasture-based dairy systems in New Zealand operate within narrow reproductive windows, where effective monitoring of cow health and fertility is critical to whole-herd performance. In this context, CowManager®, an ear-tag-based precision monitoring system, has become a valuable tool for veterinarians and farmers aiming to enhance reproductive outcomes without increasing labour demands or disrupting pasture-centric management.

This abstract outlines the practical use of CowManager insights across New Zealand dairy herds, with a focus on behavioural data application from the transition period through to the end of mating. Particular emphasis is placed on how heat and health monitoring modules inform real-time decision-making across key reproductive stages.

Key areas of application include:

- Transition behaviour monitoring, where deviations in activity or eating patterns at a mob or herd level inform early interventions around nutrition or management.
- Days to first heat, tracked with precision and used as an indicator of calving recovery and reproductive readiness.
- Age group efficiency, where stratified reproductive data identify lagging cohorts (e.g. first-calvers) and quantify their impact on overall herd performance.
- Number of heats prior to mating start, which supports planning for non-cycler identification and targeted synchrony or hormonal intervention.
- Mid-mating progress tracking, including estimation of in-calf rates, detection of phantom heats, and assessment of whether further reproductive interventions are warranted.

CowManager provides a new layer of data insight that enhances the quality and timing of veterinary advice, while enabling farmers to act early and confidently. These tools are being used to support more informed decisions around nutritional management and herd management, during the critical mating period.

In conclusion, the integration of CowManager data into seasonal pasture-based systems offers a scalable, labour-efficient opportunity to improve reproductive performance. This approach aligns with the ongoing drive for precision technologies that complement rather than complicate New Zealand's pastoral systems.

MASTERING MASTITIS - OUR MILK QUALITY JOURNEY

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Mastitis is the largest single animal health cost in dairy farming. Changes to satisfy consumers' demand for milk quality, better animal health, carbon reduction, fewer antibiotics and minimisation of waste are all issues the industry must address.

Kaituna is a pasture-based, System 3 farm in North Canterbury where Aaron and Holly Jackson have been based for 8 years as sharemilkers. After a successful first season (121,000 cells/ml somatic cell count (SCC) average) the second season began at 184,000 increasing to 230,000 cells/ml alongside which clinical mastitis cases and antibiotic resistance emerged in the herd.

The Jackons implemented a science-based approach to mastitis management, hoping to improve their position, reduce their antimicrobial use, getting milk quality and mastitis issues under control.

Bulk tank culture identified a subclinical *Staph. aureus* issue that needed attention. Individual cow testing was used to identify and segregate *Staph. aureus* cows. Tools to help milk quality were implemented to assist, including the use of on-farm culture (for high SCC and clinical cases of mastitis) and increased utilisation of RMT testing. A procedure at first milking after calving to reduce the risk of day 2-4 mastitis using drying off procedures (teat spraying, alcohol wiping, and tail trimming) was introduced to control mastitis in early lactation. Other procedural changes implemented included avoiding skin contact with cows (and calves), not feeding milk to calves from cows with mastitis and infection control measures between cows at milking time. A selective approach for clinical mastitis based on on-farm culture results was adopted in conjunction with their veterinarian, and a selective dry off approach using cow history (including herd testing) and RMT was introduced. The biggest challenge was management of the Staph. aureus cows and these were managed out of the herd over time.

For four consecutive seasons, Kaituna has reduced antibiotic use, and no longer has an antibiotic resistance issue. For four consecutive years Kaituna has placed first in Fonterra regional and North Canterbury Veterinary Centre Milk Quality awards (last year STD SCC averaged 51K).

Time taken to conduct the new processes and procedures was a negative factor, but this was balanced by less time spent with mastitis cows including time treating, separating and subsequent milk waste, culls and treatment costs.

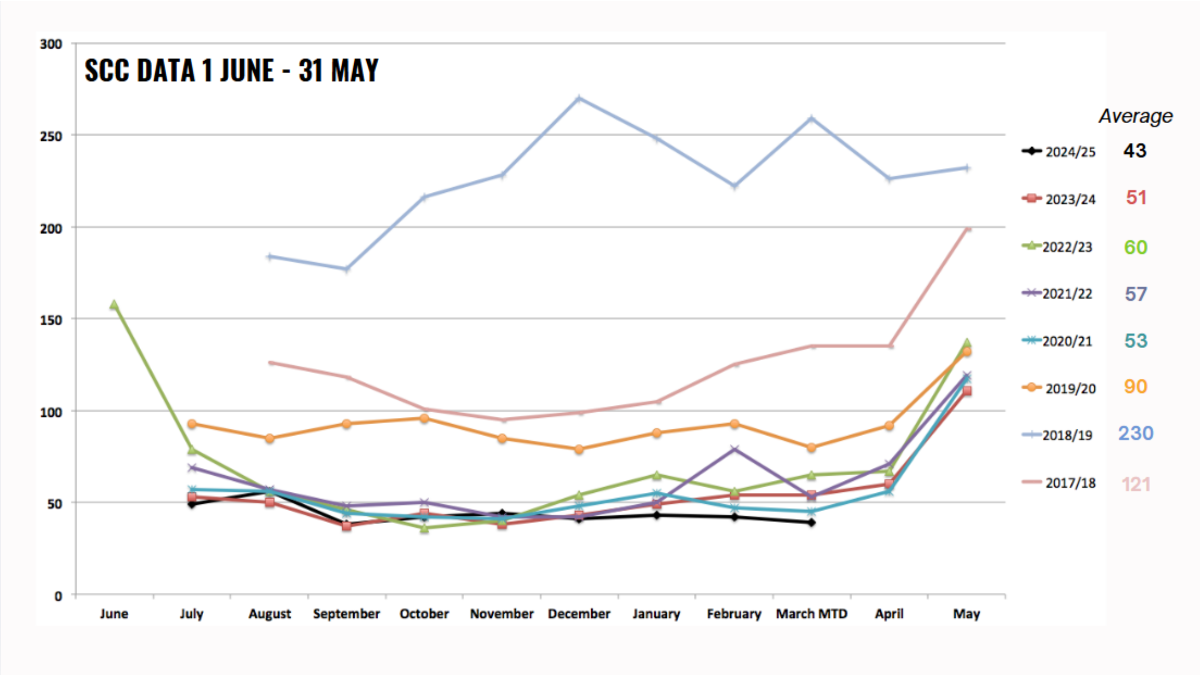

Figure 1. Kaituna farm SCC from 2017 to 2025 STD.

Somatic cell counts in New Zealand have been static for 10 years, and work is needed to improve these. Improving the useful lifespan of cows, implementing selective dry cow antibiotic therapy and reducing antibiotic use, the Jacksons' journey as farmers is a relatable example to consider the impact of small changes using a science-based data driven approach as a feedback loop. Examples where consistent results at low cost have been achieved may provide encouragement to others and showcase how New Zealand pastoral farming could answer some current industry issues.

IMPROPER BACKING GATE USE WITHIN COWSHEDS LEADS TO INCREASES IN MILKING TIMES AND LAMENESS

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Improper use of backing gates within dairy sheds leads to inefficient milking (driving up labour costs), increased cow stress and discomfort (driving up cow lameness).

When moved too quickly or too often cows experience pressure and stress, this causes agitation and reduces cooperation during milking. These stress factors can lead to cows developing hoof problems which significantly impact health and productivity of the animal. Every lame cow costs the farmer somewhere between $250 and $500 per year.

With the industry seeing a change in the demographic of NZ farm staff towards an increased number of international staff and a growing size of NZ dairy herds, we are also seeing increases in on-farm training challenges and increasing variation of backing gate use across herds. This variation in operation disrupts the smooth flow of cows into the milking area resulting in longer milking times, animal stress and increased labour costs as cows and milkers are required to adapt on-the-fly on any given day to these changing conditions. These issues are driven by improper use and training of staff.

Use of advanced artificial intelligence (AI) standardises backing gate movements across the entire milking season, removing the human element that drives the inefficiencies.

Livestock Visibility Solutions (LVS) has built a world-first system that utilises computer vision, machine learning, and integrates into the existing dairy farm infrastructure to standardise backing gate movement. This product, Flow, standardises movement based on cow density and automatically moves the gate within the following parameters:

- density dropping in the yard,
- moves no more than once every 30 seconds,
- moves a fixed percentage of the yard.

LVS has integrated and installed hardware into nine farms. Measuring all farms over two complete milking seasons against a control farm. Milking times were measured by the Flow system from when the first cow was "seen" to enter the yard until the last cow was "seen" to leave the yard.

On average, consistent use of Flow saw a decrease in milking times of 18.55%, self-reported they saw a decrease in average lameness of 15-20% and a decrease in power cost of 9%.

Table 1. Milking times of Flow compared to the control farm.

	Control	Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6	Farm 7	Farm 8
Shed size	60	60	60	60	60	40	60	54	50
Shed type	Rotary	Rotary	Rotary	Rotary	Rotary	Herringbone	Rotary	Rotary	Rotary
Yard type	Round	Round	Round	Square	Square	Square	Round	Round	Round
Herd size	1,100	1,250	1,400	1,350	1,400	850	850	700	650
Average hours per milking	3	2.8	3.2	2.95	3.1	1.9	1.9	1.5	1.45
Average seconds per cow	9.81	8.06	8.22	7.86	7.97	8.04	8.04	7.71	8.03
Variation from control (%)	0	17.86	16.19	19.87	18.80	18.03	18.03	21.42	18.20
Average milking reduction					18.55%				

Table 1 shows the farm data as a comparison against the control farm. These data indicate that herd size, shed size or configuration, or yard shape is less important than standardising backing gate movement across milkings/herds.

Using the above, financial modelling was conducted for Flow farmers, looking at three key aspects:

1. labour savings,
2. lameness savings,
3. power savings

Using industry-standard costs derived from DairyNZ, modelling shows Flow farmers saved $13,750 in reduced lameness, $6,023 in reduced power costs, and $27,732 in labour savings. On average, Flow farmers saved $47,505 (gross) per season.

Using Flow to standardise backing gate control and movement greatly improved milking efficiency. Decreased milking times and improved animal health outcomes led to an average improvement to the farmers' bottom line of $47,505 (gross) per season.

WHO? WHAT? WEARABLE! LESSONS FROM VET-LED FARMER PANELS ON PRECISION DAIRY ADOPTION

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Veterinarians play a crucial role in supporting farmers' animal health decision-making. Wearable technology, such as collars, boluses, and tags, is already used on many farms to support management decisions, yet a large number of farmers are still deciding whether it's the right fit for them. Can wearable technology realistically help solve their on-farm problems or aid in their aspirations?

Anexa Veterinary Services hosted a vet-facilitated farmer panel featuring experienced early adopters of wearable technologies from a range of companies. The goal of the discussion was to help prospective users critically assess their own situations and learn from peers who had already navigated the adoption process.

The event revealed valuable insights into farmer motivations, expectations, and technology use. Interestingly, and in contrast to our veterinary perception, 'animal health' was cited by farmers as the most predominant motivation for investing in wearable technology. There were consistent opinions from both vets and farmers that wearable technology is expected to reduce workloads around mating and help with heat detection. These findings highlighted a possible expectation mismatch but also a valuable opportunity for veterinarians to actively support the adoption decision-making process and help farmers better use their data.

Early veterinary engagement in the technology journey fosters stronger partnerships and ultimately leads to better outcomes for animal health, farm productivity, and long-term success.

IN-VIVO MONITORING: UNMATCHED PRECISION VIA BOLUS SENSORS

J. Hill

SmaXtec Limited

The idea for smaXtec was born from the curiosity of two engineers who stumbled upon a problem in dairy farming: rumen pH measurement is highly valuable for research and improving dairy farming but could previously only be done with great difficulty and for a few cows. The founders quickly realised that there had to be a better solution. As pioneers, they started developing sensors that continuously collected data inside the cow. After a few years, the concept had evolved into a university research project, and today, smaXtec is the global market leader in internal cow monitoring systems using bolus technology. What began with pH measurement soon revealed even greater potential - the rumen provided access to unique and highly valuable data.

As smaXtec expanded, new parameters and features were added to its monitoring capabilities:

- TruRumi™: This innovation brought the addition of precise rumination activity data, made possible by direct measurement in the reticulum. This enables dairy farmers to make better-informed decisions on health, nutrition, heat detection, and calving.
- TruDrinking™: This AI-powered feature made smaXtec the first and only system to provide accurate, individual data on water intake and drinking cycles for each cow – critical for early health insights and management.
- TruAdvice™: By combining bolus technology with artificial intelligence, TruAdvice™ delivers the first-ever disease indication notifications. By analysing millions of data points, the AI calculates the probability of specific diseases. For example, an alert may indicate a 90% likelihood of mastitis, ketosis, or milk fever – enabling farmers to intervene early before any visible symptoms appear.
- From monitoring to health management: With the introduction of the Digital Assistant, smaXtec has moved from monitoring to proactive, preventive health management – empowering farmers with actionable insights and customised lists.

Among all the features, pH measurement has always been a key component from the very beginning. To measure pH levels, smaXtec developed a pH bolus, which allows for the gold standard in identifying feed management issues. The pH value reflects how acidic or alkaline the rumen is, and since the forestomach is highly sensitive and influenced almost exclusively by feeding (unlike rumination activity), it is an ideal parameter for evaluating and optimising nutrition. The more stable the pH value, the better the environment for efficient rumen flora. With this information, dairy farmers can detect feeding issues, monitor changes in feed quality, and optimise nutrition for both individual animals and groups.

How the system works:

1. SmaXtec boluses measure inner body temperature, drinking behaviour including drinking frequency and water intake, rumination via reticulum contractions, movement activity, and pH directly in the reticulum.
2. The Base Station automatically reads the data. The Climate Sensor provides additional information on the outside temperature, humidity, and atmospheric pressure in the barn.
3. In the smaXtec Cloud TruD™, the data is analysed using artificial intelligence and proven algorithms.
4. The data is displayed through graphs and alerts in a customisable app and software, accessible via smartphone or PC.

ON-FARM USE OF VIRTUAL FENCING IN GRAZED DAIRY FARM SYSTEMS

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The use of wearable technologies has increased in the past five years in New Zealand (NZ) dairy systems. One of the more novel and potentially transformational wearable technologies is virtual fencing (VF). We believe between 5 - 10% of NZ dairy farmers are utilising VF on their dairy farms. However, there has been limited information captured about how the approach is being used on-farm and what is the potential impact on hours worked and grazing management. The aim of this study was to analyse the impact of VF use on grazing and the wider farm system.

A qualitative, semi-structured method was used to examine the use of VF on dairy farms. Twenty interviews were conducted in 2023, half in Canterbury and half in Waikato. The interviews covered themes including farm system description, investment rationale, use of technology for operational management, data and interface interaction and impacts on the dairy workplace. Farmers were identified through professional networks and were selected to provide a range of farm systems, sizes and ownership structures. Interviews were voice-recorded, transcribed, and analysed using inductive content analysis methodology with Atlas.ti software.

Farmers in the study highlighted a range of benefits, operational management changes, farm systems adaptation and implementation challenges when using VF. Overall, participants felt the use of VF technology was positive for their farming practices, particularly control over more intricate grazing practices and herd management. The technology enabled time to be saved on farm at key times of the day, such as early morning and in management of grazed crops. Predicted financial benefits were not obvious through many of the interviews and a large benefit of the VF system was non-financial, such as greater control of aspects of herd management, new data streams for decision making, making tasks on-farm easier, enabling more visibility over herd management practices and more opportunity to complete tasks from home or remotely.

Grazing management practices and outcomes represent a large opportunity from VF technology, due to fast feedback loops for decision making, high visibility on animal/pasture interaction, and a greater level of control around grazing methods, such as accurate break sizing and timing to optimise utilisation.

Farmers implementing VF on their farms represent a first tranche of a potential wave of VF users in the next decade. Interview participants were generally positive about the usefulness and usability of the technology and were quickly adapting to its use. Realising greater financial value of VF will likely be important to farmers, particularly with fluctuating seasonal milk prices.

USE OF DRONE BASED REMOTE SENSING TO DETERMINE THE SPATIAL DISTRIBUTION OF CATTLE DUNG UNDER CONVENTIONAL AND REGENERATIVE MANAGEMENT

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In grazed pasture systems up to 60% of dung and 55% urine is returned unevenly, covering only 15 to 35% of the paddock. Increasing the percentage of the paddock receiving dung and urine each year will improve the recycling of nutrients, reduce annual nutrient requirements and lower the risk of nutrient losses. Regenerative grazing practices, where animals are stocked at higher stocking densities and moved more frequently than conventional grazing practices, are promoted in part on that basis they result in a more even return of dung and urine, reducing the impact of the operation on receiving environments.

The objectives of the study were to (1) determine whether a drone mounted with a Red, Green, Blue (RGB) camera could identify and map the spatial distribution of dung in a grazing area, (2) test the sensitivity and specificity of this method compared to the "gold standard" of Global Positioning System (GPS), (3) establish if a regenerative grazing practice influences dung and urine distribution.

A drone mounted with an RGB camera was used to locate and map the spatial distribution of cattle dung in a study comparing conventional pasture management (e.g., pasture was of grazed for 3 days) and regenerative pasture management (e.g., cattle were moved multiple times a day). A DJI Mavic 3 drone with an RGB camera was flown 30 m above the ground, taking photos with 75% overlap. The photogrammetry program pix4d combined the images to make one large image. Individual dung patches were marked on the aerial images in ArcGIS Pro. The location of dung patches from 12 cells (4 conventional cells, 8 regenerative cells) was recorded by hand using an RTK Trimble GPS to validate the accuracy of the drone-based method.

In all 12 grazing cells the drone method located up to 95% of dung patches identified by the GPS, even in challenging conditions (e.g., higher pasture covers, wet conditions with some pugging of the soil). In general, the drone detected fewer dung patches than the GPS. The spatial distribution of the dung patches measured by the two approaches was comparable particularly in areas with mid to high dung distribution. Under conventional grazing, the mean number of dung patches per hectare was 1,173 (minimum 471; maximum 1892). Under regenerative management, the mean number of dung patches per hectare was 1,610 (minimum 533; maximum 3098). The number of dung patches deposited was not significantly different by management, regenerative grazing resulted in greater variation in the spread of dung patches. Cattle dung return had a higher degree of clustering under the conventional than regenerative grazing practice, where dung was more evenly spread across a paddock under this management.

The study has established that remote sensing of dung patches using a drone offers efficiencies that are not possible using the traditional approach of in-paddock identification, while retaining high efficacy with a low false positive identification rate. This new method could be used to map dung patches and help to identify opportunities for more targeted nutrient application using variable rate technologies.

AGSCENT GHG METHANE MEASUREMENT SOLUTION FOR ON-FARM DECISION MAKING IN DAIRY SYSTEMS

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Methane emissions from dairy production represent a significant challenge for the industry, accounting for a substantial portion of global methane emissions while also representing energy loss in animal systems. The Agscent Air, a greenhouse gas (GHG) sensor designed specifically for on-farm use, offers dairy producers a practical tool to monitor and measure livestock emissions in real-world conditions. This self-calibrating, low-maintenance technology provides a solution to the common challenges of methane measurement in livestock systems, which include emission variability, methodological limitations, scale issues, environmental interference, technical complexity, and cost barriers.

The Agscent technology employs Tuneable Diode Laser Spectroscopy (TDLAS), a sophisticated approach commonly used in laboratory settings, to achieve high precision in methane detection. Complemented by NDIR CO_2 sensors, the system continuously records methane and carbon dioxide concentrations. The Agscent GHG 2100 standalone system can be integrated into dairy infrastructure including feed bins, water points, and robotic milking systems, while the GHG OW system combines methane measurement with liveweight monitoring through Optiweigh integration.

Research conducted at multiple institutions has validated the effectiveness of Agscent's approach. Studies at Sydney University found strong correlations ($P < 0.001$) between Agscent Optiweigh measurements and GreenFeed system CH_4 measurements ($r \sim 0.70$). Cornell University research demonstrated significant correlations between the Agscent Air standalone sensor and reference chamber measurements, with Pearson's correlation coefficients of 72% for methane and 66% for carbon dioxide. Research at Hartpury University's dairy shed showed that time-series analysis of methane amplitude during milking demonstrated statistically significant correlations with total herd emissions, confirming the technology's ability to effectively monitor dairy herd methane during routine milking. For dairy producers, this measurement capability translates into several valuable applications.

Continuous methane monitoring supports data-driven decision-making regarding feed formulations, animal selection, and management practices. By identifying high methane emitters, farmers can implement management strategies that improve animal health, productivity, and digestion efficiency. The technology's ability to establish accurate emission baselines positions dairy operations to demonstrate sustainability commitments, potentially access voluntary carbon markets, and prepare for future regulatory requirements. In dairy-specific applications, the system can be deployed within feed bins to measure breath emissions while cows consume feed, integrated into robotic milking systems, or used for shed-level measurements. Hartpury University's research specifically demonstrated the technology's effectiveness in monitoring herd methane during milking routines, opening new possibilities for dairy emissions management without disrupting normal farm operations.

As the dairy industry faces increasing pressure to reduce its environmental footprint while maintaining productivity, the Agscent GHG technology offers a practical, accessible, and scientifically validated approach to measuring methane that can support strategic decision-making, improve efficiency, and potentially create new market opportunities based on verifiable emissions data.

FEED CONVERSION EFFICIENCY PREDICTION BASED ON MEASURED CO2 PRODUCTION FROM LACTATING DAIRY COWS

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Improving feed conversion efficiency - such as energy corrected milk production (ECM)/gross energy intake (GEI) - is a strategy to mitigate CH_4 intensity (g/kg ECM) in dairy cows. However, determining ECM/GEI under grazing and on-farm conditions is challenging, as GEI cannot be directly measured. Gas emission measurements, including CO_2, are becoming more common under farming conditions and have been proposed as a proxy for feed efficiency when GEI cannot be measured.

The objective was to determine the relationship of ECM/CO_2 production or residual CO_2 (RCO_2; observed – predicted from ECM and metabolic body weight (MBW)) with measured ECM/GEI in lactating dairy cows fed fresh pasture-based diets in respiration chambers.

Data were compiled from seven respiration studies involving 120 lactating Kiwi-cross dairy cows, including records on CO_2 production, BW, GEI and ECM. Additionally, CO_2 production was predicted with 5 extant equations based on ECM and MBW to enable calculation of RCO_2, a proxy measured previously linked to residual feed intake. Pearson correlation and linear regression analysis were conducted in GenStat v23 to determine the relationship of ECM/CO_2, RCO_2 and other measured parameters with ECM/GEI. Among the tested parameters, ECM/measured CO_2 had the strongest correlation with ECM/GEI (r=0.94). ECM/BW (r=0.84) and RCO_2, calculated based on two CO_2 equations (r=-0.84, -0.89), also had strong correlations with ECM/GEI. The ECM/GEI (% of GEI) could be predicted with ECM/measured CO_2 (kg/kg) with the REML regression equation (with study as a random effect in the model): ECM/GEI = -0.5925 + 14.04 × ECM/CO_2 (r^2=0.88). Furthermore, ECM/GEI had a strong negative correlation with CH_4/ECM (r = -0.81), but a weak correlation with CH_4 production (g/d; r=-0.23) and yield (% of GEI; r=-0.21). In conclusion, ECM/CO_2 was strongly associated with ECM/GEI. Improving this trait on-farm will simultaneously reduce (i.e., improve) residual feed intake and CH_4/ECM in lactating dairy cows.

USING DAILY MILK METER AND WALK-OVER SCALE DATA TO IMPROVE THE PREDICTION OF DAIRY COW-LEVEL ENTERIC METHANE EMISSIONS

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Enteric fermentation from dairy cattle is one of the largest sources of greenhouse gas (GHG) emissions in New Zealand and is a key category within the national GHG inventory framework. The New Zealand GHG inventory methodology (NZGHGI) to estimate enteric methane (CH_4) emissions in dairy cattle assumes, for simplicity, that lactating cows maintain a constant body weight (BW) throughout each lactation.

This study aimed to evaluate the effect of BW changes throughout lactation on estimated CH_4 emissions in grazing dairy cows. Data from 871 cows from a dairy unit in the Waikato region were obtained for the 2023-2024 lactation season. The data included daily records for walk-over BW and milk meter milk yields (MY), along with sporadic body condition scores (BCS) and herd tests. Random regression models (RRM) with Legendre polynomials were used to fit the trajectories of BW, MY, BCS, and the fat and protein percentages in milk (F% and P%, respectively) on days in milk (DIM) over the first 270 days of lactation. Legendre polynomials of order 3, 4, and 6 were considered the best fit to model MY, BCS and BW, respectively. A second-order polynomial was the best fit for modelling milk fat% and protein%. The estimates of BW, BSC, MY, fat%, and protein% were used to calculate total metabolisable energy requirements (ME_{total}), dry matter intake (DMI), and CH_4 emissions under two scenarios. The first scenario (S1) assumed a constant body weight over the lactation (NZGHGI default), estimated as the mean BW for each cow. The second scenario (S2) considered daily BW changes. CH_4 emissions per cow were 44 g/d (95% CI: 36-51 g/d) higher for S1 than for S2 ($p<0.001$) during early lactation when cows lost BW. This relationship reversed after 53 DIM when CH_4 emissions were 22 g/d (95% CI: 20-24 g/d) lower in S1 than in S2 ($p<0.001$) for the rest of the lactation when cows gained BW (Figure 1). This was due to the BW loss cows experienced during early lactation when they mobilized energy from body tissues for milk production, followed by a subsequent BW gain during the rest of lactation. An analysis of variance showed a significant effect of parity and breed on the estimation of CH_4 emissions under both scenarios. CH_4 emissions for the total lactation of 270 days were similar between S1 and S2 (79.3 and 81.8 kg, respectively). However, since at 270 DIM, cows had not reached the initial BW and BCS, there would be a higher extra energy requirement during the dry period that the S2 would account for due to the BW and BCS gain the animals experience during this time. The estimation of CH_4 emissions in dairy cattle requires inputs from traits that have repeated measures over the production season. RRM, with functions such as orthogonal polynomials, were useful to model longitudinal data, particularly if the traits measured changed gradually over time. Further attention is needed to model the edges of the lactation period, where the curves exhibit high sensitivity to data distribution.

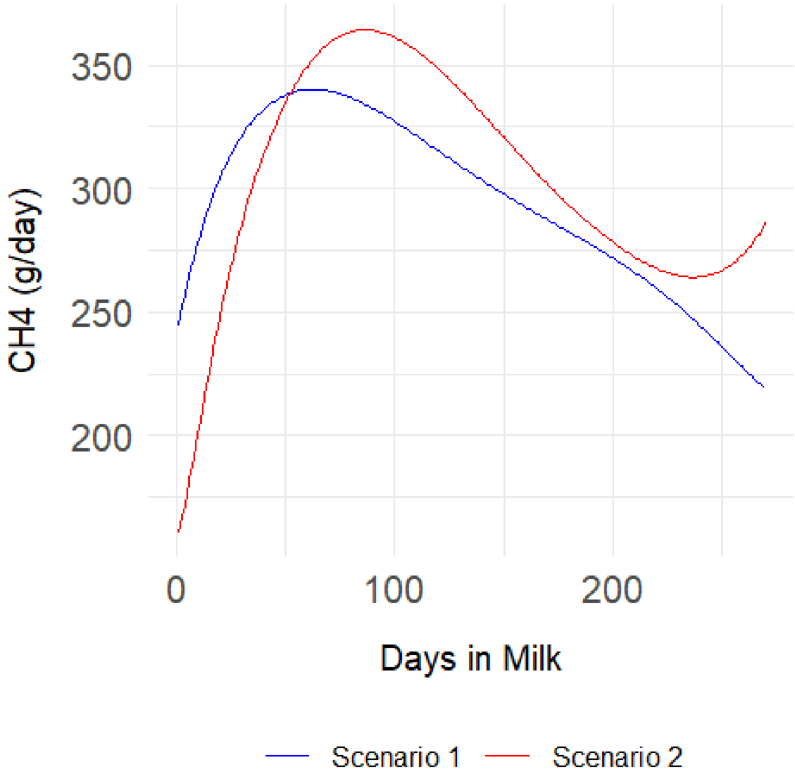

Figure 1. Estimated methane emissions (CH_4, g/d) in New Zealand dairy cows for the first 270 days in milk, assuming a constant body weight over lactation (Scenario 1) and considering body weight changes over lactation (Scenario 2).

A PROTOTYPE MILK-BASED INDICATOR TOOL FOR FARMERS TO MANAGE HERD DIETARY NITROGEN SURPLUS AND REDUCE NITROGEN LOSS RISK IN PASTURE-BASED DAIRY SYSTEMS

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In pastoral dairy systems, the amount of protein (and therefore nitrogen [N]) relative to energy in the herd's diet often exceeds their requirements for maintenance and production. This surplus dietary N is predominantly excreted as urine onto pasture where it is at risk of being lost to the environment via leaching or gaseous emissions. Limited options exist to provide insights and feedback for strategic or tactical decisions to manage risk of N loss to the environment throughout the lactation season, with most farmers relying on retrospective analysis using annual data reported through their milk processors or models such as OverseerFM.

We investigated if bulk milk urea could be a useful near real-time indicator of herd dietary N surplus or deficit (relative to requirements) and urinary N loss risk in pasture-based systems. Multiple analytical approaches and datasets (including a phenotyping study, observational studies of commercial dairy farms, and meta-analysis of published data) were used to determine relationships between milk urea and dietary N use efficiency (milk N ÷ diet N), dietary protein supply, N output in milk, and urinary N excretion. From this, we established that milk urea was moderately positively associated with urinary N excretion and herd dietary N surplus, accounting for about half of the variation in each parameter. A bulk milk urea concentration above ~25-30 mg/dL suggests an increasing risk of dietary protein surplus, higher urinary N excretion and lower dietary N use efficiency (Figure 1). A milk urea concentration below ~17-22 mg/dL may indicate a risk of insufficient dietary protein and should only be considered along with analysis of other diet, animal and management information.

These analyses have enabled the development of a prototype bulk milk urea-based indicator tool, which farmers can use to optimise their N use efficiency, increase their awareness of N loss risk and identify when mitigations could be utilised to reduce high urine N loading onto pastures at critical risk periods for N leaching. When combined with other farm information at both a tactical and strategic level, this tool could support decisions for improved efficiency of N imported onto farm as fertiliser or supplementary feed, and optimisation of grazing management to reduce the risk of surplus dietary N.

Developing this bulk milk urea indicator tool has harnessed input from farmers, researchers, rural professionals and milk processors. The prototype online tool allows farmers to visualise their herd's bulk milk urea data in near real-time during the season and make comparisons to previous years as well as district averages. It also includes guidelines that support farmers to understand how they can use the tool, interpret their bulk milk urea data, and consider management options to reduce their risk of herd dietary N surplus or deficit, or apply practices to reduce the risk of higher urinary N loading.

The bulk milk urea indicator could complement other tools farmers use to manage environmental risk such as farm environment plans and annual environmental reports or modelling. Widespread adoption of this tool could help farmers to optimise N use efficiency and achieve significant reductions to their N loss risk.

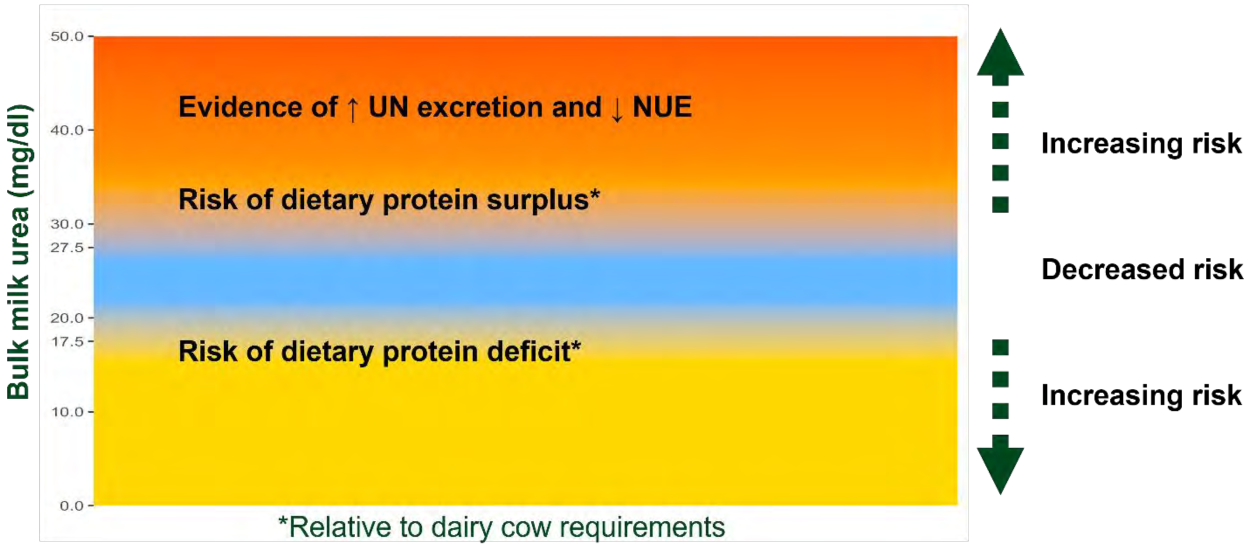

Figure 1. Proposed bulk milk urea zones for pastoral dairy systems. This gradient could be used as a first pass indicator alongside other diet, management and animal information. UN = urinary nitrogen, NUE = dietary nitrogen use efficiency.

A SOIL HEALTH DASHBOARD FOR NEW ZEALAND PASTORAL SOILS

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The health of agricultural soils plays a pivotal role in ensuring sustainable food production and ecosystem stability. To support land managers and researchers in assessing and improving soil health, we have developed an interactive Soil Health Dashboard using R Shiny. This prototype web-based application integrates field and laboratory data to provide a comprehensive, user-friendly platform for visualizing soil health indicators, interpreting results, and informing management decisions at the farm level.

The dashboard begins by collecting farm-specific details, including the name, address, and location of soil monitoring transects, allowing for easy identification and spatial referencing of each assessment site. These details provide context for site-specific soil conditions and facilitate longitudinal tracking of soil health over time. The application supports the entry of standard soil chemistry and organic matter properties reported by commercial laboratories, as well as field-collected data, such as visual soil assessment scores and biological observations performed by farmers or advisors. Users can input this data manually or upload it in bulk, ensuring flexibility and accessibility for various user groups.

Upon data entry, the dashboard computes and presents soil health indicator values through an intuitive set of visualizations. A bar chart compares individual indicator values to pre-defined target ranges, enabling users to quickly identify whether a given metric falls within optimal, suboptimal, or critical thresholds. This visual approach simplifies the interpretation of complex data and helps prioritize areas of concern. The application also includes a radar plot, which aggregates all indicators into a single graphic. Each axis of the radar plot represents a soil health metric, and the distance of each point from the centre reflects how close that value is to the optimal range. This feature allows for rapid assessment of overall soil condition and highlights the most divergent indicators.

To understand the impact of the soil health indicators when they are not at target, the dashboard links the indicators to specific biological functions, beginning with pasture production and relative yield. It calculates which indicator is most limiting to this function using a rule-based or data-driven approach. This process is important to understand the impact of soil health on farm performance to enable targeted interventions. These targeted interventions are given for each indicator, with context-specific management options tailored to whether the values are within or outside of target ranges. These suggestions are grounded in agronomic research and practical field experience, helping users make evidence-based decisions to enhance soil function and productivity.

We will provide case studies to show the how the Soil Health Dashboard can be applied to generate downloadable reports that include farm details, data inputs, visual summaries, and recommended management actions. This prototype Soil Health Dashboard advances our ability to understand and manage our pastoral soils.

IMPROVING MANAGEMENT OF DAIRY FARM EFFLUENT USING IOT TECHNOLOGIES

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Managing effluent well on farm is critical not only for environmental compliance, but also for ensuring nutrients from effluent are distributed effectively and in the intended place. This project explored how LoRaWAN-enabled IoT systems can be used on dairy farms to automate the collection of data related to routine tasks and enable remote monitoring and control. LoRaWAN is a low-power, long-range wireless communication technology that provides cost-effective connectivity for remote, low-energy devices. A project was undertaken to apply this to the monitoring and management of dairy farm effluent (DFE) to support improved compliance, environmental protection, and nutrient utilisation.

Co-funded by Sustainable Food and Fibre Futures (MPI) and private IoT industry, the project aimed to develop IoT devices collecting accurate, near real-time data related to effluent storage and application. This was intended to:

- Reduce the risk of environmentally harmful effluent application events.
- Improve nutrient management through better data on where and when effluent was applied.
- Lower the administrative burden associated with demonstrating compliance.
- Investigate farmers' attitudes towards IoT adoption and its perceived value.

Following prototype development, nine farms across Taranaki, Waikato, and Canterbury participated in trials. These represented various effluent systems: travelling irrigators, centre pivots, and lateral systems. Each was fitted with a LoRaWAN gateway, effluent pond level sensors, and mobile applicator trackers with GPS, pressure sensors, data loggers, and transmitters. Where farm systems mixed water and effluent, pump monitors were installed to differentiate irrigation events.

Data was transmitted to a central server and displayed via the Water to Grow mobile interface. Real-time alerts notified farmers of high pond levels. Effluent events were detected by pressure sensors and mapped with data on location, volume, duration, and depth. Application data was validated through pond volume changes and prior bucket test results. Farmer feedback was gathered through interviews and group meetings.

The system produced data increasing farmer awareness of pond levels and application patterns, including logs of duration, location, volume, and depth. Several farmers proactively reduced pond levels based on this data. Two farms used the system as evidence of compliance with Farm Environment Plan objectives. No consent breaches or runoff events occurred. Farmers reported improved confidence in IoT for effluent management and reduced compliance effort.

The trial phase was essential to identify the best fit for the emerging technology. Challenges included network dropouts, pressure sensor blockages, and GPS inaccuracies for short application runs (under 15 minutes). These have been addressed in ongoing prototype development. The value of the data could be significantly increased by integrating additional variables like soil moisture deficit, rainfall, wind, and soil type to support precision nutrient management. Integration with fertiliser plans would enhance nutrient traceability. Future developments include pump control integration to minimise environmental risk.

The IoT system enabled real-time effluent pond monitoring and mapped application events, offering farmers a valuable tool that reduced compliance effort and built trust in digital technologies. A second-phase trial will test enhanced sensors and integrations with environmental and pump data. Market readiness is anticipated in early 2026.

Date	Start Time	End Time	Duration	Spreader	Run	Paddock(s)	Volume App.	Area Spread	App. Depth	Fluid Pressure
20/04/25	9:07:23 am	9:24:14 am	17 min	Gun #4	Gun 4	P10	10,000 L	590 m²	17 mm	95 KPa
20/04/25	7:31:17 am	7:55:21 am	24 min	Gun #4	Gun 4	P10	14,000 L	1,000 m²	14 mm	96 KPa
19/04/25	5:08:55 pm	5:47:18 pm	38 min	Gun #4	Gun 4	P10	23,000 L	1,400 m²	17 mm	97 KPa
19/04/25	7:49:01 am	8:28:56 am	40 min	Gun #4	Gun 4	P10, P8	24,000 L	1,800 m²	13 mm	95 KPa
19/04/25	5:16:56 am	5:56:56 am	40 min	Gun #4	Gun 4	P8, P15	24,000 L	1,900 m²	13 mm	90 KPa
18/04/25	3:00:57 pm	3:48:57 pm	48 min	Gun #4	Gun 4	P15	29,000 L	2,800 m²	10 mm	91 KPa
18/04/25	6:20:58 am	7:08:58 am	48 min	Gun #4	Gun 4	P15	29,000 L	2,100 m²	13 mm	100 KPa
17/04/25	4:42:37 pm	5:38:19 pm	56 min	Gun #4	Gun 4	P18, P20, P15, P12	33,000 L	2,800 m²	12 mm	100 KPa
17/04/25	6:50:37 am	7:46:37 am	56 min	Gun #4	Gun 4	P20, P22	34,000 L	2,600 m²	13 mm	92 KPa
16/04/25	4:46:25 pm	5:30:38 pm	44 min	Gun #4	Gun 4	P22	27,000 L	2,300 m²	11 mm	100 KPa
16/04/25	7:24:29 am	8:24:29 am	1 hr 0 min	Gun #4	Gun 4	38, P22	36,000 L	3,000 m²	12 mm	100 KPa

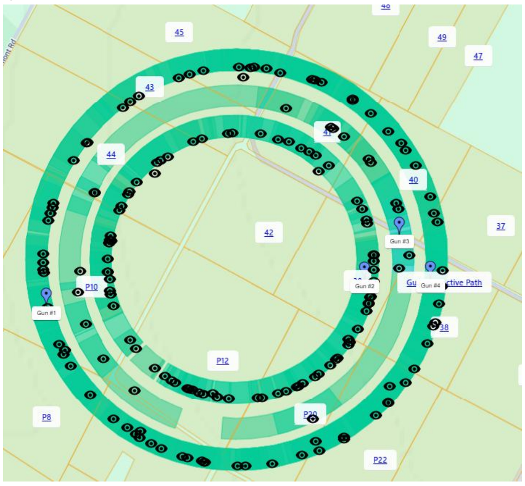

Figure 1. Example of the effluent application event log and map collated from one farm using a centre pivot.

WATER - MORE THAN A COMMODITY...

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The scenic flat plains of the Ashburton District of Central Canterbury are home to a $3.2m agricultural economy driven largely by dairy farming and supported by irrigation.

MHV, a farmer-owned co-operative irrigation scheme, supports some 200 farms over 58,000 ha across the Hekeao/Hinds Plains of mid Canterbury between the Hakatere/Ashburton and Rangitata Rivers. MHV has operated under Plan Change 2 of the Canterbury Land and Water Regional Plan since 2018, which requires that 'Hill-fed Lower' and 'Spring-fed Plains' surface waterbodies have an annual median NO_3-N concentration of 3.8 and 6.9 ppm, respectively, by 2035. To meet this goal 94% of MHV farmers have achieved an A FEP audit grade in the 2023/24 season.

In September 2016, MHV initiated a monitoring programme that sought to understand the changes in NO_3-N concentrations in the groundwater due to ongoing and/or changing land use activities within the area. As the focus of the monitoring programme evolved over time, so too did the design of the programme, such that the initial survey of 29 bores developed into 60 surface water sites and some 160 bores monitored on a monthly and quarterly basis, respectively.

In addition to providing water quality data, this programme has had several unintended beneficial outcomes, such as increased farmer engagement with environmental issues; support for catchment groups and the development of community projects, such as wetlands and riparian planting strategies; research and engagement opportunities with Canterbury, Lincoln and Otago Universities; as well as increased engagement with industry agencies and actors, such as DairyNZ and local Iwi. In doing so, this programme has facilitated and enabled evidence-based decision-making that has informed and empowered the farming local community.

This paper will outline the key learn learnings from this journey, the intended and unintended benefits, as well the logistics, costs and potential pitfalls.

THE USE OF ENVIRONMENTAL DNA (EDNA) DATA IN LIFE CYCLE ASSESSMENT (LCA) FOR ESTIMATING THE IMPACT OF FARMING ON BIODIVERSITY

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Agricultural production is a major contributor to biodiversity loss worldwide. While still an important mechanism for estimating species diversity on-farm, current practices in on-farm biodiversity assessment (e.g. ecological surveying) can be costly, labour- and time-intensive and site-specific. Life cycle assessment (LCA) is a widely accepted tool for assessing the environmental impacts of production systems (including agriculture) across their entire lifespan (i.e. cradle-to-grave) that is used to provide validation of products' environmental credentials for applications such as market access and compliance. However, current LCA tools for assessing biodiversity are significantly underdeveloped, requiring the aggregation of a significant amount of secondary data. Environmental DNA (eDNA) sampling and analysis have emerged as relatively straightforward, inexpensive and appropriate tools for attributing species diversity values to specific agricultural production sites. The integration of eDNA data into LCA studies examining biodiversity could provide a primary data source for more accurately estimating species diversity on-farm compared with current LCA methods. This could allow agribusiness value chains to more accurately estimate on-farm impact(s) on local species diversity, thereby scientifically verifying biodiversity impacts and improvements over time.

PRECISION CONTROL OF VACUUM AND PULSATION IN CONVENTIONAL MILKING SYSTEMS

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DeLaval has introduced new technology that adjusts milking vacuum level according to milk flowrate (DeLaval Flow Responsive Milking™, FRM). In a conventional milking system, milking vacuum drops as milk flowrate increases resulting in the highest milking vacuum occurring at the lowest milk flowrate (beginning and end of milking). When FRM is applied this relationship is reversed and the highest milking vacuum occurs during the peak flow period of milking.

An observational study was conducted on a commercial dairy farm in Northen Germany milking about 850 Holstein cows per day with a 60 stall DeLaval PR3100HD rotary milking parlor. The average production level of the herd was 33.4 kg/cow/day and 12.2 kg/milking. Conventional vacuum control (CON) maintained constant milkline 45 kPa vacuum during the entire milking process, while the FRM system component, DeLaval Flow Adjusted Vacuum (FAV) applied milkline vacuum of 40 kPa milkline vacuum during the low flow period and 48 kPa when the milk flowrate of an individual cow exceeded 2 kg/min. The CON and FRM treatments resulted in average claw vacuum of 40 kPa and 43 kPa respectively during the peak flow period. A switchback design was used CON-FRM-CON with each treatment applied for 3 weeks resulting in over 200,000 milking records.

Peak milk flowrate increased by 12% ($p<0.0001$), average milk flowrate increased by 4% ($p<0.0001$), and milking duration decreased by 4% ($p<0.0001$) at the udder level for the FRM treatment. The effects were more pronounced in slow milking and low yield quarters resulting in more uniform milking of quarters. Modeled parlor throughput increased by 4% to 7% depending on the percentage of cows that were completely milked in one turn of the parlor. This study was not designed to detect differences in milk yield or mastitis risk. We did, however, examine milk yield and bulk tank SCC data and saw no evidence suggesting a change in either that could be attributed to the vacuum control treatment, nor did the farm manager note any changes or concerns.

The occurrence of rough teat ends was slightly reduced during the FRM period with no meaningful difference in the occurrence of teats with blue color, palpable rings, or petechia. The combination of reduced vacuum during the low flow period of milking and the decrease in milking duration are likely factors that are protective of teat tissues.

A second study was performed activating a second component of FRM, DeLaval Flow Adjusted Stimulation™, (FAS) in which a vacuum of 38 kPa, pulsation rate of 50 cycles/min, and pulsation ratio of 30:70 were applied until the milk flowrate exceeded 0.5 kg/min at which time a pulsation rate of 60 ppm and ratio of 65:35 were applied and when the milk flowrate exceeded 1.6 kg/min a milkline vacuum of 48 kPa was applied. The control used the same vacuum settings but did not adjust pulsation settings. Cows that were milked using components of FRM (FAV and FAS) had lower odds of short-term teat tissue changes and forced take-off, as well as a higher peak milk flow rate than with FAV alone. Research has shown that this combined control strategy allows for the attachment of milking units prior to full milk ejection without teat congestion occurring during the low flow period either at the beginning or end of milking.

ASSESSMENT OF LOW-COST NEAR INFRARED SENSOR FOR DETECTION OF MILK *DE NOVO* FATTY ACIDS

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De novo fatty acids (FA) are markers of milk fat synthesis and the metabolic status of lactating animals. The concentration of C18 fatty acids (particularly C18:1 cis-9) in milk enables the early detection of cows experiencing severe negative energy balance. Management practices can influence the production of *de novo* FAs (C4:0 to C14:0) in bulk tank milk, with farms producing lower levels of these FAs typically yielding less milk fat and protein per cow per day. Milk fatty acids are also potential indicators of enteric methane emissions.

Fatty acids in bulk tank milk and individual cow samples support management strategies, but tools to routinely assess *de novo* fatty acids on-farm remain limited. Miniaturized Near InfraRed (NIR) instruments are user-friendly, minimally invasive, rapid and cost-effective, showing utility in milk analysis based on fat content and composition.

This study assessed the performance of a Miniaturized NIR to predict concentration of *de novo* fatty acids (e.g. C4:0, C6:0 and C14:0), C18:1 cis-9, total saturated fatty acids, total monounsaturated fatty acids, total short-chain fatty acids and total branched-chain fatty acids, investigating its potential to describe the variation in concentration of milk fatty acids across the milking season. The goal was to assess its value for on-farm management in precision dairying.

Samples (n = 483) from 114 farms, varying in lactation stages within two production seasons, including different dairy breeds (both dairy and beef breeds) were used to fit a support vector model using parameters estimated in our previous study. Models were fitted for the above fatty acids.

Milk from individual cows (n=40) from two farms with distinct production systems (i.e. conventional and regenerative), were sampled in spring, summer and autumn to represent seasonal variation (n=120). In addition to NIR analysis, the fatty acid profiles were also determined using the gold-standard gas chromatography method.

The model showed R^2 varying between 0.67 and 0.78 and Ratio of Performance to Deviation (RPD) between 1.75 and 2.15, across the nine attributes. These metrics align with results from independent studies using NIR spectrophotometers. The NIR-predicted values obtained from milk from the two farms varied across each season following similar trends as concentrations assessed with the gas chromatography method. Our results demonstrate the potential of the miniaturized NIR sensor for accurate, low-cost on-farm monitoring of milk fatty acid composition, particularly for tracking trends throughout a season.

Our findings highlight the strong potential of low-cost NIR for on-farm assessment of milk fatty acid composition, while also noting the advantages and current limitations of this approach.

Acknowledgement: This work was supported by funding from the New Zealand Ministry of Business, Innovation and Employment (MBIE) through the AgResearch Strategic Science Investment Fund, as part of the Food Integrity Programme – Traceability and Transparency and Te Whenua Hou Te Whenua Whitiora for access to the milk samples. The Te Whenua Hou Te Whenua Whitiora programme is a Sustainable Food and Fibres Futures partnership between the Ministry for Primary Industries, Ngāi Tahu Farming, Te Ngāi Tūāhuriri Rūnanga, New Zealand Bioeconomy Institute (AgResearch and Manaaki Whenua – Landcare Research), DairyNZ and the Agribusiness Group and Soil Connection are science providers and advisors to the programme.

ENHANCING EFFICIENCY, TRACEABILITY, AND SUSTAINABILITY IN DAIRY FARMING THROUGH PRECISION AGRICULTURE TECHNOLOGIES

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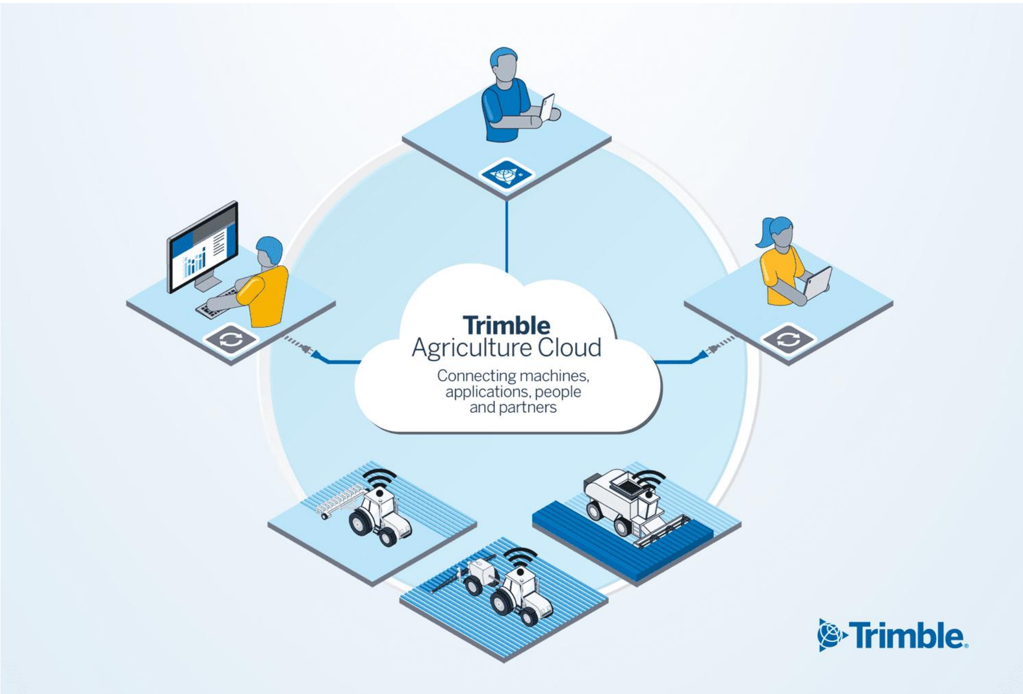
New Zealand's dairy sector faces growing pressure to meet regulatory demands, reduce environmental impact, and enhance transparency without sacrificing productivity. Rising input costs, stricter nitrate leaching limits, and market expectations for verified sustainability are reshaping priorities. For dairy farmers and policymakers, the challenge is achieving measurable environmental performance while maintaining economic viability. Data-driven precision agriculture offers a scalable, cost-effective pathway to achieving these dual goals.

This presentation outlines how an integrated, data-backed precision farming solution delivers real results across New Zealand's dairy operations. We will demonstrate how leading farms, supported by Vantage NZ's technologies, improve nutrient efficiency, enhance traceability, and ensure full compliance with environmental regulations – all while reducing operational waste and input costs. The objective is to showcase how strategic investment in precision agriculture can align on-farm practices with national policy outcomes and global market standards.



A mixed-method approach was utilised, incorporating online research, peer knowledge and farmer interviews on Precision Agriculture and Dairy Farming, focusing on the implementation of Variable Rate Application (VRA) for nutrient delivery, digital farm recordkeeping platforms, job management systems, GPS-integrated machinery, soil moisture probes, weather stations, electromagnetic (EM) soil surveys, and precision nutrient management practices.

A suite of proven technologies is there for farmers to enable more efficient, traceable and accountable farm management:

EM Soil Mapping enables zone-specific nutrient strategies based on soil variability, preventing over-application and reducing input costs.
Soil Moisture Sensors optimise irrigation scheduling, conserving water and preventing nutrient runoff.
On-farm Weather Stations provide hyper-local data to time inputs more accurately and minimise risk.
Variable Rate Application (VRA) maps combine EM, yield, and soil test data to enable targeted, efficient input delivery.
Trimble GPS Systems and Task Management Platforms automate field operations and create auditable digital records for regulatory and supply chain reporting.
Rate-controlled application hardware ensures precise, real-time nutrient and agrochemical delivery, minimising overlap, soil compaction, and waste.

These tools work in concert to support data-informed operational decisions, provide transparency for stakeholders, and reduce environmental liabilities.

On-farm results present obvious financial and compliance benefits:
Input reductions in fertiliser use.
Fuel and labour savings through automation and GPS-guided accuracy.
Improved regulatory compliance with auto-generated, timestamped proof-of-application records.
Enhanced traceability across nutrient and water use for FEP and sustainability reporting.

These outcomes confirm that precision technologies are not just agronomic tools – they are strategic assets for managing environmental risk and achieving verified sustainability at scale.

For farm managers and policymakers, the adoption of data-backed precision agriculture is a critical enabler of next-generation dairy farming. It strengthens environmental stewardship, enhances brand credibility in premium markets, and streamlines compliance with evolving regulatory requirements. Importantly, it allows large-scale operations to scale efficiently while remaining within environmental limits. This approach aligns with both commercial performance goals and national policy targets for climate resilience, water quality, and emissions reduction, positioning New Zealand dairy as a global leader in sustainable, high-output farming.

STANDARDISATION ENABLES DIGITISATION ENABLES INTEROPERABILITY ENABLES OPTIMISATION ENABLES CERTIFICATION

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Precision dairy farming is growing rapidly and promises unprecedented opportunities for optimising production, enhancing animal welfare, and improving environmental sustainability.

Many innovative technologies are emerging in this field and being adopted, such as:
virtual fencing and pasture/grazing optimization using cow collars,
remote animal health monitoring using telemetry, and
milking operations optimization using milking robots.

The full potential of these innovations, and their use at scale is, however, often limited by poor integration and data exchange among different systems. On a farm this could mean that the above-mentioned innovations, each of which produces and consumes data that are part of a farm management information system "whole," are implemented in silos that cannot "talk" to each other. This friction is wasteful (e.g. requiring double data entry) and is frustrating for the producer.

Enabling frictionless data integration requires a fundamental mindset shift towards interoperability, where diverse digital tools communicate and work together effectively, not just within the farm, but across agrifood systems, having solved:

1. the syntactic interoperability problem, where different systems can produce and consume data in the same format;
2. the semantic interoperability problem, where different systems can understand the meaning of each other's data, through the use of common code lists, data dictionaries, etc.; and
3. the commercial motivation problem, where hardware and software manufacturers do not perceive a need to integrate with others.

These problems do not just exist for the producer; we argue that standardisation, particularly through ISO Technical Committee 347 (ISO/TC 347, Data-driven agrifood systems) provides a foundation for solving the interoperability problems at scale for all the actors in the system, e.g., as shown interacting with producers in Figure 1.

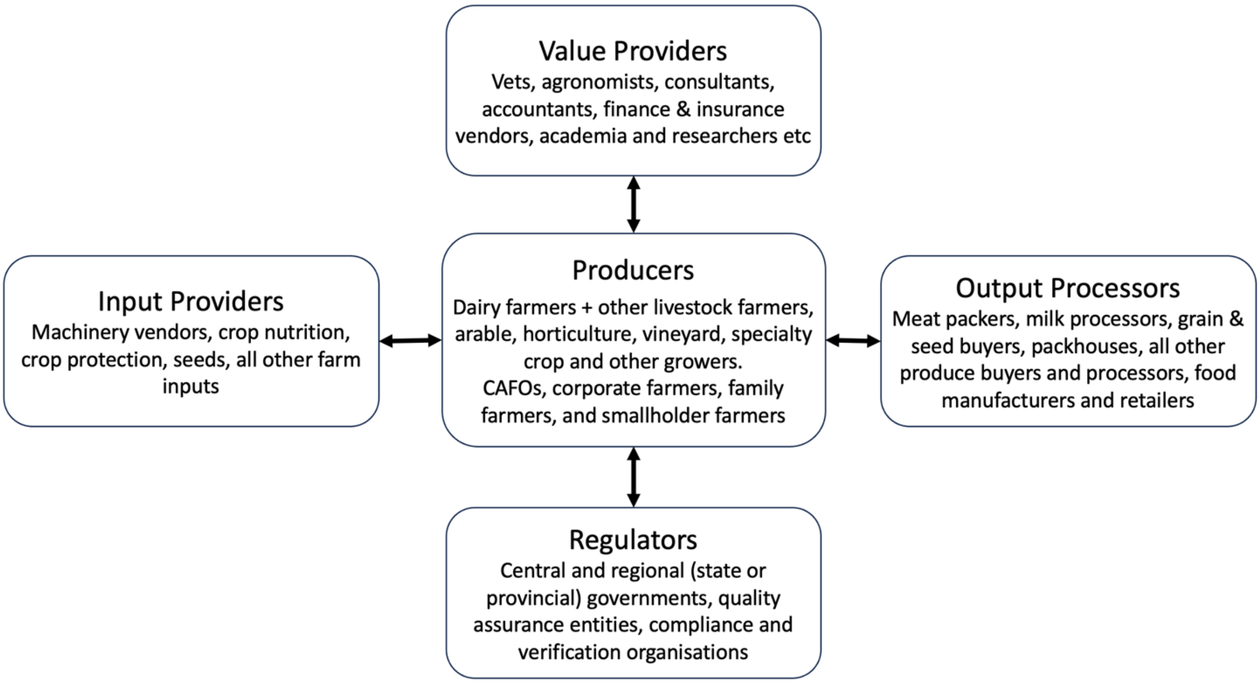

Figure 1. Data flows between producers and other agrifood system actors.

Retrofitting interoperability onto existing products is often costly, inefficient, and can limit the full value proposition of innovations. By embracing standards-based design from the outset, researchers and developers can create systems that seamlessly integrate with other tools and platforms, fostering a more collaborative and data-driven environment. This not only benefits producers but also empowers other actors, such as value providers and regulators, with consistent and reliable data for informed decision-making.

Regarding the commercial problem, the combination of pressure from frustrated customers of non-interoperable systems and new market opportunities for interoperable systems has already worked in some industry segments (e.g., ISOBUS-based farm machines and implements) to motivate standards adoption.

In conclusion, optimising contemporary farming is a heavily data-dependent endeavour that involves multiple actors exchanging data across multiple systems. The presenter will show, with NZ and international examples, how these data can drive decisions only if their meaning is preserved, which at an industry-wide level requires the establishment and widespread adherence to robust, pan-sector standards.

ISO/TC 347, within which New Zealand is a first-class citizen, offers a framework for achieving this standardisation, paving the way for a future where seamless data exchange and system integration unlock the full potential of digitisation, ultimately leading to truly optimised, certifiable dairy farming practices.

PRECISION CONTROL OF MILKING IN AUTOMATIC MILKING SYSTEMS

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A study was performed on a new vacuum control technology, Flow Responsive Vacuum (FRV), applied at the quarter level in an automatic milking system (DeLaval International VMS). The study was performed on a farm in Northen Italy milking Holstein cows using one pen of cows that had free access to one automatic milking system with conventional vacuum control and another automatic milking system with FRV. The study ran for 111 d, during which time the pen contained between 120 and 128 cows that had free access to either milking station, producing a dataset with more than 32,000 milkings. The average production level of the study group was 41.9 kg/cow per day with an average milking frequency of 2.8 times/d and average milk yield per milking of 15.2 kg.

The FRV system measures vacuum in the short milk tube, near the teat-end and used to maintain teat-end vacuum at a pre-determined level (45 kPa) throughout milking. This new control technology was compared to the standard method of vacuum control where vacuum is held constant at 45 kPa in the receiver and the vacuum drop in the milk tube results in a progressively lower vacuum at the teat-end as milk flowrate increases. The FRV control system had 12% more milk harvested per minute of box time ($p<0.001$), 16% higher peak milk flowrate at the quarter level ($p<0.001$), and 103 g more udder milk yield than expected ($p<0.001$) indicating more complete milking.

There was no significant difference in post milking teat condition as a result of several methods employed to manage teat congestion:

- Optimized and standardized stimulation and lag times to ensure milk ejection has occurred when teatcups are attached, thus eliminating low flow period at the start of milking.
- Optimized milking intervals in automated milking systems to reduce milking cows with low udder fill.
- Optimized pulsation settings to avoid lost time of extended d-phase duration and increase the milk:rest ratio.
- Development of a liner with effective congestion relief that will support higher milking vacuum levels and milk:rest ratios without producing TEHK or excessive mouthpiece chamber vacuum.
- Timely teatcup removal to eliminate the low flow period at the end of milking, greatly reducing teat tissue stresses that are most pronounced during the low flow / high mouthpiece chamber vacuum period of milking.

The average milk flowrate for high producing US Holstein herds in 1995 was about 2.6 kg/min at the udder level or 0.65 kg/min at the quarter level. The coordinated combination of the numerous control technologies described here produced a quarter level average milk flowrate of 1.5 kg/min or approximate doubling over the past 30 years.

REVISION OF ISO STANDARDS FOR MILKING MACHINES - ISO 21355

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International Standards are the distilled wisdom of people with expertise in their subject matter who know the needs of the organizations they represent, e.g. manufacturers, distributors, installers, customers, trade associations, users, regulators. The International Standards Organisation (ISO) has enabled trade and cooperation between people and companies the world over since 1946. The International Standards published by ISO serve to make lives easier, safer, and better. ISO has produced 25351 standards which are adopted by 171 member countries.

ISO standards are reviewed routinely every 5 years to determine if they remain relevant or require revision or withdrawal. Following the 2022 review, member countries voted for revision of the four Milking Machine Standards. The revision is being undertaken by a working group drawn from eleven member countries representing research, manufacturers, field advisers. The resulting Committee Draft will be circulated for wider consideration and voting.

The scope of the current standards states "This International Standard specifies the minimum performance and information requirements and certain dimensional requirements for satisfactory functioning of milking machines for milking and cleaning. It also specifies minimum requirements for materials, design, manufacture, and installation".

The revision is based on the most up-to-date scientific research and recognises that technical design alone cannot guarantee a satisfactory outcome. A key element is to demonstrate the adequacy of the vacuum production and regulation function of any milking system. The new standard specifies milking time tests, performed while milking animals and with the milking system under normal use conditions.

A satisfactory outcome is determined by the milking system's ability to maintain adequate and intended average vacuum in the claw and/or teatcup liner during milking and the ability of the pulsation system to operate within the manufacturer's specifications.

The new standard also recognises that many systems, automatic and conventional, are in continual use and traditional testing may not be feasible.

Another major change is that supporting guidance, traditionally included in informative annexes, will be removed and repositioned as freely available International Dairy Federation Bulletins. Specific reference will be made to Bulletin 396/2005 of the International Dairy Federation for complete evaluation of milking performance, including non-machine related aspects. Guidance relating to vacuum pump capacity, air and milk line sizing, evaluating cleaning of teats/udders and detection systems for abnormal milk is being revised for publication as separate IDF bulletins.

This paper is presented to an international audience of interested parties by the leader of the drafting group to report on progress to publication of the new standard, and incorporated revisions.

EFFECT OF DIFFERENT VACUUM SETTINGS ON COW COMFORT

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In instances where there is little or no milk flow during milking, such as during bimodal milk let down or delayed milk ejection (DME), cows' teats are exposed to high milking vacuum which can cause discomfort. Discomfort has been associated with increased stepping and kicking behaviours during milking. Automatic vacuum adjusting technology that responds to an individual cow's milk flow might be an alternative to control this negative effect of DME. The objective of this study is to evaluate cows' behaviour during the milking process when using different vacuum settings.

We will enrol one farm equipped with a parlour with vacuum adjusting technology (Flow Responsive Milking, DeLaval) and milking recording software (DelPro, DeLaval). We will follow a completely randomized design where the experimental unit will be the cows. A cow's inclusion criteria consist of being more than 7 days in milk (DIM), no clinical mastitis cases in the last 14 days, and no lameness cases in the last 14 days. We will randomly allocate the treatments to each milking stall (30 stalls). The treatments will be consistent vacuum setting during the entire milking process at 44 kPa (control), initial vacuum of 44 kPa before peak milk flow followed by vacuum of 49 kPa during peak flow (flow adjusted vacuum treatment), and consistent vacuum setting during the entire milking process at 49 kPa (high vacuum treatment). We will evaluate cows' stepping behaviour as a proxy of comfort during milking. For this, we will use accelerometer data loggers placed in the milking cluster of each milking machine, secured within a custom-made case. From milking recording software, we will collect individual cow information corresponding to the milking session when the experiment is conducted, including animal number, parity, DIM, group, time of start milking session, stall number, flow 30-60, and yield. Flow 30-60 will be utilized to categorize milkings as DME or normal. We will match the data from accelerometers with the parlour data by time and stall number. We will collect data during a single milking. For data analysis, we will conduct an analysis of variance. Our response variable will be number stepping and kicking during milking session and our main explanatory variable will be treatment. Additional covariates will be parity, DIM, group, DME presence, and yield.

We hypothesise that cows in the flow adjusted vacuum treatment will have a reduced number of stepping and kicking incidences during milking.

This experiment will be conducted in June 2025 and preliminary results will be available to be presented at the meeting.

UTILISING MACHINE VISION TO REDUCE LABOUR BY AUTOMATING TEAT SPRAYING ON PASTORAL FARMS

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In 2023, GEA Farm Technologies and AgriAI (a Waikato-based start-up) identified a clear market need for an automated teat spray system designed specifically for herringbone parlours on a pasture-based system. The goal was to ensure complete and consistent teat coverage to maintain herd udder health, while significantly reducing the labour required.

To achieve this, the system needed to address three key challenges to automate the teat spraying process. It required exceptional levels of spray accuracy and coverage, consistent application to every cow within the herd, and optimal efficiency to minimise the use of teat spray solution.

To meet this challenge, GEA and AgriAI formed a partnership. Combining GEA's expertise in animal health, teat spray technology, and mechanical design with AgriAI's advanced machine vision and computing capabilities. The result was the iSPRAY-VISION – an advanced walkover system that integrates a top-mounted camera array, real-time cow tracking, and an intelligent mechanical spray design to deliver three key outcomes:

- accurate identification and tracking of every cow in the exit race,
- consistent and uniform spraying across the entire herd,
- optimal teat spray application using crossfire nozzles to ensure complete barrel coverage for each animal.

The integrated technology, designed specifically for dynamic cow flow, uses AgriAI's machine vision technology to accurately identify individual cow positions regardless of bunching or erratic behaviour, enabling precise timing and targeting of the teat spray.

Early trials involved a new spray applicator tailored for optimal coverage and cow movement. Local veterinarian Tim Cameron (VET+ENT Te Awamutu) assisted in evaluating the spray performance by manually assessing teat coverage on a sample of cows using paper towel swabs. While the presence of observers affected natural cow behaviour during these tests, early results showed strong spray coverage when cows were properly aligned over the system.

To further refine the system without influencing cow behaviour, engineers employed passive validation methods using slow-motion side-on footage. This analysis confirmed accurate spray timing and application. Across three trial installations, 96% of cows received complete teat barrel coverage – even in the presence of erratic behaviour or grouped movement.

Feedback from trial farmers was overwhelmingly positive. Those switching from manual hand-spraying reported time savings of 20 – 30 minutes per milking, with no compromise to udder health. Farmers transitioning from older automated systems observed improved coverage and significantly reduced cell counts.

Following the success of the trials, the first commercial systems were installed in January 2025, marking a significant milestone in automated teat spraying.

IDENTIFICATION OF DETRIMENTAL MILK FLOW PATTERNS IN DAIRY COWS USING MACHINE LEARNING: IMPLICATIONS FOR MILK YIELD

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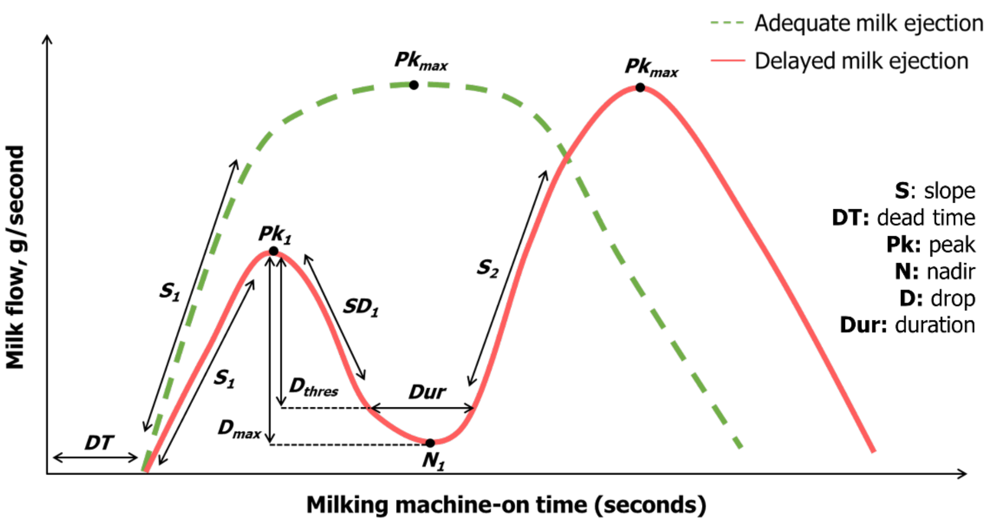
Delayed milk ejection (DME), defined as the presence of bimodal curves, reduces milking efficiency and has been associated with milk loss and increased risk for intramammary infection. Evidence suggests a need for evaluation of its current definition and that additional patterns could also be detrimental to udder health.

Objectives were to 1) apply machine learning algorithms to classify and characterize milk flow patterns in dairy cows milked through robotic milking systems and, 2) evaluate the association between different milk flow patterns and milk production. Lactating dairy cows (n = 368) from a single farm equipped with five automated milking systems were enrolled. Milk flow curves were collected daily from all milkings from calving to 200 days in milk (DIM). Data were recorded at the quarter level, resulting in 436,336 milking sessions and 1,745,372 quarter-level milk flow curves. Analyses were conducted using Python 3.13.3. Curves were segmented into 5-second intervals over the first 2 minutes of milking. Features describing slope dynamics were extracted (e.g., S1, SD1, S2). Density-based spatial clustering of applications with noise was applied to group milk flow curves. Model hyperparameters were optimized (epsilon = 70, minimum samples = 8). Linear regression models were developed in SAS 3.81 to assess milk yield differences across clusters. Dunnett's adjustment was used to compare clusters against the normal curve. Clustering analyses yielded 15 distinct clusters, with most curves not clustered (88.4%) or classified as noise (11.5%). Ten clusters were identified as bimodal based on a drop in flow ≥ 200 g/min. Nine clusters showed significantly reduced quarter-level milk production compared to quarters with normal milk flow (4.56 ± 0.30 kg/milking), with milk yields ranging from 1.68 to 2.43 kg/milking (i.e., reductions of 2.88 to 2.13 kg; $P < 0.01$). Only 4 clusters were associated with reduced milk yield per milking session at the cow level (6.5 ± 1.68 kg, $P < 0.01$; 8.3 ± 1.81 kg, $P = 0.02$; 9.4 ± 1.68 kg; $P = 0.08$; 10.4 ± 0.89 kg, $P = 0.01$) compared to normal quarters (14.7 ± 0.93 kg). Clusters were characterized by sharp drops in flow (D_{max}; ≥ 600 g/min) with nadir (N_1) reaching 0 g/min. Slope-based clustering identified distinct bimodal milk flow patterns, but not all were associated with an acute drop in milk yield per milking session. Only specific patterns were linked to lower production, indicating that the presence of bimodality alone may not be a reliable indicator of milking inefficiency. Current definition of DME may overestimate the impact of certain curve types. While clustering based on slope dynamics was informative, most milk flow curves were not assigned to clusters, suggesting the need for advanced methods, such as convolutional neural networks, and the inclusion of additional curve features to improve classification. Findings support the re-evaluation of DME criteria and the development of more refined monitoring tools for milking efficiency.



VALIDATION OF A COMPUTER-VISION ARTIFICIAL INTELLIGENCE MILKING PARLOUR MONITORING SYSTEM

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Optimizing milking practices is essential for cow welfare and milking efficiency. This requires alignment with natural cow behaviour and seamless integration with staff routines to reduce the risk of intramammary infections, maintain udder health, and maximize milk production. However, challenges, such as high staff turnover and inconsistent training, can hinder consistent milking performance. Without remote monitoring technology, external specialists – such as veterinarians and milk quality consultants – often need to make multiple farm visits to assess milking routines across different shifts and personnel before identifying areas for improvement.

The integration of computer-vision artificial intelligence (AI) into milking parlours offers a promising solution. AI can detect deficiencies and suboptimal practices during milking, providing regular reports that highlight opportunities for improvement without the need for time-consuming on-site visits.

The objective of this study was to validate a computer-vision AI milking parlour monitoring system (CattleCare Inc., Marina del Rey, CA, USA) by comparing its reports with assessments made by two trained human observers. A camera was installed at the exit end of the parlour on two commercial dairy farms using conventional GEA milking systems (one operator per shift) located in Southwestern Ontario, Canada. One hour of footage from two milkings (August 2024) on each farm was retrospectively analyzed by the research team and compared to the automated reports generated by the AI software. Human observers were blinded to the AI results prior to conducting their analyses.

Average milking time per cow (calculated as the mean of the longest and shortest milking times per turn), prep-lag time (the interval from first teat contact to milking unit attachment for all cows in the turn), and the occurrence of issues during milking (e.g., missed cleaning, reuse of towels, skipped forestripping, or use of a cell phone) were assessed in each milking shift and compared between methods. Intraclass correlation coefficients (ICC) were calculated for continuous variables to evaluate the agreement between AI and human measurements.

The average turns per hour were 10.0 ± 0.15 and 10.4 ± 0.73 for Farms A and B, respectively. The average milking time per cow was 5:06 ± 1:54 min for Farm A and 4:06 ± 1:37 min for Farm B. All events flagged by the AI software (n = 17) were also detected by the human observers, and no additional events were identified by the observers that were not detected by the AI. The ICC for milking time (n = 42 turns) was 0.90 [95% CI: 0.83 – 0.94, $P < 0.001$], and for prep-lag time (n = 85 cows) was 0.98 [95% CI: 0.97 – 0.99, $P < 0.001$].

These findings indicate strong agreement between AI-generated and human-observed measures. The validated AI system provides a reliable and efficient alternative to manual observation for evaluating milking routines in conventional parlours.

Concurrent session 4

December 5, 2025, 1:30 pm – 3:00 pm

4A | Applications and decision support tools

FARM-LEVEL NEEDS FOR IMPROVED DATA AND ANALYTICS IN DECISION MAKING

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There is an increasing amount of digital data available to dairy farmers and research suggests that there is a significant untapped potential for enhanced use of this data. Not all data are useful however, and there is not clarity around where the most valuable opportunities for data use on-farm are. This study aimed to explore the questions:

- What are the main issues identified in the literature related to incorporating data into farm decision making?
- What are major opportunities identified in the literature related to incorporating data into farm decision making?
- What are the data/information requirements within farmer decision-making?

A structured literature review was conducted using the PRISMA 2020 methodology. Peer review literature from 2010-2025 in the Scopus and Google Scholar databases were identified using a range of search term strings (applied to article title, abstract and main body) including: data, information, technology, digitalization, digital, decision, planning, operational, strategic, dairy, farm, system, need, demand and requirements. The initial search resulted in 1711 articles identified, and a subsequent assessment of titles reduced this to 94 articles. Assessment of the abstracts reduced the dataset further to 45 papers. These papers were then allocated among the project team for review against the research questions and insights captured in an Excel spreadsheet for theming by the team.

The review highlighted a range of themes in the literature. Technology design was a theme that involved the need for data and technologies that are flexible to fit a wide range of farm systems contexts and different needs of farmers and advisors, the need for collaborative co-design in technology development, and pathways for ongoing iteration and user feedback in design. Integration of data was a common theme in studies on agricultural technology and data, and included the inefficiency of current integration approaches, integration of data being a core component to achieve FAIR principles and the potential need for FAIR principles that are dairy specific, and that integration is not only needed at the farm level but also to enable advisory business models to support farmer data use. Questions were raised around the actual need for precision in farm-level decisions, including a need to focus on rapid, tangible and simple answers to the decision-making needs of farmers, particularly at the operational and tactical levels. Trust is an important factor, not just trust in how farm data are used and by whom, but also trust that the data created by sensors is accurate and useful, that it's grounded in robust research and development and trust that companies are continually investing to ensure data and systems won't become obsolete. Other themes that emerged included the importance of farmer-advisory interactions around farm data, the need to responsibly develop artificial intelligence systems, and the tension between decision simplification versus cognitive overload. The insights from this review provide a valuable guide to the research, development, and policy needs related to farm-level digital data into the future.

BEYOND THE BROCHURE: A DEALER'S PERSPECTIVE ON PRECISION DAIRY TECHNOLOGY ADOPTION IN THE REAL WORLD

T.G. Allison

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As a dairy equipment dealership based in rural Wales, we are closely involved in the rollout and support of automation and precision dairy technologies across more than 400 farms. Our position straddles technical delivery and on-farm application and provides a distinct and often overlooked perspective in the wider conversation on dairy innovation.

Over the past five years, we have observed a sharp increase in interest around automation, primarily driven by structural challenges within the sector: labour shortages, financial uncertainty, and pressure to capitalise on limited-time government grant schemes. While this trend reflects a growing appetite for precision tools, it also exposes a worrying pattern - many technology investments are made reactively, based more on urgency and fear than on a well-matched understanding of system functionality, integration, or long-term sustainability.

From our direct experience, this often leads to poorly scoped projects, implementation challenges, and in some cases, complete system failure. Farmers are understandably disillusioned when expensive technologies fail to deliver, and this undermines both trust in innovation and the broader goal of digital transformation in agriculture. Conversely, where systems are carefully matched to a farm's needs, infrastructure, and operator capability, the results can be transformative.

This presentation will share insights from our lived experience as installers and long-term support providers, drawing on hundreds of conversations with farmers and numerous examples of both successful and unsuccessful technology adoptions. Topics will include:

- How urgency (driven by grant schemes or external pressures) can distort decision-making.
- The often underappreciated factors that determine system success - from acknowledging system limitations, to data literacy, to staff buy-in.
- Where manufacturers and advisors may unintentionally mislead, and how to align expectations with reality.
- The importance of ongoing dealer involvement to ensure post-installation success.

Our goal is not to critique innovation, but to contribute practical insights that complement the research-led and policy-driven discussions we hope can be found at this conference. We believe that integrating real-world, dealer-level experience into the wider dialogue can help ensure better outcomes for all stakeholders involved in the adoption of precision dairy technologies.

We would welcome the opportunity to share these observations and learn from others working at the intersection of technology, farming, and implementation.

WHAT 'SMART' TECHNOLOGIES ARE IRISH DAIRY FARMERS USING AND WHY: DRIVERS AND BARRIERS TO TECHNOLOGY ADOPTION IN A PASTURE-BASED SYSTEM

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A rise in availability of 'smart' (automated, precision, digital, robotics) dairy technologies has promised solutions to myriad pressures, such as improving productivity, reducing environmental impacts and enhancing social wellbeing. However, the level of adoption of these technologies (i.e., automatic feeders, herd management apps, milking robots) by Irish farmers operating in a predominately pasture-based system remains varied, with many being adopted more slowly than expected. The slower uptake of digital technologies is partly explained by high investment costs, lack of understanding about new technologies, insufficient data on real costs and benefits and challenges integrating them into existing systems. These factors, alongside cultural attitudes and behavioural determinants, complicate farmers' decision-making from first encounter with a technology to investment and use, post-adoption. This study contributes knowledge about what kinds of technologies and at what rate Irish dairy farmers are adopting them, and some reasons behind farmers' adoption decisions.

To assess adoption rates and understand some technology decision-making factors, Irish dairy farmers were asked 'technology use' questions through the autumn 2024 National Farm Survey's (NFS) Additional Survey. Farm socioeconomic data will be used to perform statistical analysis to identify levels of technology adoption and types of determinants which influence adoption decisions. The survey sample was 850 farms (representing dairy, cattle rearing, cattle other, sheep, tillage, mixed livestock), with 300 in the dairy sample; 737 total surveys were returned, with 261 from dairy.

Dairy farmers were asked three questions: 1) dairy technology use, 2) associated benefits, and 3) associated barriers of adopting technologies. Categories used to assess decision-making factors included animal health/welfare, labour, financial, social, and environmental. NFS Recorders asked farmers questions on farm, as part of a longer survey, and responses were manually recorded. To increase interest and efficiency, dairy tech questions included tables and easy to use tick boxes. The study approach is supplemented by insights from QuantiFarm (a Horizon Europe project which motivated this study) about how multi-factored determinants influence farmers' decisions to adopt or not adopt digital agricultural technology solutions (DATSs).

Statistical analysis from survey data (released June 2025) will examine relationships between characteristics already gathered by the NFS, like farmer age, education, herd size, farm location, farm size, number of days cows on pasture, and responses about the types of dairy technologies used and reasons behind their use. It will be particularly useful to compare dairy technology use (2024, 2018 NFS Additional Surveys) in light of ongoing labour challenges.

This study gains insights from Irish dairy farmers about what and how they are using 'smart' technologies in a largely pasture-based dairy system. Results can build knowledge about smart technology usage trends in an Irish context, offering insights into some drivers and barriers in the adoption process, particularly important amidst ongoing labour challenges, global trade uncertainties, and the changing climate. DATSs adoption may be accelerated by measuring and demonstrating how these solutions help farmers meet uncertainties. Providing verifiable data about technology adoption is critical to ensure stakeholders are best positioned to support farmers' efforts to balance profitability, social wellbeing, and environmental compliance.

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Thanks to the participating farmers, NFS Farm Recorders, Trevor Donnellan, Brian Moran, Emma Dillon, Paula Palma Molina, Pablo Silva Bolona.

REDEFINING EXCELLENCE IN AGRIBUSINESS ADVISORY: THE ROLE OF THE RURAL ADVISOR IN THE MODERN WORLD

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This paper, based on research as a part of completing a Nuffield scholarship, examines how the role of the rural advisor who supports farmers is evolving. The desired outcomes from this research were to redefine what excellence looks like in agribusiness advisory, and as a result, increasing productivity in the primary sector, whilst at the same time reducing the environmental footprint of both the advisor and the dairy farmer.

The research highlights that technology is rapidly influencing not only farming practices but also advisory services. For those advisors whose role is purely focused on providing only technical advice, the impact of technology may be rapid and profound, to the point that their role may not exist in the future. However, this automation of data analysis increases the importance of the interpersonal skills that have traditionally separated a great advisor from a good advisor. This has implications on how future advisors are selected and trained, and how we use technology to sustainably lift productivity. The paper provides a series of issues and recommendations for those in the rural advisory sector to consider. These recommendations are summarised in the following table.

Table 1. Recommendations for rural advisors.

•	• Recommendation
1	Advisory firms to employ data managers on behalf of farm businesses to manage data better.
2	Advisory firms to employ their own tech specialists to support their own team.
3	Establishment of partnerships with data analytic businesses will ensure that rural advisors are not 'locked out' of access to data.
4	NZ government and industry to accelerate efforts to improve rural internet connectivity. Rural advisors to be proactive with farmer clients in seeking out cost effective internet solutions.
5	NZ government and industry to accelerate efforts to improve data sharing and data interoperability.
6	Advisory firms to develop an AI strategy for their business, to ensure information and recommendations are handled correctly.
7	Advisory firms offering a team approach, with consultants offering specialist advice between advisory firms. Aggregation of advisory firms (nationally and internationally) will assist in managing the complexity of farm businesses and also the creation of scale necessary to develop new data management systems. Smart use of technology at the farm level to aggregate and synthesise large amounts of data.
8	Advisors can play a pivotal role in evaluating and filtering new agritech opportunities. To do this advisors will need to be familiar with the latest agritech opportunities relevant to their field of expertise. Ensure that any new technology is adding value to the farmer, not just cost.
9	Review the education and development requirements for new rural advisors, addressing the need for additional skills such as GIS, data mining, and use of AI.

	Review the personality styles that are required for advisors of the future. There is likely to be an increased emphasis on interpersonal skills over the traditional knowledge and analytical skillset.
10	With reference to the previous recommendation, there may need to be a complete rethink of requisite skill sets and personality traits to ensure new advisors can become proficient in a much shorter timeframe.
11	Farm advisory firms have an opportunity to lead the development of farmer friendly AI software. This will likely require collaboration with software development firms and policy developers of AI regulation. Advisory and agritech firms need to be involved with policy development and regulatory frameworks.
12	Embrace the automation of certain tasks (e.g. pasture assessment, livestock condition scoring) and focus on using the information provided to add value to the farmer. Utilise AI to auto generate recommendations and reports, or parts thereof. Clever use of AI will enable rural advisory businesses to 'scale-up', reaching a wider audience and having a greater impact.

USING A STEP-BY-STEP VISUAL TRAINING APP (KNOWBY) TO UPSKILL FARM TEAMS, INCREASE AUTONOMY, PERFORMANCE, AND JOB SATISFACTION

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Ever felt you are in a horror / comedy movie giving or receiving instructions? People and communication are one of the biggest challenges our industry faces.

Technology has been embraced in the dairy industry to drive efficiency, allow us to scale and more recently to aid in the reduction of reliance on a shrinking labour pool. This may reduce the labour required on farm but the tasks required of those remaining are changing and becoming more complex (e.g. learning how to set up breaks and bring cows to the shed using Halter is far more complex than sitting on a bike behind cows on a laneway).

More complex tasks require better training than "show and tell" which is the predominant form of training on farms. Even with simple tasks once we go beyond two to three steps most people fail when trying to repeat the task. Have you ever wondered why after showing someone how to find a fault in a fence they come back two hours later and there is still no power on the farm?

This is explained by cognitive load theory. This is the limitations of retaining information in our working memory. Essentially for people to be able to repeat complex tasks they need to be taught in a way that doesn't overload them. Teaching using techniques that break a task into steps and uses visual learning is far more effective.

Apps are generally low-hanging technology but can make big differences in a business.

Knowby is an app platform whereby businesses build their own step-by-step instructions on tasks or safe use procedures. It is simply a template that you either build one step at a time uploading images or ultra short video with text like you'd post on social media. Or with groundbreaking multi-module AI Knowby has developed upload a video of a process and have it transformed into step-by-step instructions of short video and text in seconds. Auto translated into 130 languages it becomes a powerful tool for everyone in your team.

The end user of Knowby can simply search within their site for instructions or better still access links via auto generated QR codes within the app that are placed at point of use. Imagine opening a pivot panel with start instructions there or scanning a QR code on the back of a fence tester. They simply digest the process one step at a time like scrolling through social media and are empowered to complete the task.

Knowby doesn't replace training, it is simply a tool to not only help train but to allow people to go back to for reference whenever they need to if they "can't quite remember". So Knowby allows businesses to build their own step-by-step instructions based on cognitive load theory quickly and easily. They are as easy to build and digest as using social media.

Knowby speeds up onboarding and training. It ensures people know how to use and maintain expensive equipment. And it allows you to build safe work procedures that will actually help make people safer.

Knowby is already being used across multiple farms in Australia, New Zealand and the States improving outcomes and empowering people. And reducing the number of texts and phone calls key people receive daily on "how do I do....?"

PERCEPTION OF CHILEAN DAIRY FARMERS REGARDING AN APP FOR AN EARLY WARNING AND MONITORING SYSTEM FOR HEAT STRESS

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Climate change has increased temperatures and more frequent heat waves worldwide, posing challenges for the dairy industry. Dairy cattle can cope, most of the time, with adverse climate conditions by adjusting their physiological and behavioral mechanisms to maintain stable body temperatures, but this negatively affects their productivity and welfare.

A multidisciplinary team with the participation of the Austral University of Chile, DeLaval S.A., the Chilean Dairy Consortium, and APROVAL Leche AG (Milk producers association) has been addressing the issue of heat stress in Chilean dairy cattle since 2022. A key outcome of this project was developing and implementing an early warning system (app) for heat stress in Chile, called "Térmometro Lechero". This app is based on validated thresholds of two thermal comfort indices (Temperature and Humidity Index (THI) adjusted by solar radiation and wind speed, and the Comprehensive Climate Index (CCI)) for the eight dairy regions of Chile. Both are estimated from data obtained from NOAA (National Oceanic and Atmospheric Administration, USA) with a spatial resolution of 27x27 km and can be accessed by smartphones or tablets using iOS or Android operating systems.

The study aimed to assess Chilean dairy farmers' perceptions of heat stress in cattle and their interest in a tailored early warning system. To gather insights, a survey was conducted using the QuestionPro platform and was emailed to dairy farmers across various regions of the country. Responses were received from producers in 28 communes (N=98), providing a representative geographic coverage of Chile's main dairy regions. Most respondents were producers with herds exceeding 500 animals, operating primarily pasture-based systems, and managing year-round calving. The results showed that although 85% of producers have a general understanding of heat stress, there is a significant knowledge gap; only 46% understand its specific physiological impacts on animals and production. There was a strong willingness to embrace improvement and technology: 91.6% expressed interest in formal training on managing heat stress, and 88% were open to using a mobile app for real-time risk monitoring and practical mitigation tips. Ultimately, 73% of respondents indicated a willingness to pay an annual subscription fee to ensure continued maintenance and technical support. In contrast, only 27% preferred a free basic version of the application, which offers solely heat stress risk prediction capabilities. In conclusion, these findings confirm that Chilean dairy producers are not only aware of heat stress but see it as a significant threat to the sustainability of their businesses. The gap between general awareness and applied knowledge points to a need for targeted technical training. This presents a clear opportunity to direct efforts towards extension and technology transfer initiatives.

B+LNZ DAIRY BEEF PROGENY TEST

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Beef + Lamb, Wellington, New Zealand

The B+LNZ Dairy Beef Progeny Test (DBPT) has been running for 10 years. This presentation will be an update on the results, operational learning, industry impact and next steps for an important piece of NZ genetics infrastructure.

The DBPT is an industry good initiative designed to identify bulls that produce high performing beef calves while also meeting the needs of dairy farmers. Bulls are screened into the DBPT with good EBVs.

The progeny test has progressed from proving beef EBVs in dairy-cross animals in a NZ commercial setting, to now giving breeders and breeding companies a method of national benchmarking and confirming the performance promised by these EBVs before the bulls are used widely as semen sires. This develops trust in wider beef EBVs over time, as NZ dairy mating practices evolve.

B+LNZ works with DBPT host sites across NZ to assess the performance of progeny from promising beef sires at the dairy, rearing and finishing farms, and at slaughter.

We will present the important outcomes from the DBPT that are relevant to precision dairy farming, utilisation of breeding values to develop more profitable dairy and beef systems, and NZ and international relevance.

https://beeflambnz.com/news/blnzs-dairy-beef-progeny-test-enters-new-phase

USE OF THE CLEANED TOOL AS A PRECISION FEEDING STRATEGY FOR FEEDING AGRO-INDUSTRIAL BY-PRODUCTS TO DAIRY COWS IN THE PERUVIAN AMAZON

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Livestock production in the Peruvian Amazon faces the challenge of increasing productivity while minimising environmental impact. One promising strategy to address this issue is to supplement feed with local agro-industrial by-products, which are often discarded. The use of these by-products would improve nutrient cycling and the resilience of livestock systems. However, the impact of including these alternative feed resources needs to be clearly understood. The aim of this study was therefore to use the CLEANED tool to estimate the production and environmental impacts of dairy farms feeding their animals agro-industrial by-products in the humid tropics of Peru. The CLEANED tool is an easy-to-use, Excel-based tool developed by the Alliance Bioversity International - CIAT for quickly analysing the environmental impact of livestock systems before changes are made. Using parameters relating to livestock, crops, feed, land and manure, it models the impact of interventions on land use, productivity, economics, water usage, greenhouse gas emissions and soil health.

For this study, data were collected from twelve representative dairy farms over two seasons (wet and dry), with average productivity values obtained via semi-structured interviews. Milk, grass and supplement samples were analysed at the Food Nutrition Evaluation Laboratory of the National Agrarian University of La Molina. Milk was analysed for fat and protein content. The forage samples were analysed for dry matter, crude protein, neutral detergent fibre, acid detergent fibre, ash and ether extract. The information obtained on the characteristics of the evaluated farms, the production data and the nutritional value of the pasture and milk in both the dry and wet seasons were entered into the spreadsheets of the CLEANED X version 3.0.1 tool. Two scenarios were evaluated, each with a different diet. The scenario 1 (diet A) consisted of animals grazing *Urochloa brizantha*, while Scenario 2 (diet B) consisted of grazing plus cocoa hulls at 30% of the concentrate offered. The concentrate was fed to the animals at 6 kg per day and was formulated on the basis of maize and soybean cake. Production (kg milk/ha/year), environmental impacts through water use (m^3/kg product) and greenhouse gases (t CO_2 eq/ha/year) were estimated. The tool showed that Scenario 2, under the feed conditions mentioned above, had 45.1% higher level of milk productivity (kg FPCM/year/ha) compared to Scenario 1. Similarly, in terms of water use, Scenario 2 required less water to produce a unit of product (0.78 vs. 0.55 m^3/kg product, respectively). However, it is important to note that in terms of GHG, Scenario 1 had lower emissions (12.77 vs. 14.86 t CO_2 eq/ha/year, respectively). In the context of a circular economy, the results of this study highlight the importance of using CLEANED as a precision feeding strategy to explore the use of lesser-known feed resources, thereby contributing to waste minimisation and the sustainability of dairy production systems in the Amazon region.

AUGMENTED REALITY IN DAIRY FARMING: IMPROVING PRODUCTIVITY AND TRAINING EFFICIENCY

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Augmented reality (AR) is gaining traction across industries for its ability to overlay digital content onto the physical world, enhancing user interaction, performance, and learning. The frequent, standardised, and knowledge-intensive tasks in dairy farming make it a promising field for AR applications. This study investigates the feasibility and effectiveness of AR in supporting routine operations and training activities on dairy farms, with a specific focus on task performance and user acceptance.

The objectives were to: (1) develop and evaluate practical use cases of AR-based applications tailored to specific dairy farming tasks; (2) assess the impact of AR on task efficiency and accuracy; (3) evaluate the effectiveness of AR as a training tool compared to traditional methods; and (4) gauge user perception and acceptance of AR within the dairy farming context.

The research was structured around three use cases, for which dedicated AR applications were developed using Microsoft HoloLens 2 and Unreal Engine:

- Use Case 1 (UC1), On-Farm Information Retrieval and Recording: AR-enabled QR codes were installed on paddock gates, allowing users to retrieve paddock information (e.g., area, layout, hazards, and stocking capacity) through the headset. Usability was evaluated using a Technology Acceptance Model (TAM)-based questionnaire.
- Use Case 2 (UC2), Body Condition Scoring (BCS) Training: Twelve participants were split into two groups. One group used an AR application providing real-time visual guidance for BCS assessment, while the other used a traditional paper-based booklet. After assessing 12 cows, the groups switched methods. Accuracy, intra-observer consistency, and user feedback were collected and analysed.
- Use Case 3 (UC3) – Equipment Inspection Procedures: Participants with varying levels of experience conducted lengthy and difficult routine equipment inspections with and without AR-based step-by-step guidance. Task performance was assessed based on speed, accuracy, and user observations.

Across all three use cases, AR demonstrated notable benefits. In UC1, TAM results indicated high user acceptance, with perceived usefulness (PU) of 3.87 ± 0.47 and perceived ease of use (PEOU) of 4.05 ± 0.33 on a 5-point scale. In UC2, AR training for BCS was considered more engaging and easier to follow, leading to higher scoring accuracy and consistency. The immersive interface supported an intuitive understanding of the scoring process. In UC3, inexperienced workers using AR outperformed experienced staff using traditional methods in both speed and accuracy. These results highlight the potential of AR as an effective knowledge support tool, especially for novices. However, challenges such as hardware costs and integration into daily workflows were identified as barriers to adoption.

Augmented reality shows strong potential to enhance productivity, streamline training, and support real-time decision-making in dairy farming. Its hands-free, intuitive interface is particularly valuable in fast-paced or safety-critical environments.

Future work should focus on improving usability, exploring cost-effective deployment strategies, and involving farmers in co-designing solutions that integrate seamlessly into farm routines. With sustained investment and collaboration, AR could become a key enabler of digital transformation in precision dairy systems, especially as AR delivery devices become less bulky. The near-future development of lightweight AR interfaces, such as smart glasses or contact lenses, will further enhance user experience and open new possibilities for implementation.

4B | Forage and feeding, December 5

COMPARISON OF RUMINATION AND EATING TIME MEASUREMENTS OF MULTIPLE WEARABLE TECHNOLOGIES

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Wearable technologies are increasingly used to monitor dairy cow behavior, yet differences in measurements between systems may affect data interpretation. This study compared rumination and eating time data from four commercial systems – Nedap, SmaXtec, Farmlife, and CowManager – mounted on the same Holstein cows housed at the WKU SmartHolstein Lab.

Average daily rumination times (mean ± SD, minutes) were CowManager: 518 ± 142; Farmlife: 502 ± 113; Nedap: 502 ± 114; and SmaXtec: 478 ± 163. Concordance correlation coefficients (CCC) were high between CowManager and Nedap (0.970) and between Farmlife and Nedap (0.999). In contrast, SmaXtec showed lower agreement with other systems (CCC range: 0.013 – 0.206). Bland-Altman plots revealed minimal bias and narrow limits of agreement among CowManager, Farmlife, and Nedap, but wider limits and lower average values for SmaXtec.

Average daily eating times (mean ± SD, minutes) were CowManager: 230 ± 102; Farmlife: 177 ± 67; and Nedap: 278 ± 92. CCC values indicated moderate agreement: CowManager vs. Nedap (0.886), CowManager vs. Farmlife (0.772), and Farmlife vs. Nedap (0.532). Bland-Altman plots for eating times showed moderate bias and wider limits of agreement across comparisons.

Rumination times were most consistent among CowManager, Farmlife, and Nedap, while SmaXtec recorded lower and more variable values. Eating time measures showed greater variability across all system comparisons.

EMPLOYING A COLLAR-BASED ALGORITHM TO PREDICT DRY-MATTER INTAKE FOR EVALUATING AND IMPROVING FEED EFFICIENCY IN DAIRY COWS

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Feed efficiency (FE) is an important trait which is well established as hereditary and directly affects profitability and sustainability. A limiting factor to individual FE determination is reliable individual dry matter intake (DMI) data. Integrating economic parameters, such as feed cost and milk price, can also enable the calculation of income over feed (IOF), measuring the profitability of the cow, based on DMI and milk data.

Current DMI equations require data which is expensive or unavailable in commercial farms and have slope bias, making them less accurate in cows with high or low DMI. Moreover, they do not consider data from cow sensors, which are becoming common in commercial farms.

Accordingly, the objectives of this work were: 1) to develop an algorithm based on AfiCollar (neck-tag) data to accurately predict individual DMI and combine it with individual milk data to calculate FE 2) to examine the heritability of the calculated FE.

Individual DMI data from 350 cows wearing AfiCollars (Afimilk, Afikim, Israel) were collected in five research farms in the US, Canada and Italy. Overall, the data contained 16000 weekly data points (46 weekly measurements per cow on average). DMI was measured manually while the cows were in tie-stalls or by electronic systems (Calan Feeding System or Insentec RIC system). AfiCollar data describing eating, rumination and panting behavior was processed and combined with basic cow data (DIM, lactation, gynecology status) and milk production. Machine learning methods were used to produce a weekly DMI predicting model. The model was trained validated using leave-group-out cross-validation, where each group is a farm. Weekly DMI predicted by the model was compared to the measured DMI, the R^2 and RMSE were 0.77 and 1.82 kg, respectively (Figure 1).

To examine the heritability of FE, defined as energy-corrected milk/predicted DMI, data from five different Israeli commercial dairy farms was collected. The average FE between 100 and 200 DIM of the latest lactation of each cow was calculated. FE of dams (n=280) was correlated with that of their offsprings (n=340), R^2 was 0.27 and p-value <0.0001. FE from 145 offspring of 25 bulls with at least 5 offspring each was collected, and the significance of the bull effect was determined using ANOVA F-tests, p-value was 0.01.

These results demonstrate that this collar-based algorithm accurately predicts individual DMI. FE and IOF calculated based on DMI data can be powerful tools to optimize commercial farm management tasks. For example, using IOF to optimize the time of culling should help farmers optimize their profit from cows designated for culling. Moreover, the maternal effect on offspring FE suggests that using FE as a main parameter in breeding strategy determination can improve offspring efficiency.

This work presents a new method to accurately predict individual DMI in commercial farms. The relationship between parental and offspring FE suggests it can be used to improve herd efficiency and sustainability.

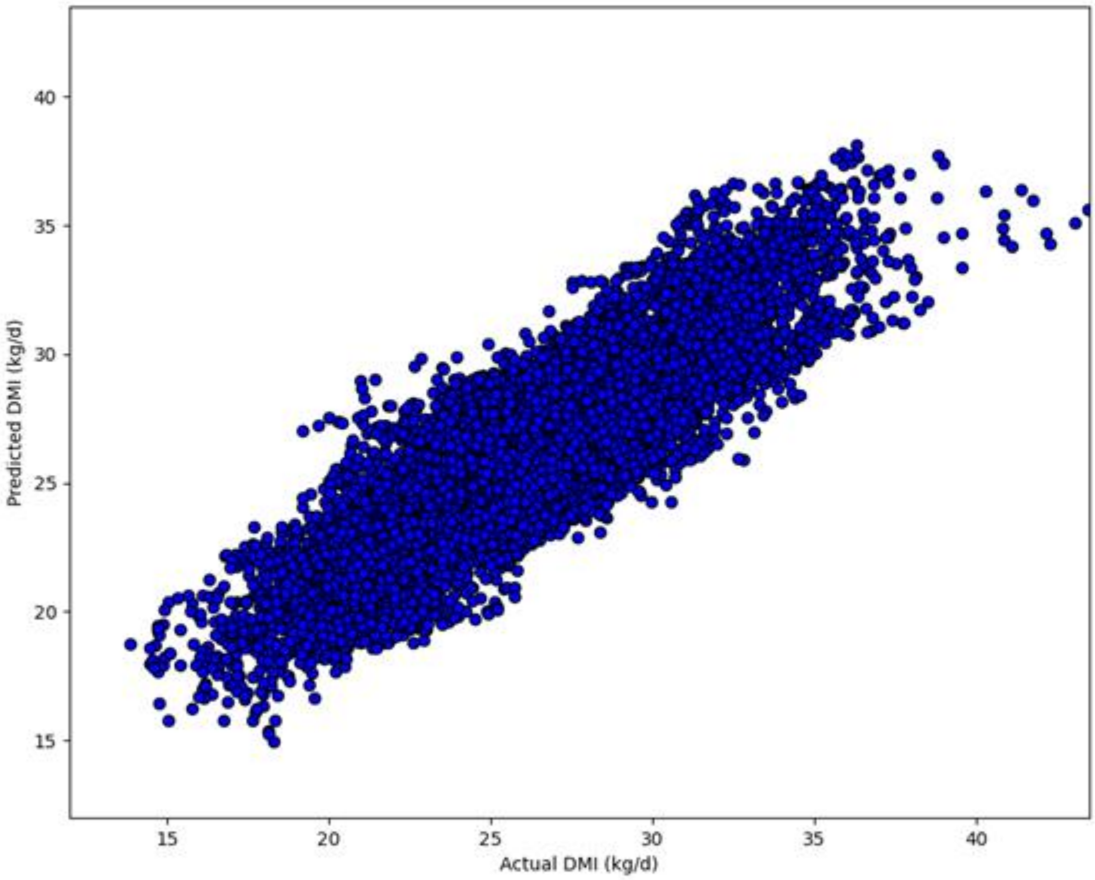

Figure 1. Correlation between actual measured DMI and DMI predicted by the model in the four validation farms. Each point represents a weekly result of an individual cow.

A RAPID APPROACH TO CROSS-CALIBRATION BETWEEN TWO SENSORS FOR PASTURE BIOMASS ESTIMATION

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Automated methods to estimate available pasture biomass offer time and labour savings to livestock farmers and researchers alike. Large ground-truth datasets are typically needed to calibrate sensors for this purpose; however, this is an inefficient process that needs to be repeated whenever new sensors come to market. The aim of this case study was to consider whether Planet SkySat (PSS) imagery could be rapidly calibrated using biomass predictions from a UAV-borne RedEdge-P (REP) camera (Micasense, Seattle, WA) as reference data.

The study area was a pasture agronomy plot site at the Ellinbank SmartFarm (VIC, Australia). A PSS image captured on 02/08/2024 and an REP image captured one day prior were used for cross-calibration. Image processing was completed in ArcMap 10.8.1 (ESRI, Australia). The images from the two sensors were georectified and resampled to the same resolution. The image from the REP was converted to biomass using its pre-existing model, which is driven by structure-from-motion height and the Core Red Edge Triangular Vegetation Index (CRETVI; Chen *et al.*, (2010)). A CRETVI map was also generated from the PSS imagery however the CRETVI equation was modified using the mean of the red and near infra-red bands to replace the red-edge band. A thousand random points within the survey area were generated and the REP biomass estimate and PSS-derived CRETVI value were extracted where each point fell. Linear, cubic, and quadratic regressions were fitted between the two parameters and the best fitting model was selected. Four further PSS images captured from September - November 2024 were used for independent validation. In each, PSS-predicted biomass values were extracted from paddocks on the Ellinbank SmartFarm where ground-truth biomass values had been recently obtained using a calibrated rising plate meter (RPM). RedEdge P biomass predictions were also gathered for the same areas and simultaneously compared against RPM.

Of the regression models tested for PSS calibration, the cubic model had the highest LCCC (0.58) and also produced the least mean absolute error (409 kg DM/ha). In the independent validation test, PSS-predicted biomass had high concordance with RPM values (LCCC = 0.78; Figure 1a). The root mean square error of prediction was 561 kg DM/ha and the mean absolute error of prediction was 433 kg DM/ha. The LCCC of REP-predicted biomass with PRM values was 0.71 (Figure 1b) and the LCCC between the two sensors' predictions was 0.73.

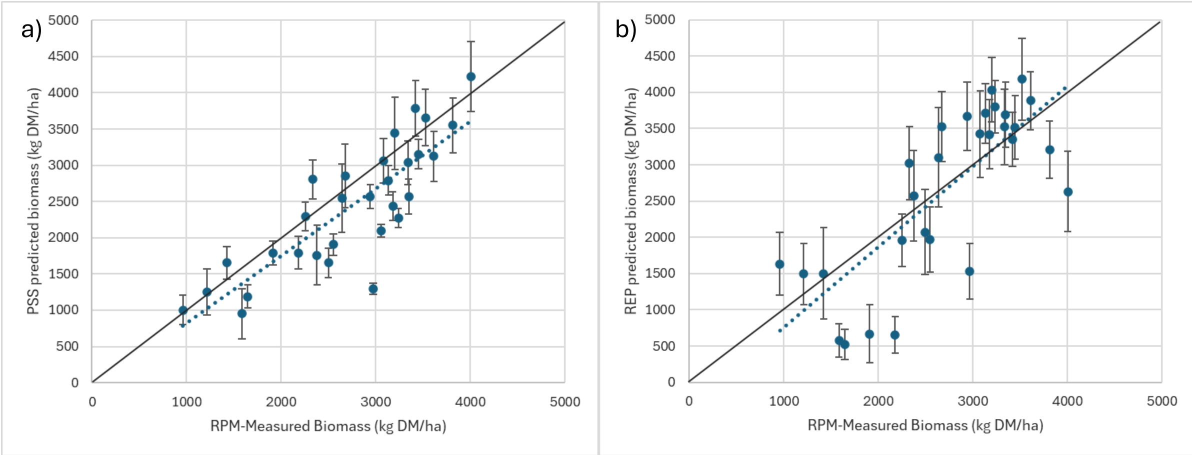

Figure 1. A comparison of RPM-measured biomass and (a) Planet SkySat (PSS)-predicted or (b) RedEdge P (REP) predicted biomass in the study area. Horizontal error bars show the standard deviation of sensors' predictions within each validation area.

In conclusion, rapid cross-calibration between similar sensors may enable rapid extension of pasture biomass monitoring capability to new platforms. Through this method PSS was able to generate acceptably accurate pasture biomass predictions in the range of 1,000 – 4,000 kg DM/ha for this one study location, however wider scale testing is still required.

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POTENTIAL OF ADVANCED GEOSPATIAL TECHNOLOGIES AND MACHINE LEARNING IN PRECISION MAPPING OF LAND AND PASTURE REOURCES ON DAIRY FARMS

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High resolution data (e.g., sub-paddock, patch-level) on pasture cover and quality, soil nutrient fertility, and the geolocation of individual trees could together with animal data enable a significant advance in precision management of dairy farms in New Zealand. In reality, we know that our land and associated pasture resources are highly variable across farmed landscapes. Capturing that spatial variability will inform the grazing plan, variable rate fertilisation, and better target soil management practices even within a single paddock. These solutions are increasingly achievable with the advances of geospatial technologies.

Our objective was to demonstrate the potential of advanced geospatial tools for precision mapping of land and pasture resources, using three farm case studies, one with a focus on pasture cover, one on soil health, and the third to consider tree shade and its potential impacts in pastoral farm landscapes. We evaluated the benefits of higher-resolution spatiotemporal data (e.g., location to sub-paddock level), identified gaps that prevent broader application, and proposed future research and practical solutions to address these challenges.

For pasture and soil nutrient fertility mapping we utilised an integrated approach combining spatial machine learning, remote sensing, GIS, and field surveys to map farm-scale resource information. The predictive models utilised remotely sensed indices, topographic data, and management practices as explanatory variables, with pasture covers and soil nutrient data used for training and validation to generate detailed spatial patterns. Tree data derived from LiDAR point cloud; alongside a digital surface model and digital elevation model were used in a 3D geospatial model to quantify and visualise the spatiotemporal pattern of shadow cast by individual trees on farm as well as the pattern of the solar intensity impacted by trees.

This approach has the capability to collect high-resolution (1 m^2 to 100 m^2) spatiotemporal data, including detailed pasture cover and quality distributions, spatially explicit soil nutrient fertility, and tree shade patterns linked to solar radiation. This resolution enables precise visualisation of resource distribution and variability across farmed landscapes, supporting data-driven management decisions. This includes applying targeted fertilisation to deficient areas within a paddock, identifying damaged pasture patches and implementing targeted reseeding, and identifying optimal locations for precision tree planting to improve cow comfort.

To enable the broader application of geospatial technologies, we recommend: (1) for pasture cover and quality, integrating Radar and LiDAR to mitigate cloud cover and topographical challenges; (2) for soil mapping, using a comprehensive set of indicators (nutrient fertility, organic matter, physical and biological properties) with spatial approaches to quantify interactions between soil indicators; (3) for tree mapping, incorporating species, age, and morphology (e.g., crown shape, canopy volume) to improve models of impacts on pasture, animals, soils, and water quality. Addressing gaps such as data sampling strategy, seasonal variability, and spatially weighted model will further enhance the model's performance and scalability.

IN SEARCH OF THE HOLY GRAIL: WILL TECHNOLOGY HELP US MEASURE PASTURE PERFORMANCE?

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Pasture eaten is a key driver of profitability in grazing-based dairy systems and also serves as a critical metric for assessing trends in pasture growth. However, the ability to measure pasture eaten accurately remains a difficult and labour-intensive task, which presently limits the scale at which measurements can be made. In this paper, we describe the purposes for which pasture measurement is either helpful or required for stakeholders including farmers, researchers, and government. We explore how the level of accuracy, timeliness, temporal and spatial scales required for each application can be determined. Then, for the purposes described, we review the current state of the art technologies and the challenges, comment on the ability of emerging technology to address these challenges, and describe remaining gaps for which solutions are yet to be found.

INTEGRATING APSIM AND REMOTE SENSING TO PREDICT MAIZE SILAGE BIOMASS

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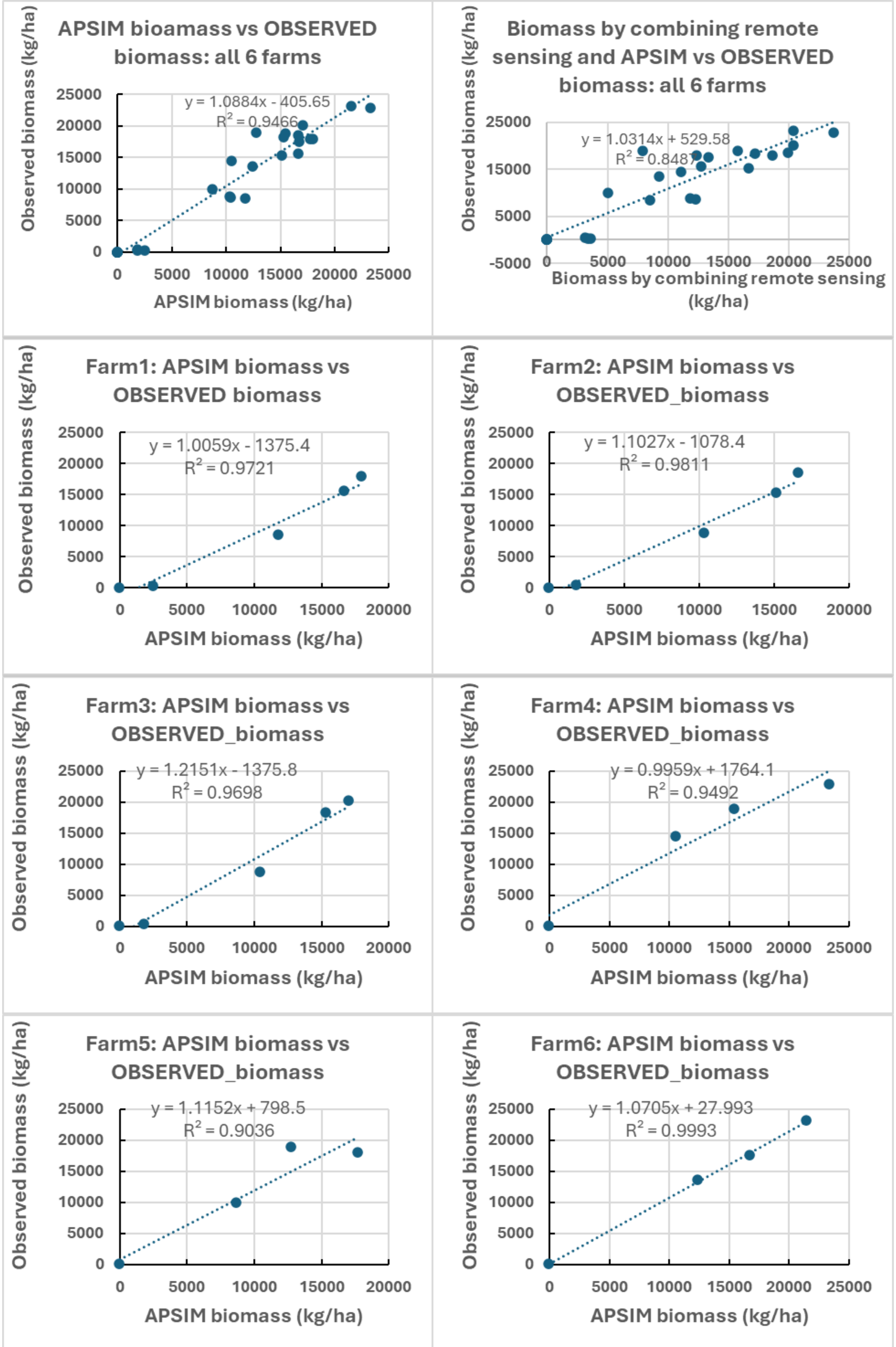
Recently, we demonstrated that the biophysical Agricultural Production Systems sIMulator model (APSIM) can be used to assess interannual variability of maize silage yield and harvest index (HI). However, APSIM cannot easily capture field variability or reflect real time crop status. Remote sensing provides spatial and temporal coverage of a paddock, able to detect real time canopy conditions and biomass using various indices. However, remote sensing does not simulate physiological processes e.g., soil N status, grain filling. Therefore, integrating APSIM and remote sensing may allow dynamic yield forecasts and quality predictions. Our ultimate goal is to integrate APSIM with satellite data to improve yield and quality predictions and enhance dairy farmers' ability to monitor and manage crop growth in real-time.

We collected both field and remote sensing data from maize crops grown for silage on six commercial NSW dairy farms during 2023-24. Data were collected at four crop stages: V6, flowering, grain filling and final maturity. At each stage, two plants were harvested and multiplied by the plants per ha to obtain dry matter yield. Final harvest yield was calculated by harvesting two 5 linear m maize rows and drying samples in an air-forced oven. Remote sensing data from Sentinel-2 were collected throughout the growing season and biomass yield was simulated using APSIM. Finally, APSIM and sentinel data were combined to investigate if an integrated approach could predict biomass more accurately than APSIM. In this process, NDVI was retrieved automatically from Sentinel-2 based on geospatial coordinates. These data were used to calculate potential and actual real time fAPAR. Intercepted solar radiation was calculated by multiplying fAPAR (NDVI)*intercepted radiation by APSIM. Biomass accumulation was calculated by summating the intercepted radiation (fAPAR plus RUE of APSIM). Contrary to our hypothesis, our results showed that APSIM alone predicted biomass with high accuracy (R^2 = 0.95; Figure 1) compared to the combined APSIM-remote sensing data (R^2 = 0.85; Figure 1). Accuracy of predicting biomass by APSIM was also high for individual farms although there is potential for improvement under dryland conditions. The reduced performance of the combined method may be due to calibration needs on the date of data collection including cloud cover, and resolution limits, which needs further studies. Our results showed that APSIM alone currently provides more accurate biomass prediction for maize silage compared to the combined APSIM-remote sensing approach.


APSIM bioamass vs OBSERVED biomass: all 6 farms
y = 1.0884x - 405.65
R² = 0.9466
Observed biomass (kg/ha)
APSIM biomass (kg/ha)
Biomass by combining remote sensing and APSIM vs OBSERVED biomass: all 6 farms
y = 1.0314x + 529.58
R² = 0.8487
Observed biomass (kg/ha)
Biomass by combining remote sensing (kg/ha)
Farm1: APSIM biomass vs OBSERVED biomass
y = 1.0059x - 1375.4
R² = 0.9721
Observed biomass (kg/ha)
APSIM biomass (kg/ha)
Farm2: APSIM biomass vs OBSERVED_biomass
y = 1.1027x - 1078.4
R² = 0.9811
Observed biomass (kg/ha)
APSIM biomass (kg/ha)
Farm3: APSIM biomass vs OBSERVED_biomass
y = 1.2151x - 1375.8
R² = 0.9698
Observed biomass (kg/ha)
APSIM biomass (kg/ha)
Farm4: APSIM biomass vs OBSERVED_biomass
y = 0.9959x + 1764.1
R² = 0.9492
Observed biomass (kg/ha)
APSIM biomass (kg/ha)
Farm5: APSIM biomass vs OBSERVED_biomass
y = 1.1152x + 798.5
R² = 0.9036
Observed biomass (kg/ha)
APSIM biomass (kg/ha)
Farm6: APSIM biomass vs OBSERVED_biomass
y = 1.0705x + 27.993
R² = 0.9993
Observed biomass (kg/ha)
APSIM biomass (kg/ha)

THE USE OF IMAGE ANALYSIS TO QUANTIFY PLANTAIN CONTENT IN MIXED SWARDS

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Plantain (*Plantago lanceolata* L.) inclusion in mixed swards has been highlighted as a potential way for mitigating nitrogen (N) losses from the New Zealand pastoral system. Plantain has been shown to reduce N leaching through both animal and soil-based mechanisms. A greater understanding of the relationship between plantain contents (as a proportion of total dry matter) in mixed swards and N losses via leaching is critical to the successful integration of plantain into temperate grazed pasture systems. This requires an analysis of varying plantain contents and N loss via leaching. However, the dry matter proportion of plantain present relative to the total dry matter grown may not be the only factor dictating N leaching losses through the profile. The fraction of plantain relative to other species (namely ryegrass), weeds and bare ground may be critical to understanding N leaching losses under plantain.

This experiment tested the hypothesis that image analysis could be used to assess the relationship between plantain as a fraction of area and of herbage dry matter. A field lysimeter experiment in the Waikato region was used to compare plantain fractions from five nominal plantain sowing rates with perennial ryegrass (equivalent to 0, 15, 30, 50 and 100% plantain as a proportion of dry matter) on two contrasting soil types (allophanic and gley). Pasture was harvested to a uniform standing height of 50 mm above the soil surface at approximately every four weeks depending on the level of plant growth. For each lysimeter, the harvested herbage was dissected (plantain, ryegrass and other) and subsequently dried at 65°C to determine dry matter yield. The area of ryegrass, plantain and bare soil within the circular lysimeter was estimated from post-harvest images obtained directly above each lysimeter. The correlation between the plantain fraction from image analysis and plantain dry matter proportion had an R^2 of 0.87. However, the actual dry matter proportions of plantain for the intermediate treatments were lower than the nominal sowing rates creating an uneven spread in the data. For the treatments which included ryegrass, the correlation between the ryegrass fraction from image analysis and the measured ryegrass dry matter proportion had an R^2 of 0.21. The proportion of bare ground coverage was not influenced by the plantain content of the pastures. Using regression analysis between the images and dry matter measurements, this study demonstrated that images can be used successfully to determine the composition of plantain in a plantain-ryegrass sward but may not be as accurate for determining the ryegrass component. Further investigation into its use with a greater variation in plantain content over different seasons would be useful.

A LIBRARY OF DAIRY FORAGE SPECTRA FOR THE FUTURE

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Field, plot, and lab-based plant phenotyping using various sensors has significantly improved the measurement of pasture forages. To ensure prediction accuracy, it is crucial to collect calibration and validation data with every new sensor and forage. However, the increasing focus on diverse swards with multiple novel species has made these processes prohibitively time-consuming and technologically challenging.

Spectral libraries offer a solution by allowing the differentiation of homogenous or mixed pixels and spectra into discrete classes and proportions without extensive in-situ calibration and validation for each sensor. Notable libraries, such as ECOSTRESS, USGS, and the Australian National Spectral Database (ANSD), support multiple sensors, many of which were not available when the libraries were established. These libraries contain spectra of photosynthetic and non-photosynthetic vegetation, but spectra related to grasses represent less than 1.1% of the primary libraries. This highlights a significant gap in the foundational science needed to enhance innovative and efficient forage agronomy for the dairy industry.

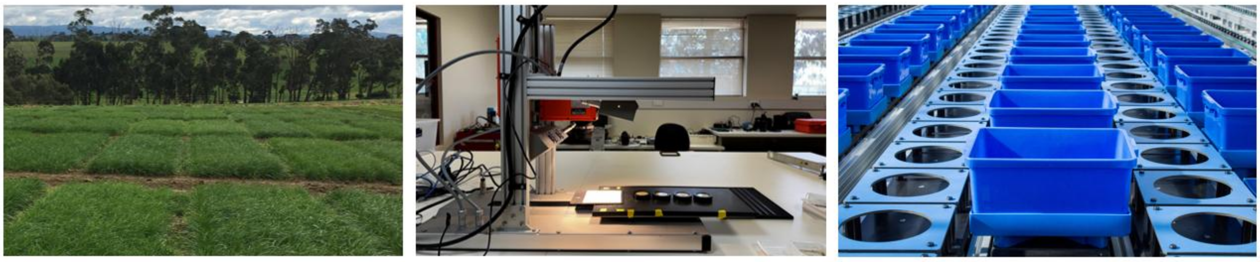
Plant architecture is a key contributor to many reflectance models, significantly improving predictive accuracy when adequate spectral and structural information is available. However, canopy architecture is complex and challenging to model due to variations in plant structure influenced by factors including planting density, growth stage and age. Incorporating a structural component into a forage spectral library will enable forage research to utilise new sensors, reducing calibration burdens and enhancing research outcomes and efficiency.

The project's objectives include collecting high-quality pure spectra and 3D architectural data from various forage species being used within current dairy forage projects. These data will facilitate the development of 3D structural traits for the species and enhance the translation of findings across current and emerging sensors. They will also improve estimations of the botanical composition of destructive samples at the leaf level and relate this to the botanical composition, fractional cover, nutritive characteristics, and dry matter yield in swards.

Data collection will be undertaken using nursery plots of each forage species and in glasshouse-grown pots (Figure 1). Two observations of the field plots will yield distinct plant views: benchtop imaging will focus on leaf-level hyperspectral qualities, while plot imaging will provide a canopy-level nadir view, resembling observations from UAV and satellite systems.

Initial benchtop imaging will concentrate on single species characteristics, followed by creating a botanical composition through a series of composite tests. This reverse engineering process will enable a wide range of sward compositions to be evaluated without the complexities of managing such diverse swards in plots and will reduce the need for time-consuming species sorting. Additionally, lab-based sensors will image whole plants in pots, allowing for a vertical structural view of the plant and its components throughout its growth cycle.

This observational approach will produce a complete spectral and structural record of forage species, allowing for spectral analyses like Spectral Angle Mapper and machine learning methods, such as Random Forests Techniques like Principal Component Analysis and neural networks, will also be assessed for the estimation of biomass, cover, nutritional characteristics, and DM yields.



1. Field observations of canopy cover (in-situ)

- FieldSpec4 (350 – 2500)
- Atmospheric and radiometric calibration.
- Light shroud measurements
- Open sky light interception measurements
- Single species plots, 4 replicates

Seasonal spectral profile per species

2. Lab observations (destructive samples)

- FX17 (900 – 1700 nm)
- FieldSpec4 (350 – 2500)
- Single species AGB
- Designed composition mixes

Seasonal spectral profile per species and designed mix

3. Short-term 360° observations (tubs)

- RGB
- Single species per tub
- Three density treatments

Species structure from RGB images, per species

Figure 1. Forage observations will be made at the canopy, leaf and plant level.

MANAGING PASTURE WITH PRECISION

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Effective pasture management relies on three things: accurate, high-quality data; the ability to interpret those data and make confident decisions; and the tools and labour required to act on those decisions with precision.

Research has demonstrated that even modest improvements in pasture data accuracy can lead to significant gains in feed allocation, animal performance, and overall farm profitability. While early digital tools enabled record keeping, planning and tracking, the labour required to manually gather and interpret data remained a key barrier. New technologies are stepping in to fill these gaps. Wearables and remote sensing products on the market provide farmers with valuable live and historical data to keep track of pasture with more frequency and granularity than could ever be captured manually. With this level of detail farmers can better understand which specific areas or animals are most impacting farm performance and address those.

In this session, we'll explore some of the latest technology that is available to farmers and ways that data and precision management can be used. As tools like satellite imagery offer pixel-level pasture insights and virtual fencing removes constraints around break size and frequency, farmers are no longer limited by traditional infrastructure or labour. Just as electric fencing reshaped rotational grazing, this next wave of technology will require the industry to rethink how grazing is managed and optimised. We'll also discuss the future potential for AI-driven decision support systems that not only highlight issues but also recommend specific actions based on a farm's unique goals and conditions.

4C | Data connectivity and insights

DATA MANAGEMENT IN DAIRY RESEARCH

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Every day in dairy research, enormous amounts of cow, herd and feedbase data are generated, with significant challenges arising due to the increasing number of additional data-generating technologies available for deployment. The ability to simultaneously collate multiple data streams into evidence-based, analysis-ready and actionable management information remains highly constrained. This presents a clear need and opportunity to explore how collated data can be organised into actionable management insights. The Sensing Data into Actionable Insights (SDAI) project within the DairyFeedbase (DFB) program has reviewed research data generation from the current and past DFB research programs and identified over 80 individual datasets. While numerous published works describe data collation methods and frameworks, the challenge is finding an option that can accommodate the variability of data available in dairy research and compile it in such a way that it is ready for multiple different research data analytics using current and novel numerical modelling. The integration framework must also be sensor-agnostic to enable future technology integration. This challenging task aims to ultimately enable complete farm monitoring and management for researchers and the dairy industry, and in the short-term, enable more efficient and insightful research outcomes.

A review of peer-reviewed open-access articles searching for open-source data ontologies and schemas identified 19 relevant to developing a dairy-focused data schema for research data and five dairy industry-specific systems that differed in scale, specificity and application. This demonstrates that although there is a common understanding of the importance of data interoperability, no single framework can accommodate all data sources, particularly in a complex agricultural system like the dairy industry. There were, however, five key themes common across the relevant systems: data quality, data standards, data integration, object-based data management systems, and decision support tools. Using this broad review, the SDAI project proposed a framework incorporating elements from most articles, emphasising the five key themes.

Importantly, the proposed framework allows for data staging from raw research data to analytic-ready data, and finally into a curated data warehouse, enabling external data sharing (Figure 1). The DFB framework stages both the collation and curation of dairy data. Three experimental databases (soil, forage and animals) support the experimental collection and relevant sensor measurements. Manual experimental data collection protocols are sometimes modified to improve collation; however, as the focus is on enabling improved research analytics, the collation methods are not strict and are established using large collections of historic data. The development of the DFB framework shown in the figure is currently underway. The initial focus has been to secure the most-used and at-risk data, which has been animal-related experimental data and climate reference data. The next focus will be on forage-related experimental data sets, imagery used across experiments and the related forage library. This framework aims to support long-term data collation and improve analysis efficiency for researchers in the dairy industry.

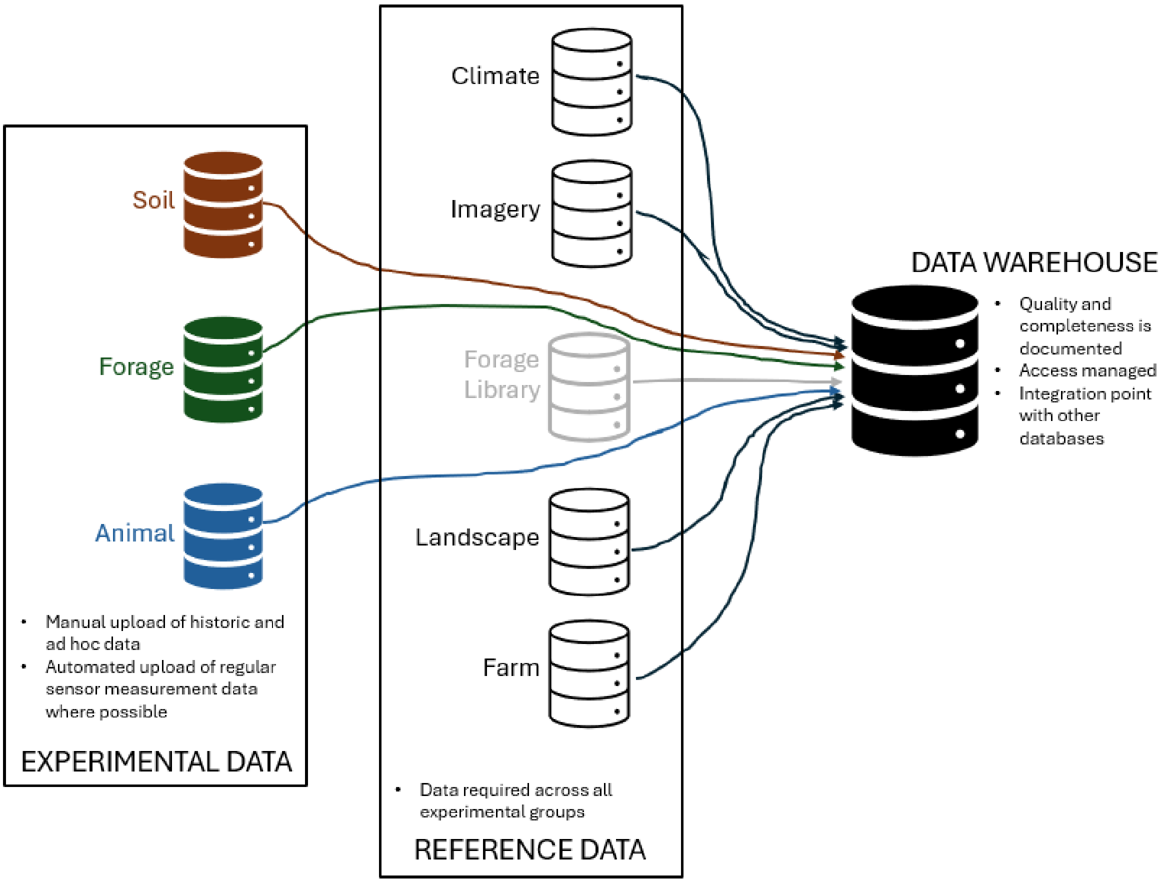

Figure 1. An overview of the DairyFeedbase data management framework, which effectively integrates research-specific data, general dairy industry information, and comprehensive reference datasets.

THE USE AND IMPACTS OF PRECISION LIVESTOCK FARMING TECHNOLOGIES ON DAIRY FARMS: A POST-ADOPTION STUDY

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There is an increasing interest in the adoption of digital tools and sensors in modern livestock farming, including wearable devices that monitor dairy cows 24/7 (Marino et al., 2023). However, post-adoption studies exploring how such technologies have been used over time are rare (Montes de Oca Munguia et al., 2021). Research shows that technology adoption and use is not linear, so a deeper understanding of individual user experiences is required (Rose et al., 2023). It is therefore essential to gain a better understanding of what information from precision livestock farming (PLF) technologies is being used for decision-making; and critically, the impact it has had on the farm, farm workers, and the cows themselves.

An on-line survey was prepared to seek the views of those working on dairy farms on the use of digital technologies, whether they use anything today or not. The survey was circulated through the farming press, with coverage in printed editions and via their social media channels. Key dairy industry organisations and veterinary practices also distributed the survey through their online newsletters and social channels. The survey is expected to close at the end of May 2025.

As the survey is still underway, these findings are preliminary and will be subject to further analysis. The main drivers for PLF technology adoption were to improve heat detection, save on labour, and improve efficiency and productivity. However, it is already noted that the data generated from devices not only differed but were being used in different ways and to different extents. Data were being actively used for decision-making on dairy farms; with heat detection (93%), activity monitoring (80%) and sickness/disease detection (70%) being the most prevalent uses. The biggest benefit of PLF technology to animal welfare was the early detection of illness or disease; often before clinical signs were observed by farm staff, which allowed for earlier intervention. Despite all of this, most respondents indicated that they were not using their PLF technology to its full extent and a more in-depth analysis will be completed to understand why this is.

For respondents not using PLF technologies today, almost half thought they would likely install a technology in the next 5 years. It is therefore critical we understand the everyday perspective now, as this could facilitate effective adoption and use in the future.

Findings are currently interim (but will be final by 4th International Precision Dairy Conference) and analysis of the full data will provide a greater insight into the practical application of PLF technology. It is anticipated that follow-up qualitative interviews will be completed with some participants from this study to gain a deeper understanding of technology use, challenges and opportunities. By learning how individual dairy farmers engage every day with digital technologies, we can identify what is required to optimise adoption pathways in the future. The work will also generate recommendations for manufacturers, farm advisors and industry groups, to enable them to better support farmers in transitioning to and optimising the use of digital technologies.

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APPLICATION OF PID CONTROL TO SUPPORT DAIRY HEIFER PLANNING

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Accurate production of the target number of dairy heifers calving in a period on dairy farms is difficult. Often, the actual number of dairy heifers calving is determined using sexed female dairy semen approximately 32 months earlier, conception rates and actual losses to birth and to first calving. Dairy producers periodically review heifer projections and may manually adjust the use of sexed semen to make corrections when projections are deemed off target. Such adjustments are more art than science and are likely not optimal. In industrial control systems, PID (proportional–integral–derivative) controllers are the mechanism commonly used to manage processes that require continuous control and automatic adjustment to remain on target. The hypothesis for this study was that the application of PID controllers may improve the accuracy of heifer production. Therefore, the objective was to develop, apply, and optimize PID controllers to the problem of automatic control of the production of heifers through adjustment of the use of sexed semen.

To study the problem, a Monte Carlo process model of the heifer calf production system was built. The model was parameterized based on an actual dairy farm and included weekly variations in number of inseminations [90,110], actual and estimated conception rates [40%-50%], and actual number of conceptions from sexed inseminations. Autocorrelations created weekly dependencies on past data. The genetic merit of each animal was simulated from a N (0,100) distribution. The target was 20 conceptions to sexed semen weekly, which implied that roughly half of all inseminations should be to sexed semen (with the remainder to beef semen). A model run included 1000 weeks of simulations. Input into the PID controller was the weekly difference between expected and target number of conceptions to sexed semen. Two methods for the PID controller to automatically adjust the weekly expected number of sexed semen inseminations were explored. The first “number” method was to use sexed semen for every insemination until the desired number of sexed semen inseminations was reached in a week. This method therefore ignored the genetic merit of animals. The second “genetic” method adjusted a genetic merit threshold. Animals with a genetic merit above this threshold were inseminated with sexed semen. For each method, the best proportional, integral, and derivative settings were found by minimizing the sum of squared errors in one run. Results from 20 independent runs were averaged. Results showed that both PID control methods were able to automatically adjust the number of sexed semen inseminations to minimize the average weekly error (< 0.1), regardless of the starting inputs. The average weekly standard deviation was slightly smaller for the “number” method (3.8) vs. the “genetic” method (4.3) but the average genetic merit of animals inseminated with sexed semen was $87 for the “genetic” method vs $0 for the “number” method. Results using simple bang-bang adjustments were only slightly worse. In conclusion, this first exploration of PID control methods to the problem of dairy heifer production showed promising results, but many questions regarding optimal settings remain for further research.

ENHANCING GLOBAL INTEROPERABILITY IN LIVESTOCK DATA

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The International Committee for Animal Recording (ICAR) facilitates advancements in animal management, traceability, genetic improvement, and research. It promotes exchange among stakeholders, such as livestock breeders and farmers, researchers, and industry organisations, contributing to improved animal health, welfare, and increased sector productivity. The ICAR Animal Data Exchange working group plays a vital role in establishing common standards for interoperability of livestock data and supporting collaboration between agritech innovators and the wider industry.

Traditionally, ICAR data exchange messages have focused on interoperability for core animal records including parentage, reproduction and milk production or growth. A new generation of ICAR messages are designed to support animal monitoring and management technologies and will provide a framework for wider integration of data from a variety of systems including wearable sensors and location monitoring devices, camera systems, and feed intake monitors. The presentation will discuss how new ICAR specifications support continuous animal health and performance monitoring, detection and response to issues, and a cohesive view of the farming system.

A common specification that is being adopted globally also enables ready integration of livestock data into farm systems analysis, supporting feed planning, nutrient management, and modelling and planning for greenhouse gas emissions abatement. The presentation will explore a concrete example of livestock data from different sources, connected through ICAR-compliant APIs, to be used in emissions monitoring and decision support.

TECHNOLOGICAL CHANGE, MILKING-RELATED PRACTICES, AND THE FEATURES OF HIGHLY EFFICIENT MILKING IN PASTURE-BASED SYSTEMS

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Digital agriculture technologies are becoming more prevalent on farms globally, however there is limited robust data on actual adoption rates and the potential impact of these technologies on the farming workplace. In this study, a survey of 500 New Zealand dairy farmers was conducted in 2023 with the aim of: 1) assessing the on-farm adoption of dairy workplace technologies, and 2) the potential impact of automation technologies on reducing hours of work through milking efficiency.

The results show that NZ dairy farmers have invested more in dairy automation technology than in animal monitoring technology, particularly those technologies that support a 1-person milking operation, and adoption levels were higher on farms with rotary parlors. Comparing the current data with a similar study conducted in 2018, the use of automated cup removers (ACR), automated teat spraying, and automated drafting in rotary parlors has increased more than 10 percentage points over the 5 years, from 77%, 70% and 49% to 88%, 83%, and 61% for these technologies, respectively.

The impact of technology use on milking efficiency was explored by comparing technologies installed in parlors on farms ranked in the upper and lower quartiles according to the cows milked/h.person metric. This metric is strongly influenced by the number of people used in the parlor to milk and the number of clusters installed. The upper quartile of both rotary and herringbone parlors were around 10 years newer in age and had a third more clusters installed than the lower quartile.

Three technologies that support 1-person milking in rotary parlors are ACRs, automatic teat spraying and automatic drafting. These are installed in 97%, 97% and 73% of parlors in the upper quartile, respectively, where 98% of parlors operate with 1-person milking, with 53 clusters installed and 284 cows milked/h.person, on average. Comparatively, the proportion of parlors with the 3 technologies in the lower quartile was 76%, 67% and 44%, respectively, with 41 clusters installed and 91 cows milked/h.person, on average.

For herringbone parlors, the upper quartile had slightly more installations of ACRs (34%) and automatic teat spraying (17%) and more than twice the installations of automatic drafting, (36%), than the bottom quartile at 28%, 13% and 15% for these technologies, respectively. Parlors in the upper quartile had more clusters installed (32) and milked more cows/h.person (150) than the lower quartile with 24 clusters installed and milking 63 cows/h.person, on average. Parlors in the upper quartile had 1 person milking for up to 30 sets of clusters before additional people were required.

Cow wearables were the only animal monitoring technology with significant market growth in the 5 years since the 2018 technology survey. The proportion of herds with wearables was 11% and 28% for herds milked in herringbone and rotary parlors, respectively, and 16% of all herds at the time of the current survey.

This study showed that the nature of work continues to evolve on NZ dairy farms, with automation and digital technologies having an influence on the efficiency of key tasks, such as milking.

DATA FOCUSSED PROJECTS FOR DAIRY SYSTEMS VIEWED THROUGH A NATIONAL LENS

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Data collected for decision making within a dairy farming system typically exists at a cow, paddock, herd or farm enterprise level and often, when described, the data focus is on a particular aspect of the production system, such as mastitis management. This abstract widens the lens to examine how the Australian dairy industry has collectively invested in research and development projects to build data-driven frameworks and processes for cow, paddock and farm decision support. In some examples, the projects remain in a research phase with development into farm or industry adoption yet to take place. Projects which are in the adoption phase are: DataConnect for collection and analysis of cow-level information; Forage Value Index for paddock-level decision making on ryegrass cultivar choice; and DairyBase and Dairy Farm Monitor for farm enterprise-level biophysical and financial performance. Projects currently in the research phase are the DairyUP cow- and herd-level "Unlocking the potential of the cow" database; Dairy Feedbase "Sensing data into actionable insights" and the DataGene partnered International Dairy Data Exchange Project, principally for exchanging cow- and herd-level information. Investment of industry funds in the described projects does not reflect a complete absence of commercial operators in this area. Rather, it acknowledges and responds to the requirement for collective industry action, at a national level, to accelerate delivery, coordinate effort and support sovereign capability and capacity in areas such as breeding values. There is a strong case for pre-competitive cooperation and investment to enable data aggregation and decision support tool creation. A multi-pronged approach to project work in the described areas further supports the application of technology on farm so that better decisions, within an individual farm production system, can be made. Ideally this approach lowers the risk for flat or decreasing on-farm productivity. Given the increased volatility of terms of trade for dairy farm inputs and milk pricing, enhancing productivity is essential for the sustainability of dairy farm systems. More than the majority of other primary production systems, dairy farming has the most decision-making points across a day, week, month or yearly timespan. The ability to efficiently turn accurate data into evidence-based decision-making remains even more vital as average herd size increases. In addition, the ability to use data to create performance metrics at a farm and industry level will continue to increase in importance.

UTILISING ANIMAL BEHAVIOUR DATA TO ENHANCE FARM PERFORMANCE

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As high-resolution data becomes increasingly available on pasture-based dairy farms, accurately quantifying cow behaviour and feed allocation, the next challenge is understanding what patterns are linked to improved outcomes, such as higher milk production or increased fertility. While there is no shortage of opinions on what optimal behaviour looks like, robust large-scale evidence remains limited. This is especially true for feed allocation variables which are difficult to measure accurately at scale in pasture systems.

Improving our understanding of how these variables relate to farm outcomes can help to inform herd management decisions and aid in the interpretation of the vast amounts of data available to farmers through wearables and other on-farm technology.

This session will share insights from an analysis of Halter's large-scale datasets, which link individual cow behaviour, reproduction and feed allocation, with a focus on the calving transition and mating periods. Findings highlight that many behavioural variables during the calving transition are associated with both milk production and fertility, with the most critical window being the four days post-calving. Behaviour during the mating period was also linked to conception success.

THE IMPACT OF EXPANDING DATA CONNECTIVITY IN AUSTRALIAN HERDS

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Data connectivity has been a recognised issue in the Australian dairy industry since at least 2010, with the first report into the need to aggregate data. Since then, DataGene, an industry owned and industry good organisation, has been working to create a Central Data Repository (CDR) for the industry and to connect data sources to enable farmers and industry to make data-driven decisions. This project is called DataConnect and is partially funded by Dairy Australia.

DataConnect has now been running for two years and has moved from understanding the needs of farmers, to a proof of concept, through to implementation. The project aims to connect farm management and other on-farm software to the CDR and enable access to more accurate farmer tools, such as the Fertility Focus and Mastitis Focus Reports. By contributing their data into the CDR, farmers are also making milk recording and genomic testing easier for themselves as there will be less double entry of information into the milk recording or genetic evaluation systems. With increased data flowing into the CDR, the reliability of breeding values should also increase.

In addition, DataConnect includes a dairy industry data audit which identifies key data collected on farm and data pain points for farmers and from these findings explores options to improve data connectivity and decision making.

Throughout this project, the team have encountered a range of challenges, such as data quality, the perceived ownership of data, data silos, old technologies, new technologies and farmer frustration. For instance, old versions of software may not be able to connect easily to industry databases and new technology may exist in a silo with no data connections at all. After two years, DataConnect provides insight into the challenges and opportunities of integrating data and leveraging this data for farm decisions. It is creating opportunities for new reports and tools at both industry and farm levels. Farmers can make better management decisions and industry can gain insight into health events on farms. Increased health event observations will also enable future research to create new breeding values to improve the health of Australian herds.

One direct benefit of DataConnect is to enable farmers to access a new industry tool, the Mastitis Decision Support app which uses the farmer's data and machine learning to help farmers use antibiotics judiciously.

Critically, DataConnect also enables a better understanding of a broad variety of data sources and how they connect, or more often, do not connect. This will inform industry discussion and priorities for future data connections and decision support tools. DataConnect demonstrates that data aggregation will play a significant role in the future prosperity of the Australian dairy industry. Not least because aggregated datasets enable exploration of the uses of artificial intelligence to improve decision making.

DAIRY DATA, SCIENCE AND REPORTING USING A MODERN SCIENCE WORKFLOW

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The proliferation of on-farm sensors, wearables, and robotic systems in precision dairy farming generates unprecedented volumes of high-velocity data. However, translating this "big data" into actionable, farm-level insights remains a primary challenge, often hindered by data silos and a lack of scalable, reproducible analytical pipelines.

This presentation introduces the "Modern Science Workflow" (MSW), an integrated project designed to bridge this gap by providing the critical infrastructure for data-driven science, as well as the skills and capability required, and a continuous improvement approach. Our workflow leverages a centralized cloud data warehouse (e.g., Snowflake) for scalable ingestion of high-frequency sensor data, a robust analytics platform (e.g., Posit Workbench with R) for advanced modelling, and version control (e.g., GitHub) to ensure scientific reproducibility and collaboration. Ingestion of a range of non-sensor data from farms relating to pasture, cows and equipment is being improved with and enhanced with digital approaches. This framework provides the foundation to effectively develop and deploy robust machine learning models for early disease detection and behavioural monitoring, ultimately enabling the delivery of validated, timely decision-support tools that enhance animal science and farm profitability. In addition, near real-time data flows enable live reporting of research results, creating an engaging platform for interested farmers to gain additional insights and facilitate conversations, reducing the lag time to industry.

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