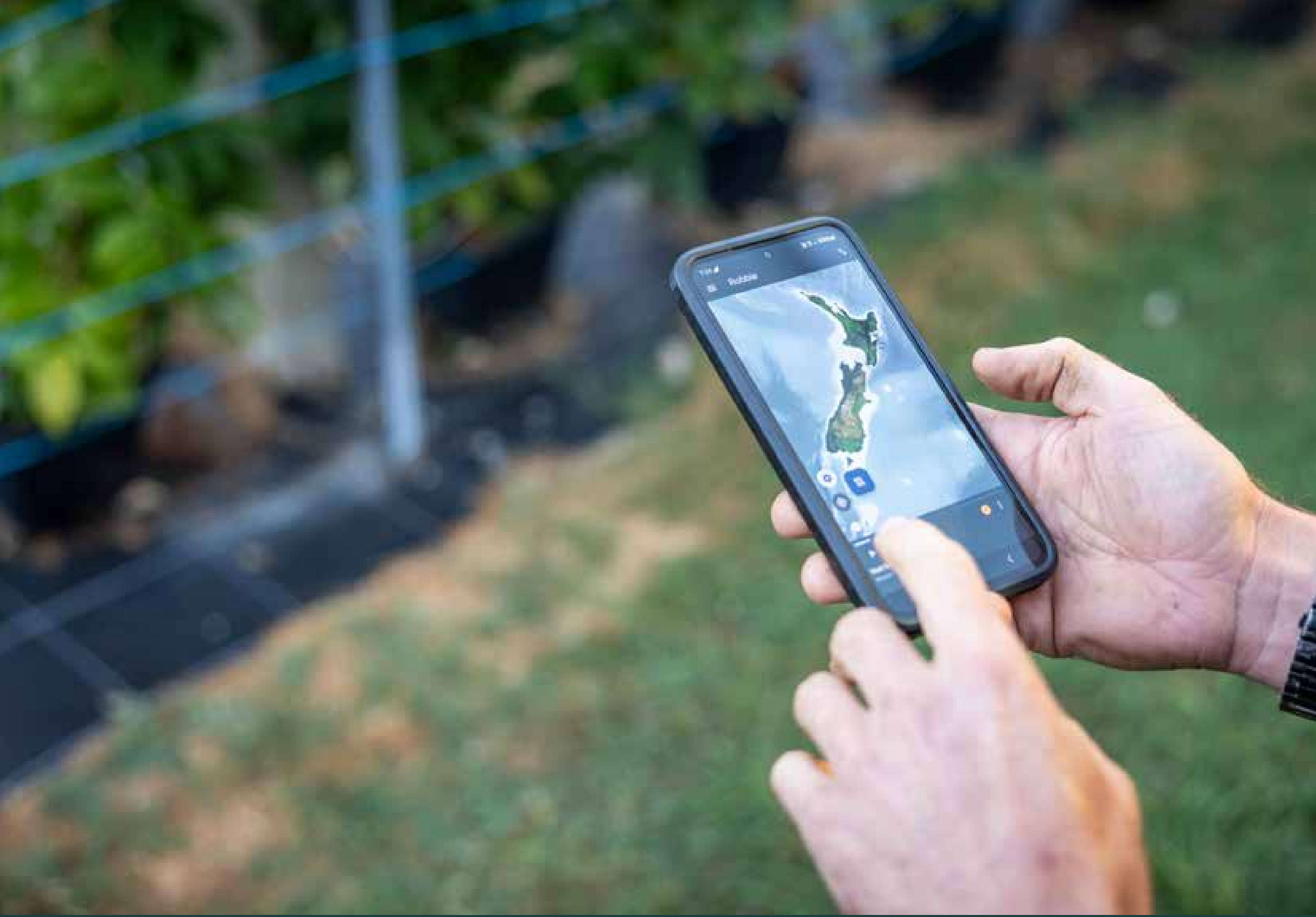

Safer By Design: The Role Of Technology In Farm Safety

JUNE 2026

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1. Executive Summary:

Designing Out Danger — Technology As A System Lever For Safer Farms

Despite decades of regulatory reform, industry leadership, and investment in awareness and education, New Zealand agriculture continues to experience persistently high rates of fatal and serious injury.

Farm injuries are not confined to unusual events or inexperienced people. They often happen during ordinary work – operating vehicles, moving livestock, applying chemicals, working alone, or making decisions under fatigue and pressure. In other words, risk is built into the way many farm tasks are designed and performed.

"New Zealand agriculture has reached a critical point in its safety journey."

This points to a clear limitation in the sector's current approach to health and safety. Awareness has improved. Regulation has strengthened accountability. But these gains have not been enough to shift the high over-representation in harm and risk of the sector.

"...even experienced operators working in familiar environments remain vulnerable to harm."

The problem is not that farmers do not understand risk. It is that traditional safety strategies – centred on training, procedure, and behavioural compliance – still rely on people making the right call, every time, in conditions that make perfect judgement difficult. On farm, decisions are shaped by fatigue, time pressure, wider business stresses, environmental variability, and cultural norms that often prioritise productivity and self-reliance.

As a result, even experienced operators working in familiar environments remain vulnerable to harm. The sector has become better at recognising risk. It now needs to become better at designing systems that reduce or remove it.

Technology: The System Lever Solution

Technology has an important role to play in that shift. Not as a standalone fix, but as a system-level control that can change how work is performed. The greatest safety gains come from technologies that reduce reliance on human judgement and align with higher-order controls: removing people from high-risk environments, substituting safer processes, or detecting hazards before harm occurs.

"The sector has become better at recognising risk. It now needs to become better at designing systems that reduce or remove it."

Autonomous and remotely operated machinery, drones, virtual livestock systems and automated handling technologies can reduce direct exposure to rollovers, animal interactions, chemical use and hazardous terrain. Sensing and monitoring tools – such as proximity sensors, stability monitoring, fatigue detection and environmental sensors – can provide real-time warning and, in some cases, automated intervention.

At a broader level, digital platforms and telematics can make risk more visible. By bringing together data on vehicle use, environmental conditions, operational behaviour and incidents, these systems can help farm managers and governance bodies move from reactive reporting to earlier, more proactive risk management.

> "Safety technology needs to be framed as part of better farm system design, not as another compliance burden."

Implementation Is Key

The benefits of technology are not automatic. Poorly integrated systems can reduce situational awareness, create alert fatigue, or be bypassed if they feel impractical. The use of data also raises questions about privacy, ownership and trust. Adoption will remain uneven where farms face barriers such as cost, connectivity, technical capability or misalignment with existing ways of working.

Safety technology needs to be framed as part of better farm system design, not as another compliance burden. Farmers are more likely to invest when technology also improves productivity, reduces workload, or strengthens overall farm performance. Practical case studies, peer learning and clear cost-benefit examples will be critical to broader adoption.

This paper reframes how farm safety can be understood and addressed. It shows why approaches centred only on compliance and behaviour have limits, and how technology-enabled system design can help reduce exposure to stubborn risks. It also considers where technology is already working, where it is still emerging, and what conditions are needed for successful implementation.

New Zealand agriculture has reached a critical point in its safety journey. The opportunity now is to move from managing risk in the moment to designing more danger out before work begins. That will require better infrastructure, stronger governance, improved connectivity, access to capital, technical support and coordinated action across industry, government and the wider rural sector.

This shift does not diminish the importance of people, leadership or culture. It reinforces them. Technology works best when it supports human judgement, strengthens decision-making and makes safer choices easier in the real conditions of farm work.

The future of farm safety will be shaped by how well the sector can move from recognising risk to redesigning the systems that create it. The challenge is no longer simply identifying solutions. It is implementing them in ways that are practical, accessible, scalable and aligned with the realities of farming.

> "The opportunity now is to move from managing risk in the moment to designing more danger out before work begins."

2. Strategic Foundation:

Why Awareness Is Not Enough

AT A GLANCE

- Agriculture continues to carry a disproportionate share of fatal and serious workplace harm in New Zealand.
- The sector's safety challenge is shaped by history, culture, regulation, economics and everyday operating conditions.
- The core issue is not a lack of awareness alone, but the limits of behaviour-led controls in complex farm systems.
- The opportunity is to use technology as part of system design, not simply as another compliance tool.

2.1 The Case For Change

Agriculture remains one of New Zealand's highest-risk sectors for fatal and serious workplace harm. WorkSafe New Zealand data and sector analysis show that agricultural workers are disproportionately represented in fatal injury statistics, particularly in incidents involving vehicles, machinery, livestock and environmental hazards (WorkSafe New Zealand, 2024a).

ACC data shows the wider burden of non-fatal harm. In 2024, ACC accepted more than 17,000 farming-related injury claims, with recovery and rehabilitation costs exceeding $120 million. Many of these injuries happened during routine work – operating vehicles, handling livestock, using machinery or applying chemicals (Statistics New Zealand, 2024).

Despite its global reputation for efficiency and innovation, the New Zealand agricultural sector continues to face persistent health and safety challenges. Research shows that farm injury patterns are shaped by the interaction of environmental hazards, operational pressure, cultural norms and systems that can normalise risk (Lilley et al., 2020; Cryer et al., 2014; Sissons, 2016).

The sector has increasingly recognised that these risks require coordinated action. The Farm Without Harm strategy, launched by Safer Farms in 2021, represents a sector-wide commitment to reducing physical and psychosocial harm through better system design, technology adoption and leadership engagement.

This literature review provides the foundation for the wider white paper by examining:

- the scale and nature of harm in New Zealand agriculture
- the regulatory and strategic framework for farm health and safety
- why harm persists despite greater awareness
- the role of technology as an emerging mechanism for harm prevention

Together, these factors build the case for a more focused examination of technology-enabled approaches to harm reduction on New Zealand farms.

2.2. Cultural Context: Resilience, Innovation And Risk

New Zealand farming has a strong history of innovation, adaptability and market discipline. Those strengths have helped the sector improve productivity and respond to changing conditions. But the same cultural traits can also normalise risk, or frame health and safety as administrative compliance rather than operational risk management (Sissons, 2016; Nielsen, 2015).

> "Farm harm persists not because risks are unknown, but because exposure remains embedded in everyday work."

17,000+ farming-related ACC claims in 2024

2.3 Statistical Profile Of Farm Harm (2002–2025)

The scale of harm in New Zealand agriculture remains a critical concern for the sector's social licence to operate and workforce sustainability. While some injury indicators have improved over the past two decades, agriculture, forestry and fishing continue to record among the highest rates of work-related harm in the country (Statistics New Zealand, 2024; WorkSafe New Zealand, 2024a).

> "New Zealand farming's culture of resilience is a strength – but it can also normalise risk."

Work-related injury claims show both progress and persistent risk. Across all industries, the incidence rate of work-related injury claims has declined steadily since the early 2000s. But agriculture, forestry and fishing continue to sit above the national average, reflecting the physical demands of farm work and constant exposure to machinery, animals and environmental hazards (Statistics New Zealand, 2024).

ACC claims data further demonstrate the scale of non-fatal harm within the sector. In 2024, ACC accepted more than 17,000 new farming-related injury claims, with total recovery and rehabilitation costs exceeding $120 million (ACC, 2025). Many of these injuries occur during routine tasks such as vehicle operation, livestock handling, and machinery use, indicating that hazards are embedded in everyday farm activities.

Fatality And Serious Injury Trends

Agriculture continues to account for a disproportionate share of work-related fatalities in New Zealand. WorkSafe New Zealand reports that the sector regularly accounts for around one quarter of all workplace fatalities, despite representing a much smaller share of the national workforce (WorkSafe New Zealand, 2024a).

Vehicle-related incidents remain a major concern. Tractors, quad bikes and side-by-side vehicles continue to be leading causes of death and serious injury on farms (WorkSafe New Zealand, 2024a). International research shows a similar pattern, particularly in countries with extensive pastoral systems (Cryer et al., 2014).

A notable recent trend is the increasing involvement of utility vehicles, including side-by-side vehicles, in fatal incidents as their use across the sector has grown.

These vehicles can provide stability advantages over traditional quad bikes, but serious incidents still occur when restraints are not used or when vehicles are operated on steep or unstable terrain (WorkSafe New Zealand, 2024b; Safe Work Australia, 2023).

Comparative Incidence Rates Of Work-Related Injury Claims Per 1,000 FTEs

Year	Agriculture, Forestry & Fishing	Manufacturing	Construction	Total Industry (Average)
2017	184	154	159	103
2019	182	161	157	100
2021	174	164	144	91
2023	149	151	127	86
2024	131–140*	135–145*	120–125*	80

*Provisional statistics. (Statistics New Zealand, 2024; 2025)

$120M+ recovery and rehabilitation costs in 2024

The Economic Cost Of Failure

Farm-related injuries carry a significant economic cost, as well as the human cost of injury and loss. ACC estimates that the direct cost of farm injury claims exceeds $120 million each year, covering medical treatment, rehabilitation and compensation payments (ACC, 2025).

These figures do not capture the full impact. Lost productivity, disruption to farm operations, replacement labour, and the psychological effects on families, colleagues and rural communities all increase the true economic burden of agricultural injury (Wren & Barrell, 2010; Scott, 2023).

Taken together, the data shows that awareness alone is not enough. Agriculture remains persistently exposed to serious harm. Addressing these risks requires systemic interventions that reduce exposure to hazards, not behavioural awareness alone.

2.4 Regulatory Framework

The Regulatory Crisis And The Birth Of Worksafe

In 2013, the Independent Taskforce on Workplace Health and Safety concluded that New Zealand's work health and safety system was fundamentally failing to prevent workplace harm (Independent Taskforce on Workplace Health and Safety, 2013). The Taskforce identified systemic weaknesses, including:

1. Confusing regulation: Fragmented, overlapping laws and unclear compliance expectations undermine consistency and accountability.

2. A Weak regulator: Insufficient capacity, capability, and coordination limit effective guidance, enforcement, and harm prevention.

3. Poor worker engagement: Worker participation mechanisms are weak and underutilised compared with peer jurisdictions.

4. Inadequate leadership: Limited health and safety capability and inconsistent leadership across organisations reduce system influence and exemplar behaviour.

5. Capability and capacity shortfalls: Widespread gaps in knowledge of risks, hazards, and regulatory obligations across workers, managers, and regulators.

6. Inadequate incentives: Weak enforcement, low inspection probability, and limited penalties reduce deterrence and fail to reward compliance.

7. Poor data and measurement: Fragmented intelligence and limited risk insight constrain targeted intervention and system improvement.

8. Small-to-Medium Enterprises (SME) challenges: Resource constraints, informal management, and inadequate safety systems, compounded by insufficient regulator support.

9. Risk-tolerant culture: National culture shaped by Kiwi stoicism and scepticism of regulation, enabled acceptance and defence of unsafe practices.

10. Weak protections for at-risk populations: Some groups faced higher injury risk due to communication and literacy barriers, yet policies often applied poorly targeted one-size-fits-all approaches.

The Taskforce recommended a stronger, specialised workplace health and safety regulator and modern legislation aligned with international best practice. In response, the Government established WorkSafe New Zealand in 2013 as the primary workplace health and safety regulator.

This marked a significant shift for New Zealand agriculture. The establishment of WorkSafe and the introduction of the Health and Safety at Work Act 2015 changed legal responsibilities across the sector. It also created cultural friction and regulatory confusion that industry and government is still working to resolve.

The Health And Safety At Work Act 2015 (HSWA)

The Health and Safety at Work Act 2015 (HSWA) came into force in April 2016 and now forms the primary legal framework for workplace health and safety in New Zealand (MBIE, 2019). Modelled closely on the Australian Model Work Health and Safety legislation, it emphasises proactive risk management rather than reactive compliance (WorkSafe New Zealand, 2017a).

Its central shift is simple but important: organisations are expected to identify and control risks before harm occurs, not just respond after an incident. For agriculture, this matters because farms are not controlled industrial environments. They are dispersed worksites, with varied equipment, seasonal labour, changing weather and dynamic operating conditions.

PCBUs And The Primary Duty Of Care

The Act introduced the concept of the Person Conducting a Business or Undertaking (PCBU), as the central duty holder responsible for workplace health and safety (Health and Safety at Work Act, 2015). In agriculture, PCBUs may include farm owners, farming companies, sharemilkers and agricultural contractors.

PCBUs have a primary duty of care to ensure, so far as is reasonably practicable, the health and safety of workers and others affected by the work. Importantly, this duty cannot simply be transferred or delegated to someone else.

Reasonably Practicable And The Hierarchy Of Controls

The standard of "reasonably practicable" requires PCBUs to consider the likelihood of a hazard, the severity of potential harm, and the availability and cost of suitable control measures (Health and Safety at Work Act, 2015). To achieve this, WorkSafe New Zealand expects the agricultural sector to utilise a Hierarchy of Controls (WorkSafe New Zealand, 2017a).

The "Hierarchy of Controls", where the first priority is the elimination of the hazard. If elimination is not possible, risks must be minimised using substitution (e.g., swapping a toxic chemical for a non-toxic one), isolation (e.g., fitting protective guards), or engineering controls (e.g., rollover protection on vehicles). Only after these higher-order controls have been exhausted should administrative controls and personal protective equipment (PPE) be used as a final line of defence.

> "...abandon the 'she'll be right' attitude and adopt higher-order engineering controls..."

WorkSafe provides good practice guidance on critical risks such as tractor operation, hazardous substances and environmental monitoring. Industry-led organisations also provide practical, grassroots guidance focused on designing harm out of daily agricultural operations. Central to this is the *Farm Without Harm* strategy led by Safer Farms, which urges farmers to abandon the "she'll be right" attitude and adopt higher-order engineering controls, such as installing Crush Protection Devices (CPDs) on quad bikes through initiatives like the "Safer Rides" scheme (Safer Farms, 2024).

Organisations also strongly emphasise managing psychosocial risks, with Farmstrong advocating for the "Five Ways to Wellbeing" and prioritising adequate sleep, nutrition, and downtime to prevent fatigue-induced errors (Whitelock, 2025). Furthermore, practical operational advice from insurers and industry bodies highlights the need to consult farm hazard maps before working, reduce vehicle speeds on corners, keep front-end loaders positioned low to maintain a safe centre of gravity, restrict children from riding unrestrained on farm machinery, and safely utilise new technologies like drones for routine tasks like mustering and water inspections (Federated Farmers, 2025; FMG, n.d.).

2.5 2025 Regulatory Reform

In July 2025, Workplace Relations and Safety Minister Brooke van Velden announced a programme of reforms intended to simplify New Zealand's health and safety regulatory framework and make it more accessible for small businesses and rural sectors (van Velden, 2025). The proposed reforms were framed as a move toward a more practical and proportionate system focused on managing critical risks while reducing unnecessary administrative burden.

A key element of the reform programme is the strengthened role of Approved Codes of Practice, or ACOPs. These codes provide practical guidance on how organisations can meet their duties under the Health and Safety at Work Act. While historically advisory in nature, the proposed reforms emphasise ACOPs as a clearer pathway for demonstrating compliance with regulatory expectations (MBIE, 2025).

The Approved Code Of Practice (ACOP) Model

Under the proposed approach, compliance with an approved code of practice would provide a form of "safe harbour". In practice, this means businesses following the code could show they had taken reasonably practicable steps to manage risk (van Velden, 2025).

This approach is particularly relevant for agriculture, where prescriptive regulation can be difficult to apply across diverse farm systems. ACOPs are designed to translate legislative duties into practical guidance that reflects how work is actually performed within a sector. By aligning regulatory expectations with real-world operating conditions, the model seeks to improve both compliance and safety outcomes.

Sector-Specific Agricultural Reforms

As part of the reform programme, the Minister requested that WorkSafe New Zealand develop new agricultural codes of practice in consultation with industry stakeholders (van Velden, 2025).

Two priority areas were identified.

1. Safe farm vehicle operation

Farm vehicles remain the leading cause of fatal and serious injuries in the sector. The proposed code is intended to provide practical guidance for tractors, quad bikes, side-by-side vehicles and two-wheeled motorbikes across the diverse terrain typical of New Zealand farms. The aim is to ensure that guidance reflects modern agricultural practices, equipment capabilities and the realities of farm work environments.

2. Roles and responsibilities in agriculture

Agricultural work often involves multiple businesses operating on the same property, including fencing contractors, shearing teams, veterinary services and spraying contractors. The second proposed code focuses on clarifying overlapping duties between PCBUs under the HSWA when multiple parties share responsibility for managing risks (MBIE, 2025).

Clearer guidance on shared responsibilities is intended to improve coordination of risk management and reduce uncertainty around compliance obligations.

Together, these reforms aim to balance regulatory clarity with practical implementation, particularly for sectors characterised by small businesses and complex operating environments such as agriculture.

2.6 The Farm Without Harm Strategy (2021)

A System-Wide Response

The Farm Without Harm strategy, launched by Safer Farms in 2021, represents a sector-led commitment to improving health and safety outcomes across New Zealand agriculture (Safer Farms, 2021). It was developed with industry organisations, regulators and rural leaders, and is built on a clear premise: reducing harm on farms requires coordinated action across the entire farming system.

The strategy marks an important shift. Rather than relying mainly on regulation and enforcement, it calls for collective industry leadership – with farmers, rural professionals, industry bodies and government agencies working together to design harm out of agricultural systems (Safer Farms, 2021).

At the heart of the strategy is a clear recognition: farm injuries and fatalities are not always isolated events. They often arise from ongoing exposure to hazards embedded in everyday operations. As a result, the strategy emphasises better system design, stronger leadership capability, and the adoption of safer technologies and infrastructure (Safer Farms, 2021; WorkSafe New Zealand, 2024a).

Priority Risk Areas

The Farm Without Harm strategy identifies several priority areas where harm is concentrated and targeted intervention can make a meaningful difference in injuries and fatalities.

Vehicles and machinery

Vehicles and mobile machinery are consistently identified as leading causes of fatal and serious injury on New Zealand farms. Incidents involving tractors, quad bikes, side-by-side vehicles and other mobile equipment account for a significant proportion of fatal farm accidents. (WorkSafe New Zealand, 2024b).

Livestock handling

Handling livestock presents ongoing risks associated with crushing, kicking, and trampling. These injuries often occur during routine activities such as yard work, drafting, or veterinary procedures, particularly when workers operate in close proximity to large animals (Safer Farms, 2021).

Psychosocial harm

The strategy also recognises that harm is not only physical. Fatigue, stress, isolation and workload pressure can all affect decision-making and increase the likelihood of errors in high-risk situations, including machinery operation and livestock handling (Safer Farms, 2021; WorkSafe New Zealand, 2024a).

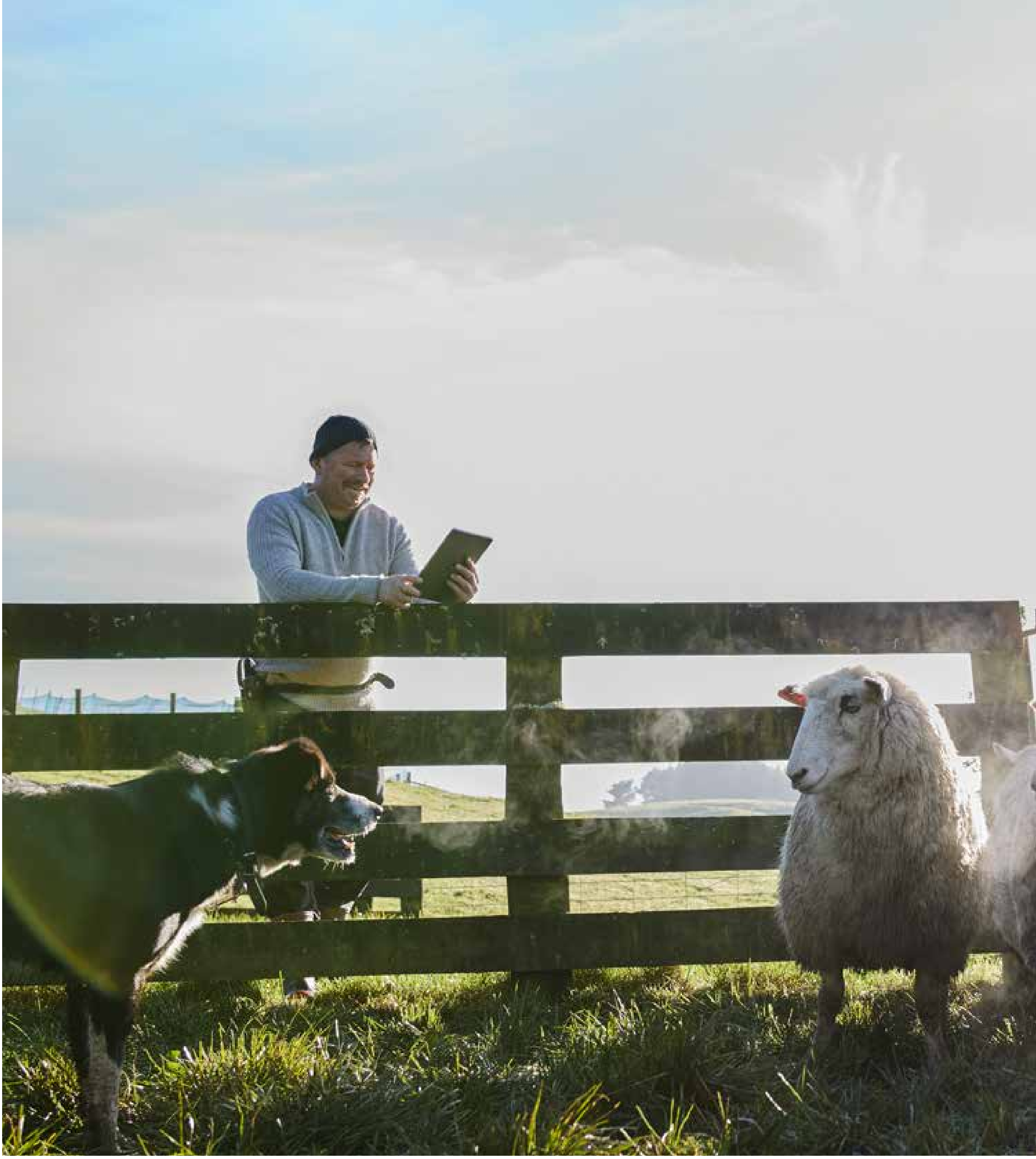
Chemicals and airborne risks

Exposure to agrichemicals, airborne particulates and hazardous gases is a less visible but significant source of occupational risk. Long-term exposure can contribute to chronic health conditions, while acute exposure may occur during mixing, spraying or confined-space work (WorkSafe New Zealand, 2024c).

Technology And System Design

A central theme of Farm Without Harm is the need to move beyond awareness campaigns and behavioural messaging, toward interventions that change how farm work is designed and performed (Safer Farms, 2021).

Technology is an important enabler of that shift. Advances in sensing systems,



automation, digital reporting platforms and precision agriculture tools create opportunities to reduce direct exposure to hazards, improve monitoring of high-risk environments, and support better decision-making.

When integrated effectively into farm systems, these technologies can complement leadership, training, and infrastructure improvements to support the long-term goal of designing harm out of agricultural work.

The practical barriers to adoption – including cost, connectivity, capability, trust and fit with existing farm systems – are examined in Section 8.

3. Vehicles And Mobile Plant

Removing The Operator From The Danger Zone

AT A GLANCE

- Vehicles and mobile plant remain one of the most significant sources of fatal and serious harm on New Zealand farms.
- Traditional controls such as training, procedures, helmets and seatbelts remain necessary, but rely heavily on consistent human judgement.
- Automation, remote operation, stability monitoring, telematics and proximity detection can reduce exposure before an incident occurs.
- Adoption depends on practicality, compatibility, cost, connectivity and farmer trust.

"Vehicles are almost always involved in fatal farm workplace accidents."

Vehicles and mobile plant remain one of the biggest sources of fatal and serious harm in New Zealand agriculture. WorkSafe New Zealand has identified persistent harm linked to farm vehicles and machinery, particularly in dairy, beef and sheep farming, where tractors, quad bikes, side-by-side vehicles and other mobile machinery are used in difficult, varied and often remote environments (WorkSafe New Zealand, 2024b).

Farm Without Harm also identifies vehicles and machinery as a priority risk area, noting that vehicles are almost always involved when someone dies in a farm workplace accident (Safer Farms, 2021).

"Vehicle harm remains stubborn because the risk is built into the way farm work happens."

3.1 Context Of Vehicle And Mobile Plant Risk In New Zealand Agriculture

The risk profile associated with agricultural vehicles is shaped by the realities of farm work. Agricultural vehicles are not operated in controlled, predictable environments. They are used across steep hill country, unstable or saturated soils, and ground conditions that change with weather and season. Visibility can be reduced by dust, rain or low light. Vehicles are also often used in close proximity to livestock, fencing, other machinery and workers (WorkSafe New Zealand, 2024b; Safer Farms, 2021).

Farm vehicles are rarely used for one task alone. In a single day, the same vehicle may be used for mustering livestock, spraying, transporting materials, feeding stock, or repairing infrastructure. That flexibility is useful, but it also increases exposure to rollover, collision and entanglement hazards.

Quad bikes and side-by-side vehicles are a particular concern because they are used across many different tasks and terrain types. Risk can increase quickly when terrain stability, load configuration or operator balance are compromised (WorkSafe New Zealand, 2024c; Safe Work Australia, 2023).

Importantly, many serious incidents involve experienced operators who know the equipment and the environment. This shows the problem is not simply a lack of awareness. When the work itself requires people to operate machinery in dynamic and unpredictable conditions, risk cannot be managed through training and procedure alone (Cryer et al., 2014; McNoe, Chalmers, & Langley, 2005).

3.2 Existing Controls And Why Harm Persists

Despite decades of safety campaigns and improvements in equipment design, farm vehicles and machinery remain a persistent source of serious harm within the agriculture sector. Administrative, behavioural and engineering controls are widely promoted, but injury investigations suggest they have not fully addressed the structural risks built into farm vehicle use (WorkSafe New Zealand, 2024b; Safer Farms, 2021).

Administrative And Behavioural Controls

WorkSafe guidance and industry initiatives rightly focus on operator competency, task-appropriate vehicle selection, helmet and seatbelt use, maintenance routines, and safe operating procedures. Campaigns promoting quad bike helmet use, restraint use in side-by-side vehicles and regular maintenance have helped strengthen safety awareness across the sector (WorkSafe New Zealand, 2024c).

Awareness matters, but it still relies on people making the right call in conditions that often make that difficult. Farm work is shaped by fatigue, time pressure, weather, terrain and seasonal peaks such as calving, lambing and harvest, when long hours and physically demanding tasks can reduce attention and increase risk (Safer Farms, 2021; WorkSafe New Zealand, 2024b).

As a result, safety approaches that rely primarily on behavioural compliance may struggle to fully address the underlying structural risks associated with farm vehicle operation.

Engineering And Equipment-Based Controls

Engineering controls are designed to reduce harm without relying entirely on operator behaviour. In farm vehicle safety, these include rollover protection, crush protection, safer vehicle design and guarding systems.

Rollover Protective Structures (ROPS) are a well-established safety feature on tractors and are required on tractors purchased new from September 2001. When used with seatbelts, ROPS can significantly reduce the risk of fatal crushing in rollover events. However, older tractors may lack compliant structures, and the protective benefit is reduced when seatbelts are not worn (Reynolds & Groves, 2000; WorkSafe New Zealand, 2024c).

For quad bikes, Crush Protection Devices (CPDs) are designed to create survivable space during rollover incidents. They do not prevent rollovers, but they can reduce the risk of fatal compression injuries when a vehicle overturns. CPDs are available in New Zealand and have been supported through incentive programmes, although their effectiveness depends on correct installation, model compatibility and operator acceptance (Safe Work Australia, 2023; Quadbar, 2024).

“Awareness matters, but it still relies on people making the right call in conditions that often make that difficult.”

Side-by-side vehicles are often promoted as a safer alternative to quad bikes for many farm tasks. Their lower centre of gravity, integrated rollover protection and steering wheel configuration can improve stability and occupant containment (WorkSafe New Zealand, 2024c). But they are not risk-free. Fatalities still occur when seatbelts are not worn, doors are not used, or vehicles are operated on steep or unstable terrain (Safe Work Australia, 2023; WorkSafe New Zealand, 2020).

Power take-off (PTO) entanglement remains another serious machinery hazard. Protective shields and guards are standard requirements, but incidents continue when guards are missing, damaged or removed for maintenance (WorkSafe New Zealand, 2024b).

These examples illustrate that while engineering controls provide important safety benefits, their effectiveness can be limited by inconsistent use, ageing machinery fleets, maintenance challenges, and the operational realities of farm work environments.

3.3 Emerging And Applied Technologies – The Age Of Smart Machines

Elimination Through Automation

The most effective way to prevent vehicle-related harm is to remove people from high-risk tasks altogether.

Autonomous and remotely operated machinery offers a pathway to do that. In horticulture and arable systems, autonomous tractors and robotic platforms can now perform tasks such as cultivation, spraying and hauling without an onboard operator. By moving the person from the machine to a remote monitoring role, the immediate risks of rollover, crush injury and collision can be significantly reduced, and in some cases removed (Bechar & Vigneault, 2016; Duckett et al., 2018).

New Zealand-based Robotics Plus has commercialised Prospr, an autonomous platform designed for orchard and vineyard operations. Prospr uses LiDAR, cameras and AI-based perception systems to build a three-dimensional view of its environment, helping it distinguish between vegetation and critical obstacles such as people or machinery (Robotics Plus, 2023). The safety benefit goes beyond labour substitution. Automating spraying can also reduce exposure to chemical and airborne hazards, while easing the physical strain of long operating hours during peak seasonal periods.

Remote vehicles and drones are being used to take people out of physically demanding and hazardous work. SwagBot, for example, is an AI-powered electric vehicle designed for rugged farm environments. It can navigate uneven terrain, tow equipment, assist with moving cattle and monitor livestock using onboard sensors (Bender et al., 2020). Drones are also being used for aerial mustering, property surveys, water-point checks and infrastructure inspection (Hunt et al., 2018). With machine learning, thermal cameras and GPS tracking, these systems allow farmers to monitor stock and farm conditions across large areas without needing to be physically present.

The main safety advantage of remote vehicles is that they remove workers from high-risk environments. Traditional mustering often relies on quad bikes, two-wheeled motorbikes or helicopters, all of which are associated with serious injury and fatality risk in agriculture (WorkSafe New Zealand, 2024b; Safe Work Australia, 2023). Replacing the rider or pilot with a robot or drone can reduce the risk of rollovers and aviation accidents. These technologies also create distance between people and livestock, lowering the risk of crush injuries, kicks and other close-contact harm. Robotic vehicles can reduce physical strain by taking over heavy towing, while drones can allow farmers to check stock or assess hazards during poor weather without putting themselves in unnecessary danger.

Remote livestock management technologies offer a similar opportunity. Virtual fencing systems such as New Zealand's eShepherd and Halter use GPS-enabled collars to guide stock movement or provide animal condition data. These systems can reduce the need for physical mustering or welfare checks by quad bike or motorbike (Umstatter, 2011; Halter, 2023). While they are often adopted for productivity and pasture management, they can also reduce exposure to hazardous activities.

However, several barriers currently limit widespread adoption. Drone operations may be limited by aviation regulations, particularly when flying beyond the operator's line of sight (Civil Aviation Authority of New Zealand, 2022). Battery life, weather, complex terrain, weak GPS signals and poor rural connectivity can also affect reliability (OECD, 2017). High upfront costs, integration complexity and the need for technical skills remain barriers, especially for smaller farms and hill-country operations.

In the near term, partial automation may offer a practical bridge. Remote-control post drivers, for example, allow operators to stand clear of machinery while driving fence posts. These kinds of technologies may not remove all risk, but they show the direction of travel: less exposure, greater distance from harm, and safer systems designed around the realities of farm work.

Substitution And Intelligent Machine Design

Substitution technologies aim to replace higher-risk equipment or practices with safer alternatives.

Side-by-side vehicles have already been adopted by many farms as an alternative to quad bikes. But substitution only works when the safer option is used as intended. The safety gains can be undermined when restraints are not worn, doors are not used, or vehicles are operated beyond their limits. Newer side-by-side vehicles with improved stability control, braking assistance and seatbelt interlocks offer a step forward from earlier models (Safe Work Australia, 2023).

Seatbelt interlocks are a good example of technology shifting safety from advice to engineered control. Rather than simply reminding the operator to wear a restraint, these systems limit or prevent vehicle operation unless the seatbelt is engaged. Similar systems are already common in mining and heavy vehicle fleets, but remain less common in agriculture (Caterpillar, 2024; Komatsu, 2024). Polaris, for example, has developed a system that restricts vehicle speed to approximately 24 km/h if the driver's seatbelt is not fastened.

> "…a system that restricts vehicle speed to approximately 24 km/h if the driver's seatbelt is not fastened."

More advanced interlock systems can also reduce the risk of bypassing. Sequential systems may combine seat sensors, seatbelt detection and ignition control to prevent start-up unless the driver is correctly seated and restrained.

Some newer side-by-side vehicles also use intelligent suspension systems. These monitor vehicle tilt, speed, steering angle and braking behaviour, then adjust shock absorbers in real time to help maintain stability across uneven terrain. In practice, this means the machine is no longer passively responding to rough ground. It is actively helping the operator manage it.

However, operator acceptance remains a factor. Interlock systems may be perceived as inconvenient and may be expensive or avoided when retrofitting existing machinery.

Engineering Controls And Predictive Monitoring

Engineering controls are also becoming smarter. They are moving from static protection toward real-time detection, warning and, in some cases, automatic intervention.

Proximity detection systems, adapted from mining and construction, use radar, GPS or RFID tags to detect when vehicles are operating too close to workers or other machinery. Audible and visual alerts can reduce collision risk in busy environments such as yards, loading areas and harvest operations (Park et al., 2017).

More advanced pedestrian and collision detection systems, such as TORSA, use LiDAR, real-time kinematic GNSS positioning and AI vision to detect collision trajectories with centimetre-level precision. At higher control levels, these systems can intervene automatically to help prevent imminent collisions.

"...from static protection toward real-time detection, warning and... automatic intervention."

Tilt sensors and stability monitoring systems provide real-time feedback when safe slope thresholds are exceeded. By continuously measuring vehicle angle, they can alert operators when rollover risk is increasing (Teletrac Navman, 2024; John Deere, 2024).

Active Rollover Protection (ARP) systems go further. They extend electronic stability control by detecting rollover conditions and automatically reducing engine torque or applying braking force to help stabilise the vehicle (Polaris, 2024; BRP, 2024).

Sensor fusion adds another layer of protection. By combining radar, LiDAR and camera data, automated platforms can build a more reliable picture of their surroundings. This helps compensate for farm conditions where dust, low light or poor visibility may limit a single sensing system (Bechar & Vigneault, 2016).

New deployable Crush Protection Devices are also being developed for quad bikes. These systems monitor vehicle pitch and automatically activate protective structures when rollover thresholds are exceeded.

Power take-off (PTO) entanglement is another area where smarter engineering may reduce reliance on behaviour alone. Traditional PTO guarding relies on maintenance discipline and behavioural compliance. Emerging smart-PTO systems use sensors to automatically disengage rotation if a worker enters a defined danger zone or if abnormal torque loads are detected.

While these systems can strengthen situational awareness, they need to be implemented well. Data management, privacy, sensor maintenance and calibration all affect reliability. Poorly designed systems can create false alerts, encourage over-reliance, or cause operators to tune out if alarms are too frequent or poorly targeted.

However, these risks are manageable and do not outweigh the benefits. When properly calibrated and integrated into broader safety systems, intelligent engineering controls can shift vehicle safety from reactive response to earlier detection and intervention. They are not yet mature or accessible in every farming context, but the direction is promising: systems are becoming more reliable, more usable, and better aligned with the realities of farm work.

Administrative And Governance Integration

Modern vehicle safety technology means we can see risk clearer than ever before.

Virtual reality (VR) training is also emerging as a useful way to improve vehicle and mobile plant safety, particularly where real-world training is difficult, risky, expensive or inconsistent. While VR does not remove the underlying hazard in the way automation or remote operation can, it can strengthen administrative controls by allowing people to experience high-risk scenarios in a safe, repeatable and measurable environment.

"We can see risk clearer than ever before."

FMG's rollout of a VR quad bike and side-by side vehicle training programme, following a successful pilot using Gfactor technology, provides a relevant New Zealand example [FMG, unpublished, 2026]. VR training can reduce learning decay compared with passive classroom or video-based approaches. The pilot identified opportunities to use scenario-based data to target further training and reinforce safer decision-making. Participant feedback also suggested that the immersive format increased engagement, supported learning without judgement, and created more practical conversations about farm vehicle risk – with strong demand for further training.

Fleet-level dashboards can bring telematics data, maintenance schedules, incident logs and corrective actions into one oversight system. This gives directors, farm owners and managers clearer visibility of how machinery is being used, where risk is showing up, and where intervention may be needed (Eastwood et al., 2019).

Modern agricultural tractors and mobile plant are increasingly equipped with telematics and sensor networks that capture real-time data, including location, speed, engine performance and vehicle orientation (OECD, 2017). When this information is integrated into digital dashboards, supervisors can monitor patterns of vehicle risk and adjust field operations accordingly.

For example, data on hard braking, excessive speed or repeated use of high-risk terrain can help identify unsafe patterns before they lead to harm. These insights can feed into driver scorecards, maintenance planning, training needs or changes to how work is scheduled.

Predictive modelling also has a part to play. Platforms that combine terrain mapping, satellite imagery and environmental data can help identify areas of elevated rollover risk before work begins. When linked to digital hazard registers, vehicle risks can be understood alongside terrain, weather and workload, rather than treated as isolated safety issues.

However, the effectiveness of these systems depends on how well they connect. Without interoperability between platforms and consistent data standards, useful information can remain fragmented, underused or difficult to act on.

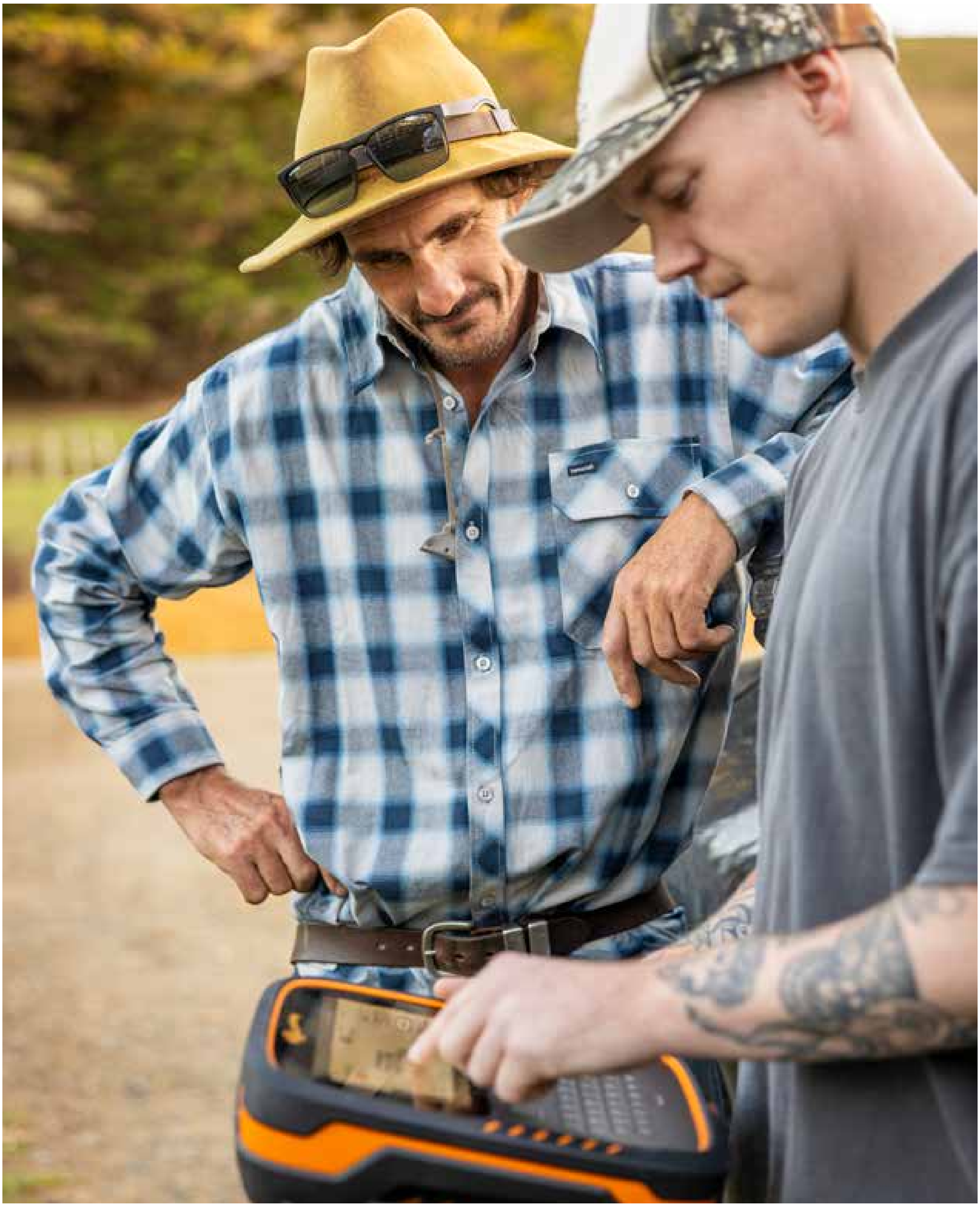
Behavioural And PPE-Level Technologies

Some technologies still sit closer to behavioural or PPE-level controls, but they can provide important support when workers are operating alone or under pressure.

Fatigue monitoring systems, adapted from mining and transport, use AI-based computer vision to detect microsleeps and distraction. Fatigue risk management tools, including aviation-derived models such as the Samn-Perelli fatigue scale, can also help assess cognitive alertness before high-risk tasks (Caldwell et al., 2009).

Retrofitting solutions are available for vehicle fleets but application in agriculture in New Zealand would need to be tested, e.g. situational awareness is important whether monitoring PTO implements or livestock so distraction detection would require context.

Man-down sensors are wearable devices or smartphone applications that detect falls, prolonged inactivity, or abnormal body orientation. Using accelerometers and tilt sensors, these systems can automatically trigger GPS-enabled alerts to emergency contacts or monitoring centres (GetHomeSafe, 2023; SoloProtect, 2024).



Unlike manual emergency alerts, automated "man-down" systems detect impacts or immobility and initiate alerts without requiring user action. These technologies are particularly relevant for workers operating alone in remote farm environments.

Adoption may require addressing worker concerns regarding privacy and data monitoring, particularly where continuous location tracking is involved.

4. Livestock Handling

Redesigning The Human-Animal Interface

AT A GLANCE

- Livestock handling risk is structurally embedded in routine farm work such as drafting, weighing, loading and veterinary procedures.
- Yard design, stockmanship and safe procedures improve safety, but cannot remove the unpredictability of animal behaviour.
- Virtual fencing, smart collars, automated drafting and restraint systems can reduce the frequency and intensity of close-contact handling.
- The best technologies improve safety while also reducing physical strain, workload and operational pressure.

"Safer livestock handling is not about removing people from animal care. It is about redesigning the moments where people are most exposed to harm."

Livestock handling remains a persistent source of serious harm in New Zealand agriculture. Working with animals is a major contributor to injury, with common harm pathways including being struck by livestock, falls, and body stress injuries that build up through routine handling tasks (Safer Farms, 2021; WorkSafe New Zealand, 2024b).

Hospital-based studies show the same pattern. Cattle and other farm animals account for a significant number of agricultural trauma admissions, often involving crushing, trampling or kicking injuries sustained during everyday farm work (Tosswill et al., 2018).

The Farm Without Harm strategy identifies animal handling as a priority risk area and points to the need for better-designed systems, automation and technology that reduce close-contact exposure between people and animals (Safer Farms, 2021). However, interaction between livestock handlers and animals remains central to animal husbandry and care, which limits the degree to which higher-order controls can completely remove exposure to risk.

1,300+ people injured by livestock each year in New Zealand

4.1 Context Of Livestock Handling Risk In New Zealand Agriculture

New Zealand's pastoral farming systems require regular, close interaction with cattle, sheep, deer and other livestock. More than 1,300 people are estimated to be injured by livestock each year in New Zealand (Gulliver, 2025). Three of the four most common agricultural injuries involve livestock handling activities, including being struck by animals or slipping during yard work (Safer Farms, 2021).

Routine tasks such as drafting, weighing, pregnancy scanning, tagging, drenching, loading and veterinary treatment often require animals to be confined, moved or restrained. This puts workers close to large, reactive animals in constructed environments such as yards, races and crushes (WorkSafe New Zealand, 2024b; Grandin, 2014).

The livestock risk profile is shaped by three main factors:

1. Livestock are powerful and unpredictable.
A single misdirected movement in a race or yard can crush a worker against rails or gates. Kicks, head movements and sudden surges can cause serious trauma, even in well-designed facilities (WorkSafe New Zealand, 2024c; Grandin, 2014).

2. Yards are often used for many different jobs.
The same facility may be used for different stock classes, contractors and seasonal operations. Changes in animal temperament, handler familiarity and environmental conditions can quickly increase unpredictability (Safer Farms, 2021).

3. Seasonal pressure increases exposure.
Periods such as calving, lambing and sale preparation increase handling frequency and compress demanding work into short windows. Repetitive lifting, awkward postures and long days contribute to fatigue and cumulative musculoskeletal strain (ACC, 2025; WorkSafe New Zealand, 2024b).

Many serious livestock injuries involve skilled handlers who were familiar with the animals and facilities. This reinforces the principle that awareness and experience, while critical, do not eliminate exposure when close physical proximity is required (Cryer et al., 2014; McNoe, Chalmers, & Langley, 2005).

4.2 Existing Controls And Why Harm Persists

Administrative And Behavioural Controls

Administrative controls for livestock handling focus primarily on training, stockmanship, safe work procedures and behavioural guidance (Safer Farms, 2021; WorkSafe New Zealand, 2024b).

Low-stress handling techniques, calm animal movement, correct positioning around flight zones, and awareness of blind spots all help reduce risk (Grandin, 2014; Safer Farms, 2021). Toolbox talks, pre-task planning, crush-zone awareness and yard-specific inductions also play an important role, particularly when contractors or visitors are involved (WorkSafe New Zealand, 2024b).

However, these controls still depend on people reading the situation correctly in real time. Under fatigue, distraction or time pressure, judgement can slip. And livestock can react faster than people can respond (Cryer et al., 2014; McNoe, Chalmers, & Langley, 2005).

They also assume a consistent level of skill and confidence across workers and contractors. In reality, experience varies. The persistence of livestock-related injuries shows that good stockmanship is essential, but not enough on its own to control the unpredictability of livestock behaviour (Safer Farms, 2021; Tosswill et al., 2018).

“Livestock can react faster than people can respond.”

Engineering And Infrastructure Controls

Engineering controls seek to reduce exposure through yard design and physical infrastructure. Technology alone cannot compensate for a lack of “stock-sense,” but well-designed equipment can leverage animal behaviour to enhance safety (Grandin, 2014).

Modern livestock yards increasingly use curved races to encourage forward movement, solid-sided panels to reduce visual distractions, non-slip flooring to minimise falls, and anti-backing gates to prevent reverse surges. Well-designed drafting gates reduce the need for handlers to enter confined spaces. Head bails and crushes provide controlled restraint for veterinary procedures, while hydraulic and pneumatic systems reduce the physical effort required to secure animals (Grandin, 2014; WorkSafe New Zealand, 2024c).

“Technology alone cannot compensate for a lack of stock-sense, but well-designed equipment can reduce how often people need to be in the danger zone.”

Good infrastructure can significantly improve baseline safety, but it has limits. Older yards may not reflect modern design principles, and retrofitting can be costly or difficult (Safer Farms, 2021). Even well-designed facilities still require people to operate gates, position animals and sometimes enter close-contact zones.

Moreover, yard design reduces but does not remove animal unpredictability. Infrastructure mitigates exposure; it does not eliminate it (Grandin, 2014).

4.3 Emerging And Applied Technologies To Reduce Livestock Handling Harm

Elimination Through Remote Livestock Management

The most effective way to reduce livestock-related harm is to reduce how often people need to be in close contact with animals.

Virtual fencing is a significant step in that direction. GPS-enabled collars allow farmers to create digital boundaries and move stock using audio cues, rather than physically mustering animals by quad bike, motorbike or on foot. Over time, this can reduce both the frequency and intensity of direct human-animal contact (Umstatter, 2011; Halter, 2023; Gallagher Group, 2024).

Remote monitoring technologies, including activity sensors and smart collars, can also provide real-time data on animal health, oestrus cycles and movement patterns. Early detection of health issues may reduce emergency handling events, which often occur when animals are already stressed and more difficult to manage safely (Caja et al., 2016).

Automated drafting systems linked to electronic identification (EID) offer another way to reduce close-contact work. Animals pass through a race equipped with RFID readers and are automatically directed into appropriate pens. This reduces the need for handlers to stand beside drafting gates during high-flow movement. In cattle systems, these technologies have a practical advantage because EID tagging is already required by regulation and is increasingly integrated into New Zealand agriculture (Ministry for Primary Industries, 2023; Gallagher Group, 2024).

These technologies can significantly reduce exposure, but adoption is not simple. Capital cost, digital literacy, connectivity and signal reliability remain barriers, particularly in extensive hill-country systems (OECD, 2017).

Substitution And Automated Restraint Systems

Substitution technologies aim to replace high-contact manual handling with safer alternatives.

Advanced hydraulic, pneumatic and automated crush systems are already available in New Zealand and are being adopted by a broader range of farm businesses, although cost and replacement cycles remain barriers (Te Pari Products, 2024; Gallagher Group, 2024).

These systems reduce the physical force required to secure animals and help control sudden movement during restraint. Some advanced crushes integrate weight scales, automatic head positioning and remote gate operation, allowing handlers to work from outside immediate crush zones (Grandin, 2014).

Pneumatic systems can be faster, quieter and more compact than hydraulic systems. The quieter operation is not just a comfort feature. It can reduce the noise and stimulus that contribute to animal pressure and startle responses (Grandin, 2014).

Automatic restraint systems go further by using sensors to detect animal movement and operate the crush without manual timing. This can reduce injuries caused by fatigue, poor timing or sudden animal movement. Sensor arrays can coordinate detection at the entry gate, animal-flow point and head bail (Te Pari Products, 2024).

Auto-drafting can work as either an elimination or substitution control, depending on the task. Once an animal passes through EID readers, its tag can be linked to weight or other data, then drafted automatically based on criteria such as age, sex or weight.

In sheep systems, automated drafting races linked to EID can reduce repetitive manual sorting. Handlers can supervise flow and intervene only when needed, reducing physical strain and labour demand. However, unlike cattle, EID tags are not generally required for sheep, except in some operations such as stud breeding, which may limit broader adoption (Ministry for Primary Industries, 2023).

Robotic milking systems offer another substitution pathway in dairy. By allowing cows to enter milking units voluntarily and reducing manual cup attachment, these systems can reduce repetitive strain and direct animal contact in confined dairy sheds (de Koning, 2010).

These technologies improve conditions and reduce exposure. However, they require consistent maintenance and calibration. Smaller farms may face cost barriers, and transitional training is required to ensure safe integration.

97–98% cow identification accuracy using AI

Engineering Controls And Environmental Monitoring

Engineering technologies are increasingly enhancing situational awareness within livestock environments. Yard design that works with animal behaviour, supported by mechanical and digital technology, can reduce the risk of workers being crushed, kicked or trampled (Grandin, 2014). The goal is not only safer workers, but calmer animals, smoother workflows and less fatigue for everyone involved.

Video monitoring systems can help by allowing remote observation of animal flow and worker positioning. This reduces the need for multiple handlers to stand inside confined areas. When recorded, footage can also support incident review, training and better yard design.

In Australia, the Australian Meat Processor Corporation has trialled the Argus AI platform, which uses video and audio monitoring in processing plants to detect agitated animals and alert staff before injuries occur (Australian Meat Processor Corporation, 2022).

Video and aerial monitoring also give farmers and designers a clearer view of how animals and people actually move through yards. A bird's-eye perspective can reveal where animals hesitate, where bottlenecks form, and where handlers are forced into risky positions (Grandin, 2014). This information can be used to improve layout before, or after, construction.

Digital yard design tools are also changing how livestock facilities are planned. Virtual design applications allow farmers to test layouts before building (Metalcorp, 2023). More advanced systems can use drone or property-survey data to create 3D models, allowing farmers to walk through proposed yards using augmented or virtual reality before committing to construction.

In some cases, wearable sensors and proximity tags could be used to monitor worker safety while providing valuable spatial data. When analysed over time, these systems could reveal areas where workers, machinery, or livestock frequently experience near-miss interactions (Park et al., 2017).

Computer vision (CV) systems are beginning to show promise in identifying risky positioning around crush zones and yards. While still emerging in agricultural use, these systems could eventually provide real-time alerts when a worker is standing in a hazardous location relative to animal movement (Bechar & Vigneault, 2016).

CV technology is also being used internationally to monitor livestock health and behaviour without constant handling. AI camera systems can recognise individual animals and track movement patterns, with some models identifying cows from facial features or coat patterns with around 97–98% accuracy (Andrew et al., 2017).

These CV systems can also detect early signs of illness or stress. The CalfHealth system in the United States, for example, uses wireless sensing and robotic feeders to identify pneumonia in dairy calves before symptoms are visible (Lowe et al., 2019). Thermal imaging offers another non-contact approach, using small changes in body temperature to detect potential disease, including bovine respiratory disease, mastitis and hoof infections (Schaefer et al., 2012).

Environmental monitoring also supports livestock safety indirectly. Microclimate sensors in sheds can monitor heat-stress conditions affecting both animals and workers (DairyNZ, 2023).

Engineering controls improve visibility and reduce blind spots, but do not remove the need for skilled stockmanship. Integration with broader safety systems is critical.

Behavioural And PPE-level Technologies

Behavioural practices and personal protective equipment (PPE) have traditionally played an important role in improving safety around livestock yards. These controls sit at the lower end of the safety hierarchy because they depend largely on consistent human behaviour (Reason, 1997).

One area of development is the integration of digital technology into wearable safety equipment. New devices can monitor how a person moves while working and provide immediate feedback when potentially risky movements occur (Naranjo et al., 2025). For example, sensor-equipped belts can detect awkward bending, twisting or overreaching during close livestock work, then alert the worker through vibration. Used well, this can encourage safer movement patterns before strain becomes injury.

Other innovations that may be further on the horizon include wearable exoskeletons, which act like a supportive frame worn over the body. These devices help redistribute the weight of heavy loads away from the lower back and shoulders to the hips and legs, reducing muscle strain during repetitive tasks such as lifting, bending, or yard work (de Looze et al., 2016). Task-specific tools can also make a meaningful difference. The Electronic Docking Iron (EDI), for example, replaces traditional manual lamb docking with a trigger-activated motorised system. By automating a repetitive and physically demanding task, it can reduce musculoskeletal strain, improve efficiency and lower fatigue during high-volume work (EDI Limited, 2024).

Administrative And Governance Integration

At the administrative level, livestock handling technologies increasingly integrate with digital farm management platforms.

Many of the technologies described above also create opportunities to collect and analyse operational data from livestock handling environments. Systems that track animal movement, health treatments and yard activity can help show how animals and workers interact within handling environments (Eastwood et al., 2019).

When connected to digital safety reporting platforms, this information can help identify patterns in incidents, near-misses and unsafe conditions. Over time, aggregated data across farms or operations can guide improvements in yard design, handling practices and safety procedures.

Integrated Farm Planning frameworks can also help connect worker safety with animal welfare, biosecurity, environmental management and productivity. When livestock health, performance and safety data are viewed together, risk can be managed as part of the whole farm system, not as a separate compliance exercise (Ministry for Primary Industries, 2020).

5. Psychosocial Risk

Designing Work Around Human Capacity

AT A GLANCE

- Psychosocial risk is connected to workload, fatigue, isolation, financial pressure and the seasonal intensity of farm work.
- These risks can influence decision-making in already hazardous environments, increasing the likelihood of physical harm.
- Digital support tools, workload management systems, telehealth, fatigue monitoring and governance dashboards can help identify risk earlier.
- Technology must be implemented carefully so it supports people rather than simply adding another layer of monitoring or administration.

“Psychosocial harm is not separate from physical harm; it shapes the decisions people make inside high-risk systems.”

Psychosocial risk is increasingly recognised as a core driver of farm safety, not just a wellbeing issue. Fatigue, chronic stress, isolation and workload intensity all affect judgement, reaction time and risk perception. On farms, these pressures do not sit apart from physical hazards; they amplify them.

Unlike a machinery failure or a livestock injury, psychosocial harm often builds gradually. It can show up as exhaustion, reduced concentration, irritability or poorer decision-making – before it contributes to a serious incident. In this sense, psychosocial risk acts as an amplifier. When cognitive capacity is reduced, the likelihood of error increases across vehicle operation, livestock handling, chemical use and other high-risk work.

Addressing psychosocial risk requires more than resilience programmes or wellbeing messages. It means looking at how farm work is designed, scheduled, monitored and governed. Emerging technologies can help by identifying early warning signs, redistributing workload, and bringing psychosocial metrics into wider safety systems.

5.1 Context Of Psychosocial Risk In New Zealand Agriculture

The psychosocial profile of agricultural work in New Zealand is shaped by structural, environmental and cultural pressures. These affect worker wellbeing, but they also affect safety performance. Fatigue, stress and cognitive overload can all reduce judgement, slow reaction time and change how people perceive risk (Safe Work Australia, 2022; WorkSafe New Zealand, 2023).

“Fatigue, stress and isolation do not sit in the background. They actively increase risk.”

1. Farm workload is highly seasonal
Periods such as calving, lambing, harvest and extreme weather responses can require long hours over consecutive days or weeks. Accumulated fatigue impairs cognitive performance, slows reaction time and increases the likelihood of errors and incidents (Folkard & Tucker, 2003; Dawson & McCulloch, 2005). Unlike industries with formal shifts and rostering, many farms rely on flexible or informal work patterns, often involving lone workers. This can make fatigue-related risk harder to see and manage (Rural Support Trust, 2023).

2. Farming carries a high cognitive load
Farmers make constant decisions across weather, animal health, pasture, machinery, finance and staff. On top of that, they face increasing administrative and regulatory demands, including environmental compliance, animal welfare standards and reporting obligations. The result is sustained cognitive pressure and decision fatigue (OECD, 2017; Ministry for Primary Industries, 2020).

3. Financial volatility creates chronic stress.
Commodity prices, input costs, regulatory change and climate impacts introduce persistent stress all sit outside a farmer's control. Many agricultural businesses are also highly leveraged, which can amplify the effect of market shifts on financial wellbeing (Reserve Bank of New Zealand, 2022). This stress is often constant and can shape decision-making over long periods.

4. Isolation reduces recovery and support.
Many farmers live and work in the same place, making it harder to separate work from personal life. Geographic isolation can also limit informal peer support and psychological recovery, both of which are important protective factors against stress and fatigue (Gregoire, 2002; Farmstrong, 2023).

5. Sector culture can delay recognition of risk.
Self-reliance, resilience and reluctance to seek help are often valued in farming communities. These traits can support perseverance, but they can also delay recognition of fatigue, stress or deteriorating mental health, and reduce engagement with support services (Roy et al., 2017; Safe Work Australia, 2022).

Together, these pressures create cumulative psychosocial load. Over time, that load affects how people respond to physical hazards. Psychosocial risk does not operate in the background. It actively increases risk across vehicle operation, livestock handling, and chemical exposure.

5.2 Existing Controls And Why Harm Persists

Administrative And Behavioural Controls

Current psychosocial risk management in agriculture largely focuses on awareness campaigns, mental health literacy, peer-support networks and access to counselling. These programmes encourage early help-seeking and provide confidential support through helplines, community networks and employer-supported services (Farmstrong, 2023; Rural Support Trust, 2023). "Toolbox talks" and informal discussions are increasingly used to incorporate wellbeing into day-to-day operations, particularly during high-intensity periods.

Farmstrong is a strong example of this approach. It helps normalise conversations about mental health and creates practical, community-based support pathways. Its use of ambassadors, peer storytelling and initiatives such as "You Matter, Let's Natter" helps reduce stigma and encourage social connection between farmers (Farmstrong, 2023). Community events and agricultural gatherings also provide opportunities for connection and recovery, particularly in isolated rural environments.

At an organisational level, psychosocial risk is increasingly being incorporated into broader health and safety governance frameworks. Structured risk assessments, wellbeing surveys, and "Good Work Design" principles are being adopted in some larger agribusinesses to assess factors such as job demands, autonomy, support, and organisational culture (Safe Work Australia, 2022; Farmstrong, 2024; PeopleSense, 2024).

These tools provide valuable insight into workforce wellbeing and highlight systemic risk factors. However, awareness and support pathways do not always change the work conditions that create fatigue and stress in the first place. The persistence of fatigue-related and stress-amplified incidents suggests the sector needs to go further – from helping people cope with pressure, to redesigning work so that pressure is reduced at the source.

5.3 Emerging And Applied Technologies To Reduce Psychosocial Harm

Technology in this space is shifting from individual support tools toward system-level workload redesign and predictive monitoring.

Elimination Through Workload Redesign And Automation

The most effective psychosocial control is the removal or redistribution of excessive workload. In agriculture, this does not mean eliminating work – but redesigning tasks, systems and schedules so that fatigue, cognitive overload and prolonged high-intensity work are reduced at the source.

> "The bigger opportunity is to reduce psychosocial risk at the source."

Automation technologies discussed in earlier sections – including autonomous machinery, virtual fencing and robotic systems – have psychosocial benefits as well as physical safety benefits. By reducing repeated mustering, extended machinery operation and manual handling, they can lower cumulative fatigue and workload intensity (Bechar & Vigneault, 2016; OECD, 2017). Virtual fencing, for example, can reduce the need for repeated physical stock movements, while automated machinery can reduce long hours of direct operation (Umstatter, 2011; Eastwood et al., 2019).

Digital scheduling and workflow tools can also help farmers see workload pressure before it peaks. Farm management platforms can make seasonal workload patterns more visible, helping operators identify periods when hours may exceed safe or sustainable levels. This supports earlier decisions about task redistribution, rescheduling non-critical work, or bringing in extra labour during high-demand periods (Eastwood et al., 2019; Ministry for Primary Industries, 2020).

More broadly, "Good Work Design" principles provide a useful framework for reducing psychosocial risk at the source. This includes designing work so tasks are achievable, recovery time is protected, and job demands match worker capacity (Safe Work Australia, 2022; Farmstrong, 2024; Deloitte, 2023). In agriculture, this may require challenging traditional expectations around seasonal intensity and exploring ways to spread workload more sustainably across time.

Despite some constraints, the potential benefits are significant. By reducing reliance on prolonged manual labour and extended work hours, elimination-focused approaches address the underlying drivers of fatigue and cognitive overload rather than attempting to manage their consequences. While full elimination of psychosocial risk is not currently achievable, the direction of travel indicates increasing opportunity to redesign agricultural work in ways that support both productivity and wellbeing.

Substitution Through Early-Access Digital Support

In the psychosocial context, substitution means replacing delayed, crisis-based support with earlier, easier access to help.

AI-enabled and digitally delivered mental health tools are becoming more widely available through smartphone and web-based platforms. Many platforms use evidence-based approaches such as cognitive behavioural therapy, mindfulness and guided self-assessment, allowing people to access support confidentially and at their own pace (Firth et al., 2017; Inkster et al., 2018).

This matters in farming, where stigma, time pressure and geographic isolation can delay engagement with traditional services (Roy et al., 2017). Digital care-matching platforms can also help connect people to appropriate support based on assessed need, including counsellors, psychologists, helplines or online therapy options (Naslund et al., 2017). This is particularly useful in rural areas, where in-person services may be limited and travel can become another barrier (Rural Support Trust, 2023).

In New Zealand, digital and remote support pathways can complement services such as Rural Support Trust and Farmstrong, which already provide confidential assistance and encourage early help-seeking (Farmstrong, 2023; Rural Support Trust, 2023). The opportunity is not to replace these trusted networks, but to extend their reach across geographically dispersed farming communities.

Broader digital wellness platforms are also emerging. Platforms such as Symmio assess movement, sleep, behavioural health and injury history to identify higher-risk individuals and deliver personalised interventions (Functional Movement Systems, 2024). This shifts support from reactive intervention toward earlier recognition of fatigue, stress and cumulative strain before they affect safety-critical performance.

Engineering Controls And Predictive Monitoring

Engineering-level psychosocial controls bring objective monitoring into operational systems.

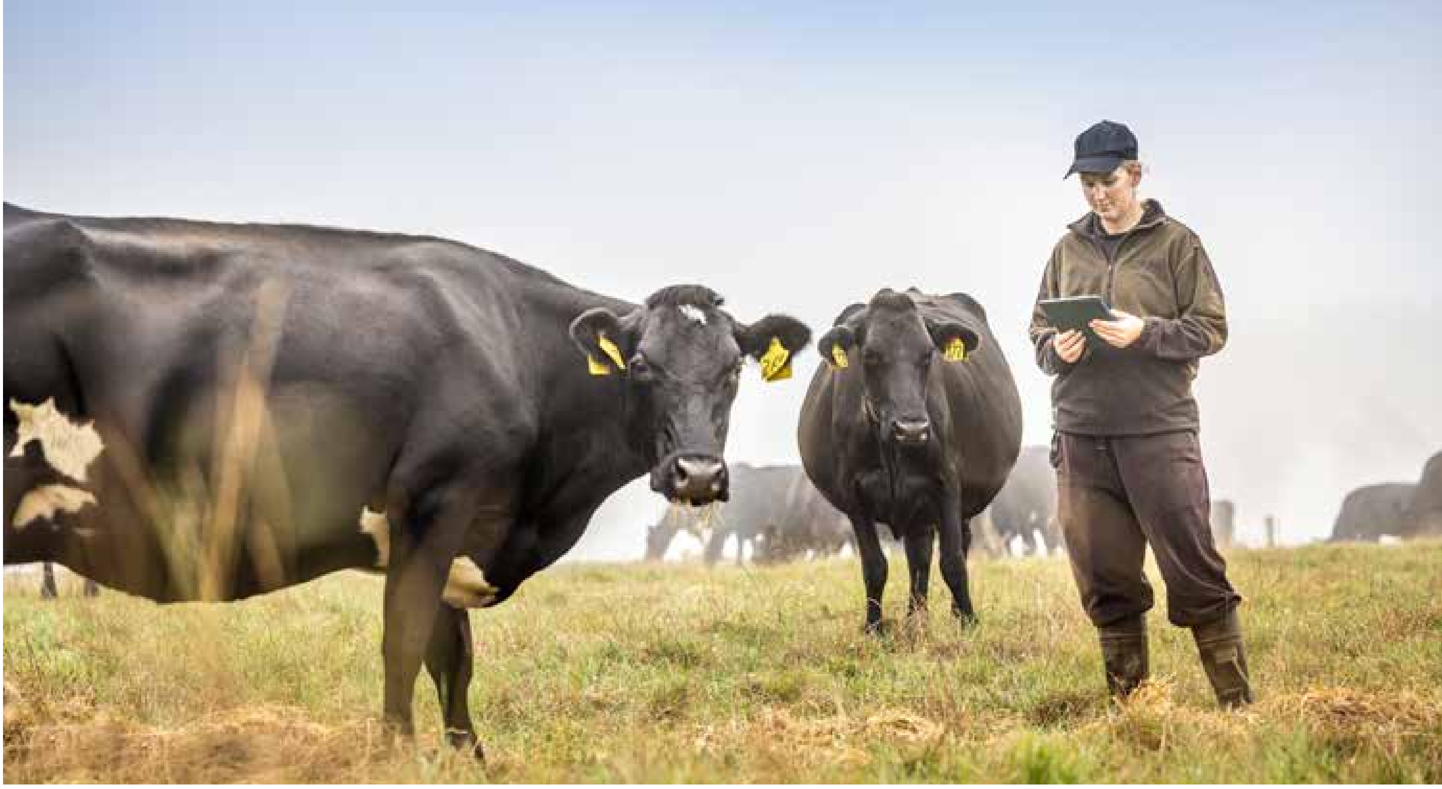
Wearable technologies are increasingly used in occupational settings to monitor physiological indicators linked to fatigue and heat stress. Smart rings, biometric wristbands and sensor-embedded garments can measure heart rate variability, body temperature, activity levels and movement patterns in real time. These signals can help detect early signs of physical strain, heat stress or cumulative fatigue before symptoms are obvious to the worker or supervisor (Martins et al., 2021; Kakhi et al., 2024; Bodytrak, 2024).

The farm context matters. Wearables need to be safe, durable and appropriate for physical work, including consideration of whether items such as rings may catch in machinery or other dynamic environments.

In mining and construction, similar systems already alert workers or supervisors when fatigue indicators exceed safe thresholds, prompting rest breaks, hydration or task reassignment (Safe Work Australia, 2022; Fatigue Science, 2025). In agriculture, these tools could help identify when workers are at higher risk of impaired concentration or slowed reaction time, allowing high-risk work to be scheduled more safely.

More advanced fatigue-detection systems, used in mining and transport, monitor neurological or behavioural indicators of reduced alertness. While not yet widespread in agriculture, they show a broader shift from subjective self-assessment toward objective fatigue metrics (Caldwell et al., 2009; Optalert, 2024).

Looking further out, incorporation of biomathematical fatigue models into other resources could offer another predictive approach to be applied in agricultural settings to better manage fatigue-related risk. These systems estimate likely alertness based on sleep patterns, time of day and accumulated work hours (Dawson & McCulloch, 2005; Fatigue Science, 2025). Many experienced managers already make these judgements intuitively during seasonal peaks, but these models make fatigue risk more visible and



measurable – including for managers who are under the same seasonal pressure themselves.

When integrated into scheduling or farm management software, these tools can help avoid high-risk tasks – such as heavy machinery operation, mustering or long vehicle journeys – during periods when cognitive performance is likely to be impaired. In seasonal farming systems, that kind of early warning could support safer planning during calving, lambing or harvest.

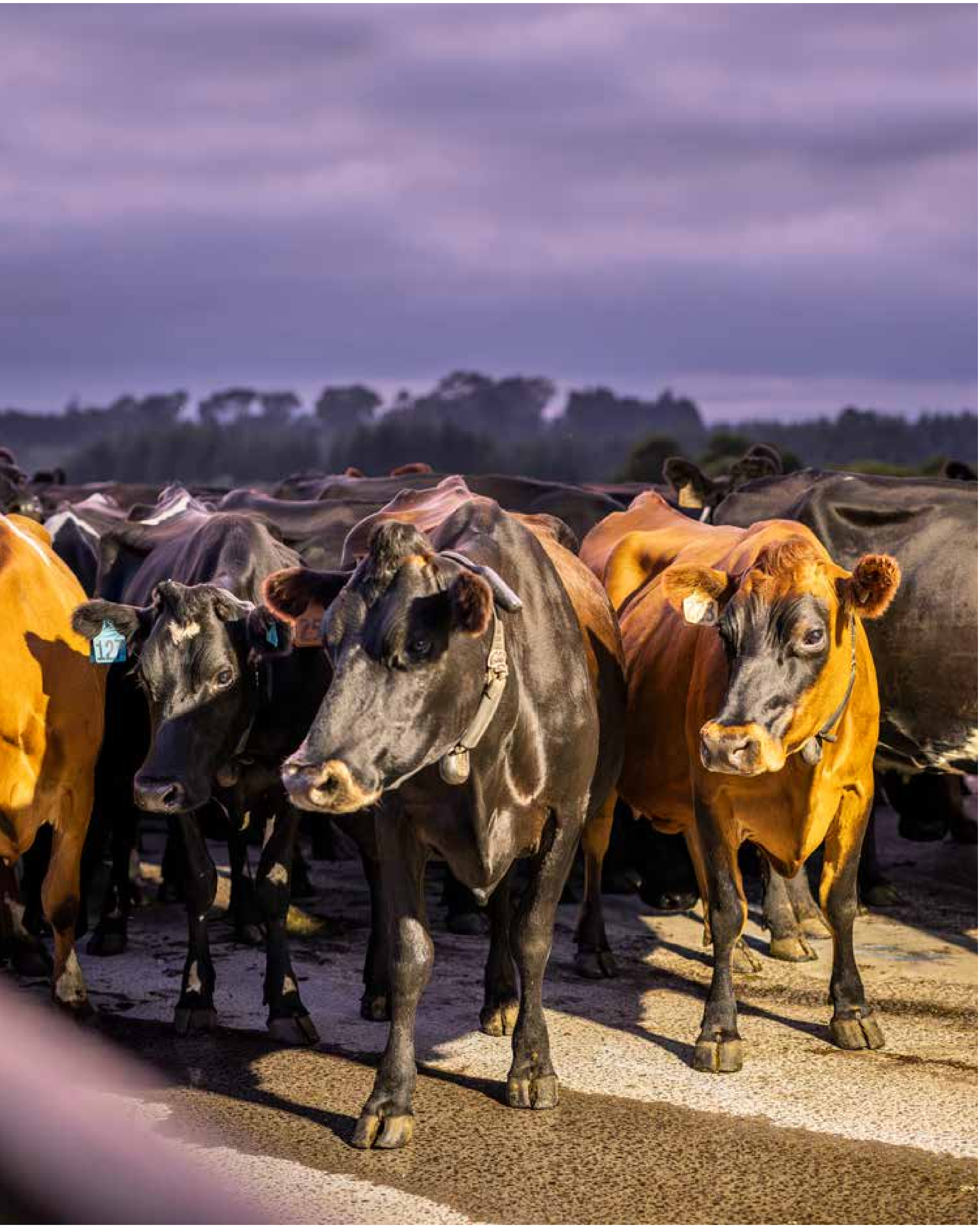
Administrative And Governance Integration

At the administrative level, psychosocial metrics can be integrated into broader safety dashboards.

Digital safety platforms can combine work hours, machinery use, environmental conditions and fatigue indicators into a single system (Eastwood et al., 2019; Safe Work Australia, 2022). This helps managers see when workers may be exposed to higher risk. For example, long hours during a seasonal peak, combined with high temperatures and extended machinery use, may signal a greater likelihood of fatigue-related errors (Fatigue Science, 2025; Bodytrak, 2024).

Rather than treating wellbeing as separate from operational safety, integrated dashboards allow fatigue and cognitive capacity to be considered alongside other safety factors. These applications and platforms are becoming more prevalent and evolving to work within farming systems (Functional Movement Systems, 2024; DairyNZ, 2023).

Integrated Farm Planning frameworks can further connect human wellbeing with animal welfare, environmental management and production performance. When psychosocial indicators are included in governance reporting, Directors and farm leaders gain visibility of leading indicators, rather than relying only on incident data after harm has occurred (Ministry for Primary Industries, 2020).



6. Chemical And Airborne Hazards

From Invisible Threat To Clear Risk

AT A GLANCE

- Chemical and airborne hazards are often less visible than vehicle or livestock risks, but can cause both acute and long-term harm.
- Traditional controls depend on correct storage, handling, PPE use, training and maintenance under variable working conditions.
- Automation, closed-transfer systems, precision application, real-time sensors and wearable monitoring can reduce direct exposure.
- Technology has strong potential where it makes safer practice easier, more accurate and less dependent on memory or manual compliance.

"Unlike vehicle rollovers or livestock injuries, these hazards are often invisible."

WorkSafe New Zealand identifies agrichemical exposure, airborne particulates and hazardous gases as persistent risks in agriculture. Unlike vehicle rollovers or livestock injuries, these hazards are often invisible. Vapours may be odourless, gases colourless, and airborne particulates too fine to detect without instrumentation. Harm may not be obvious until symptoms develop.

This invisibility contributes to normalisation of exposure and underestimation of risk. In many cases, workers do not immediately perceive harm until symptoms develop. Harm may present as acute poisoning, respiratory distress, skin injury, or chronic occupational risk.

Agriculture requires the routine handling, mixing, loading, application and storage of hazardous substances. Exposure can occur during decanting, mixing, spray application, drift events, fertiliser spreading, effluent management, storage work and confined-space entry. Environmental variability – including wind, temperature inversions, and humidity – further complicates exposure control.

Reducing chemical and airborne harm requires a shift from compliance-based protection to engineered exposure reduction and real-time verification.

6.1 Context Of Chemical And Airborne Risk In New Zealand Agriculture

The chemical risk profile in New Zealand agriculture is shaped by operational intensity, environmental conditions and system design (WorkSafe New Zealand, 2024b; Ministry for Primary Industries, 2020).

Risks vary across sectors. Fertiliser handling can generate airborne dust and particulate exposure. Effluent ponds and storage systems can produce hazardous gases. Grain fumigation may involve highly toxic gases where even short exposure can be life-threatening. Confined spaces, including silos, tanks and fruit storage environments, can accumulate oxygen-deficient atmospheres without visible warning signs (WorkSafe New Zealand, 2024b; Safe Work Australia, 2023).

Mixing and loading are often the highest short-duration exposure points. Manual pouring and transfer of concentrates into spray tanks can create splash, skin contact and vapour inhalation risk (WorkSafe New Zealand, 2024b; Croplands Equipment, 2024). Application introduces drift risk, particularly in variable wind conditions – common in New Zealand and often coinciding with seasonal peaks in application (Taylor et al., 2019; NIWA, 2023).

“Because symptoms can develop gradually, the true level of exposure may be underestimated.”

Chronic low-level exposure is also a concern. Repeated minor exposure over a season, or several seasons, may contribute to respiratory conditions, neurological effects or skin disorders (Pearce et al., 2020; EHINZ, 2023). Because symptoms can develop gradually, the true level of exposure may be underestimated.

6.2 Existing Controls And Why Harm Persists

Administrative And Behavioural Controls

Chemical safety management in agriculture relies heavily on regulation, training and documented procedures (WorkSafe New Zealand, 2024b; Standards New Zealand, 2017).

Training and certification help establish baseline competency in hazardous substance handling. Safety Data Sheets (SDS) provide information on product hazards, handling requirements and emergency response. Hazardous substance inventories track chemical storage and quantities. Pre-application planning helps account for wind direction, temperature and proximity to sensitive areas (WorkSafe New Zealand, 2024b; EPA New Zealand, 2023).

Increasingly, many farm businesses are moving from paper-based systems to digital tools that support these administrative controls. Mobile-accessible Safety Data Sheet databases allow workers to retrieve hazard information through phones, tablets or QR codes placed on storage areas and containers (Chemwatch, 2024; HazardCo, 2024).

Digital chemical registers can also track product inventories, training certification and compliance documentation in real time. This centralises information that may otherwise sit across binders, spreadsheets or individual systems, making hazard information easier to access during chemical handling (Figured, 2024; Trev, 2024).

“These controls provide important layers of protection. But they do not fully remove exposure pathways.”

These tools improve access to information. But they do not, by themselves, remove exposure. The highest-risk moments still often occur during physical handling, transfer and application.

Engineering And Equipment-Based Controls

Engineering controls in agricultural chemical management aim to reduce exposure by placing a physical barrier between workers and hazardous substances (WorkSafe New Zealand, 2024b; Standards New Zealand, 2017).

Personal Protective Equipment (PPE) remains widely used when handling agrichemicals, including respirators, chemical-resistant gloves, protective clothing and eye protection. When correctly selected, fitted and maintained, PPE can significantly reduce skin and inhalation exposure during mixing, loading and spraying (NIOSH, 2020; WorkSafe New Zealand, 2024b; 3M, 2024).

However, PPE effectiveness depends on correct use. Filters must be replaced. Equipment must fit properly and be stored correctly. Workers must wear the right protection consistently. In hot or physically demanding conditions, PPE can be uncomfortable, increasing the risk that it is used inconsistently or removed during the task (Safe Work Australia, 2023).

Enclosed tractor cabs also provide separation from spray drift, dust and fine particulates during application. Modern tractors often include filtration systems designed to reduce contaminated air entering the cab (John Deere, 2024; CNH Industrial, 2024). However, some systems may not effectively filter fine chemical vapours or very small aerosol particles (ASABE, 2020).

Cab protection can also degrade over time. Filters wear out, while door, window and ventilation seals can also fail. Protection can be undermined when operators open doors on hot days. In many cases, cab pressure is not actively monitored, meaning operators may assume protection even when filtration is no longer performing as intended (Croplands Equipment, 2024).

Chemical storage infrastructure also forms an important part of engineering-based safety controls. Bunded storage areas, sealed containers and secondary containment systems help prevent leaks and spills from contaminating soil or waterways (WorkSafe New Zealand, 2024b; Environmental Protection Authority New Zealand, 2023). However, storage controls do not address exposure during mixing, transferring and applying chemicals – the moments when workers are most likely to come into direct contact with concentrated products (Safe Work Australia, 2023).

These controls provide important layers of protection. But they do not fully remove exposure pathways. This has led to growing interest in technologies that reduce the need for manual handling and provide more reliable monitoring of airborne hazards during chemical use.

6.3 Emerging And Applied Technologies To Reduce Chemical And Airborne Risk

Elimination Through Automation And Reduced Chemical Use

The most effective way to reduce chemical exposure is to remove or significantly reduce the hazardous substance, or remove the worker from the exposure zone.

Fortunately, environmental regulation and consumer demand for sustainably grown food are encouraging movement away from highly hazardous synthetic pesticides toward safer biological inputs and softer chemistry alternatives (Milligan, 2026; Feijao et al., 2022; Stewart, 2025). Fertiliser innovation is also reducing risk, with microbe-enhanced and controlled-release formulations designed to lower toxicity and improve soil health (Milligan, 2026; Feijao et al., 2022; Nutrien Ag Solutions, 2024; Ravensdown, 2024).

Autonomous and semi-autonomous spraying systems, including drone-based platforms, create another pathway to reduce exposure. By conducting spray operations remotely, these systems remove the operator from the immediate spray zone. Rather than relying only on PPE or cab filtration, they create physical separation between people and chemicals (DJI Agriculture, 2024; XAG, 2024).

Autonomous and semi-autonomous spraying systems – including drone-based platforms – represent a further elimination pathway in certain agricultural systems. These systems use GPS guidance, machine vision and environmental sensors to navigate fields and apply chemicals precisely (DJI Agriculture, 2024; XAG, 2024). This can reduce inhalation and skin exposure, support more consistent application and, in some cases, reduce overall chemical use (John Deere, 2024).
In steep terrain, remote spraying may also reduce rollover risk by removing the operator from the machine.

However, adoption remains limited by cost, regulation and the complexity of operating across diverse agricultural environments (Civil Aviation Authority of New Zealand, 2022).

Precision agriculture can also reduce total chemical volume. Spot-spraying systems use sensors to identify weeds and apply herbicide only where needed, lowering the amount of chemical used and reducing application frequency (John Deere, 2024; Trimble, 2024). This does not eliminate exposure entirely, but it can reduce the overall exposure profile of routine spraying.

Laser-based weed control is emerging internationally as a more direct elimination pathway in some cropping systems. By using targeted thermal energy to destroy weeds, these systems remove herbicide from the process altogether (Carbon Robotics, 2024).

Substitution Through Closed And Controlled Transfer

Where chemical use remains necessary, substitution technologies aim to replace high-exposure handling with safer, more controlled processes.

Closed Transfer Systems (CTS) are one of the most significant developments in reducing exposure during mixing and loading. Instead of manually pouring chemical concentrates into spray tanks, these systems use sealed couplers between the chemical container and sprayer. Product is transferred through a closed circuit, reducing splash, vapour release and accidental spills. Once empty, the container seals before disconnection, further reducing exposure risk. These systems are widely promoted in Europe and are increasingly being introduced into precision spraying systems internationally (European Commission, 2022; BASF, 2024).

Automated chemical mixing and dosing systems offer another step forward. These platforms measure, meter and mix chemical formulations based on predefined application prescriptions. By removing manual measuring and pouring, they reduce skin contact and inhalation risk. Integration with GPS-enabled application systems can also improve calibration and reduce operator error during mixing (John Deere, 2024; Trimble, 2024).

Closed-loop induction hoppers and chemical induction units are also becoming more common in advanced spraying systems. These units draw concentrates directly into the spray system under controlled suction, reducing open-container transfer. They can also minimise chemical waste and improve mixing accuracy (Pentair Hypro, 2024; Ag Leader, 2024).

Drift-reducing nozzles and electrostatic spraying systems improve droplet formation so chemicals are more likely to reach the target and less likely to become airborne. Larger or electrically charged droplets are less prone to drift, reducing inhalation risk and off-target exposure (TeeJet Technologies, 2024; ESS, 2024).

Controlled-release fertilisers reduce application frequency by delivering nutrients over a longer period. Fewer applications mean fewer handling events across a season (Ravensdown, 2024; Nutrien Ag Solutions, 2024).

These technologies improve baseline safety, but they rely on correct installation, maintenance and supply-chain alignment. Packaging compatibility and supply-chain alignment may influence the adoption of these closed systems.

Engineering Controls And Real-Time Monitoring

Engineering controls are moving from assumed protection to verified protection.

Advanced cab filtration systems create positive-pressure environments inside tractor cabs, helping prevent contaminated air from entering. Integrated sensors monitor internal air quality and pressure, confirming whether the protective barrier is working as intended (John Deere, 2024; CNH Industrial, 2024).

Portable multi-gas detectors, already common in construction, mining and wastewater, are increasingly relevant to agriculture. These devices continuously monitor atmospheric conditions for gases such as hydrogen sulphide, methane, ammonia and carbon monoxide, providing audible and visual alerts when concentrations exceed safe thresholds (Honeywell, 2024; Dräger, 2024). In agriculture, they are particularly relevant around effluent ponds, manure storage, grain silos and confined or semi-confined environments.

Wearable and portable air-quality monitors can now detect particulates and chemical vapours in real time. They can now measure fine particulate matter, volatile organic compounds and other airborne contaminants associated with spraying, fertiliser handling or chemical application (Aeroqual, 2024; TSI Incorporated, 2024). This gives workers immediate feedback, allowing them to leave hazardous environments before exposure reaches harmful levels.

More advanced monitoring systems can connect to digital platforms and farm management software. If sensors detect elevated vapours or gases, alerts can be sent to mobile devices or central safety dashboards. This allows supervisors to intervene, adjust work practices, or pause operations until conditions improve (Blackline Safety, 2024; MSA Safety, 2024).

Environmental monitoring can also improve spray decisions. Precision agriculture systems can integrate wind speed, temperature and humidity data to identify when spray drift risk is elevated (Trimble, 2024; Pessl Instruments, 2024). By warning operators or delaying application when conditions are unsuitable, these systems can reduce off-target exposure for workers and surrounding communities.

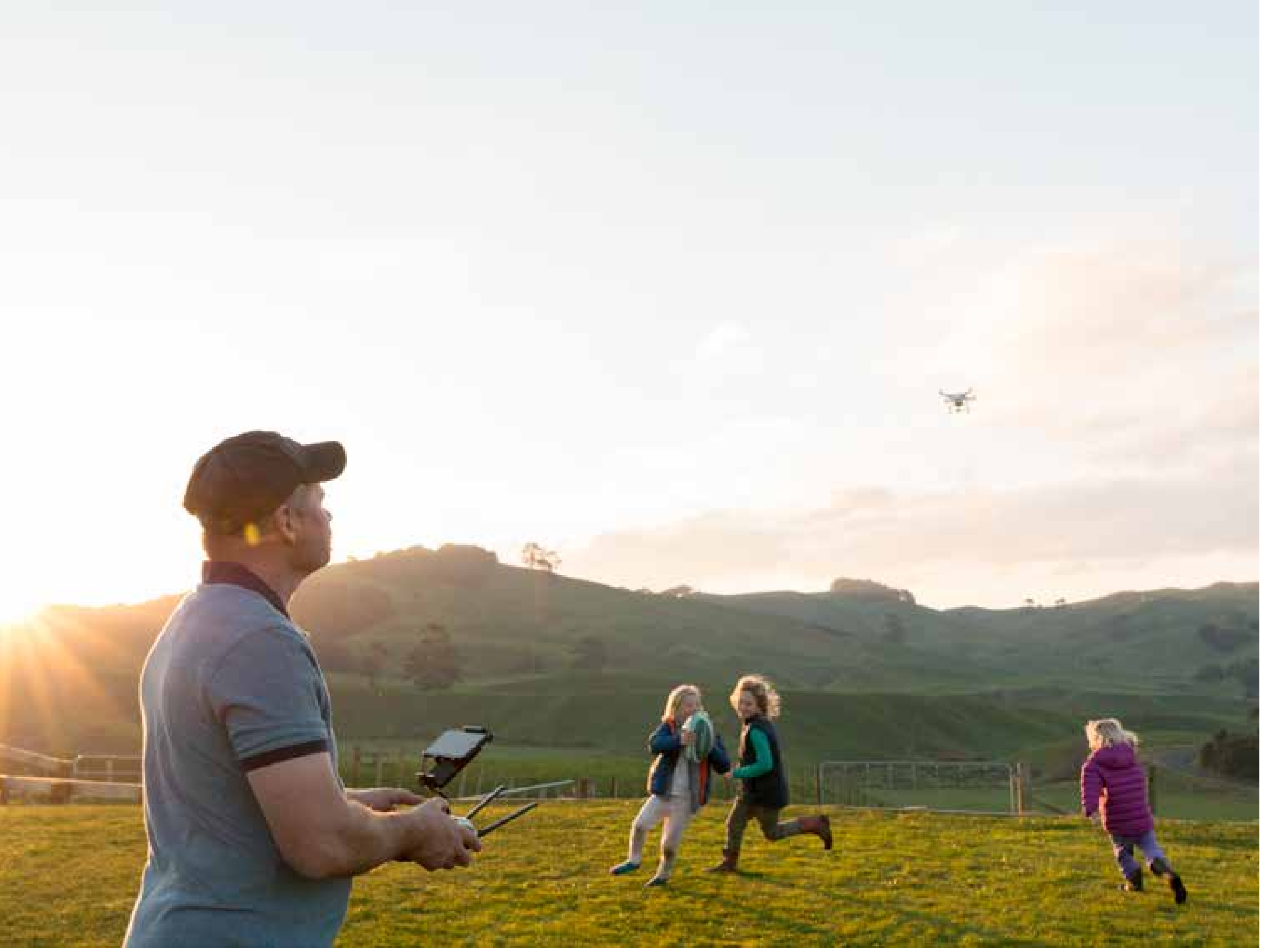
> "A shift toward more intelligent protective systems that combine traditional PPE with real-time monitoring and digital safety management."

While these engineering technologies strengthen exposure monitoring, they do not eliminate chemical hazards entirely. Well-maintained and appropriately calibrated sensors provide valuable alerts and insight into exposure risks, but without appropriate procedures and operational controls the underlying hazards may remain.

Behavioural And PPE-level Technologies

Recent advances in PPE are shifting traditional passive protective gear into systems capable of actively monitoring environmental conditions and worker behaviour. Smart PPE integrates sensors, wireless communication, and digital platforms to provide real-time feedback on both exposure risks and physiological indicators associated with chemical handling and airborne hazards.

Smart respirators and wearable air-quality sensors can detect airborne contaminants such as pesticide aerosols, dust and chemical vapours. When levels exceed safe thresholds, they can alert the wearer through visual, audible or vibration signals (Dräger, 2024; MSA Safety, 2024). Some systems can also monitor filter performance and notify users when filters



need replacing, helping ensure respiratory protection remains effective during long spraying or mixing tasks (3M, 2024).

Biometric monitoring is also being built into wristbands, smart clothing and safety helmets. These systems can measure heart rate variability, body temperature and movement patterns to identify early signs of heat stress, fatigue or excessive strain during chemical application (Bodytrak, 2024; Kenzen, 2024). Alerts can prompt rest breaks or task changes before reduced cognitive performance increases the likelihood of error.

Connected PPE systems extend this further by linking wearable devices to cloud-based safety platforms. Exposure data, movement patterns and alerts can be aggregated across operations to identify recurring chemical risks and guide improvements in procedures, equipment or training (Blackline Safety, 2024; MSA Safety, 2024).

Behavioural coaching tools also contribute to safer work practices. Motion sensors in wearable devices can detect unsafe movements, poor posture or entry into hazardous zones during chemical handling. The device can then provide immediate haptic or audio feedback to encourage safer behaviour (StrongArm Technologies, 2024; Kinetic, 2024).

Together, these innovations illustrate a shift toward more intelligent protective systems that combine traditional PPE with real-time monitoring and digital safety management. While they do not eliminate chemical hazards entirely, they provide earlier warning of exposure risks and strengthen the effectiveness of behavioural safety controls in agricultural environments.

Administrative And Governance Integration

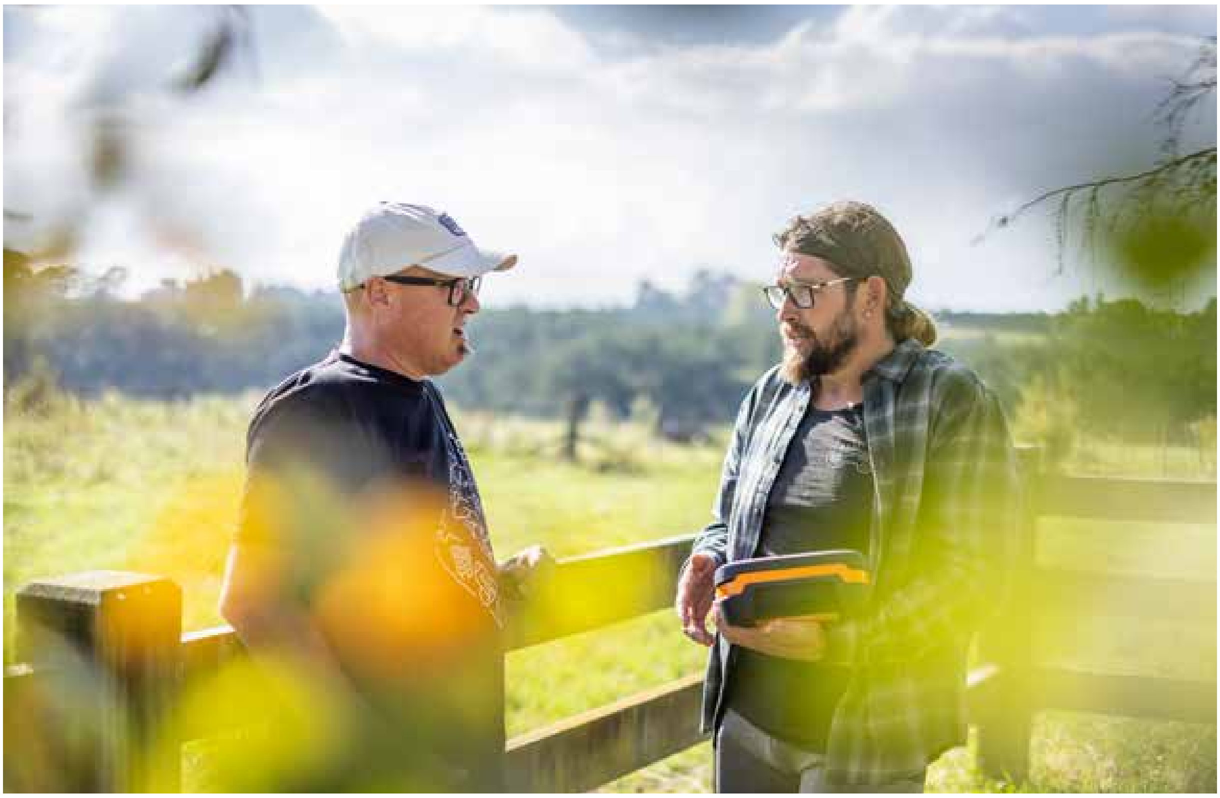
Digital chemical management platforms are replacing static documentation with information that is easier to access, update and act on.

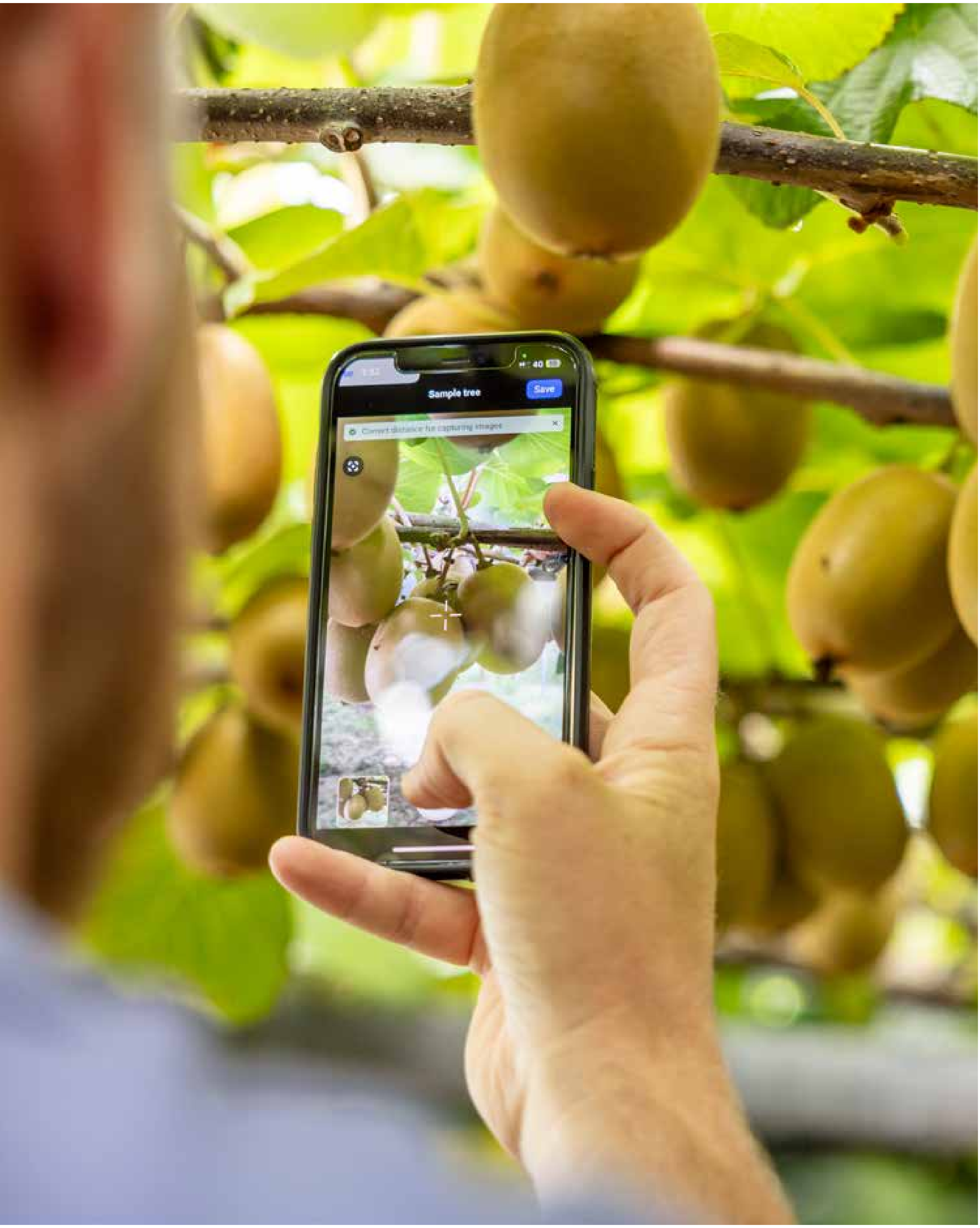
Mobile Safety Data Sheet libraries and digital hazardous substance registers have already improved access to chemical information. Emerging systems are going further by automating inventory, product identification and task-specific guidance (Chemwatch, 2024; EcoOnline, 2024; Resolution Farming App, 2024; Trev, 2024).

RFID and NFC container tags allow chemical containers to be scanned using mobile devices or equipment sensors. This can automatically retrieve hazard information, update inventory records and confirm the correct product has been selected (Avery Dennison, 2024; Zebra Technologies, 2024). Some digital platforms are beginning to use AI to interpret Safety Data Sheet information and provide simplified, task-specific safety guidance for workers (Chemwatch, 2024; EcoOnline, 2024).

In parallel, precision spray systems are increasingly integrating chemical databases directly into application equipment. These systems can verify application rates, flag incompatible mixtures, display safety warnings and automatically record chemical usage (John Deere, 2024; Trimble, 2024). By linking hazard information directly to operational equipment and digital safety platforms, these technologies reduce administrative burden while improving the accuracy and accessibility of safety information during chemical handling and application.

Interoperability with environmental management platforms can also align chemical application, environmental compliance and worker safety. This reduces duplication and improves audit readiness, while supporting more proactive management of chemical risk.

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7. Safety Reporting, Compliance And Governance Systems:

From Recording – To Predicting

AT A GLANCE

- Reporting and governance systems are often fragmented, paper-based or reactive, limiting their value for preventing harm.
- Digital platforms can make reporting easier, connect safety data with operational data and reveal patterns that are otherwise hard to see.
- Predictive analytics, dashboards and automated detection can support earlier intervention and better governance oversight.
- The critical challenge is interoperability, trust and turning data into practical decisions, not simply collecting more information.

"If reporting only looks backwards, opportunities for early intervention can be missed."

Health and safety performance is shaped not only by physical hazards, but by how well risks are identified, recorded, analysed and acted on. In agriculture, where worksites are dispersed, labour is seasonal and daily tasks vary widely, reporting and governance systems are critical to ensuring hazards are visible, understood, and acted upon.

Many incidents, near-misses and hazardous exposures happen in isolated environments where immediate supervision is limited. That makes accurate reporting essential – not just for compliance, but for learning, transparency and prevention.

Traditional reporting systems have struggled in this environment. Paper-based processes can be slow, impractical and difficult to complete in the field. Limited rural connectivity can also make standard digital systems unreliable. As a result, near-misses and minor incidents may go unreported, reducing opportunities to learn before harm repeats.

Modern safety reporting needs to do more than record what has already happened. It needs to simplify hazard reporting, improve data visibility and give farm owners, managers and governance bodies clearer oversight of emerging risk.

Under modern regulatory frameworks, reporting is not a periodic administrative task. It is part of the primary duty of care. Hazard identification, risk assessment, control verification, worker engagement, incident investigation and notifiable event reporting all need to be documented and demonstrable.

Reporting systems therefore need to serve three audiences:

- the **regulator**, who needs evidence that risk is being managed
- the **operator**, who needs practical, real-time insight
- the **governor**, who needs oversight and assurance that systems are working

7.1 Context Of Reporting And Governance Risk In Agriculture

The reporting environment in agriculture is very different from centralised industrial sectors.

1. Farms are dispersed and often poorly connected.
Many agricultural businesses operate in areas with limited connectivity. Many are also small to medium-sized enterprises without dedicated health and safety specialists or formal reporting processes. Owners and managers often carry operational, financial and compliance responsibilities at the same time (OECD, 2017).

2. Safety data is often fragmented.
Visitor management, chemical registers, environmental plans, livestock records, training logs and incident reports may all sit in different systems, spreadsheets or paper files (HazardCo, 2024; Trev, 2024; Resolution Farming App, 2024). This makes risk harder to see and increases administrative duplication.

3. Governance expectations have increased.
Directors and trustees are expected to do more than receive periodic reports. They need to verify that health and safety systems are working in practice. Passive documentation is not enough; active oversight and evidence of implementation are required (Institute of Directors New Zealand, 2023; WorkSafe New Zealand, 2024a).

4. Many reporting systems still focus on lagging indicators.
Incident logs show what has already happened. Hazard registers document known risks, but may not reveal emerging patterns (Safe Work Australia, 2023). If reporting only looks backwards, opportunities for early intervention can be missed.

7.2 Existing Controls And Why Limitations Persist

Administrative Reporting Systems
Administrative controls remain the primary mechanism for safety reporting in agriculture. These typically include hazard registers, incident reporting procedures, training records and safety meetings designed to help workers identify and communicate risks (WorkSafe New Zealand, 2024; Safe Work Australia, 2023).

Many farms also maintain safety documentation for operating procedures, emergency response plans and contractor management. Toolbox meetings and periodic safety reviews can help keep hazards visible and reinforce safe work practices (WorkSafe New Zealand, 2024; Ministry for Primary Industries, 2020).

However, these systems depend heavily on consistent participation. Workers and managers need to recognise risks, record them accurately and communicate them through the right channels (Safe Work Australia, 2023). In busy farm environments, reporting can easily be delayed, simplified or missed altogether. Documentation confirms that procedures exist, but it does not necessarily confirm that controls are effective in practice (Institute of Directors New Zealand, 2023).

Engineering And Equipment-Based Controls
Some engineering controls also support safety reporting and communication. Radios, mobile phones and vehicle communication systems allow workers to report hazards or request help when working remotely (WorkSafe New Zealand, 2024a). Increasingly, machinery telematics and environmental monitoring systems can capture operational data that may indicate unsafe conditions (John Deere, 2024; Trimble, 2024).

While these systems improve communication and data collection, they often operate independently from formal safety reporting processes. Without integration, useful information from machinery, sensors or field operations may never inform hazard management or governance oversight.

Governance And Oversight Controls

At governance level, safety reporting often appears as periodic summaries for farm owners, trustees or Boards. These reports may include incident counts, lost-time injuries and corrective actions (WorkSafe New Zealand, 2024; Institute of Directors New Zealand, 2023).

While useful, such summaries are lagging indicators. They describe what has already happened, not whether current controls are working. Directors need insight into active risk, not just incident history (Institute of Directors New Zealand, 2023).

> "Modern safety reporting needs to do more than record what has already happened."

Fragmented data makes this harder, especially across multi-site operations. Without integrated systems, leaders may lack a clear view of safety performance across vehicles, livestock handling, chemical use and psychosocial risk (HazardCo, 2024; Trev, 2024).

From a regulatory perspective, the issue is not simply whether documents exist. It is whether the system turns information into preventive action (WorkSafe New Zealand, 2024a). When reporting is scattered across notebooks, spreadsheets and disconnected platforms, emerging patterns can be missed across seasons, worksites or equipment types (Resolution Farming App, 2024; Trev, 2024). Governance can then become overly reliant on lagging indicators, rather than leading signs of risk (Safe Work Australia, 2023).

7.3 Emerging And Applied Technologies To Transform Safety Reporting And Governance

Technological innovation is shifting safety reporting from manual record-keeping to earlier detection, predictive insight and integrated oversight. For regulators and industry bodies, the value extends beyond individual farms. Aggregated and anonymised data across multiple businesses could reveal emerging risk patterns, support targeted interventions and improve the sector's understanding of agricultural risk exposure across New Zealand.

Eliminating Reporting Friction

At the highest level, elimination within reporting focuses on removing barriers that discourage hazard and near-miss documentation.

Offline-first mobile reporting platforms address one of rural New Zealand's biggest constraints – unreliable connectivity. Hazards and incidents can be logged at the point of work without signal, then synchronised later when connectivity returns (Resolution Farming App, 2024; Trev, 2024). This removes the need to return to an office or wait for coverage, making reporting more immediate and practical.

> "The goal is not more paperwork. It is better visibility of risk before harm occurs."

Voice-enabled reporting tools further reduce friction. Workers can speak hazard descriptions into a mobile device, with speech-recognition software converting them into structured reports (Microsoft, 2024; Google, 2024). This is useful when gloves, dust, weather or language barriers make typing difficult. The easier reporting is, the more likely near-misses are to be captured. That creates more opportunities to act before harm occurs.

These tools still need to be reliable in noisy outdoor environments, and workers need confidence that speech is captured accurately. Training and system refinement remain essential.

Substitution Through Predictive Intelligence

Substitution technologies replace reactive documentation with systems that detect risk while it is developing.

AI models can analyse data from vehicle sensors, environmental monitors and operational inputs to identify emerging risk states (John Deere, 2024; Trimble, 2024). Instead of simply recording an incident after the fact, these systems can recognise when conditions are moving toward elevated risk and generate alerts.

For example, telematics integrated with terrain modelling can detect excessive slope angles during machinery operation. Environmental sensors can identify unsafe gas concentrations before confined-space entry (Blackline Safety, 2024). Work-hour tracking can flag fatigue exposure before high-risk tasks (Fatigue Science, 2025).

This represents a shift from "writing down what happened" to "spotting danger as it forms." Reporting becomes continuous hazard detection rather than post-event description.

The effectiveness of predictive systems depends on data quality, calibration and trust. Too many alerts can lead to disengagement. Too few can miss risks. Trust in algorithmic recommendations is critical.

Engineering Controls And Automated Detection

Engineering-level reporting technologies embed detection directly into the work environment.

Computer vision systems use cameras and AI to monitor indicators such as seatbelt use, entry into restricted zones, or unsafe proximity to machinery (Intenseye, 2024; Smartvid.io, 2024). Rather than relying only on supervisor observation, these systems can generate time-stamped records and alerts when thresholds are breached.

Internet of Things (IoT) sensors can continuously monitor environmental hazards such as hydrogen sulphide, ammonia, temperature, humidity or dust (Aeroqual, 2024; Honeywell, 2024). These systems act as silent reporting tools, recording exposure conditions continuously rather than intermittently.

Wearable devices can also support automated reporting. Smart helmets and biometric bands can detect falls, impacts, heat stress or extreme fatigue, then send location-based alerts (MSA Safety, 2024; Kenzen, 2024). This can reduce response time and improve the integrity of incident records.

These technologies improve visibility and responsiveness, but they also introduce important governance questions. Privacy, cost, maintenance and data security need to be managed carefully. Without clear rules and trust, automated monitoring may be seen as surveillance rather than protection.

Administrative Integration And Governance Dashboards

At the administrative level, the most transformative development is integration.

Unified dashboards can bring together hazard reports, incident trends, training compliance, environmental data and corrective actions into one governance view (EcoOnline, 2024; Enablon, 2024). This gives owners and directors access to real-time indicators, rather than relying only on periodic summaries. Importantly, dashboards should be designed around what governance needs to know – not everything the system can possibly collect.

Integrated Farm Planning frameworks link health and safety reporting with environmental management, animal welfare and biosecurity (Ministry for Primary Industries, 2020). This reduces duplication and creates a more coherent "whole-of-farm" view.

When data entered once can populate multiple systems, farms can reduce administrative duplication and improve accuracy. Instead of running separate systems for safety, environment and operations, integrated architecture allows information to flow across domains (Resolution Farming App, 2024; Trev, 2024).

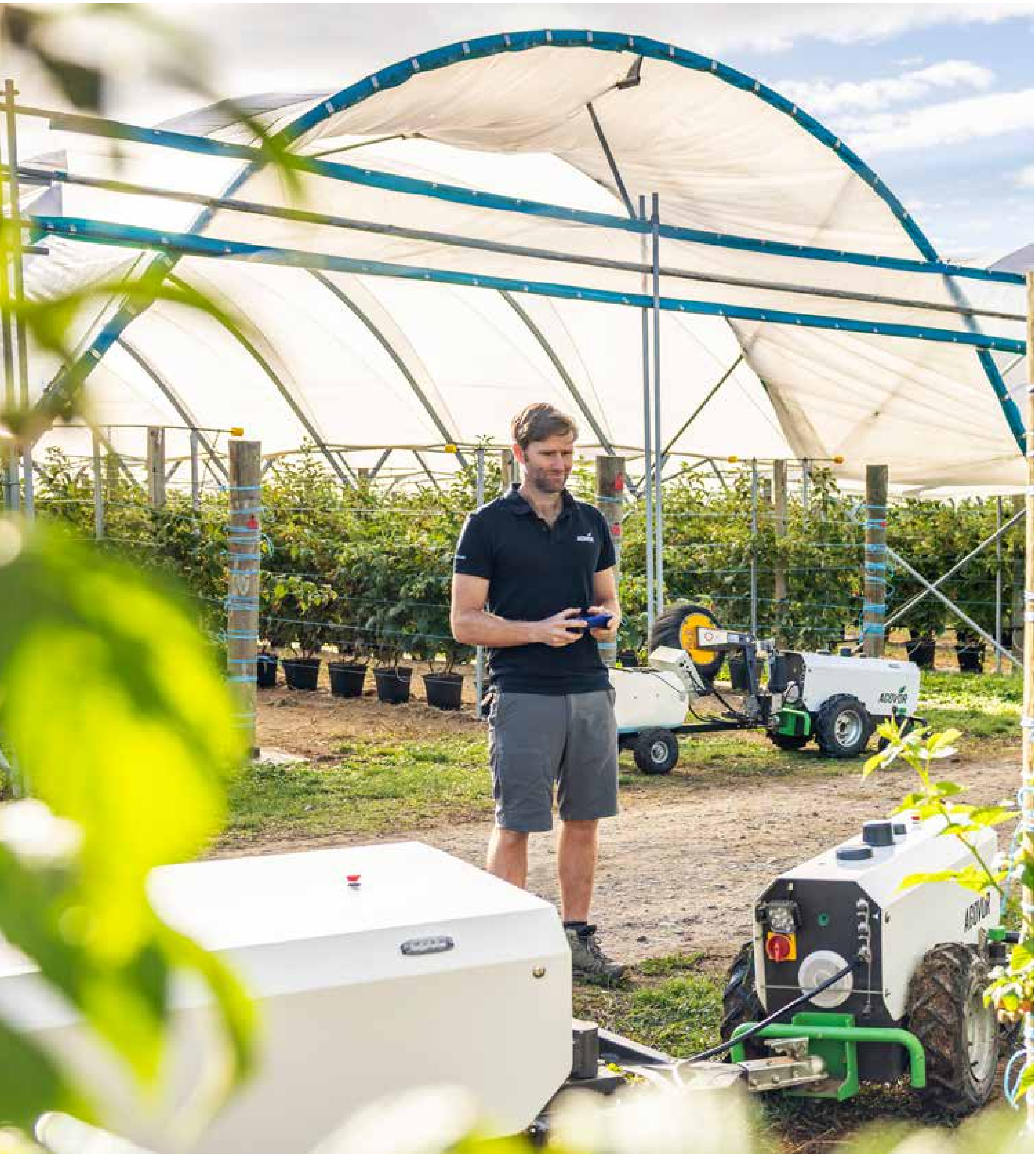
Emerging workforce competency management platforms can also strengthen oversight. These systems maintain digital records of licences, agrichemical certifications, first aid qualifications and other endorsements. Automated alerts can notify managers when qualifications are expiring or when workers are assigned to tasks requiring specific certification (MYOSH, 2024). Linked to scheduling, they help ensure high-risk work is only assigned to appropriately qualified people.

Blockchain-based or similar traceability systems represent an emerging development in governance transparency (World Economic Forum, 2022). By creating tamper-resistant records of safety activities and compliance events, such systems may support audit assurance and market access requirements. While not yet widely used, the trajectory suggests increasing demand for verifiable digital records.

Digital contractor and visitor management systems are another useful layer. Contractors, service providers and visitors can complete site inductions before arrival through mobile apps. They can review site hazards, confirm competencies and acknowledge safety procedures digitally. QR check-ins or geolocation can then confirm arrival and induction status (SiteSafe, 2024).

In addition to improving compliance with HSWA duties, these systems provide farm managers with real-time visibility of who is present on the property and whether required qualifications or endorsements are current. This can be particularly valuable during peak seasonal periods when multiple contractors may be working simultaneously across large or remote properties.

At a governance level, Integrated Farm Planning frameworks extend this concept by linking safety reporting with broader farm management systems. These frameworks integrate information on workforce wellbeing, environmental performance, animal welfare, and production outcomes within a single planning structure.



8. Breaking Down The Barriers:

Adoption, Productivity And Policy

AT A GLANCE

- Farmers are more likely to adopt technology when it is useful, practical and aligned with the way they already work.
- Safety technologies will scale when they also improve productivity, reduce workload or strengthen business resilience.
- Policy, funding, connectivity and peer learning are critical to turning technology capability into everyday practice.

8.1 Behavioural Drivers Of Adoption

For the technologies presented in this paper to become successfully integrated into our farming system, we must understand the behavioural drivers of adoption. Farmers are more likely to adopt technology when it is useful, practical and aligned with the way they already work.

> "Farmers often look to neighbours, advisers and trusted rural professionals before adopting new systems."

Behavioural models such as the Technology Acceptance Model, the Unified Theory of Acceptance and Use of Technology, and the Theory of Planned Behaviour all point to the same basic truth: people are more likely to adopt new tools when they see clear value, can use them confidently, and can integrate them into existing practice (Davis, 1989; Venkatesh et al., 2003; Ajzen, 1991).

Whether a technology will improve productivity, reduce workload, strengthen farm performance, or make a difficult job easier, are key considerations for farmers. They also weigh up cost, complexity and implementation risk. Perceived usefulness and expected economic return are consistently among the strongest drivers of agricultural technology adoption (Rogers, 2003; OECD, 2017).

Farmers often look to neighbours, advisers and trusted rural professionals before adopting new systems. Technologies are more likely to be accepted when they are proven in comparable settings, endorsed by credible people, and supported by organisations farmers trust (Rogers, 2003; OECD, 2017; Eastwood et al., 2019).

Adoption is also stronger when technology aligns with broader farming values, including environmental stewardship, animal welfare and long-term system sustainability. The more a technology supports the whole farm system, the more likely it is to become part of everyday practice (Eastwood et al., 2019; OECD, 2017).

A further consideration is whether technology-led safety interventions are reaching the population most exposed to the risks they are designed to address. Research into digital adoption across New Zealand primary industries suggests that farmers most likely to adopt new technologies are typically "Trailblazers" and "Pragmatists" – businesses that are growth-oriented, digitally confident, and actively seeking efficiency gains (AgriTechNZ, 2022).

In contrast, "Conservatives" and "Traditionalists" comprise a substantial proportion of the farming population and are particularly prevalent within sheep and beef farming systems. These groups tend to perceive lower value from digital technologies, exhibit lower confidence in their use, and are more likely to rely on established manual systems that have served them well over time (AgriTechNZ, 2022).

The same businesses are often characterised by smaller-scale operations, sole ownership structures, and farms in mature, declining, or exit-stage lifecycles. For these businesses, the economic, operational, or personal incentives to invest may be weak, particularly where succession is uncertain or investment horizons are short. Consequently, while technology has the potential to significantly improve safety outcomes across the sector, complementary approaches will remain necessary to ensure that those most exposed to harm are not also the least likely to benefit from technological change (AgriTechNZ, 2022).

8.2 Socio-Technical Barriers To Technology Adoption

Awareness and experience do not always translate into lower injury rates in high-risk industries such as agriculture. Farm incidents often involve experienced operators who know the equipment and the work environment, but are exposed to conditions where fatigue, weather, terrain, time pressure or system failures increase the likelihood of error (Cryer et al., 2014; McNoe, Chalmers, & Langley, 2005).

Several structural and socio-technical factors help explain why harm persists.

1. Many safety controls still rely heavily on human judgement.
Training, awareness campaigns and procedural guidance all improve safety knowledge. But they also depend on people making the right call, every time, in dynamic and often unforgiving working conditions (Reason, 1997; Hale & Borys, 2013).

2. Farming culture can normalise risk.
Research on agricultural safety attitudes shows that experienced operators may rely on practical judgement and familiarity with tasks, sometimes leading to an underestimation of risk or a view that formal safety processes are unnecessary (Sissons, 2016; Neal, 2017).

3. Much of New Zealand's farm infrastructure has evolved over time rather than been designed from scratch.
Farmyards, machinery fleets and handling systems are often adapted, expanded or retrofitted over many years. This can leave legacy infrastructure that does not fully align with modern safety design principles (Safer Farms, 2021).

Seasonal workload adds further pressure. Calving, lambing, shearing and harvesting can involve long hours and physically demanding work over short periods. Fatigue and time pressure reduce attention and decision-making capacity, increasing the risk of incidents involving vehicles, livestock and machinery (WorkSafe New Zealand, 2024a).

These same realities also shape the adoption of safety technology. Rural connectivity, ageing machinery, capital constraints and perceptions of new tools can all affect uptake (MBIE, 2025; Wichmann, 2022). In remote areas, limited high-speed internet can restrict the use of cloud-based systems, sensor networks and real-time monitoring platforms. Older machinery may also be difficult or costly to retrofit (MBIE, 2025).

Cost is another barrier. Farmers often need to prioritise investments that directly improve productivity or profitability, especially during periods of rising input costs or market volatility. As a result, safety technologies may compete with other capital priorities (OECD, 2017).

Technologies that feel intrusive, complex, expensive or out of step with established farming practice may be resisted, even when they offer clear safety benefits (Wichmann, 2022).

Together, these factors show that improving farm safety is not simply a matter of developing better technology. Successful harm-reduction strategies need to fit the realities of farm systems – including infrastructure, economics, culture, trust and the way work is actually done.

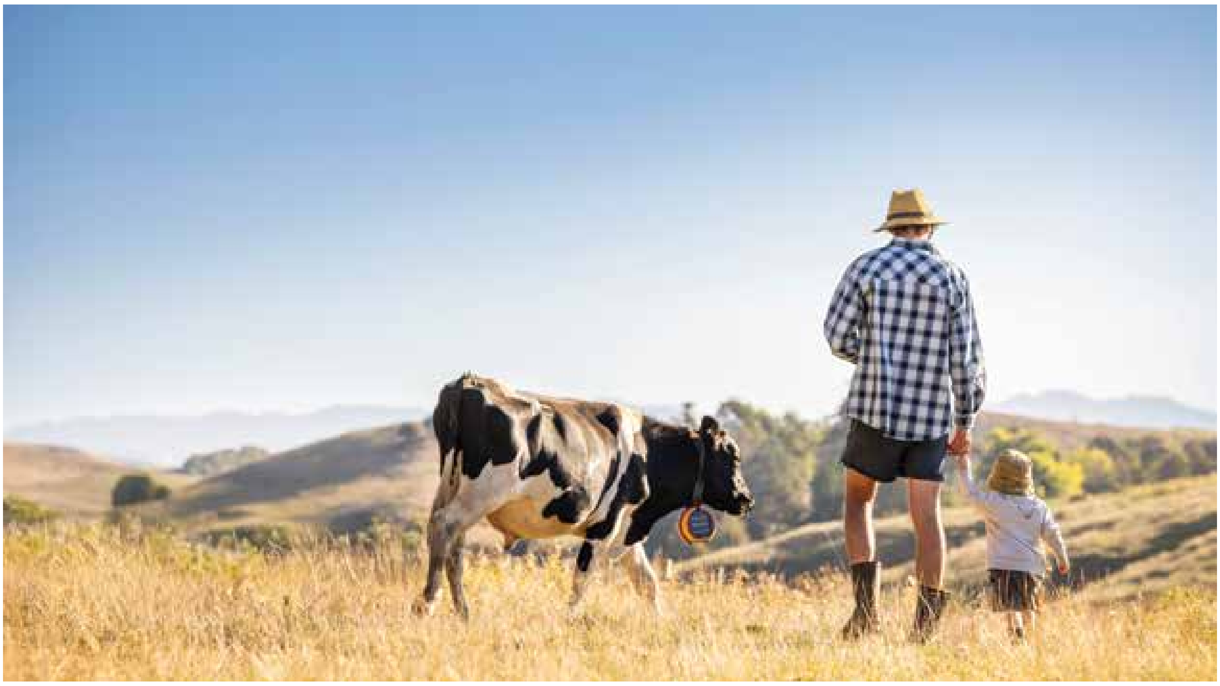
8.3 Government Support

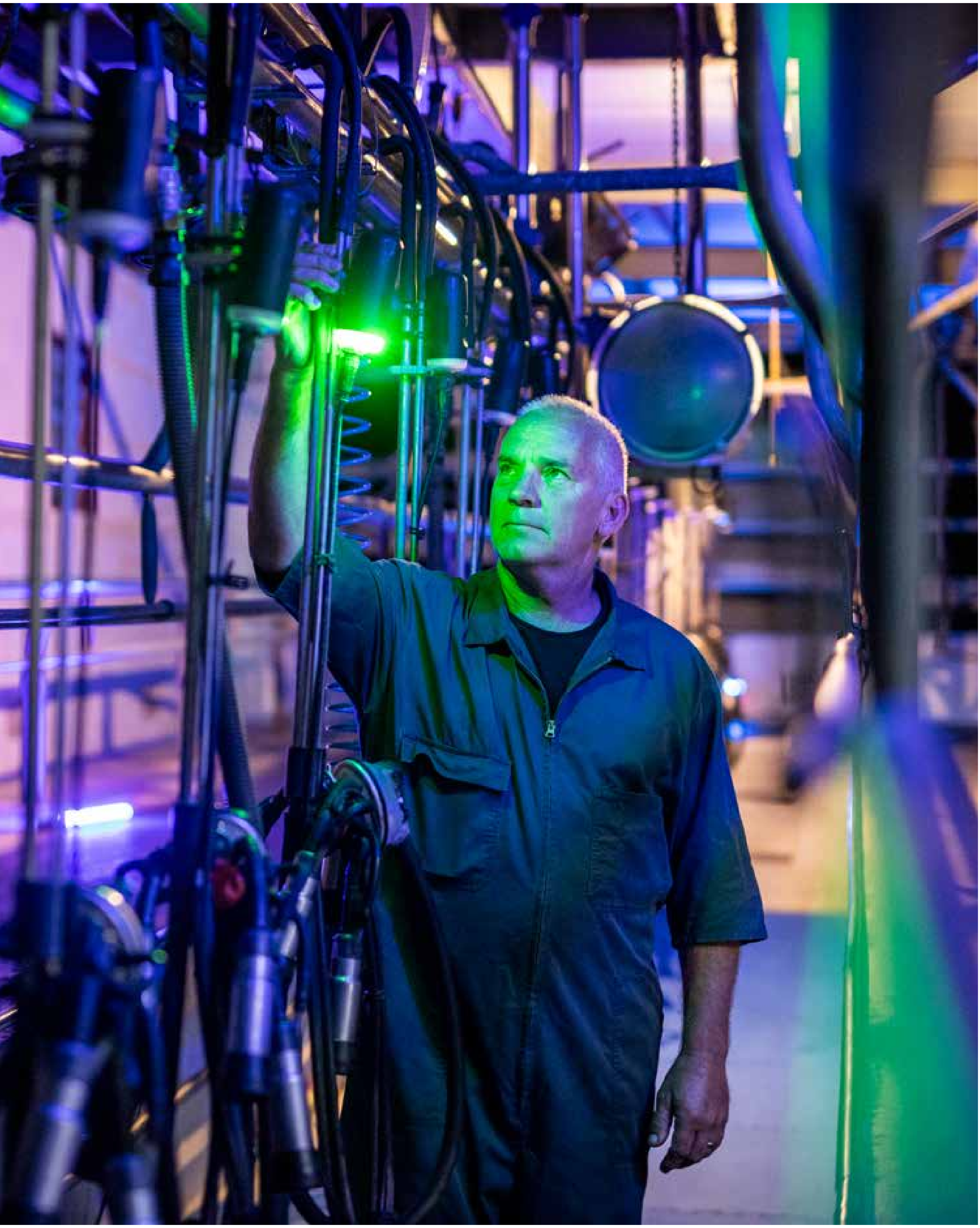
New Zealand farmers can access several tax incentives and investment mechanisms that support capital investment in machinery, agritech and farm infrastructure. These policies are designed to encourage productivity improvements and technology adoption across the primary sector.

One key initiative introduced in the 2025 Budget is the Investment Boost. This allows businesses to claim an immediate deduction equal to 20 per cent of the cost of new productive assets in the year of purchase, in addition to normal depreciation on the remaining value (New Zealand Treasury, 2025; Inland Revenue Department [IRD], 2025). For agricultural businesses, this can reduce the after-tax cost of technologies such as automated livestock handling systems, precision agriculture equipment and advanced farm machinery.

Other mechanisms include deductions for certain farm development expenditure, the Research and Development Tax Incentive, and industry-specific depreciation rates for agricultural equipment and technologies (Inland Revenue Department, 2024; MBIE, 2024).

Safety technologies may not always be the main driver of capital investment. But policies that lower the cost of modern equipment can still support better safety outcomes by helping farms replace older machinery, upgrade infrastructure and adopt systems that reduce exposure to risk.





9. Conclusion:

From Managing Risk To Designing Safer Systems

"The future of farm safety will be shaped by how successfully the sector can move from managing risk to designing it out."

New Zealand agriculture's health and safety challenge is not a failure of awareness, intent or effort. Across this paper, the literature shows that harm persists not because risks are unknown, but because exposure remains built into routine tasks. Vehicles, livestock, chemicals and psychosocial pressures are not peripheral hazards. They are part of how many farm systems operate.

This paper does not suggest that existing approaches are ineffective. It shows they are insufficient on their own. Behavioural and administrative controls have improved understanding, accountability and culture. But they still rely heavily on consistent human judgement in conditions that are variable, isolated and often high-pressure. When this is considered alongside ageing infrastructure, uneven connectivity, difficult terrain and constrained investment capacity, the persistence of harm is clearly systemic rather than incidental.

In this context, technology is best understood not as an add-on, but as a way to reshape how risk is managed. Across each risk domain, a consistent pattern emerges. Technologies that align with higher-order controls – eliminating, substituting or engineering out risk – offer the greatest potential to reduce exposure. Automation, remote operation, sensing systems and digital monitoring do more than improve awareness; they can change the conditions in which work is performed, shifting safety from managing risk at the point of action to reducing exposure within the system.

Three key takeaways emerge from this synthesis.

1. **Harm in agriculture is structurally embedded and cannot be materially reduced through behavioural interventions alone.**

2. **Technology provides a credible and increasingly accessible pathway to reduce exposure, particularly where it removes or distances workers from high-risk activities.**

3. **The effectiveness of these technologies is contingent on their integration within broader farm systems, including infrastructure, governance, and decision-making processes. Technology does not operate in isolation; it delivers value when it is part of a cohesive approach to change**.

For the agricultural sector, continued high levels of harm carry significant human, social and economic costs. They also create increasing scrutiny around workforce wellbeing, business resilience and social licence. For farm businesses, harm means operational disruption, financial pressure and personal risk. But a different trajectory is possible. The technologies examined in this paper show that exposure can be reduced, tasks can be redesigned, and risk can be managed more proactively when systems are structured to support safer work.

Adoption will not happen at scale unless it aligns with the realities of farming. Farmers are more likely to invest in technologies that also improve productivity, reduce workload or strengthen business resilience. Safety outcomes are therefore most likely to improve when safety technologies are framed as part of overall farm performance, rather than as standalone compliance interventions.

At the farm level, the practical starting point is to identify high-exposure tasks and consider where technology could reduce or remove direct risk. This may include automation, remote operation, enhanced monitoring or digital management systems across vehicle use, livestock handling, chemical exposure and environmental conditions. At industry level, adoption will need practical demonstration, peer-to-peer learning and clear cost-benefit examples grounded in real farm conditions. Policy and industry bodies also have a role in improving rural connectivity, supporting capital investment and aligning incentives with system-level safety improvements.

There is no single intervention. The opportunity is a shift in approach. Farm businesses, industry organisations and policymakers can move beyond incremental improvements in behaviour and compliance, and actively pursue the redesign of work systems. That means considering safety technology within farm planning and investment decisions, using data to inform risk management, and prioritising interventions that reduce exposure rather than simply manage it.

Looking ahead, the opportunity to use technology to reduce harm in agriculture will continue to grow. Advances in automation, artificial intelligence, sensing systems and digital integration will strengthen the sector's ability to detect, predict and mitigate risk.

At the same time, these developments will require careful attention to trust, usability, interoperability and access. Not every technology will suit every farm, and further testing and adaptation will be needed to ensure solutions are practical, commercially viable and fit for the diversity of New Zealand farming systems.

The future of farm safety will depend less on how well individuals manage risk in the moment, and more on how effectively systems are designed to reduce exposure before work begins or before an incident occurs.

New Zealand agriculture has a strong history of innovation, adaptation and leadership. Integrating technology into farm safety is the next stage of that evolution. By shifting focus from managing risk to designing safer systems, the sector can reduce harm while also improving productivity, resilience and long-term sustainability.

This pathway is credible and achievable. The responsibility now lies in implementation – translating capability into practice, and ensuring the systems that underpin New Zealand agriculture are not only productive, but fundamentally safer by design.

"The responsibility now lies in implementation…"

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