Evaluation of Cow Collar Technology

A Research report for Our Land and Water National Science Challenge, Rural Professionals Fund

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1 Executive Summary

Cow collars, including ear tags and boluses and tags with similar functions, are recent technologies which provide cow health and reproductive monitoring to improve livestock health and welfare, lift reproductive performance and reduce labour and farm costs in dairy herds. Collars incorporating virtual fencing can result in greater protection of waterways and critical source areas for improved water quality and compliance, improved pasture management and utilisation, and reduced labour for shifting stock and setting up fences, thereby contributing to improved staff well-being, work-life balance and increased job appeal. Collars for virtual fencing are also available or beef herds.

Collar technologies can be expensive, ranging from about $40 to $197/cow/year depending on the benefits available and whether technologies are leased or owned. Considerable investment capital is also required, so the decision to adopt is not made lightly. Independent and quantifiable information on benefits and costs of these technologies is limited and is usually provided by technology retailers. In this research, we investigated cow collar technologies, and developed an investment template for calculating investment returns.

Background information, and 10 interviews with farmers using 6 different technologies identified: technologies available, reasons for adoption, an assessment of the technologies (advantages and disadvantages, tangible and intangible), implementation considerations, and integration with other technologies. An investment analysis template tool for farmer and rural professional use to inform farmer decisions on adopting these was developed in association with three case studies. This project aligns with Our Land and Water Science Challenge Pathways to Transition theme.

Eleven technologies were identified, with 8 clearly being commercially available. Of these 8, only one offered virtual fencing capability (Halter®). Farmers with a range of herd sizes and systems were interviewed. The trade-off between cost and features affected the brand decision, with Halter (has virtual fencing) being considerably more expensive. Other factors affecting choice were: they addressed an issue, reduced labour requirements, own with less risk exposure to annual cost increases versus lease with access to technology updates, availability (fewer brands for earlier adopters), trust in the company (e.g. international, viewed at a neighbours), battery life, reliability and type (collar, pedometer, bolus).

Those adopting Halter technology were particularly interested in the virtual fencing aspect and the impact on labour. Labour access and quality is an industry issue. Collars reduce the requirement for labour, particularly skilled labour, free up staff for other jobs and reduce costs associated with labour. Collar technologies integrated with automatic drafting and MINDA, although they were not compatible with all drafting systems, and were not necessarily fully automatic e.g. a file with cows for mating or unwell was provided by the technology but had to be loaded into the drafting system. Nevertheless, loading a file for automatic drafting is still quicker than identifying these cows at the shed. Support from technology providers was viewed positively.

Mating and labour were primary reasons for adopting collars. Collars reduced staff required at the shed over mating, including someone skilled at identifying cows in heat being present. This can be important where unskilled staff are employed. Fewer hours and technology can make the job more attractive to staff. Where staff are employed on salary, costs may not reduce except for casual labour requirements. Staff numbers are not necessarily reduced, but staff can spend more time on other tasks. Management and labour need to be willing to pick up new skills in technology use and understanding for this to be effective. There can be less requirement for, and a loss in, basic on-farm skills e.g. heat detection, pasture management (with virtual fencing).

Nine farmers found collars useful over mating. Often, they used these initially with other heat detection aids, and once they had confidence these worked, they reduced or eliminated reliance on these. Collars were useful for monitoring heats before and during mating for AI, identifying cows with quiet heats, reducing straws required including for use of sexed semen, concentrating calving for higher production, improved conception (by up to 10%) and submission rates, and in-calf rates (1% to 5% after collar adoption). However, some farms found no improvement in submission and in-calf rates. However, seasonality means comparing between years is not necessarily reliable.

All collars could identify unwell cows which was an advantage for animal health and animal welfare, although farmer responses were variable, although false alerts can be a problem. Collars can identify unwell cows before clinical symptoms show e.g. mastitis. Some farmers manually identify unwell cows before the collar did. Collars readings are also used to manage cows in transition periods e.g. dry to milking.

Collars with virtual fencing, while expensive, had a number of benefits as well as the above. This included managing critical source areas, pasture management in wet weather to minimise damage (e.g. keep cows off the wettest areas), feeding crops, pasture allocation, back fencing and possibly shifting cows more often minimising damage and increasing pasture utilisation and growth, grazing heat maps to inform fertiliser use, and potential use for compliance. Cows can walk to shed at their own pace (less stress). Reduction in labour requirements and associated costs (e.g. housing, bikes) were major benefits. Most found implementation straightforward with collar technology fitting well in the system. It was recommended collars were installed at a quiet time of year for cows and staff to get used to these.

Modelling analysis results for the case study farms (1 Halter, 2 Allflex) showed the technology to be beneficial. More established technologies were likely to be more effective (algorithms more developed) with providers improving with more time and data. In deciding whether to adopt, it is also important to consider current levels of performance which will impact potential likely improvements achievable. Multiple access to data enables owners and managers to monitor what is happening on the farm. There is potential for consultants to use farmers' collar data to assist in advising them (as for bank apps currently), and some vets have already identified this opportunity and use and summarise clients' data to identify health, reproductive and nutritional issues in their herds.

2 Introduction

2.1 Project Context

Cow 'collars', including boluses and tags with similar functions, are relatively recent technologies with potential to benefit farming systems if tangible and intangible benefits exceed costs. These technologies are primarily used in dairy farming systems although they have the potential to be useful in beef systems, particularly those with virtual fencing (VF) capability. However, technology costs would need to reflect the fact that benefits to beef systems will differ from dairy systems, with fewer benefits for beef systems compared to dairy systems where they are used on a daily basis, for multiple purposes.

Most cow 'collar' (tag, bolus) technologies provide cow health and reproductive monitoring to assist cattle farmers to enhance livestock health and welfare, lift reproductive performance and reduce some farm costs. Technologies incorporating VF capability, such as Halter®, can result in: greater protection of waterways and critical source areas (CSAs) for improved water quality and compliance, improved pasture management and utilisation, and reduced labour requirements for tasks such as shifting stock and setting up electric fences, contributing to improved farm staff well-being, work-life balance and increased job appeal.

There has been some adoption of these collar technologies in New Zealand over the last ten years (Burton, 2022), however, independent and quantifiable information on the benefits and costs of these technologies is limited. These technologies can be relatively expensive and often require considerable investment capital up front, so the decision to adopt is not made lightly.

As Horn and Isselstein (2022) observed with respect to VF technologies, 'the potential of VF is enormous, but its economic viability still needs to be verified…'. They also observed that few farmers use VF "... because novel decision support tools have widely failed to convince the farmers of the economic advantages, the compatibility with their standard practices, and the manageable efforts for understanding, implementation, and management" (p. 162).

Farmers need to understand and be able to evaluate the benefits and costs, both tangible and intangible, associated with cow collar technologies to make informed decisions on whether to adopt and implement these and have the confidence to do so. Therefore, an independent investigation of the advantages and disadvantages of these technologies to inform farmers' decisions is timely. We proposed addressing this knowledge gap.

We used interviews, and a case study approach with investment analysis in this project. Background information was provided. Interview and case study research was undertaken to identify qualitative and quantitative information on: the technologies available in NZ, primary drivers for adopting these, an assessment of the technologies (tangible and intangible advantages and disadvantages), factors to consider when implementing these technologies, and other technologies with the potential to integrate with cow collar technologies. These findings supported the testing and verification of a cow collar investment analysis template tool to inform cow collar adoption decisions developed in association with the three case studies. This tool will be made available for farmer and rural professional use. This project links to the Our Land and Water Science Challenge Pathways to Transition theme which aims to grow "understanding of what it takes to transition to resilient, healthy and prosperous futures, and are developing tools to help" (Our Land and Water, 2023).

2.2 Target Audience

The target audience for results of this research is primarily New Zealand dairy farmers (approximately 11,000 farms) and some beef cattle farmers (approximately 23,000 farms), including Māori agribusinesses (Beef + Lamb New Zealand, 2022, p.6). Results will also be relevant to farm advisors, vets and technology providers. While the technology will not be suited, or of interest, to all these businesses, there is growing interest in cow collar technology and potential for adoption. If only ten percent of dairy farmers adopt cow collar technology, this equates to uptake by 1,100 farm businesses. Arguably, it is not unrealistic to anticipate that there could eventually be over 50% uptake by dairy farmers and 20% of beef finishing farmers in future. While benefits have not yet been quantified independently, it is anticipated that there is potential to benefit from adoption of this technology.

Specifically, the target audience for our findings will be:

- Project case study farmers who will get information to inform their farm businesses.
- Dairy farmers, including Māori agribusinesses, currently using cow collar technologies.
- Dairy and beef cattle farmers, including Māori agribusinesses, interested in introducing cow collar technologies into their farm business.
- Advisors to the dairy and beef sectors, including vets.
- Agritech businesses who have developed cow collar technology.
- Agritech businesses who provide technologies with the potential to integrate with cow collar technologies.

The Māori community has significant investment in the primary industries and take a long-term view of investment to meet cultural, social, environmental, and financial objectives. Cow collar technologies are already being trialled on some Māori agribusinesses. These technologies have the potential to deliver to the multiple objectives important to Māori enterprises. For example, cow collars can assist in keeping stock out of waterways and sensitive areas to meet Te Taiao objectives. Succession, attracting and retaining whanau to work and eventually manage Māori agribusinesses, is also an important long-term objective for many of these businesses. Technologies such as VF, that reduce time spent on mundane tasks, improve work-life balance and incorporate technology into the business, can appeal to younger staff, increasing the likelihood of attracting and retaining these next generation whanau employees to meet their business succession objective.

2.3 Research Objectives and Outcomes

This project will:

1. Provide independent, qualitative and quantitative information on: the tangible and intangible advantages and disadvantages, direct and indirect costs and savings, implementation aspects, and the impact of cow collar technologies on the farm system. The ability of cow collar technologies to integrate with other technologies was also indicated.
2. Develop an investment analysis template for cattle farmers and their advisors to assess investment in cow collar technology.

The information provided by this project, supported by the investment analysis tool developed, will help inform farmers' decisions on whether to invest in this technology and how to do this, reducing risk associated with this decision and increasing their confidence in their decision on whether to adopt. Benefits that could be realised by adopting this technology include greater and more effective uptake of these technologies leading to greater animal productivity and health, better pasture utilisation (VF), improved environmental outcomes and compliance (e.g. improved water quality, less pasture damage), advantage labour outcomes, and potentially improve economic returns.

Planned research outputs, extension activities and measures of success are shown in Appendix I.

3 Background

Early adopters are investing in cow collar technologies which offer mating and animal health benefits, including, identifying cows in heat, sick or lame cows through monitoring rumination and cow activity. Uptake is low (less than 15% of farmers) but growth had been exponential over the last few years (Burton, 2022). Some technologies also offer location and pasture management benefits, and one option recently made available in New Zealand includes VF capability (Halter). Some technology providers provide financial analyses to support their product and/or an investment template for potential clients to evaluate these. However, these analyses lack independence and may incorporate optimistic assumptions. Hence, it is timely to conduct an independent investigation of the advantages and disadvantages of these technologies to the farm system to provide information which can be used for evaluating and comparing these technologies.

3.1 Cow Collar Technologies

Cow "collar" technologies tend to come in the form of a cow collar, ear tag or pedometer, although bolus forms also occur. The majority focus on mating (heat detection largely derived from measuring cow activity) and cow health (using rumination as a key measure). Sensors measure cow activity (accelerometer), and possibly temperature (via eartag or bolus), heart rate, pressure (for rumination), and occasionally cameras or acoustics to measure cow data identify these. In contrast to external devices, boluses can measure temperature, rumen pH and sometimes water intake, which can be used to predict feed and water intake, rumination and cow health.

A cow's current activity is compared to her activity baseline (e.g. last 7 days), with changes in activity outside a pre-defined threshold generating an alert (DairyNZ, no date). Data is often transmitted via Radio Frequency Identification (RFID) towers, and a processor uses algorithms to process this data to predict whether a cow is on heat or possibly unwell. This information is made available to management and others (staff, owners, supervisors, vets), often in real time. Herlin et al. (2021) summarised the types of sensors and information that can be derived from these in his review of animal welfare monitoring technologies in pasture-based systems and their implications on animal welfare (Table 1).

Some technologies include GPS devices which can identify cow travelling speeds, distances and locations providing information on cow location, cow travel and health (e.g. lameness), and herd grazing dynamics to inform herd pasture management decisions in association with other data: the latter is an area under development with a number of technologies.

Table 1: Examples of sensors used in dairy farming, what they measure and what the alarm signal can inform the stockperson. From Herlin et al. (2021, p.829).

Type of Sensor	Measurement	Information
Activity	Activity, rumination, lying time, step count	Oestrus, calving, lameness, general health
pH sensor	Rumen pH	Rumen acidosis
Camera	Activity, feed intake, body shape	Ketosis, body condition, lameness, mastitis
Thermometer, thermography	Body temperature thermal body surface radiation	Water intake, calving, infection, lameness, general health
Microphone	Rumination time	Rumen function, general health, oestrus, calving

A few technologies are being developed with VF capability. While some are stand-alone VF technologies, others such as Halter incorporate mating and animal health functionality as well. VF operates using GPS to define placement of VF boundaries. These can be easily moved for the herd, or for individual cows, usually using a phone app. Cows with GPS functionality on their collars for VF are warned as they approach the virtual fence, initially with noise and vibration triggers, then small electric shocks if they go closer (Verdon et al., 2021). These triggers (vibration and noise) applied directionally, can also be used to herd the cows e.g. to shed for milking.

VF technologies have generally been reviewed for benefits associated with VF capability only. Golinski et al. (2022) reviewed four of these technologies, including Halter and eShepherd, and concluded that they have the potential to reduce labour, the flexibility to adapt to changing pasture conditions, and can improve precision, efficiency and options in feeding systems, but need to be adapted for more stock types and classes and need to be more cost-effective. Similarly, Horn and Isseltein (2022) reviewed grazing technologies (including identifying Cow manager, GEA CowScout, SmaXtec, eShepherd and Halter which are available in New Zealand) and came to similar conclusions. They also mentioned the need for acceptance of VF technology by authorities and the public to be supported.

The decision to invest in new technology is highly dependent on the expected relative costs and benefits from the investment, as well as other advantages such as addressing compliance, meeting environmental goals, and addressing animal welfare and labour concerns. There has been some published research, primarily international, on the advantages, disadvantages, and performance of cow collar and VF technologies. But, as Loverelli et al. (2020) observed, "Although the beneficial effects of precision livestock farming have been studied, the quantification of the environmental, economic and social sustainability of dairy cattle livestock production equipped with precision livestock farming techniques has not yet been carried out" (p.10).

Very little has been published independently on the costs and benefits of adopting cow collar technology for pastoral farming, either in New Zealand or even internationally. Horn and Isselstein (2022, citing Rogers, 2003) speculate that the reason few farmers use knowledge driven grazing management systems is "… likely because novel decision support tools have widely failed to convince the farmers of the economic advantages, the compatibility with their standard practices, and the manageable efforts for understanding, implementation, and management" (p.162). Furthermore, as they point out, "the potential of virtual fencing is enormous, but its economic viability still needs to be verified and its acceptance by authorities and the public needs to be supported" (p.153). Rutten et al. (2014) also identified the need for better understanding of the benefits of these technologies and a need for herd-specific economic models.

3.2 Benefits of Cow Collar Technology

Most collar technologies in New Zealand are targeted to dairy cows. The various benefits associated with cow collar technologies, including VF capability, were described by Burton (2022), Dairy Australia (no date), Herlin et al. (2021), Horn and Isselstein (2022), Loverelli et al. (2020) as well as mentioned by a number of the other references in the bibliography. These benefits are summarised below.

The success of a technology for a particular business is dependent on the level currently achieved on the property and potential that VF technology can achieve. Data collected and its interpretation needs to exceed that currently achieved by human ability (Burton, 2022). The majority of these technologies were developed for housed systems overseas and have an individual cow focus rather than a herd focus. Algorithms for these technologies have had to be developed for pastoral-based systems where cow activity differs.

3.2.1 Animal Health and Mating Benefits

Most collar technologies available in New Zealand offer mating and animal health benefits for dairy herds. Figure 1 demonstrates how a cow collar system for mating and animal health works. Benefits from these systems are outlined below.

- The primary benefit is improved mating performance through accurate heat detection (not only best day to inseminate, but best time of day). Technology can equal or outperform human identification which is becoming more difficult to identify with higher performing cows (lower mounting activity) (Burton, 2022). Improvements can be greatest in the first few years. Accurate heat detection means AI can be used for the whole mating period (no bulls needed for backup, thus improving health and safety). Benefits include: an increase in replacements available, effective use of sexed-semen, use of higher value terminal sires and better calves, less need for pregnancy testing, lower mating costs, and accurate cow mating information to assist with planning at calving.
- Higher milk production can be achieved through tighter calving and a lower not-in-calf rate. A 1% increase in higher 6-week mean in-calf rate is estimated to return an extra $4

per cow at a $5.50 payout (Burton, 2022). For lower performing herds, this could pay for the cost of the technology ($39 average per cow for Allflex, Afimilk and Cow Manager for 10% improvement).

- Illness can be detected early based on activity/inactivity, including picking up cows at a subclinical stage who can be pulled out of the main herd for observation e.g. for mastitis. Lameness can be identified by technologies that monitor motion activity. Temperature sensors will identify heat stress. Lameness and heat stress both negatively affect milk production.
- Labour requirements are reduced for skilled and unskilled staff. There is less dependence on key people to identify cows in heat over the mating period, and fewer staff may be needed in the shed over the mating period for this purpose. Staff less experienced in animal husbandry can use the technology to identify, or help identify, cows in heat to draft out for insemination. Staff can spend time on other tasks instead and savings can be made if fewer highly skilled staff and more less skilled staff are employed. Owners and managers can view information to ensure the correct animals are being inseminated.

Cow Manager is also being trialled in beef herds measuring grazing, ruminating, walking and temperature. The programme is particularly interested in fertility measures (age of puberty, conception dates, first post-partum oestrus) for use in breeding programmes. Other benefits to beef herds are also being evaluated (Scott, 2023).

Figure 1: Wearable device health and disease monitoring system (From Alipio & Vilena (2022).

3.2.2 GPS-enabled Pasture Management and Cow Location Benefits

GPS enables cow location identification and tracking. Benefits include the following.

- Identification of cow location.
- Information about movement patterns, herd dynamics and grazing, and pasture utilisation dynamics for planning e.g. identify calving cows, feed planning, identify how access to different quality pastures affects group dynamics.
- Some providers are looking into using information on cow/herd dynamics in association with pasture apps and technology, and even satellite measurement of pasture to assist (quantity, quality, utilisation) with pasture management and feed planning.
- Monitoring behaviour, health and welfare in association with accelerometer data.

3.2.3 Virtual Fencing Benefits

Halter and eShepherd are the only technologies currently offering virtual fencing in New Zealand, with Halter incorporating the above benefits to dairy farmers as well. Figure 2 shows how a VF system works. VF benefits include the following.

- Virtual herding is efficient for herding cattle, with no obvious impact on behaviour, health or performance as reported by Horn and Isselstein (2022). Stock can be moved using an app or computer depending on the technology. Stock can travel at their own pace, reducing lameness.
- VF provides a flexible, dynamic approach for adjusting grazing boundaries.
- VF can be used to fence off sensitive areas or dangerous areas. There is potential for lowers fencing costs, especially around riparian areas, if regional councils are agreeable.
- VF enables grazing of abandoned areas e.g. awkward shape, expensive to fence.
- A primary benefit is a reduction in labour required, with more time available for other economic activities and /or better work-life balance for staff and management. The latter is useful in attracting or retaining staff. Fewer staff resources may be needed.
- Collars for VF may also be used to collect oestrus and animal health data, as in Halter.
- Virtual herding can keep cows moving e.g. on hills to milking shed.

Pasture management benefits of VF are anticipated to be considerable. In the keynote address at a Halter-organised Dairy 2032 event in Christchurch in June 2022, Malthus (2022) noted that "the general manager of Ngāi Tahu Farming and Forestry, Will Burrett, said Ngāi Tahu adopted Halter in a 'leap of faith' by the board and management, but now has Halter collars on 25% of its 8,000 dairy cows. 'I tell you what the functionality of what we're seeing out in the paddocks, the pasture utilisation, allocation accuracy perspective is really exciting'".

In December 2023, Halter launched a beef version offering VF and in-paddock shifting only. Pasture production and utilisation (40%-70% for beef cf. 80%-90% for dairy) is typically lower in beef herds than dairy herds (Gilchrist, 2023; Scott, 2023). This beef version offers better pasture management and more flexibility (rotational grazing, back fencing, creep grazing of calves) resulting in improved production and utilisation, better pasture quality, and preferential feeding, resulting in higher beef production per hectare (Gilchrist, 2023).

Other benefits include: less fencing infrastructure required, including VF of waterways and sensitive areas (reducing need for fencing depends on regional council rules), keeping stock off sensitive areas, retiring land without reducing stocking rate, and lowering labour requirements for shifting and managing stock e.g. moving stock, temporary electric fencing and back-fencing breaks.

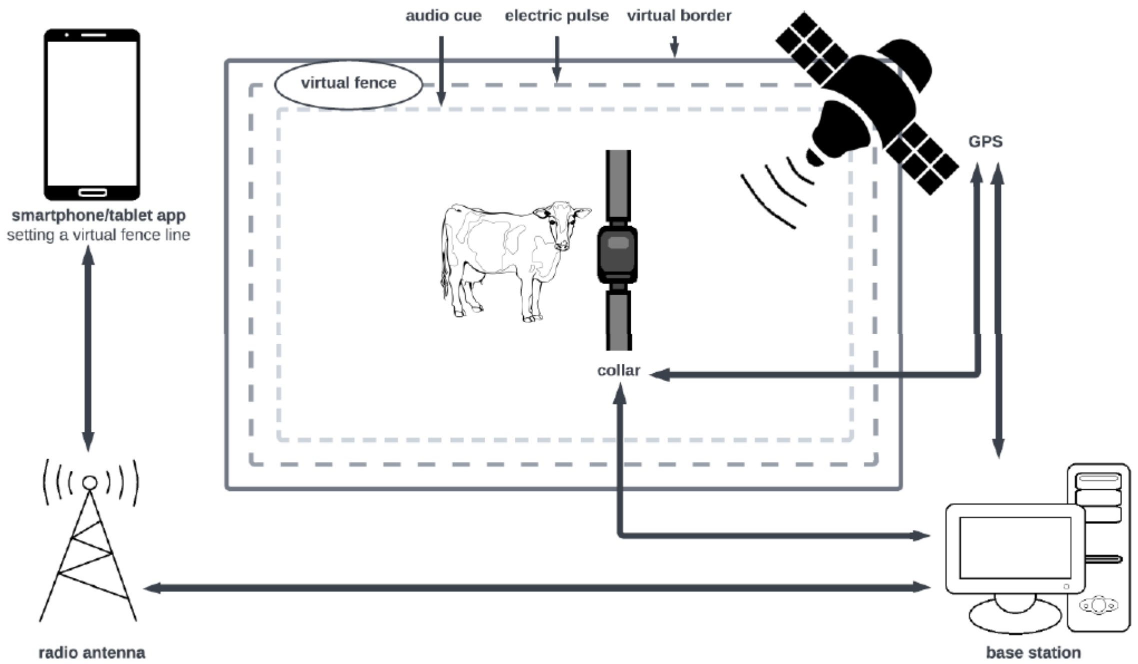

Figure 2: Concept of virtual fencing for grazing animals (from Golinski et al., 2022, p.3)

3.3 Returns to Investment

The majority of cow collar technologies used in New Zealand offer mating and animal health benefits only. Burton (2022) estimated that if these technologies could lift the 6-week in-calf rate from 67.7% (industry mean) to 78% (industry target), at $39 per cow per annum this increase alone would pay for the technology (Burton, 2022).

A stochastic simulation model was developed to evaluate the use of cow activity meters for oestrus detection in the Netherlands (Rutten, 2014), with the internal rate of return (IRR) for adopting this technology about 11%. Benefits primarily resulted from a decrease in calving interval resulting in higher milk production, and a reduction in labour to visually detect oestrus. More calves but fewer cull cows were sold, and total cow costs increased slightly with the technology. Animal health detection was excluded in the analysis although lameness and metabolic problems can be detected by activity sensors and can influence fertility and production. In their model it was assumed activity sensors performed similarly in detecting oestrus, but they noted that “the algorithm used in the sensor system will be important” (p.6883). Algorithms in well-established technologies are likely to outperform those in newer technologies since they have had more time to fine tune these to detect oestrus and animal health concerns from the data collected. In later work, Rutten et al. (2018) simulated delaying investment in technology, including oestrus sensor technology, and found no advantage in delaying the adoption of oestrus sensor technology because "… expected improvements in performance do not outweigh the advantages of immediate investments. Overall, these results highlight that uncertainty about future sensor performance and uncertainty about whether improved informed decision support will become available play important roles in investment decisions" (p.7657).

Thomas et al. (2019) designed a decision-support tool to evaluate the economics of adopting automated oestrus detection technologies in a seasonal dairy production system in New Zealand. This oestrus detection technology is relatively expensive compared to other options (e.g. tail paint, mount detection patches) and the saving in labour costs was the main advantage. Improvements in 6-week in-calf rate and 12-week not-in-calf rate would have a positive impact. However, in the example provided it was assumed visual detection and tail paint both resulted in an oestrous detection rate of 90.5%, compared to 62.4% for the technology, hence it was not surprising the technology had a negative net present value (NPV). Sensitivity analyses emphasised that different herds would see more, or less, value from investing in automated oestrus detection technologies, depending on their current reproductive management situation and the expected technology performance: calculations for decisions need to be herd-specific. It was pointed out that "automated detection may compensate for less well-trained staff in farm teams" (p.2284).

Dairy Australia (2020) recently published a break-even analysis on cow collars, which only addressed virtual herding benefits (labour and pasture benefits). Results indicated that herding technology used in a limited capacity to fetch cows had a break-even cost of approximately $77/cow. However, if labour savings and increased milk production benefits from better pasture management were included, the break-even cost could be more than $300 per cow. Maximum break-even cost for a mixed sheep & beef farm was $408/cow (on distant run-off blocks), whereas for an extensive beef farm this was $140/cow. Similar results were published by Cullen and Armstrong (2022) for a partial discounted net cash flow, possibly citing the same work with $77/cow breakeven for fetching cows to $319/cow for fetching cows, pasture allocation, and feeding later milked cows better.

Halter recently launched a beef farming version offering VF capability only, at about half the price of the dairy option ($96/collar/year for beef). Initial modelling suggests that the adoption of precision rotational grazing, Halter could achieve an improved gross margin per hectare by $348 by the second year (current GM not provided). This assumed a hill country property achieving an increase in utilisation from 59% to 80%, an increase in production from 6.5 T/DM/ha to 7.5 T/DM/ha in year 2 through better grazing management and a gross margin per kilogram dry matter of $0.16 kg DM/ha (Gilchrist, 2023).

3.4 Other Considerations

Animal health and welfare issues were raised in a number of sources, both from a positive and a negative perspective. Factors that can affect the performance of cow collar systems include: the dairy management system, the position of the device on the cow, and the algorithm used to create an alert (Dairy Australia, no date). These affect the data collected and the accuracy of the interpretation.

While technologies can result in animal welfare being monitored continuously compared to manual inspection once or twice a day, there is a reliance on accurate data interpretation and appropriate action being taken with respect to an animal's health (Herlin at al., 2021). Similarly, alerts can be inaccurate. There is a trade-off between accuracy and reliability: increased sensitivity can increase the chance of false positives, whereas lower sensitivity may result in an animal not being picked up. There is also a risk of an animal going unnoticed if the system fails and animals are not monitored. Helin et al. (2021) observed, there is no accepted method to validate sensors or determine what is required making systems comparisons difficult.

Burton (2022) reported health alerts for false positives or sub-clinical conditions where the issue is not obvious, as being problems in New Zealand. Unusual grazing behaviour as a result of poor weather can result in false alerts in pastoral systems, contributing to making it difficult to identify cows genuinely needing attention. However, his review also identified that cows could be "inactive" for up to three days before being clinically diagnosed, suggesting technology can alert users to health issues better than human identification assuming quality data and accurate interpretation. Hence, cows with alerts which may be subclinical can be monitored as a result of the alert.

Concerns have been raised in New Zealand with respect to the use of electric shocks in VF systems, and whether these VF systems could be considered 'natural'. The social acceptability of controlling cows via a collar is still to be determined (DairyNZ, 2019). VF may not be seen as 'natural' as specified in the Animal Welfare code, and the use of electric shocks as a management tool is contentious (DairyNZ, 2019; Malthus 2022). Animals differ in the time and number of electric shocks (e.g. 3 to 23 shocks each for heifers in 8 trials) required to adapt to a VF system resulting in stress, and the number of shocks to adapt can be considerably more than for an electric fence (Herlin et al., 2021). This is a welfare issue for animals that are slower learners. However, Horn and Isselstein (2022) noted no obvious negative impacts on animal behaviour, welfare and performance as a result of virtual herding systems. Malthus (2022) argued that the shocks are much lower than those from an electric fence, and are preceded by audible and vibration, and argued that collars actually enable more natural responses, such as cows being able to pace themselves and respect the pecking order in walking to the milking shed. Styger et al. (2021) assess precision technologies, particularly sensors, that can benefit animal health and found that several of these including accelerometers had application for monitoring animal health and feeding.

Vets can also use collar data to identify and animal welfare concerns in the herd and help farmers address these (Howie and Luckman, 2023).

Obstacles to the uptake of cow collar technologies in New Zealand include the following. These can be costly and not easy to use; they may go to market not fully developed (inadequate training, limited information on data interpretation and manipulation); there can be lack of integration with other technologies; and no clear plan of action (Burton, 2022). Lack of information on the technology and traditional choices can also be barriers (Loverelli et al., 2020). Burton (2022) reported mixed farmer views on after sales service depending on technology used, although views on support and training to understand and implement the technologies and troubleshoot was positive. Some technologies had too few support staff who were very busy. VF has just been released commercially and needs time to be proven. DNZ (2019).

Reporting varies between technologies. For example, Burton (2022) found Allflex and Cow Manager are designed to be operated via a computer with limited phone app functionality. In contrast, Halter is designed to be used exclusively via the app (phone or tablet) with no reporting webpage development yet, although data can be downloaded on request in spreadsheet format, although this is likely to be addressed in future. Reports on herd parameters are less available than individual cow reporting, particularly in overseas designed technologies (for housed systems). While phone apps are convenient and can be used on the go, these require internet connectivity limiting use to where there is internet. Data stored in the cloud would also require internet access. Technologies rely on the staff and management to be willing to use the technology and have smart phones to do this for some technologies. (DNZ 2019).

There is potential for the use of reports and data by other than the management and farm staff. Where the technology has been introduced to lift mating performance by less experienced management staff, owners had supervisors can access data to ensure expected cows are being inseminated and animal health alerts are being followed up. Performance improvements can be monitored. Data can be shared in a similar way to how financial data often shared e.g. bank, accountant. Some vets have already identified this opportunity. At the 2023 Veterinary conference, Howie and Luckman (2023) reported on an initiative taken by their practice, extracting Allflex data and designing well-presented, summary mating and health (including rumination) reports that can be used with clients for consultation and benchmarking. These reports provide more in-depth data than is currently available in MINDA reports and can be used to identify and advise on specific issues that may need to be addressed in the herd e.g. mating, feeding and nutrition. Their view is that the use of cow collar data, which farmers trust, enables vets to raise these concerns in a timely and objective way with clients who may otherwise feel that their farming skills are being criticised. A similar presentation was made by another vet (Krispin Kannan) who does something similar with his Halter clients. These presenters all believe there is huge potential for vets to use cow collar data to work with their clients on monitoring and benchmarking.

3.5 Technologies Available in New Zealand

Table 2 shows the cow "collar" technologies available in New Zealand as identified in November 2023. Some of these are less commonly used or still in development and testing stages. Unless stated, these are targeted to dairy cows. The purpose of this project is not to compare differences between the performance of these technologies, but to identify those available on the market and their capability which farmers can use to shortlist those they may be most interested in and want to follow up on.

The outputs column describes the type of information provided: as previously discussed, almost all have mating and animal health, those with GPS will record location and movement, and only Halter and eShepherd have VF. The three New Zealand-developed technologies are identified as such and have been developed specifically for pasture-based systems, as has eShepherd (Australian working with Gallaghers).

Price is not indicated but will reflect the level of information provided. Those that just do animal health and mating (accelerometer) cost about $40/cow/year, whereas Halter, which offers the full range of capabilities, costs from $96 - $190/cow/year depending on the package selected and features included. Information has primarily been sourced from product web pages, with some websites more expansive than others. Links are provided in Table 2. All products request anyone interested contact a company representative for more information (link to websites provided in the table). It is recommended that company webpages and representatives be contacted once a short-list of products of interest is decided. The measurements, information provided and the way this is presented for a given capability (e.g. mating, animal health) can differ between companies. However, Table 2 does provide a starting point for looking for information and identifying products with the level of capability provided. Interviewees and cases studies in this project used one of the first six technologies listed.

Integration with other technology is indicated, although this may not be seamless, particularly if it is a non-company product. Most, if not all, appear to be compatible with MINDA, and automated drafting technology. Drafting technology compatibility may vary between products which is something that would need to be considered in investing in cow collar technology. Furthermore, compatibility with these technologies is not necessarily seamless. For example, a list of cows for mating or who are unwell may be automatically produced (information required for drafting), but this information may still need to entered into the system for cows to be drafted off. Some technologies are also compatible with other products that company sells.

Table 2: Cow collar technologies available in New Zealand (as at November 2023).

Name	Device type	Outputs	Compatible	Website
Allflex	Neck collar Lease or own	Mating Cow health	Allflex milk Allflex SCC MINDA Protrack and Intelligate drafting	https://www.allflex.co.nz/senseh ub/
CowManager	Ear tag	Mating Cow health Heat stress Location	MINDA DeLaval and Protrack drafting	https://www.cowmanager.com/n ewzealand/
GEA CowScout	Neck collar	Mating Cow health Cow location and identification	Herd management software MINDA	https://www.gea.com/en/produc ts/milking-farming-barn/activity-detection-cowscout.jsp
Halter (NZ technology)	Neck collar Lease	**Dairy** Mating Cow health Virtual fencing and shifting (in and between paddocks, to shed) Cow location Pasture management Grazing heat maps e.g. for pasture and nutrient application **Beef** Virtual fencing and in-paddock shifting Cow location Grazing heat maps	MINDA DTS Bulk upload for csv files	https://halterhq.com/
smaXtec	Bolus (classic and pH types)	Mating Cow health, including mastitis and heat stress (based on inner temperature) Drinking behaviour	MINDA	https://smaxtec.com/
Tru-Test Active Tag	Neck collar or ear tag	Mating Cow health Find my cow (locate cow or lost tag if nearby)	Automatic drafters Dairy WOW 4000 (weighing) MINDA	https://dairy.farmingmadebetter.com/en-nz https://nz.tru-test.com/products/active-tag

Afimilk	Neck collar	Mating Cow health Milk sensor integration possible	Afimilk milk meters AfiLab AfiSort drafting MINDA & Protrack (previously, 2020)	https://www.afimilk.com/nz/
CowTRAQ (NZ technology)	Neck collar	Mating Cow health Cow location	TracHQ software Waikato milk meter yield indicator Sort gate 5500 (and others) MINDA	https://waikatomilking.com/products/animal-management/cowtraq-collars/
eShepherd (Australian - with Gallagher)	Neck collar	**Beef** Virtual fencing (being trialled in NZ)		https://am.gallagher.com/en-NZ/new-products/eShepherd .
Connecterra's IDA	Neck collar	Mating Cow health (being trialled in NZ for sale via Fonterra Farm Source)		https://www.ceoforlifeawards.com/blog/connecterra-expands-access-to-artificial-intelligence-technology-for-new-zealand-dairy-farmers/
Protag (NZ technology)	Ear tag	Mating Cow health Location (recently released, being trialled)		https://www.protag.co.nz/

3.6 Selecting and Implementing a Technology

3.6.1 Cow Collar Technology Systems

To select a cow collar technology, having some understanding of how these systems work and knowing the information to ask about is helpful to inform the decision. Figure 3 shows a general framework for an IOT (internet of things) system incorporating wearable technology.

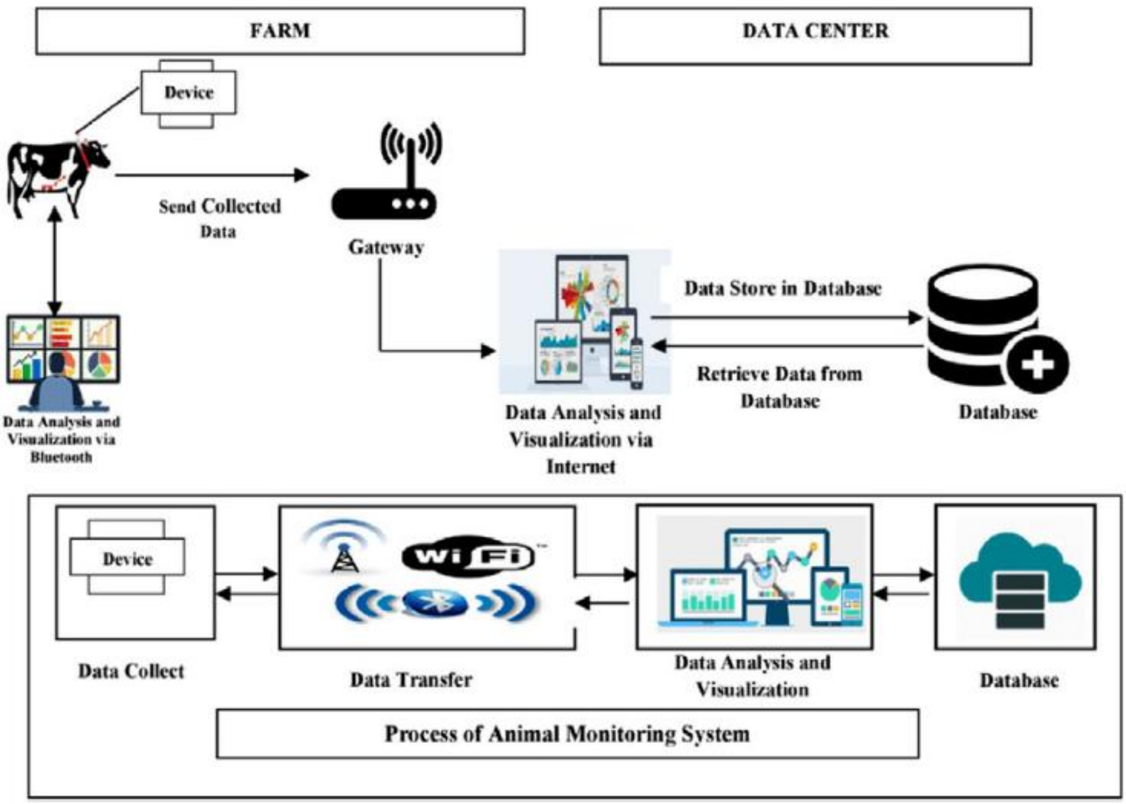

Figure 3: General framework of an IoT-based-system incorporating wearable technology (From Alipio & Vilena, 2022, adapted from Karthick et al., 2020).

The Dairy Australia (no date) guide to automated heat detection technologies provides a 4-page overview of these technologies, including how they work and what features are important in selecting a system. A precis of their description of how the technology works is provided below.

1. The monitoring device is attached to the neck collar, leg or ear and includes a sensor, a long-life battery (years) or a solar powered battery, a miniature processor, a memory device and a data transmitter. Data is recorded by the sensor e.g. motion sensors can do this multiple times per second.
2. Activity counts are regularly downloaded. Some technologies, or earlier versions of these, did this at the milking shed or barn via close proximity receivers which was better suited to overseas housed systems. However, this can now be transmitted more

frequently at a distance in real time via a gateway (towers with antennae) on the farm back to the main receiver/tower at the shed (Figures 1 and 3). This enables allows more accurate, timely data recording and interpretation. For example, Halter provides towers on-farm which are both receivers and transmitters (that is, a transceiver) with data transmitted via the towers' antennae. The main tower at the shed has wifi access, thereby linking towers access the farm to the Internet.

3. These gateways work through a private wireless network (intranet) to transmit frequent data, long distance (up to 1 km) with minimal power using radio frequency (RFID) technologies or low power wide area networks (LPWAN) to the receiver at the shed.
4. The receiver transfers the data to a base computer via a cable, Bluetooth, GSM or Wifi. Alternatively, the information can go directly to an internet-based cloud application via a cellular data network or local Wi-Fi networking technology.
5. The data can be stored, processed and retrieved. Proprietary algorithms calculate a normal baseline (e.g. activity) for each cow. The latest data is compared to this. A cow's relative activity over time is displayed in a graph with alerts to identify cows on heat or unwell. Data from more than one input (e.g. activity and rumination) can result in more accurate predictions of mating and health outputs. Over time, with more data and machine learning, algorithms can become more accurate. Hence, well established technologies may be better at predicting, but more recent ones should improve over time.
6. The information on the base computer may be able to be accessed remotely via internet to another computer, smartphone or tablet. These devices may simply receive information or may be able to input and manipulate information e.g. to control automatic drafting.

For those interested in further reading to on how these technologies work, the following papers provide descriptions of technology types, some with technology classifications: Alipio et al. (2022), Aquilani et al. (2022), Bailey et al. (2021), Campbell et al. (2018, VF), Eastwood et al. (2023), Horn and Isselstein (2022, includes VF) and Hansen et al. (2022, with emphasis on opportunities and uptake). Some papers specifically relate to VF including: Golonski et al. (2022), Lomax et al. (2019), Verdon et al. (2021) and Wilkinson et al. (2020). The following authors describe the use of sensor technology specifically: Herlin et al. (2021), Loverelli et al. (2020) and Styger et al. (2021). Algorithm development and testing are described in Chang et al. (2022), Pavlovic et al. (2021) and Simoni et al. (2023). Hoffman's (2022) thesis explores GPS technology and pasture management.

3.6.2 Factors to Consider in Selection and Implementation

The following factors need to be considered when selecting a system (primarily sourced from Dairy Australia (no date) and DairyNZ (no date).

1. Level of recording required e.g. determines sensors included and what is measured. Reasons for considering collar technologies, current level of achievement, potential for improvement, and other possible solutions should be investigated to ensure cow collars are likely to be the solution to achieve what is wanted.
2. Technology cost and expected return on investment or break-even value. Current performance and potential improvement with the technology need to be assessed. Other farmers with collar technologies can provide an independent perspective.
3. How does the technology fit in with the current system? What changes will be required?
4. Type of technology attachment e.g. leg, eartag, collar, bolus. Affects durability, collar fit, cow comfort, health and safety.
5. Battery life, and the ability to replace or recharge batteries.
6. Data transfer from the cow device to receiver e.g. real time or data collected at shed.
7. Accuracy of data recording and algorithm prediction.
8. User interface and access to information e.g. computer at shed for farm staff, to apps and reports available to multiple people on computer, phones and tablets via Wifi. Are these outputs information only, or can these be used to manage the system? Where is data stored?
9. Types of reports available and their usefulness. Are these individual cow and farm level outputs available? Who can access these?
10. Integration with other current system and other technologies e.g. MINDA, automatic drafting, milking equipment.
11. Technology funding arrangements i.e. purchase or lease. Payment for different levels of reporting?
12. Warranty period and expected life of the technology for purchase.
13. Ease of attaching and removing devices. Can these be passed on to other cows?
14. Technical backup and ongoing support available.
15. Willingness of farm staff and management to engage with the new technology. Does the manager want this to succeed and will put in the effort to do so? Do staff have the technology to use this e.g. smartphones?
16. Time required to learn and fully engage with the new system. New skills will be required e.g. effectively interpreting and acting on cow collar information.
17. Time required and how easy it is to train the animals to the system for VF, which is reported to be quite straightforward and only takes a few days.

4 Phone Interviews

4.1 Method

Following on from the background information search, the phone interview stage of the project comprised an on-line questionnaire, followed by 10 semi-structured farmer interviews with farmers using cow collar technologies. Originally, the intent was to explore the impact of cow collar technologies using only semi-structured interviews (Bryman,2016) to capture in-depth, contextual information on farmer experiences. However, an initial on-line questionnaire was added to capture initial data thereby reducing interview time or increasing the depth of information able to be captured in the half hour interviews, help in interview planning, and identify people using a range of cow collar technologies who may be willing to be interviewed.

This stage of the project largely captured qualitative data, although quantitative differences in performance between with- and without-technology were asked about in the questionnaire. However, this was difficult for farmers to provide accurately, or at all, because seasonal differences and other changes in the system can obscure technology impacts. Those who had been using technology for a short time were less likely to be able to gauge quantitative impacts, and some technologies had only been available for a short period e.g. Halter. Findings from this stage of the project contributed to the investment template development and case study research.

Topics covered in the preliminary questionnaire and in the later interviews with farm businesses, which were used as themes in the analysis, included the following.

- Cow collar use (why and how).
- Advantages and disadvantages of cow collars (e.g. profit, labour, risk reduction, animal health and welfare, fencing and races, pasture management, repairs and maintenance, resource management consents).
- Financial implications, costs and savings.
- Maintenance and service requirements of cow collar technology.
- Other technologies used with the collars and integration with other technologies.
- Implementation challenges.
- Farm systems changes required for efficient use of the technology (if any).
- Opportunities for enhanced performance from technologies.

4.1.1 Questionnaire

A questionnaire was designed to capture an initial overview of cow collar technologies. Responses were in the form of short written or numerical responses, responses to a 5-point Likert scale assessment, and comments.

Questions included:

- Farm data including factors that impact the environment: location, peak cows milked (2022/23, average previous 3 seasons, milking platform (ha), FTEs, farm system type, milking frequency, terrain, open drains, % irrigation, use of non-milking area, run-off).
- Cow collar technology: type, seasons used, initial, annual and operational costs, technology ownership, attributes identified, other technologies used, additional features that would be useful, whether likely to continue using the technology.
- Usefulness and impact on the following
    - Mating (usefulness for heat, detection, drafting and herd performance trends; submission, conception, six week in-calf, and empty rates; other benefits or disadvantages).
    - Animal health (usefulness for lame cow, mastitis, sick cow and metabolic issue detection, drafting and herd performance trends; SCC, mastitis, cow deaths and metabolic issue rates; other benefits or disadvantages).
    - Feed management and milk production (usefulness for break-feeding, in-shed feeding, crop feeding, mixed ration feeding and herd performance trends; impact on annual pasture yield, pasture utilisation and milk production; other benefits or disadvantages).
    - Environmental management (keeping stock from critical source areas, preventing pasture damage, reducing nutrient run-off risk, preparing resource consent applications, and meeting compliance; other benefits and disadvantages).
    - Labour (changes in FTEs, labour skills required, job attractiveness, management skills required; other benefits and disadvantages).
- After sales service (software technical support, equipment technical support, advice on technology use, help in understanding of reports and capability).
- Comment on challenges and systems changes in implementing the technology.
- Willingness to participate in a follow-up interview.

This questionnaire was made available via the Survey Monkey application. An introductory email with a link to the questionnaire was sent to 10 farmers known to use cow collars on the 4th May. It was then sent to an additional 8 email addresses between 4th May and 25th May, including an LIC contact, two Dairy NZ contacts, a Halter and an AllFlex contact who forwarded the email to clients/farmers that they knew used wearable technology. The questionnaire link was posted on "Cow Collar Community New Zealand" on 9th May. A reminder was sent to the initial farmer group who had not yet responded on the 15th May

(6 farmers). The questionnaire link remained open up until the 7th June, although one late response was added on the 10th June, at which stage the questionnaire was closed.

Twenty responses were received, with 14 fully completing the questionnaire (17 completed most of the questionnaire). Relatively few users, limited distribution, and the time required to complete the questionnaire contributed to this low number. However, the primary purpose was to identify potential interviewees for the project and provide base data prior to the interview so this questionnaire was adequate for that purpose.

Responses were insufficient to report meaningful statistical data, however, some analysis was undertaken, with obvious trends reported in association with the interview data results. Questionnaire data was also available to support the investment tool development and design e.g. some parameters, potential benefits and their size.

4.1.2 Interviews

As well as aiding in selection of interviewees, the questionnaire helped inform phone interview questions, thereby reducing interview time required. Ten semi-structured phone interviews (about half hour) were conducted with farmers using collar technologies to explore variation in why and how farmers use cow collar technologies i.e. topics described previously. Most interviewees were selected from those who completed the questionnaire. All interviewees completed the questionnaire. Some interviewees were directly approached to be interviewed and asked to complete the questionnaire prior to the interview. Two interviewees with limited time were asked the questionnaire questions on the phone, rather than completing it prior. The latter interviewees were cow collar technology users known to the interviewer or suggested by others e.g. farm consultancy firm, technology providers.

Interviewees were contacted a few days prior to the interview to request an interview, arrange a time to do the interview if they were agreeable, and if necessary, request that the questionnaire be completed. At the start of the interview, ethics information was provided e.g. individuals would not be identified, interviewees could choose not to answer questions, agreement obtained to record the interview for the purpose of assisting the interviewer in writing the interview up.

Interviewee selection targeted a range of technology types. Ten of the 17 farmers who completed most, or all, of the questionnaire were interviewed. Those selected were: 4 Halter users, 2 Allflex users, and one each from Cow Manager, Tru-test, SmaXtec and GEA CowScout. Of these technologies, only Halter has VF technology, Allflex is the most common non-VF technology and SmaXtec is a bolus rather than a collar or tag. This selection ensured a range of technology types were covered. Four Halter farms ensured sufficient feedback on VF technology to capture variability in views on VF.

Individual interviewees' questionnaire responses were collated by theme prior to the interviews. Interview questions covered similar themes to those in the questionnaire (example provided in Appendix 11). The interviewer used these summaries as a guide to individually pre-plan the interview questions across the themes, identifying topics for completion or clarification, or to expand on, or raise issues particularly pertinent to that business to explore. Interviews were semi-structured allowing topics of interest raised during the interviews to be expanded on. The interview was transcribed afterwards, with this data added to their summarised questionnaire results. Some views expressed in the questionnaire by farmers not interviewed were also reported (3 Halter, 2 Allflex, 1 CowTRAQ, 1 CowManager) to add further value to the results.

Data reported in this report largely comprises qualitative data collected in both the questionnaire and in the interview. The interview data was analysed using thematic analysis (Bryman, 2016), with the themes aligning with those mentioned previously (topics and questions above). The primary purposes was to broadly identify how and why cow collars were used, and the benefits and advantages of these. Cross case analysis between farmers or technologies was minimal since this was not the primary purpose of this project: interview numbers meant technologies could not be equitably compared (too few of each technology type, and results can be farm specific and do not necessarily represent use of that technology type in general).

4.2 Results

4.2.1 Interviewee and Farm Descriptions

Tables 3 and 4 describe the interviewees and their businesses, and the technology used on their farms, respectively. While numeric questionnaire data were too few to be significant, general trends and views expressed by the non-interviewed farmers are also be commented on as appropriate.

Table 3: Description of the interviewees and their farms.

	Farmer role	Herd size*	Milking platform area (ha)	FTE	Farm System	Milking frequency**	Percentage farm area irrigated
Farm 1	Manager	Small	92	2	2	OAD	0
Farm 2	Contract milker	Small	100	3.5	3	VM	0
Farm 3	Farm manager	Medium	147	3	5	TAD	95
Farm 4	Farm owner/operator	Medium	170	3	2	TAD	0
Farm 5	Farm owner/operator	Medium	282	3	3	TAD	0
Farm 6	Equity manager	Large	198	4	4	TAD	100
Farm 7	Farm owner/operator	Medium	150	2	3	TAD	0
Farm 8	Farm owner/operator	Large	360	6.5	3	TAD	100
Farm 9	Farm owner/operator	Medium	153	2	3	VM	0
Farm 10	Lower-order sharemilker	Small	110	2	1	TAD	100

*Small = <350, Medium = 350 – 700, Large = >700

**oad = once-a-day, tad = twice-a-day, vm = variable milking

Table 4: Cow collar technology used on the farms

	Technology brand	Seasons used	Ownership structure	Other technologies used			
				Inline milk meters	Shed automation	Drafting gate	Satellite pasture metering
				× = no, ✓ (green) = yes-integrates seamlessly, ✓ (yellow) = yes-integrates with upload, ✓ (red) = yes-does not integrate			
Farm 1	Tru-Test	1	Owned	×	×	×	×
Farm 2	Halter	1	Leased	×	×	×	×
Farm 3	Halter	1	Leased	×	×	×	×
Farm 4	Allflex	2	Owned	×	✓ (green)	✓ (red)	×
Farm 5	CowMananger	3	Owned + Subscription	×	✓ (green)	✓ (green)	×
Farm 6	Halter	1	Leased	×	✓ (red)	✓ (yellow)	×
Farm 7	SmaXtec	3	Owned + Subscription	✓ (green)	✓ (green)	✓ (green)	×
Farm 8	Halter	1	Leased	✓ (yellow)	✓ (yellow)	✓ (yellow)	×
Farm 9	Allflex	12	Owned	✓ (green)	✓ (green)	✓ (green)	×
Farm 10	GEA CowScout	2	Owned	×	✓ (green)	✓ (green)	×

4.2.2 Reasons for Using Cow Collar Technologies

There were several reasons that the interviewed farms adopted wearable technology for their farms, and each reason was unique to their own needs. The main reasons for wearable adoption were related to mating, labour, and future-proofing their farm system at the time of shed upgrades.

Three farmers highlighted that **mating** was their main reason for adopting wearables, and all ten farmers used the wearables for assisting with heat detection. Those that adopted a wearable technology for heat detection benefited from confidence that the wearable can provide consistent performance across the whole mating period. A SmaXtec user said having the wearable is “as good (for heat detection) as being on your A game, every day and it doesn’t matter whether I am there, or the herd manager is”. Farmer 5, a CowManager user, had a contract milker and mentioned that his wearable gave him the confidence that cow health and cycling cows were being monitored, without turning up to the shed each day.

Using wearables for creating an **efficient milking system,** especially during the mating period, was also a common theme between the interviewees. In three cases, the adoption of a wearable coincided with building a new shed, shed upgrades, and looking to future proof their milking system. Farm 7 is a split-calving system, so at the time of building a new shed, the farmer was investigating technology that could enable the one-person milking shed to continue being that labour efficient during the 14 weeks of mating (keeping that second person out of the shed). Similarly, an Allflex (previously Milfos) system was adopted by Farm 9 twelve years ago during a shed build to “future-proof” their system and improve efficiency during mating and milking.

The third main reason for wearable adoption was related to labour; for improving **labour attractiveness**, providing confidence to the farmer when **hiring green staff** and/or **reducing labour requirements** on-farm. Farmer 8, a Halter user, said he has “been able to drop the bottom-end of our labour, and also drop the jobs that people don’t want to do”. Farmer 3, also a Halter user, was looking for a way to reduce the need for a labour unit, which would at the same time resolve the farms issue of lack of staff housing. All these reasons relate back to improving efficiency, and future-proofing their farm system.

4.2.3 Brand Selection

There were six different brands of wearables used between the ten farms that were interviewed. Of these six brands, four were worn as collars around the cow’s neck, one was worn as an ear tag, and one was a bolus inserted into the stomach of the cow. The main reasons for choosing the brand of wearable were the available features, cost, timing of adoption, type of wearable and their trust in the company.

Two farmers highlighted the importance of the **features** provided by the wearable and how these could aid a solution to a current problem for their farm system, as the main reason for choosing their wearable brand. Having the option to do virtual fencing was the main reason for Farm 2 and Farm 3 choosing Halter, and how this could reduce labour requirements on their farms. The contract milker on Farm 2 said he liked that the wearable had more features, such as virtual fencing, "it will work 7 days a week, 24 hours a day, and you don't need to provide accommodation or annual leave". He was able to free up time to train his inexperienced worker on other areas of day-to-day farm management, rather than spending time putting fences up. Similarly, the farm manager on Farm 3 was attracted to the additional features that would allow him to reduce one labour unit, at a time where COVID restrictions was limiting his ability to hire backpackers or overseas workers.

The cost and the cost structure of the wearable was mentioned as one of the main factors for choosing the brand of wearable for two of the ten farmers. The variation in cost is significant for each wearable brand, but in most cases is set by how many features the wearable brand provides. Farmer 5, a CowManager user, knew what features would suit the farm needs, and chose the most cost-effective option based on that. The farm owner and sharemilker on Farm 10 were attracted to the option that was provided by GEA to own their collars, thereby avoiding the yearly subscription fees for leased collars. This reduced the risk of those annual subscriptions increasing each year, and it enabled them to upgrade the system (at extra cost) only when they felt they needed to.

The **timing of the wearable adoption**, and the **type of wearable** was mentioned by two of the ten farmers as their main reason for choosing their wearable provider. Farmer 9 was an early adopter (12 years ago) of Allflex collars (previously Milfos system), and at the time it was the main option on the market. He said "we did consider pedometers, but we were put off those because they get covered in mud, and the research reliability for grass-based systems wasn't quite the same as in the barns over in Europe". Furthermore, battery life was a consideration for Farmer 10, two years ago, when they adopted their collars. The sharemilker believed that the GEA collars were the best option at the time, but "things are moving smartly". The farm owner on Farm 7 had used collars for identification for 20 years prior to adopting a bolus wearable and had run into issues with rubbing and removing the collars at the end of the cow's life. Therefore, a bolus in the cow's stomach was the best type of wearable for their farm.

Lastly, the farmers **trust in the company** impacted their choice of wearable brand. The sharemilker on Farm 10 mentioned that he trusted the supply company as "they are a very big company worldwide, so they have been doing this sort of thing for a very long time". On a more local level, Farmer 5 gained trust in his tag wearable from word of mouth and visiting a neighbouring farm. They liked how the system worked and were able to get insight from a farmer, rather than the supply company itself, before investigating the wearable brand further.

4.2.4 Additional Technologies to Improve Wearables Function

Table 4 shows the additional technologies that the ten farms interviewed used at the shed, and for farm management. Seven of the farms had one or more of the following: shed automation (EID readers, teat sprayers etc.), inline milk meters, drafting gates and satellite pasture metering. However, three of the farms had mentioned they did not have any other significant technology.

Of these three farms, there were two main technologies that they identified that would be useful to improve the function of their wearable they had invested in. The main technologies mentioned were **shed automation** and **automatic drafting gates** to enable reduction of labour at the milking shed. Those farms that had no shed automation had no opportunity to reduce the requirement for labour in the shed, despite adopting a wearable technology. Farmer 3 invested in Halter and have also recently invested in an automatic drafting gate to improve the function of Halter for mating and allowing less labour in the shed during that time.

In addition to an automatic drafting gate, the farm manager from Farm 1 believes a **walk over weigh system** would add valuable information to that already provided by his Tru-test collars. He said “the weigh system would assist with the collars, as it weighs day-to-day to identify any cow losing weight, and then the collars may pick up on changes to their eating habits and behaviours”. He believes the information provided by the collar and the weigh system could be used to pick up feeding issues, and any trends within the herd, and therefore, allow the manager to make any required changes.

4.2.5 Technology Use

All farmers used their wearable technology for mating and animal health. Only some of the farmers used their wearable for feed management, environmental management, and labour aspects, and this was dependent on the features that the wearable provided.

4.2.5.1 Mating

How and why: Usefulness of wearables for mating.

All respondents to the online questionnaire that were analysed identified their wearable as being “very useful” for mating, except for Farmer 2, that rated their wearable as being “somewhat useful”. Using wearables for mating management, specifically for heat detection, was the most common use. There were many ways (how and why) that the participant farmers were using the wearables for mating.

Three interviewees and one Allflex questionnaire respondent were using their wearables for pre-**mating heats and monitoring the cycles of the cow**. Knowing how many times a cow has cycled, prior to mating, as well as how many days since her last heat was used for making decisions about artificial insemination. Farmer 8, a Halter user, mentioned that easily knowing whether a cow has cycled before planned start of mating (PSM) gives you options, such as doing a prostaglandin (PG) programme if they are cycling and a controlled internal drug release (CIDR) programme if not. Furthermore, the information about the number of days since the cows last heat, and the intensity of this has been mentioned as invaluable information. Farmer 10 uses this information provided by his GEA wearable to decide whether to put the cow up for artificial breeding (AB). He said "the cows are automatically drafted and then I sit behind the computer and have a look at the history and how strong the cows' heats are". Similarly, using the cows' history of heats was a key tool for an Allflex questionnaire respondent, especially late in the mating period when historically staff attention was decreasing.

Two farmers mentioned that they were using the wearables to improve the **timing** of AB and therefore, aiming to improve their conception rate. Wearable technologies can provide an indication of whether the cow is in early, mid, or late heat. Farmer 1 believes that having the information to inseminate cows at the correct time is a benefit for reducing the number of straws you are using (wastage), especially high value straws, such as sexed semen. In addition to this, the heat timeline provided by Farm 7's boluses has resulted in the farm owner reverting back to twice-a-day mating. He said he "finds the cows much easier, behavioural wise, to artificially inseminate when in the correct window". However, despite the timing benefit provided by wearables, some farmers have found it hard to trust the timing indication when other aids (tail-paint and/or scratchies) have been set off. Farmer 2 has continued tail painting because "it would be another 24 hours until the AI tech comes back to the farm and if we weren't using tail-paint I feel we would miss the cows heat all together". A similar comment was made by Farmer 3, "the cows scratchies would come on and she was rubbed raw, and the collars don't want you to mate them for another 12 hours". He then said "we were asking ourselves if we should we be putting straws in or not, otherwise on OAD mating you would only see the cow 24 hours later".

Most of the interviewed farmers were using wearables to remove the **uncertainty and need of alternative heat detection aids, and for accurate identification of cows on heat at the milking shed.** Prior to adopting collars, several farmers had found they were uncertain about cow heats when using tail-paint and/or scratchies, and were putting up many cows, which lead to straw wastage. Farmer 1 said "it's nice to know that you don't have to rely on indicators, which can make you 50/50 on whether she's on heat or not, and then you end up putting them up for AB anyway". They no longer use tail-paint on Farm 9, but they did when they first adopted collars because they did not believe the collars could be better than tail paint. The farm owner said, "the computer got 6% of cows on heat that we didn't get, but we got 2% that it didn't, so it wasn't worth the 2%, and of course the technology has got better". Wearables have also aided farmers by identifying cows easily in the milking shed if they are on heat. Halter branded wearables have an LED light that flashes, which can be noticed easily at the shed. This has been particularly useful for Farm 2 and 3 as they do manual drafting.

Farmers that were still using alternative heat detection aids (e.g. scratchies and/or tail-paint), in addition to the wearables were finding discrepancies between the two. This led to some confusion and frustration. Farmer 1 first adopted their collars partway through mating and therefore, still had scratchies on the cows. There were instances where the scratchies had not been rubbed, but the collar was identifying a heat, and vice versa. Similarly, Farm 7 found they were drafting out cows with rubbed tail-paint in the first year after adopting their SmaXtec system. However, this was confusing the owner and staff as the cow was not showing up on their phones as in peak heat. Both these farmers now rely solely on the wearable to remove this stress and confusion from the discrepancies.

A common theme mentioned by most farmers was that adoption of wearables has **reduced the mental and physical demands of the mating period**. Most systems allow you to easily obtain the information on cows that are on heat. The data can be generated consistently, day after day, without having the same person at the milking shed. Most farms mentioned of using a computer at the shed (if manual upload was required), and then copying this into their drafting system. Farm 7 has two PC systems, one in the office and one in the work area. The farm owner said "when we get to the shed in the morning and all the cows are downloaded, we just copy the list of cows into the DelPro draft system". The ability to have a consistent heat detection aid that does not require staff involvement is great for reducing key-person risk. For example, the farm owner on Farm 9 was injured a few years ago and had previously done all the heat detection and drafting. Having his Allflex system meant he could hire inexperienced University students and still obtain the same mating results, without being at the shed.

Adoption of wearables did not result in less mental stress for all farmers, during the mating period. There was mention by two farmers that their **lack of confidence** in the wearable and the number of false alerts led to frustration. The contract milker on Farm 2 did not trust their wearable for heat detection, and therefore, continued to rely on paddock checks, scratchies and tail-paint. He said "we had a significant number of cows that were in-calf to AB, but the wearable detected later heats once the bulls were out, cows that were identified as being in-calf to the bull at pregnancy testing that hadn't shown a heat, and cows that were in-calf to the bull, but the wearable detected a later heat (after pregnancy scanning)". Further investigation by this farmer showed that he had "60 odd faults between heats and pregnancy tests". There was 20+ cows that were in-calf to AI but the wearable detected heats later. Farm 3 also had instances of false or missed alerts. The farm manager said "we had 2% get in-calf to the bull, but there were no alerts of a heat from the collar. That would have been another 2% on our empty rate if we had done all AI".

Impact on mating parameters

The questionnaire data indicated that adoption of a wearable device had a positive effect on mating parameters. Of those that answered the question, most farms saw an increase in submission rate, conception rate and 6-week in-calf rate ranging between 1% and 10%.

Furthermore, empty rate for eight farms reduced between 1% and 5%, after the adoption of a wearable technology. Farm 3 saw a considerable gain in conception rate, from 53% to 63%. The farm manager believed that half of this gain was down to the collars identifying heats and half the improvement came from being able to go and find a cow that we missed during manual drafting, due to the cow location feature provided by Halter. Furthermore, the potential of cow wearables picking up quiet heats has increased the submission rate for Farm 5. The farm owner said "in the first year I was doing observations as well, I tail painted and there were cows drafted that I thought wouldn't be on heat as they had no rub marks, but I still inseminated them and most of them held". He continued to say "there is a certain number of cows that have quiet heats, and CowManager was picking these up, which increased our submission rate".

Despite most farms seeing some improvement in mating parameters it was not the case for all farms after adopting wearables. The questionnaire data showed that a proportion of farms had no change or an undesirable change to submission rate, conception rate, 6-week in-calf rate and empty rate. One farm reported an 11% reduction in submission rate. Conception rate also did not change for four farms after adopting wearable technology and three farms had a reduction ranging between 2% and 13%. Six-week in-calf rate did not change for three farms and two farms reported a reduction between 1% and 10%. And empty rate did not change for three farms and three farms reported an increase between 1.5 and 5%. However, variation in mating parameters/performance between seasons cannot easily be compared, or changes assumed to be result of the adoption of wearables. While the wearables may be contributing, there are external factors that also contribute to these values, including adverse weather conditions, which was mentioned as a possible factor by several farmers after two years of high rainfall.

4.2.5.2 Animal Health and Welfare

How and why: Usefulness of wearables for animal health

Cow wearables were used as a tool to aid detection of lame cows, mastitis, sick cows and metabolic issues. These animal health issues were alerted by the wearables due to changes in cow activity, rumination, and cow temperature, depending on the functions provided by the wearable brand used. However, the usefulness of this data was reported as being variable amongst the interviewed farmers and questionnaire respondents. For example, only three farmers classed their wearable as being very useful for lame cow detection (5 somewhat useful and 5 not useful), two farmers believed their wearable was very useful for detection of mastitis (7 somewhat useful and 4 not useful), three for metabolic issues (9 somewhat useful and 2 not useful), and four for sick cow detection (5 somewhat useful and 5 not useful).

The number of **false alerts and the timing of the alerts** was reported as the main reason for farmers not finding the health data useful from their wearable technology. Four farmers reported on being alerted to many false health alerts. The cows would be drafted out and checked, and in some cases, a vet was called to look at a cow that they could not diagnose any issue. Furthermore, most farmers believed they could identify a cow with health issues earlier than the wearable alerted them. Farmer 1 said “its never picked up a health issue before I have found it”. Similar comments were made by the sharemilker Farm 10 where he said “the collar does pick up health data, but it only concludes after a certain amount of time that something might be wrong and a good stockman usually sees instantly if there is something wrong”. Two farmers also mentioned it can take between seven hours and 48-hours before their wearable alerted them that a cow was dead (had been euthanised). However, despite these frustrations, the wearables did provide some data that was used to make decisions about animal health and treatments.

Identifying **lameness cases and reducing lameness** was one way that farmers were using wearables. Lameness reduction was more evident on farms that had wearables with virtual fencing capabilities. This was because the cows were moved onto the race and towards the shed at their own pace, rather than being followed by a motorbike. Farmer 8, a Halter user, has found his lameness has reduced by over 50%. This is because “the cows walk to the shed without being pushed and they can see where they are going, they can get into a single line, and they can walk on the best part of the track”. Similar comments were made by the equity manager on Farm 6, on another large-scale farm, that uses Halter. However, there was still mention by several farmers that they will nearly always notice a lame cow before their wearable picked up on the health aliment.

In some cases, wearables were used for identifying **sick cows or cows with mastitis.** The wearables were able to alert on a decrease in cow activity, rumination, or a change in temperature, depending on the features provided by the wearable. However, it must be noted that no wearable could diagnose a specific type of health aliment e.g. a type sickness, mastitis, lameness. They can only provide an indication that something has changed for the cow and then the staff need to identify the problem. For example, on Farm 8 anything that has a health alert, is taken and loaded into their Protrack drafting system before afternoon milking and is drafted out and assessed. On farm 7, they have developed a protocol at the shed, based on health alerts provided by their bolus wearable. The farm owner said “we RMT the cow, and if that is clear, we look for a sore foot”. If nothing clinical is found then a homeopathic treatment is used, and they are finding that 80% of these cows do not go clinical, and they have reduced their antibiotic use by 70%. This shows that if a consistent and thorough system is developed in the shed, the health information provided by the wearables can be used as a tool to identify and reduce health issues.

Wearables users that pay for rumination data features have identified this information as being very valuable. **Rumination data**, as well as the ability to **monitor cow movements** between breaks (Halter), has been used for managing transition cows. Farmer 9, an Allflex user, believes he has a lot less **metabolic issues** now that he can monitor rumination activity during the dry cow to milking cow transition. He believes his wearable is picking up signs of metabolic stress 12-24 hours before they are seeing clinical signs. He said “we have set an alarm for cows that are ruminating less than 200 mins per day, as they could have some ketosis, or milk fever”. Farms 5 and 6 reduced metabolic disorders by 5%. Farmer 7 is also actively using the rumination data from his SmaXtex system, and now has a 5-day check for post-calvers. For example, “we open her graphs and set a target of 300 mins per day before they are cleared for milking”. In addition to this, three Halter users mentioned they use the ‘failure to complete a shift’ alert provided by their wearable to identify cows with metabolic issues, or sick cows without going to the paddock. Farmer 8 uses his virtual fencing feature to shift his colostrum cows around 5am, and if they all move to the next break the staff know it will be okay to check them later, but if something did not complete that shift then they can act on it before milking.

One wearable user is provided with **a calving index** from his bolus. This has allowed him to change his calving system and bring his calvers back to a calving paddock, close to his house, “we now run a much bigger springer mob. One person looks at the springer mob list, and they come onto the feed pad at the end of milking, and they are drafted through the shed.”. This is not only a big-time saver, compared to their old system of drafting in the paddock, but the farmers believes the calves get a good feed of colostrum, calf identification is easier, and there is “a lot less stress”. This calving index, provided by SmaXtec is based on a ¾ to 1 degree drop in body temperature during the cows calving phase. Two CowManager users, also mentioned of their wearable providing an indication of calving, whether that was a change in temperature (ear tag), or a change in activity.

Impact on animal welfare and behaviour

Wearables have the capability to monitor cow activity and behaviour, which can in turn, could improve animal welfare due to the farmers awareness of these changes. As mentioned in the section above, health aliments, metabolic disorders and calving status can all be monitored, and in some cases, picked up on before clinical signs or serious health issues are showing. Cows can be drafted, treated (if required) and monitored.

Heat stress and cow water intake are two factors that can be monitored by the information provided internal bolus wearables. The ability to do this may become more important for pasture-based cows, as the climate warms. The farm owner on Farm 7 can monitor water intake, “when she goes to the trough the cow’s internal temperature will drop, and it estimates from the ambient temperature and the duration of that temperature drop how many litres of water she has drunk”. In addition, the farmer can manually calculate the thermal heat index, as an indication of heat stress. Last year he measured it manually based off the humidity and ambient temperature from the local weather station and the internal temperature provided by the bolus. This information is used to determine whether he puts Betaine into the shed feed, which is a mineral, that can aid with heat stressed animals.

Three farmers with wearables that had virtual fencing mentioned that their **cow behaviour** had changed. The contract milker on farm 2 believed his cows were very sensitive to the virtual fencing alerts, "anything out of routine, like not going to and from milking to a new break, is when the cows get flustered and don't know what is going on". He also mentioned that they have had issues with the cows not wanting to graze into the corners of breaks, or cross across a grazed line that was previously a virtual fence line to gain access to a trough. In contrast, two other farmers using virtual fencing found their cows were calmer, especially due to their ability to walk to the milking shed in their own time. Two farmers mentioned cow collars rubbing.

4.2.5.3 Feed Management

Most farmers that used their wearable for feed management had virtual fencing features. All farmers that were using Halter branded wearables found them "very useful" for break-feeding pasture and crops. Their wearable technology can assist with pasture allocation, break feeding crops, and in turn, increase pasture utilisation and production. Users without virtual fencing features found their wearable "not useful" for break-feeding and crop-feeding. However, in some cases, they were used to monitor rumination data and feed allocation.

Farmers that were able to use virtual fencing features found it very useful for **pasture allocation and monitoring**, especially those that used an allocation App alongside the wearable (e.g. Halter have a phone App that has pasture management features). Every farmer using Halter used this app to accurately draw breaks and allocate pasture and/or crop to their different mobs of cattle. Pasture cover information, either from manual measurement or satellite measurement is input into the app, along with a growth rate to develop a map of the farm pasture covers. This is continuously updated as paddocks are grazed and Farmer 6 believes "it is more accurate, compared to measuring it once a week". The farm manager on Farm 3 also uses it to monitor his spring rotation planner. For example, "If I know I can only give 6ha a day (based on my spring rotation) and I have 5 mobs, then I can split it up and it will tell me once I have reached 100% allocation for daily pasture allocation". He also mentioned that is easy for his staff to calculate if there is a pasture deficit, and therefore, what supplement could fill that.

The ease of pasture allocation, and the accuracy of break-feeding with virtual fencing led to users mentioning an increase in **pasture production and utilisation**. For medium to large farms, the increase in pasture production was most evident in the shoulders of the season when their herd sizes were reducing. For example, the farm manager on Farm 3 mentioned he does not lose growth during the peak of the season as he generally feeds a whole paddock, but during the shoulders of the season, when he is down to 200 cows, then it may take a week to get through a paddock, and the ability to back fence easily results in significant regrowth behind the cows. Increased pasture growth late in the season, due to re-growth has increased the confidence of Farmer 8 to “push his system, and milk longer on twice-a-day in the season and capture more milk”. In addition to this, some virtual fencing users believe they have increased utilisation due to the ability to easily give the cows small, but frequent breaks of grass. For example, the cows on Farm 8 are now allocated up to six grass breaks per day since they had Halter installed, instead of two breaks. The farmer said “they are getting small breaks until they clean up and then we move them on”. He believes they are utilising up to 1.5 tonnes more pasture.

Crop feeding has been simplified for virtual fencing users, also. Once again, the ability to easily allocate and monitor break fencing from an App has aided this. Three Halter users mentioned they manage their crop feeding at an off-farm runoff from home and visit them less regularly than previously. Farmer 3 manages his three different mobs of Angus bulls between Kale and Beet. He said “they sleep on the Kale and then have the Fodder Beet during the day”. Once the cattle are finished their Fodder Beet allocation (set time), the virtual fencing feature of his wearable directs them back down a laneway to the Kale for the night. The GPS monitoring and ability to know if a bull has ‘failed to complete a shift’ allows him to visit them less regularly. The accuracy of allocation is also important for Farmer 8, as he mentioned “I might go out and step the crop over 2m and then I may have a smaller female go and step it out as 1.5m the next day because she has different step sizes”. Having the virtual fencing removes the potential for this inaccuracy and lack of consistency. He also believes there is less breakouts, which were often caused by a wire falling over in the wet.

Wearable users that did not have a virtual fencing feature were limited for uses in pasture management. However, several Allflex users and the CowManager user mentioned using the **rumination data during feeding transitions, and to monitor whether the cows were fully fed**. Farmer 9 monitors his rumination data, and after adverse weather conditions, he can determine whether he allocated enough feed, a learning for future scenarios. An Allflex questionnaire respondent also made comment that himself, and his farm staff, “liked checking the rumination data to check pasture allocation”. It is one tool that can used by the farmer to monitor how well they had allocated their feed.

Some wearables may also in the future provide a measure **dry matter intake**. The farmer on Farm 7, a SmaXtec bolus user, mentioned that his wearable does have a feeding module that is monitoring diets, however, this is quite new and based around barn systems. He believes they are working on measuring dry matter, which in addition to water intake, could “open many things for measuring productivity of cows”.

4.2.5.4 Environmental Management

Wearables with virtual fencing functions have a been classed as “very useful” by all users for managing critical source areas (CSA), reducing pasture damage, and reducing nutrient runoff. Like pasture management, the useability of wearables without virtual fencing was limited for environmental management, except for some use for collating information for compliance.

Wearables that have virtual fencing capabilities have been used by all interviewees and questionnaire respondents to **manage cattle movements in wet weather, reduce pasture damage and protect CSA**. The flexibility of shifting cows more regularly, easily, from a distance and into breaks of all sorts of regular or irregular shapes have been identified as valuable during adverse weather events. Farm 8 is made up of "hills, gullies, north faces and south faces", and it is easy to now move them more frequently and put them into areas of the paddock that are drier, or away from water courses. Farmer 3 also believes that due to there being no fixed fence line, his colostrum mob no longer walk up and down the fence line, which has reduced his pasture damage in the spring period. Similarly, he can manage soil damage and pugging, to an extent, on his winter crops, as they can easily hold them off wet areas of the paddock. This is made possible due to the ability to draw any break shape or size and being able to start anywhere in the paddock. For example, "we now start in the middle of the paddock, near a trough, and work our way forwards, whereas previously, we would have put a reel around the trough and back to the front corner", which risked soil damage from cattle walking up and down a race.

Two Halter users also mentioned that they are better able **to monitor, minimise and manage cattle camp areas and nutrient loading.** Farmer 6, said the ability to easily back fence with virtual fencing means "the cows don't camp in the same entry and exit of the paddock, which leads to better spread of nutrients across the paddock". The farm manager on Farm 3 is trialling using the information provided by Halter from heat maps (where the cows spent the most time) to soil test different areas of the paddock. This could be used for variable rate fertiliser applications; however, this would only be most cost effective if the fertiliser trucks had comprehensive variable rate fertiliser capabilities. The manager said that "last winter we only had 6 months of data, but it was interesting to see the difference between the fronts and the backs of the paddock". The information was used for his capital fertiliser. In the future, having the ability to monitor and manage all fertiliser applications could greatly improve farm efficiency.

Wearables can gather information for **compliance or** provide auditors with confidence that the farm environment is being monitored. Although, it seems this space is not widely explored by farmers yet, an Allflex user, mentioned that "there are features that could be useful", such as knowing the exact number of cows on his farm every month for his supply company. In addition to this, the farm owner on Farm 6 had a recent ECan audit and he was able to explain how his virtual fencing collars were able to assist him with managing CSA and wet areas in adverse weather.

4.2.5.5 Labour

Labour was an important attribute for all farmers, with wearable technologies used to reduce labour hours, and/or to improve working conditions for the mating period and general labour. In addition to this, every questionnaire respondent and interviewed farmer believed that adopting a wearable increased the attractiveness of their job.

Mating labour

Wearables were used to **reduce staff fatigue and pressure** during the mating period. Three interviewed farmers commented on the value of improving staff working conditions during this period. Farmer 9, who previously had one experienced staff member picking his cows every morning mentioned "it's important having those mornings off, it makes people much happier", and he is also able to hire casual staff during that period, without adding stress. And although, farmer 5 thought it was important to still teach the basic skills required to pick cows on heat, removing that pressure for himself and the staff removed the stress.

General labour

Many farmers mentioned of **reduced labour hours required for their farm**, especially for wearable users that have virtual fencing as there was less time spent walking cows to the shed and erecting temporary fencing. It was reported by some farmers that their staff hours worked have reduced by up to 10 hours per weeks. However, this did not always equate to a financial labour saving. For example, Farmer 3 mentioned that he has had a significant reduction in labour hours "but the manager and 2IC are on salary so they do less work, but we are still paying them the same amount". The virtual fencing capability of his wearable means there is an hour of labour-saving bringing cows to the shed, but his staff are not using this time to be more efficient, instead they are having longer breaks. In contrast, Farmer 7, a SmaXtec user believes the reduced hours spent picking cows on heat at the shed has provided significant financial labour savings. The farm is split calving, and he said his bolus wearable, "is a $14,000 labour saving just from not needing someone watching for cows on heat".

Furthermore, there was improvements seen in **labour efficiency and requirement** for some wearable users. Two farmers, both Halter users, have reduced their FTE's by at least 1, however, the success of this has been variable between the two farms. Farm 8 was able to employ two less staff for general farm tasks, but the owner has employed a full-time riparian planter, so his labour requirement has shifted. He did mention that he is now more efficient for shifting breaks, "I'm doing three times the number of shifts, that's probably two labour units worth of work", which he believes is a massive increase in labour efficiency. Farm 3 was also able to drop 1 labour units, so he was running 500 cows with 2 FTE, after he adopted halter. However, he ran into issues when "one was on days off and one got sick", and his staff did not enjoy the extra number of milkings they were required to do.

Some farmers reported a minor shift **in skill requirement**, after adopting wearables, for staff or management. There is an increased need for technology use and understanding, as well as data management and understanding. The farmer on Farm 1 mentioned that “you must be able to use the information that you are getting”, and understanding this is key to successful adoption of wearables. Furthermore, the farm owner on farm 7 believes that because farmers are relying on technology, they must “learn to be a lot better with data management”. All farmers found the support from their provider useful during this “learning” phase.

The shift from manual farm skills to technology-based farm skills has raised some concerns from farmers, especially **the potential loss in basic cues and on-farm skills.** There was mention from three farmers of this, and the difficulty of training a new staff member manually once the technology is adopted. For example, Farmer 7 said “now that we don’t see as much milk fever because we are picking them up before they become clinical it is hard to teach staff about clinical cases and how to treat them”. Furthermore, the farm manager on Farm 3 believes that “staff can get lazy and skip checking water troughs or gateways”, instead they do it all from their phone and forget about those small but important tasks when shifting cows.

Increased staff engagement was mentioned by a couple of farmers. Farmer 5 observed “We’ve had a couple of staff members that have been right into and looking at it all the time. It does generate a lot of interest”. Similarly, an anonymous Allflex farmer commented that “The younger staff have enjoyed the tech side and engaged actively with it, but it has meant that we haven't taught them heat observation and tail paint skills that they would need in many others jobs, or if the system failed”.

4.2.6 Technology Integration, Implementation and System Changes

4.2.6.1 Implementation and Integration

All the interviewed farmers, and farmers that completed the online questionnaire said they found the implementation of their wearable into their farm system relatively straight forward once they had learnt how to use and trust the technology. Once the hardware (e.g. receivers, antennae, PC, processer) was installed and the wearable put on/or in the cows, the biggest challenges with implementation were integration between the wearable and other technology on the farm, gear failure, data settling periods and cow training (if applicable).

Every wearable requires some hardware to function and communicate the data it is collecting. This meant that all farmers needed to organise **and install a type of antennae and receivers** across the farm. Farmer 5 had 15 antennae installed across his farm, which “talk to each other and relay back to the home base to provide real-time information”. He then had it linked to his cow shed computer. The number of these receivers/transmitters with antennae (e.g. towers) depended on the type of wearable they were adopting, the size of the farm and the shape of the farm. For example, farmer 2 mentioned that they required three strainer posts for the towers and “each one reaches 900m, so it just depends how long and narrow the farm is and the contour”.

Each wearable requires a certain length of time for **data settling a**nd collection for the herd to establish the base data for each cow before any useful alerts are provided. For example, farmer 5 said “every cow’s activity range is very different”, and it took them at least 7-10 days for his CowManager tags to establish a base. Farmer 7 said he had to turn off all the animal health alerts because the number they were getting was overwhelming, and they had just put them in during October when they were focusing on mating. It was not until later, after things had settled, that they developed some sound protocol to start using the health data. Two farmers mentioned of making the mistake of putting them on in the middle of mating or too close to the start of mating, which effected the success of the wearable during mating in that first year of use. Farmer 10 explained that considerable time and patience is required, with thought given to timing.

> *Patience. Especially the first year, half the herd was on heat until we tinkered with it. I had used all this kind of tech in Holland. A lot of people had them before I left there. You must use your phone for so many things these days, so it was easy to pick up…. We didn’t get the collars in time. That was a big mistake. We were milking and trying to put collars on, it was a real pain. Just the initial setup, but a lot of technology is like that. But once its setup its brilliant. I wouldn’t go back to no collars, but hey, I’m not paying. (Farmer 10)*

The integration of each farm’s wearable with other in-shed and on-farm technology was challenging for some. Farms that had the same branded technology or technology owned by the same company (e.g. Allflex collars and Protrack drafting gate) had the greatest success with integration and automation. For example, farmer 10 has all GEA technology, including the milking plant and “it all integrates well”. An improvement in integration was one of the most common “wants” by interviewed farmers and questionnaire respondents, including “integration to MINDA and Farmax”, “better interchange with MINDA to compare production with rumination” and “full integration of pasture measurement from satellite”. Where farmers had lack of integration between technologies, they needed to manually upload data, such as, manually uploading the list of cows on heat from the wearable into their drafting system.

> *We’ve got the DelPro herd management system in the shed. It does integrate to some point, but we have kept it separate. We had the integration on for a little while, but it wasn’t 100% what it should’ve been. I’m passionate about keeping my databases up to date. I found it easy to just duplicate it. It was more efficient, and the data was definitely right when I did it. It does have integration with MINDA now. (Farmer 7)*

We've got Protrac, but Halter doesn't integrate very well with MINDA yet. It just has a click download wearables data. Yes, its pasture IO, and it doesn't upload automatically. (Farmer 8)

Yeah, we have Protrac in the shed and we need to draft cows out from the information that Halter gives us we had to manually upload each number. But since then, Halter has started integrating with MINDA, so Halter is now talking to MINDA so you can set drafts from Halter from what MINDA has said. (Farmer 6)

Four farmers mentioned that gear failure has been a challenge during the implementation stage and beyond. This failure has been related to different types of wearables, and some level of failure is expected with any technology. Farmer 7 mentioned that "you must be onto failed boluses, especially through mating", as this would affect the overall success of the wearable's performance for the farm. Solar powered batteries have caused issues on two farms and Farmer 3 had about "30 cows a day last winter with flat collars", due to the lack of sunshine. However, farmer 6, who also had a couple of issues with flat collars, believed that his collars may not have been fully charged when they were put on. Lastly, water damage, may explain the number of replaced collars for an anonymous Halter user.

Virtual fencing users also had to **train** their cows to respect the fencing system. However, every user said the training was straightforward, the cows responded quickly, and there were very few break outs afterwards. Farmer 6 trained his heifers in May when they came back from grazing, and they were "trained within a day", which was typical for most farms. Farmer 2 spent a couple of weeks training his cows and used a reel 20 m in front of the grazing line, "you let them interact with the collar for a few minutes and then you go and wind up the reel", so the learn the command from the collar that they can cross into the next break. Training during a low stress period is key to success.

4.2.6.2 System Changes

Every interviewed farmer mentioned of no major system changes due to adopting a wearable technology. However, some farmers had made system changes, by choice, after adopting the wearable technology, due to the ability to do so. For example, farmer 7 was able to change his calving practices (see Section 4.2.3.2) due to his bolus providing a calving index and remove bulls from his mating system. Farmer 8 is now shifting his cows 6 x per day to increase pasture utilisation, which is enabled easily with his virtual fencing and farmer 6, also a Halter user, has been able to run an extra herd (two to three) to "take the pressure off his younger cows, and feed them differently if needed. Farmer 3 was making a more significant change to his system which enables more effective use of the technology and resources available.

It was just adjusting the systems, the other big change we are doing is we are dropping 450 cows this year to drop more shed time. The other one I did was put in

30 cup removers, at the same time as putting Halter on. This allowed only one in the shed. It made milking 30 mins longer, but they only milked in the shed OAD (except for mating). It meant they got more sleep-ins. We also ran two mobs over mating, an AI mob and a bull mob, but that also dragged-out milking because you have to stop and change gates. That didn't quite work out how we wanted. Dropping to 450 cows next year will drop that half hour off milking…. I could potentially drop supplement [due to better pasture utilisation], which would drop my milk production. But I am at the stage that I can measure everything. I can look at all my marginal returns and I am more likely to intensify than to reduce my feeding system. Halter is a fixed cost, the same as your interest or irrigation cost. It's a dilution solution thing. So, if I did 550 per cow compared to 500 per cow, the Halter cost is less per milk solid. (Farmer 3)

4.2.7 Technology Support

All thirteen farmers that completed the technology support section of the online questionnaire rated their wearable provider as somewhat to very helpful for support. This support included software technical support, equipment technical support, and advice on use of technology. One farmer mentioned that his provider was not helpful for understanding reports and capabilities, which is an important factor contributing to any farmers success of using a wearable technology.

The interviewed farmers supported the information that was collected from the online questionnaire and said they had found the helplines (through phone or the providers App), as well as email very supportive and the responses timely. Farmer 7 mentioned that he really liked the support from his provider because "we are using them every day for different things and they're coming in with a different set of eyes", which allows the technology company to evolve itself, as well as the farmer. A similar comment was made by an anonymous Halter user, "they are very open to feedback and continue to evolve the technology based on farmer needs/wants".

4.3 Interviews Summary

4.3.1 Reasons for Wearable Adoption and Brands Chosen

- Farmers adopted wearables for several different reasons, unique to their own needs. These included: as an aid for mating (heat detection), improving milking efficiency, and reducing labour requirements and/or labour attractiveness for their farm.
- The wearable brand was chosen based on the farmers needs and how the wearable features provided could aid this, the cost, timing of adoption, the type of wearable, and the farmers trust in the company.
-

4.3.2 Mating

4.3.2.1 Use of Wearables for Mating

- All interviewed farmers and questionnaire respondents used their wearable for mating management and as a heat detection aid.
- Wearables were used for monitoring pre-mating heats and monitoring cow cycle history to make informed decision prior to PSM.
- The information provided by the wearables was used to determine the correct timing of AB to try and increase chances of conception, and therefore, reduce AB straw wastage.
- Farmers did not need to use other heat detection aids (e.g. scratchies and/or tail-paint). However, some farmers found it hard to trust the wearable solely for heat detection, which in some cases, led to discrepancies between heat detection aids and the wearable technology.
- Wearables were used during the mating period to reduce the mental and physical demands and reduce key-person risk.
- In some cases, the farmers lack of confidence in the wearable, and the large number of false alerts for cows on heat, led to mental stress and frustration.

4.3.2.2 Impact on Mating Parameters

- The questionnaire data indicated that in most cases, adopting a wearable had a positive effect on farm submission rate, conception rate, 6-week in-calf rate and empty rate.
- In some cases, farms had no change, or a decrease in farm submission rate, conception rate, 6-week in-calf rate and empty rate. However, mating parameters could not be compared between pre- and post-wearable adoption in this study due to unknown changes to management and environmental influences to each dairy herds mating performance.

4.3.3 Animal health

4.3.3.1 Use of Wearables for Animal Health

- Cow wearables were used as a tool to aid detection of lame cows, mastitis, sick cows and metabolic issues.
- Animal health issues were alerted to the farmer due to changes in cow activity, rumination, and cow temperature, depending on the functions provided by the wearable brand used. However, it then required the farmer to identify the specific health aliment (e.g. the cow is lame, has mastitis or is sick).
- The animal health information and its usefulness were reported as being variable amongst the interviewed farmers and questionnaire respondents.
- The number of false alerts and the timing of alerts was reported as the main reason for farmers not finding the health data useful from their wearable. Most farmers believed they could identify a cow with health issues earlier than the wearable alerted them.
- Identifying lameness cases and reducing lameness cases was one way that wearables were used for animal health management. This was more evident on farms that had a wearable with virtual fencing capabilities, as it removed the need to have a motorbike following the cows, which allowed them to walk at their own pace.
- Some farmers used wearables to aid identification of sick cows or cows with mastitis. The wearables were able to alert on a decrease in cow activity, rumination, or a change in temperature, depending on the features provided by the wearable.
- Farmers are able to use rumination activity data, as well as monitor cow movements to manage cows during transition periods (dry cow to milking cow) and metabolic issues.
- Some farmers were able to be alerted to cows calving, either from a “calving index” provided by the technology, or assume she is calving due to change in activity or temperature.

4.3.3.2 Impact on Animal Health and Welfare

- Wearables have the capability to monitor cow activity and behaviour, which can in turn, could improve animal welfare due to the farmers awareness of these changes. Cows may then be identified, monitored and treated (if necessary).
- One farmer was able to monitor his herds heat stress and water intake and add Betaine (mineral) to his in-shed feed, if necessary. The ability to monitor heat stress may become more necessary as climate warms for pasture-based cattle.
- There was mention of cow behaviour changing for three farms that used virtual fencing. These farmers had contrasting experiences; One farmer’s cows had increased anxiety when routine changed and they could not work out the virtual fence demand, and two farmers believed their cows were calmer since they implemented virtual fencing, especially because they were now able to walk to the shed in their own time.

4.3.4 Pasture and Feed Management

- Virtual fencing users found their wearable “very useful” for break feeding pasture and/or crops. Wearable users did not find their technology useful for this, but in some cases, monitored rumination during periods of diet transition.
- Virtual fencing users found their wearable useful for pasture allocation and monitoring, especially when the information was used in the providers App. This enabled them to easily allocate and monitor pasture and crops.
- Virtual fencing users have seen increased pasture production and utilisation since adopting the wearable technology, as they can easily back fence and give the cows small, but frequent shifts. The greatest gains for increased pasture production and utilisation were seen in the shoulders of the season.
- Off-farm crop feeding has been simplified for virtual fencing users, due to the ease of allocating and monitoring animal movements, without visiting the paddock.

4.3.5 Environment

- All virtual fencing users found their wearable technology useful for managing CSAs, reducing pasture damage, and reducing nutrient runoff.
- Managing cattle in wet weather, to reduce pasture damage and protect CSAs was made easy with virtual fencing due to the ability to shift cows regularly, into any break size or shape and from distance.
- The ability to easily back fence with virtual fencing reduced stock camps and nutrient loading.
- Heat maps were used by one farmer to determine where cows spent the most time to aid his fertiliser application decisions.
- Although not widely explored by farmers yet, there was mention of wearable technology providing and collating information required for compliance.

4.3.6 Labour

- Every questionnaire respondent and interviewed farmer believed that adopting a wearable increased the attractiveness of their job.
- Wearable technology was used to reduce staff fatigue and pressure during the mating period.
- Farmers mentioned of reduced labour requirements after adopting wearable technology, especially for those with virtual fencing as the need to manually bring cows to the shed and erect temporary fences is removed.
- Reduced hours didn’t always result in reduced labour costs for the farm as most staff are paid an annual salary.
- Increased labour efficiency and reduced FTE requirement was achieved by two interviewed farmers. However, this required a system change (reduced cow numbers) for one of the farmers.

- There was mention of a minor shift in labour and/or management skill requirements. There was an increased need for technology use and understanding, as well as data management and interpretation skills.
- The shift from manual farm skills to technology-based farm skills has raised some concerns from farmers, especially the potential loss in basic cues and on-farm skills.

4.3.7 Technology support

- All the farmers that completed the technology support section of the online questionnaire rated their wearable provider as somewhat to very helpful for support. This support included software technical support, equipment technical support, and advice on use of technology.
- There was mention of an increased need for support to understand reports and the capabilities of the technology.
- The interviewed farmers found their helplines (via email, phone or the provider App) were helpful and had timely responses.
- It was evident that the wearable technology providers are open to feedback from farmers and are looking to move and evolve the technology alongside New Zealand farmer's needs.

4.3.8 Implementation

- All the interviewed farmers, and farmers that completed the online questionnaire said they found the implementation of their wearable into their farm system relatively straight forward once they had learnt how to use and trust the technology.
- Each wearable requires a certain period for data collecting and settling, once put onto/into the cow to establish a base ("normal") for each cow. This should be considered when adopting collars e.g. do not adopt too close to mating or calving.
- The integration of wearable technology and the success of automation with other on-farm technology (e.g. drafting gates) was challenging for some farmers. Farms that adopted a wearable technology of the same brand or a brand that integrates with other technology on the farm showed the greatest success of automation.
- Virtual fencing adopters need to consider a training period for cattle once they collars are adopted. Doing this during a low stress period (e.g. before calving) was key to success.
- Virtual fencing users may want to consider the level of water trough access cows are allowed to ensure they reap the pasture utilisation from easily being able to back fence.
- Farmers were not required to make any significant changes to farm systems when they adopted a wearable technology. However, some farmers chose to make changes to increase the effectiveness of their wearable such as, increasing the number of grass breaks per day to increase utilisation, and adding another milking to ensure all younger cows were fed optimally.

5 Investment Analysis Template Development

In this component of the project, an investment analysis template for independent industry and farmer use was developed using a discounted cashflow analysis approach, in association with Case Study 1.

5.1 Method

The first case study was with a Central North Island family farming business. They agreed to be involved in this project and interviews were held with business decision makers and the manager on their farm that had cow collars technology installed (Halter). Access was provided to physical and financial information relevant to the financial analysis of the cow collar adoption decision.

Topics covered in the interviews with farm business included:

● cow collar use (why and how) and other technologies used with the collars

● advantages and disadvantages of cow collars (e.g. profit, labour, risk reduction, animal health and welfare, fencing and races, pasture management, repairs and maintenance, resource management consents)

● financial implications, costs and savings

● implementation challenges

● ongoing maintenance and service requirements of cow collar technology

● opportunities for enhanced performance from technologies and integration with other technologies

● farm systems changes required for efficient use of the technology (if any)

In this phase, an investment template was developed for the farm business investment analysis. Halter technology provided benefits in mating, animal health, pasture management and VF, Hence, this template was expected to capture technology impacts for other cow collar technologies that only have a subset of these benefits. The template was informed by the information collected in the interviews and Case study 1, including multiple benefits and costs, both tangible and intangible across multiple aspects e.g. environmental, economic, compliance, health and production, labour. The template captures the financial benefits, but qualitative benefits and costs were also captured. The approach used in a break-even analysis on cow collars for virtual herding, published by Dairy Australia (2020), helped inform our approach. Similarly, work on investment analysis tools for oestrus detection by Thomas et al. (2019) and Rutten et al. (2014) was consulted. The Case Study 1 business was provided with the template and the analysis for feedback.

5.2 Model Description

The ‘philosophy’ used in the building of the Excel spreadsheet model was to provide the user with enough options that may become apparent with the use of the different cow collar technologies to give a robust indication both in farm production from the cow herd as well as changes to the cashflow from both the costs and benefits of user ‘cow collars’ or similar technologies. With the user able to provide their own numbers around productivity, returns and expenses the model out comes are tailored to each individual user. A ‘Dashboard’ page where the user can enter key farm factors, such as farm size, cow numbers and productivity is provided. These details are able to be ‘influenced’ by entering potential changes (improvements or otherwise) and they affect the final productivity, income and expenses of the farming business. There is also a page where the farms annual budget is able to be entered. Where relevant these number can also be acted upon by the ‘influencer’ cells on the Dashboard. This results in two sets of income and expenses. The first is the “existing:” model and the second is the “new” or modified model. The results of these two models are compared and allows a decision to be made on whether or not to go ahead and adopt certain technologies. All the data provided by the user including depreciation and a modified loan schedule to capture any new accommodation that may be built goes into a 10 year discounted cashflow (DCF). Which is the core of the model. Income is derived from the user input on the Dashboard and expenses from the budget sheet. Within the DCF whilst income and expenses at year 0 are as per the budget and Dashboard and entered, from year 1 onwards expenses are acted upon by a 2% pa inflation rate and income by a 1.7% annual increase (income tends to increase at a slower rate than inflation over time). This accounts for the steady downwards slope on the DCF graph shown the results page. The results provided to the user are the changes in cow numbers and productivity. These, while important, are not the main decision results and as such achieve a lesser profile on the “Dashboard”. The main results which are calculated on the DCF are put into a bold highlighted Results Box. They include the cash difference between the two systems (yr 0) and the results of the DCF over the 10 year cashflow period used. These results are the Internal Rate of Return (IRR) both in Real and Nominal terms (nominal being without the influence of inflation) (IRR is the annual rate of growth that an investment is expected to generate). The Net Present Value (NPV) results are also provided again in Real and Nominal. The model is set with a 6% discount rate to achieve the NPV however users are able to change this on the Dashboard. (NPV is the current value of a future sum of money or stream of cash flows given a specified rate of return).

Within the DCF all income is taxed with benefits coming from depreciation. Loan payments for the new accommodation are also taken into account. Users have the option of using either company tax (28%) which research has shown is what the majority of dairy farms utilise and the PAYE approach. If the farm is a partnership the income can be split (by selecting appropriate influencer on dashboard) and then tax is recombined and the net figure goes into the DCF.

Positive indicators for adopting the technology come from a positive net cash benefit as this takes into account the additional costs involved in the cashflow as well as the benefits. An IRR that meets or exceeds what the user considers adequate to adopt the technology and a positive NPV (real) also at the appropriate discount rate.

The following pages (General Instructions for the use of the DCF model) are extracted from the “Notes” sheet in the model provides instructions to the users. These instructions are suggested to be read before attempting to use the model. Much of the model is hidden and or locked to help prevent users inadvertently entering data into cells or modifying those which contain formula and interfering with the operating of the model.

As some users may find some complexity in using the model, it is suggested a filled in version with guideline numbers in be made available to assist users familiarising them in using the model.

5.2.1 General instructions for the use of the DCF model.

Users need to fill in their budget (Budget sheet) and once completed need only to have access to the “Dashboard” page. Farm details are put in along with production details. Once completed (left hand column) then only alter coloured cells on the right-hand side (Read Notes page for finer details). These will then alter the financial figures and results.

These results go into a 10-year discounted cash flow (DCF)

Results are shown as net income Cash income (pre-tax) after the addition of the technologies.

The investment returns are also shown after allowances for depreciation, house loans (if applicable) and inflation etc spread over a ten-year period. These results are shown as both Internal Rate of Return (IRR) and Net Present Value (NPV). They are shown as before changes are made and post changes (with technologies) and also as Nominal (pre-influence of inflation) and Real Post influence of inflation with is included at 2%.

Farmers/Users need to make realistic assessments on the benefits the different areas of the farm may receive from the technologies employed.

Below are the details included on the DCF notes pages to assist in guiding users through process.

5.2.1.1 Data entry

On Dashboard only green coloured cells can be altered without cutting formulas.

Enter all assumptions as positive numbers or percentages.

Farmers need to make their own assumptions as to the benefits or otherwise of the influence of 'new technologies'.

Users will need access to their most current set of farm accounts or budgets to have the best information to complete model.

Farm details are entered on the left side of the Dashboard page (column C). Changes due to the addition of technologies available (Column J), the right side.

Add data to only the coloured cells. Results will appear on the plain while cells. When farm details are entered, it could be useful to then full in the Budget page as then results can be observed as changes are made.

Only cows are counted on farm model as this is where the benefits and costs are assumed to be associated. So, if replacements are on farm, then there is a lower cow stocking rate rather than 'clog' data with additional livestock classes. However, grazing costs drop.

If herd fertility lifts, then the cull cow price improves incrementally due to additional selection pressure being able to be applied to the herd.

If mating is condensed production improves incrementally and build upon increases from all alterations in the "production" cells".

5.2.1.2 Housing and Farm Costs

Farm Costs Changes flow through to the Budget page and are captured there.

Animal health costs are expected to decrease with all additional tech options.

There is evidence that using Virtual Fencing can reduce labour requirements this may also result in less bike(s) and staff.

The labour cell can reduce (or increase staff) and the bike cell can reduce bikes (up to 2). This reduces vehicles costs in the budget.

The existing model has the option of building new staff accommodation, the alternative decision maybe to utilise new technologies to avoid this expense. A $400,000 cost of building is the expected estimate of staff new accommodation. But users are able to provide their own figures.

New Building R&M costs estimated at $5000 PA plus the cost of servicing a building loan.

The new technologies system has the option to include potential rent from the freed up accommodation unit which may be available if staff reduced.

On the Budget page the cells K39 and K40 are locked and show the results of the selection of term and value of new house loan and interest rate.

5.2.1.3 Pastures and compliance

An assumption option is that Virtual Fencing (VF) could give improved pasture utilisation this can be captured by either lifting stocking rate or improved utilisation (or both).

With VF there is the possibility of reducing fertiliser usage through more precise application. However, some may decide with more cows more N is required although there are Regional Councils limitations.

VF is being accepted by Regional Council as a legitimate form of fencing and recording and stock movements. This will lead to a reduction in compliance costs from 3rd party auditors and experts as the farmer should be able to provide evidence of fencing off vulnerable areas (even temporarily) and cow movements.

5.2.1.4 Capital Set-up

Cell J54 relates to the cost of VF towers and divided by 10 to give an annual cost to the system. As it is leased this is not included in depreciation.

5.2.1.5 Results Section

Results Section (M4 to R11 on Dashboard) are provided as difference of net cash benefits (or losses) based upon the budgeted income less expenses of the existing situation I.e. without influence of technologies compared against that generated by the income less expenses of the system influenced by the technologies (and expenses).

In addition, based upon the 10-year discounted cash flow (DCF) the IRR (Internal Rate of Return) is shown as a comparison both in Nominal and Real terms (I.e. without inflations influence, Nominal, and with inflations influence, Real).

Finally, NPV (Net present Value) is provided with the discount rate able to be altered on Dashboard. Generally, a 6% rate would be considered 'normal'. This is also provided for both before and after technologies inclusion and Nominal and Real.

NPV provides the amount, over the period of the DCF generated as profit, over (or less than) the return that would be achieved at the nominated discount rate. It should return zero when the discount rate matches the IRR.

Below the results section is included; A graph that shows the existing cashflow vs the new cashflow over the first 9 years of the DCF (year 10 omitted due to distortion of inclusion of salvage values).

There are also include three Sensitivity tables which illustrate the different impacts some of the costs of setting up the VF and non-VF system can have on the net cash situation. For non-VF the tables are for either leased or brought collars.

5.2.1.6 Budget Sheet

Users enter the annual budget into column E. This is in the pale green colour. No other cells should be touched on this sheet.

The budget results which are altered as a result of changes to technology are shown in column H. The results of the current (existing) budgeted and the altered (new) are carried through to the DCF and fed into the results.

5.2.1.7 Depreciation

Users have the option to enter their own values for depreciation in the green cells on the depreciation page. Currently the rate is set at IRD levels for diminishing values. The values from the existing situation also feed into the new situation with the addition of any new capital costs. If a building option is selected for the existing situation (pre using tech) it automatically goes into the existing depreciation schedule.

The exception to above is the addition of new housing which does get added to the schedule if selected and has a DV rate of 2%.

A caveat to all rates regarding building depreciation rates is the changes to government policy which are likely to change (be removed) which will entail an update to model.

5.2.1.8 Loans

The only loan considered relevant in model is that associated with the new accommodation building. Users are able (if selecting option) to put in value of building, which then becomes an amortised loan; select the term of the loan and the interest rate. It automatically enters the DCF. Other capital costs are annualised (i.e. divided by the estimated length of life of items and spread over the 10 years of the DCF. This is to simplify the modelling and potential loan components for item which in reality may have little value.

5.2.1.9 Tax

The model is already set on company tax (28%). However, this can be turned off and PAYE activated. The model can calculate tax liabilities based upon whether the user is a "sole trader" or a partnership. The number of partners need to be entered. No option for Trusts is provided to keep model simpler and given the 39% current rate will likely affect few users.

5.3 Case Study 1

Case Study 1 (CS1) is a property owned by a farming company. The manager and some members of the management team were interviewed for CS1.

5.3.1 Farm Description (CS1)

- Manawatu region.
- 330 ha milking platform near ranges so can be wet in winter.
- 1000 cows at peak milking.
- System 2 to 4 (feed dependent, system 3 last season), with twice a day-milking.
- Calving date 1 August. Short season (cold, wet winters) – usually dry off end May.
- Support blocks – one local and one further away in region.
- 80 paddocks, been increasing size, reducing number.
- Cows usually wintered on the milking platform but due to a wet winter off this year.
- Young replacement stock is grown off-farm post weaning.
- Carrying 3.03 cows/ha compared to the region average of 2.52 cows/ha.
- Milksolids production was 384,000 kg MS (last season).
- 402 kgs MS per cow (last season) compared to regional average of 411 kg MS per cow.
- Four FTE staff, including the farm manager and three other staff. Supervision and budget support is provided by the farming company management team.

5.3.2 Use of Cow Collar Technology (CS1)

5.3.2.1 Technology Selection

The property has used Halter collars for about 1.5 seasons, trialling these cow collars on this farm with a view to using on other farms in future if these prove beneficial. The trial has been pushed out for a second year. The primary driver for adopting collar technology was access to, and retention of labour, and the potential to reduce staff numbers by one (increase in viability with a $80 to $90K cost reduction). Halter was expected to make the job easier and more attractive to management and staff, which is beneficial in attracting and retaining staff. Staff requirements are also changing with casual staff less available and more permanent staff being married which is likely to result in the requirement for another house: technology that maintains or reduces labour requirements would avoid this cost.

Other impacts and cost reductions expected from using Halter included:

- Less R&M e.g. bike maintenance – fewer bikes, less use, requirement for pigtails and fence reels reduced or eliminated.
- Fertiliser reduction based on grazing information.
- Improved pasture availability and management (utilisation).
- Improved reproduction.

- Improved animal health.
- Improved environment management e.g. stock off sensitive areas.
- Lower capital expenditure e.g. one less bike, no house required.

In the future, improved mating performance would provide the possibility to use sexed semen (for heifers) with the best producers, taking advantage of a more compacted first mating cycle. However, the impact of a more condensed calving on rearing complex and calf storage requirements would need to be considered.

Cost was a consideration with comparison made between Halter and an alternative (which does not provide fencing, labour and pasture benefits. Cow Manager, which is a tag rather than a collar system offers similar animal health and mating benefits. Tags last about 5 years with some opportunity to recycle tags from cull for younger cows. Cow manager was $62/cow/year compared to Halter for $192/cow/year (subscription / lease system with Halter owning of the collars) which was considered quite expensive. So, the extra $130/cow/year difference represents fencing, labour and pasture benefits. Installation of the 5 towers costs about $30,000 with Halter retaining equipment ownership. This included installing two extra towers to enable land at the edges of the farm to be incorporated into the dairy system. Sensors and solar panels are expected to last about 20 years. They liked the idea of leasing equipment rather than purchasing this and anticipate (hope) that the price will drop in future. They observed that there will be other systems coming which can be costed for comparison in future.

If Halter works well on this farm, there is the potential to use this on another farm with more advanced Protrack (milk meters and herd management measurements). This would enable production and feed impacts with Halter to be monitored and compared.

5.3.2.2 Functionality

There were some setup issues with Halter due to water getting around solar panels on the collars which was not ideal since putting collars on and replacing these was a difficult job. However, Halter provides good service and was helpful in getting collars replaced.

The cows were trained relatively quickly, although some pushed through the geo fence initially. The cows have become accustomed to fenceless farming and no longer respond to bikes or vehicles as a movement indicator. Thought needs to be given to collar use e.g. staggering cows to come to the shed so they are not all pushed to go up the race at once. If cows have to be moved across the road, labour is required to do this in person, and cows have to wait somewhere until this can happen so this is not automatic.

Halter system does not work seamlessly with the basic Protrack drafting system on the farm, although a work around is possible i.e. cows for mating or with poor health are identified by Halter and this information is manually entered into Protrack for drafting them out.

A Halter app is available, and the manager observed that all staff have ready access to cow data on the phone app, especially animal health and mating, and were proficient in understanding and interpreting this. All but one, take an active interest in monitoring cow records. Management thought that some improvement due to halter technology is likely to be because of increased awareness by staff (monitoring and control impact).

Management observed that Halter has not developed a system for reporting as yet. Halter will provide what they ask for (spreadsheet of data from their database) but report options available are not clear. A more structured reporting system would be beneficial with a website available to run reports. They speculated that basic reports could be available at no cost, with extra reports charged for. They would also find it useful if they were able to benchmark across whole group of farms recorded on Halter which they indicated Halter is thinking about.

5.3.2.3 Animal Health

Halter is used for animal health monitoring (rumination monitoring). Identification of a problem is not always sufficiently timely to make a difference. Lame cows can be identified. However, there has been no improvement in the number of lame cows, although the manager suggested pushing the whole herd up at once may have contributed to this and it has also been an abnormally wet season.

5.3.2.4 Mating

The empty rate has dropped 2%, and there has been a 2% increase in 6 week in-calf rate (74% versus 72%). However, they had been implementing interventions to affect cycling so there was an improving trend anyway thus it is hard to know whether this was due to the Halter technology.

The manager was at the shed every morning during mating to identify the cows on heat. Tail paint is used as well as Halter. The manager observed that Halter identified some cows with little rubbing of tail paint but found they were about to come on heat, so this identification was accurate. He observed that the app showed a clear change in movement when cows are on heat, and he therefore believes he can trust the technology and has confidence in the algorithms. Consequently, he will not need to be at the shed every morning over mating in the coming season since Halter is accurate in predicting cows on heat and all staff have access to this information. Furthermore, he may not even use tail paint.

Management made a couple of comments with respect to cow collars regarding mating performance. They noted some company farms without collars are doing better than this farm with Halter which they put down to the salaried staff e.g. manager experienced in mating management and identifying cows on heat, but this would also require more hours worked to achieve this. They have also installed Cow Manager collar technology (mating and animal health monitoring) rather than Halter on another company farm where the manager is very good with pasture management, so this is primarily to improve mating.

5.3.2.5 Pasture Utilisation and Management

In investing collars with fenceless farming capability, they are hoping to achieve better pasture utilisation and production. Using Halter allows breaks to be shaped to suit the best pasture allocation. Large areas do not need to be left to allow access back to a trough, and breaks can be easily back-fenced on the app to stop further trampling. An advantage of this is pasture can start to regrow the following day rather than 5 days (or whatever) later, once the paddock has been completely grazed. Breaks can easily be allocated in smaller and more frequent areas resulting in less pasture being tramped into the ground. Farm walks have been used to measure pasture, and there has been an increase in pasture grown and consumed. The company has been pleased with these improvements in pasture. Satellite from space technology was considered for pasture measurement but results were poor and inconsistent.

It was also mentioned that grass grub can be an issue and virtual fencing can be used to help manage cocksfoot pastures which are 'bug' tolerant but need tighter management. An awkward-shaped area on the boundary with some sensitive areas which was not able to be used previously on the milking platform can now be incorporated as grazing for milking cows using virtual fencing.

5.3.2.6 Compliance and Environment

Management hope to reduce compliance costs by using virtual fencing. This makes it easy to keep cattle out of sensitive areas, and boundaries can be changed according to weather e.g. if wet, stock can easily be kept off wet areas in the paddock. Evidence of where cattle have been grazing is recorded and available to provide to councils if required. Discussions with the regional council suggest that local councils virtual fencing technology is likely to make meeting compliance requirements easier in future.

There is potential for the use of virtual fencing on a runoff where crops are used, but cost of additional towers an issue. A mobile tower could provide a solution if possible? Apart from time and effort putting up breaks, this could resolve the situation where a few cows trample pigtail standards and go through fence breaks.

Fertiliser can be strategically applied avoiding areas such as stock camps that are readily identified with virtual fencing technology.

5.3.2.7 R&M

Bike costs are not reducing even though it was expected they would with less bike use e.g. fewer breaks going up etc. The manager speculated that this was due to bike servicing scheduling happening as per usual when it could potentially have been reduced.

5.3.2.8 Labour

The wage drop potential has not yet been seen in costs. About 20% drop is expected (no reduction in FTE but reduction in hours worked). Time saved from shifting cows and setting up breaks has been used to catch up with other jobs on the farm such as maintenance, fencing and weeds.

Management observed that technologies need the right manager to maximise potential. One of the biggest success factor is managers 'need to own it'. Other technologies have been less successful because of lack of staff interest. Halter is simple for staff to use – all they need is a smart phone with the app and an incentive to use this. The manager observed that all but one staff member were interested in using the app to monitor the cows. So as previously mentioned, some of the positives seen may come from the monitoring process leading to better management.

5.3.3 Analysis Results (CS1)

The financial model to assess the benefits or otherwise of adopting new technologies on cow dairy farms was tested against several case study farms. One of these used Halter (Virtual Fencing or VF) technology, the other two utilised Alflex collar technology.

The VF farm (Case study 1) situated in the central North Island provided comprehensive input data which was used in the model. As the farm was already using the VF technology the results will be artificially inflated over what is already being achieved. However, the results are still relevant as it is the difference achieved that is the important aspect of the study. The VF option provides the animal health options of the non-VF technology, although the VF currently lacks the self-drafting "Protrack" or similar technology most of the other options have at present. Animals identified for removal from herd for more specific attention need to be manually entered into the self-drafting system. However, the costs of the Protrack system were included in the set-up costs of the VF system ($25,000 spread over 10 years). Although the Protrack investment may have been made prior to VF investment it is included as part of the package to avoid 'under reporting'.

On the model the "Tech Influence" cells were cleared and progressively added, and results recorded.

Initially the capital cost cells were filled in. This added an additional $ to the budget costs. It was made up of $30,000 capital costs for on-farm towers and technology to support collars. This amount was divided by 10 (annualized) and spread over the term of DCF. The annual cost of collars per cow was added ($194) plus an amount ($2 per cow) for an assumed future data report option., plus the costs of the Protrack system ($3,040 annually). Progressively, the general cells (relevant to both VF and non-VF options) were completed (Cells J4 to J17). These cells acted upon animal health assumptions on milk production and cow and calf survival rates. The improvements entered into these cells were an arbitrary 1% to 2% improvement. This resulted in the financial cost to the system reducing to $66,026 and a lift in milk production of 16,062 MS (16MS per cow) or 4.2% over the year.

These results are likely to be similar for both VF and Non-VF farms using the same assumptions.

Farm cost changes are assumed to be greater for the VF farm than other systems due to the influence over the whole farm system. These cells (J22 to J32) influence Labour (20%), Animal Health (AH) (4%) R&M (5%) and regrassing and fertilizer costs (10% and 5%). Again, the amounts entered were arbitrary but considered realistic 'seat of the pants' numbers. These changes returned an additional $55,146 to the budget and along with the production increases led to a positive $121,172 on the budget.

Finally, the VF production change cells (J48 and J50) were filled in. These cells provide the biggest influence on the system (and budget) as they influence stocking rate, effectively a proxy for pasture growth rate and utilisation which captures better pasture management. With a 5% increase in both factors the budget benefits increased by $484,955 to net (after the additional costs) $383,339 or an increase of 35% in net cash income pre-tax. This was largely due to a 14.9% increase in milk volumes but (only) a 6.75% increase in expenses. If due to the need for less staff an accommodation unit become available and was able to be rented out at $350 per week an additional $18,200 was generated which moved the Pre-Tax benefits up to $403,539 (as shown below).

A full breakdown of the cash benefits and a return on investment are shown in Table 5. The IRR provides a 4% return above the existing system or an increase of 45.8% and the NPV in Real terms (inflation taken into account) provides an addition $3,714,853 over the ten-year period of the DCF and at a 6% discount rate.

Table 5: Case Study 1 DCF analysis without new house and rent available.

Results					
Net cash benefits (yr1)			**$ 403,539**		
		Nom	Real		
IRR	Existing	10.89%	8.72%		
	with Tech	14.97%	12.72%		
NPV	Existing	4,865,241	2,490,946	**6.0%**	(discount rate)
	With Tech	8,995,698	6,205,799	**6.0%**	(discount rate)

In the Case study 1 farm, there was also discussion of the potential for building additional accommodation to make employment on the farm more attractive to future employees. Assuming the cost of new accommodation is $400,000 and payments were only interest only at 7% then Net Cash Benefits fell by a corresponding amount (Table 6). This also had the effect of reducing the returns on the IRR and NPV for the "existing situation" as the additional staff was in lieu of investing in technology. The reduction in IRR and NPV in the existing was through the lift in the amount invested (the new building) plus additional costs of interest and principal in the 15 year term amortised loan that was used to finance the house.

Table 6: Case Study 1 DCF analysis with new house and no rent.

Results					
Net cash benefits (yr1)			**$ 429,257**		
		Nom	Real		
IRR	Existing	10.36%	8.20%		
	with Tech	14.79%	12.54%		
NPV	Existing	4,410,735	2,046,093	**6.0%**	(discount rate)
	With Tech	8,810,759	6,038,501	**6.0%**	(discount rate)

While all aspects of the VF provided improvements to farm productivity and profitability, the increases in stocking rate and pasture utilisation provided the biggest gains. An observation on several VF farms observed is that farms with rolling hills I.e. unlike Canterbury irrigated farms, stand to make the greatest gains in this area due to the existing difficulty under conventional fencing systems to intensify fencing and provide back fencing. These 'rolling' farms also have greater potential to have water courses running through the farm (be them perennial or temporary). Therefore, they would also get greater gains in benefits to compliance costs. Both of these aspects of farm management should provide real attraction to farmers.

6 Investment Analysis Model Testing and Verification

The model developed in the first stage on the work was tested in association with Case Studies 1 and 2.

6.1 Method

We worked with Case Study farms 2 and 3, using the template developed, to provide an investment analysis for these businesses. Two Canterbury farms with Allflex cow collar technologies agreed to taking part in interviews and template testing instead. As for Case Study 1, they were interviewed. They were provided with the analysis and template and asked for feedback. The template was refined based on case study feedback from all case studies. A Māori farming business had expressed interest in being involved, and considered the project outcomes would be useful to them. However, critical staff changes meant they were unable to participate.

6.2 Case Study 2

The farm in Case Study 2 (CS2) is owned and overseen by rural professionals (previously dairy farmers), with a lower order sharemilker for day-to-day management. The CS2 farmer interviewed is the dairy farm owner and rural professional. As a rural professional, he also has regular dealings with dairy farmers and is part of a farm discussion group.

6.2.1 Farm Description (CS2)

- Mid-Canterbury region.
- 158 ha milking platform with irrigation (98 ha owned, 60 ha leased). 140 ha effective.
- 500 cows on-farm at peak milking. Aim for 540 cows in two years with same resources.
- System 3 to 4 (Cows wintered off the milking platform and limited additional feed brought on)
- OAD milking for 2 weeks after calving then moving to twice a day-milking. Maintains condition pre-mating for better conception rates, and reduces pressure on staff allowing them to focus more on calving herd.
- 130 ha support block leased within 1.5 km of the milking platform. 70 ha dryland, and 40 ha irrigated with baleage and forage crops for winter grazing grown on this block. A small amount of purchased supplementary feed is bought on to the milking platform.
- Cows mostly wintered off the milking platform.
- Young replacement stock grown off-farm post weaning.
  Cows estimated to be fed 5.5 tonne DM per year. Over 3 tonnes utilised over lactation.
- Calving begins July 24th, budgeted mean date August 10th, all cows dried off by 31st May (185 -190-day lactation).
- 500 cows is 3.57 cows/ha compared to the regional average of 3.48 cows/ha.

- Milksolids production is 260,000 kgs MS last season.
- Just over 520 kgs per cow, compared to regional average of 435kg MS per cow, putting the farm into the top 5% category. Aim is to achieve 540 kgs MS/cow.
- Three permanent FTE staff, including the sharemilker. 2IC has been with the sharemilker for over 15 years and another staff member has worked on the property for over two years. Owners have a part-time role overseeing the general running of the property and filling in gaps when able.

6.2.2 Use of Cow Collar Technology (CS2)

6.2.2.1 Technology Selection

Collar technology employed on the farm is Allflex. The owner is performance driven, and his main motivation for using Allflex is animal health and production monitoring to get the best from the cows, identify actual and potential problems contributing to not achieving milk production targets. He is motivated by benchmarking, and familiar with on-farm and farm support technology and encourages others to use it.

The Allflex model used on the property was described as the basic model which provides 'heat detection' and the cows rumination pattern. The collars are leased from Allflex on a 7-year program. The monthly cost is $3.50 per collar ($42 per year). The cost was identified as between 8-9 cents per MS.

He looked at Halter but considered this too expensive for him and most farmers to consider, given that other systems are readily available and cheaper. He indicated that if he was at a different stage in dairying, he may have considered Halter for moving stock and other functions, but for now, he is solely production driven so prefers the Allflex system. Nevertheless, he knows farmers who use Halter and appreciated its potential for freeing up labour to do other things and looking for ways to motivate new directions.

6.2.2.2 Functionality

The system adopted was chosen for cost and the back-up service provided i.e. lower cost than many competitors but a complete back-up service. Within this it met all the owner's requirements and expectations.

6.2.2.3 Animal Health

The owners and staff have a strong interest in the rumination rate of cows which is the indicator of the health status of the cow. Approximately 450 is the daily rate of a healthy cow. Cows that deviate from this are monitored with action taken as appropriate. 'Sick' cows are identified early and usually given a long-acting but non milk withholding antibiotic. The death rate within the milking herd is about 1.2% or 6 cows. A couple of these could have been identified earlier with a better animal health monitoring system, although they died from very fast acting metabolic disorders.

6.2.2.4 Mating

During mating, cows ready for mating are identified via a 'list' generated by the Allflex system provided to the office computer every morning. These are drafted off through the Protrak system for AI. After 2.5 weeks approximately 55% of the herd is in calf. At 2.5 weeks, cows are scanned to confirm pregnancy status. At the 6-week stage 75-79% of cows are in calf. The only time tail paint is used is when cows have been scanned empty or exhibiting dry behaviour after the AI process. This is to provide an additional back-up to the Allflex system but it is still the Allflex system where the most reliance is placed. By the end of the mating period the dry rate is 10-12% dry.

6.2.2.5 Labour

The owner finds Allflex system intuitive and easy to use, as do his farm team. They are competent with the Allflex technology with no issues identified.

6.2.3 Analysis Results (CS2)

The second and third case study farms are both located in Canterbury and as such have similarities in their make-up. Both are flat and are irrigated and use Alflex collar systems. Where there were gaps in the financial information use was made from the Dairy NZ Canterbury budget example for 2023-24. As with the VF system, this farm which had a milking platform of 186 ha, had been using the Alflex system for several years prior to the being analysed, but it is the differences shown that are important. Data was input into the second case study at the rates as done for the VF farm with the capital cost being for the Alflex system and the Protrack drafting system. On this farm the cow collars were purchased (with costs annualised). This put an additional annual cost of $21,088 into the farming system. No VF costs were included.

Progressively, the general cells (relevant non-VF options) were completed (Cells J4 to J17). These cells acted upon animal health assumptions on milk production and cow and calf survival rates. The improvements entered into these cells were an arbitrary 1% to 2% improvement. This resulted in the financial cost to the system being eliminated and an additional $201,074 was gained by the system. and a lift in milk production of 22,293MS (32MS per cow) or 5.2% over the year. The increase over the VF farm results is due to the greater MS production being achieved per cow by the Canterbury farm and a case of 'the rich getting more rich'.

Farm cost changes are assumed to be greater for the VF farm than other systems due to the influence over the whole farm system. These cells (J22 to J32) influence Labour (6%), Animal Health (AH) (4%) R&M (0%) and regrassing and fertilizer costs (0% and 0%). Again, the amounts entered were arbitrary but considered realistic 'seat of the pants' numbers. As shown, considerably less adjustments to the non-VF farm due to less impact upon the overall system. This resulted in only a $8,351 increase in farm cost. This was largely due to the additional tech costs but offset but a 6% labour reduction created by the use of the Protrack system. The farmer said he felt that 84 hours of labour were being saved over the season. These changes along with the production increases led to a positive $201,074 on the budget.

A full breakdown of the cash benefits and as a return on investment are shown below. (Table 7). The IRR provides a 2.67% return above the existing system or an increase of 17.3% and the NPV in Real terms (inflation taken into account) provides an addition $1,929,919 over the ten-year period of the DCF and at a 6% discount rate.

Table 7: Case Study 2 DCF analysis

Results					
Net cash benefits (yr1)			**$ 201,074**		
		Nom	Real		
IRR	Existing	17.73%	15.42%		
	with Tech	20.46%	18.09%		
NPV	Existing	9,064,519	6,711,447	**6.0%**	(discount rate)
	With Tech	11,207,067	8,641,366	**6.0%**	(discount rate)

While all aspects of the technology provided improvements to farm productivity and profitability, the increases were limited to cow production. The net profitability lifted by $287 per cow.

6.3 Case Study 3

The farmer interviewed in Case Study 3 (CS3) is a 50-50 sharemilker. He has been share-milking on the current property for over 5 years.

6.3.1 Farm Description (CS3)

- Mid-Canterbury region.
- 202 hectares. 186 ha effective milking platform with irrigation.
- 700 cows plus another 10 'carry-over' cows on-farm at peak milking.
- System 3 to 4, with twice a day-milking.
- Cows are largely wintered off the property grazed out.
- Young replacement stock are also grown off-farm post-weaning.
- Carrying 3.76 cows/ha compared to the region average of 3.48 cows/ha.
- Milksolids production is 360,000kgs MS (total average last 2 years).
- Just over 514 kgs per cow, compared to regional average of 435kg MS per cow, putting the farm into the top 5% category.
- Three FTE staff, including the sharemilker, a 2IC who has been with the sharemilker for over 15 years and another staff member who has worked on the property for over two years.

6.3.2 Use of Cow Collar Technology (CS3)

6.3.2.1 Technology Selection

The property has used Allflex (heat-time) collars for approximately 2.5 years. The main reasons for selecting this collar system were back up support ("back up support is second to none"), and to a lesser extent, cost. Other collars were investigated but the "support and training" from Allflex was the major selling point.

They use the 'Heat-time' Allflex option which is considered to be a basic system, but they felt that this provides sufficient useful information for their needs. Collars were purchased rather than leased. The reason for this decision was a profitable season, and as the sharemilker commented "we were struggling to get rid of money" (spending on profitable investments). The cost then was $186 for a collar, and these had a 5-year guarantee but expected life of 7 years. This put the collar cost at between $3.10 per cow per month (over 5 years) down to $2.20 (over 7 years). Collars from culled cows can be reused on young cows entering the herd.

6.3.2.2 Functionality

Putting the collars on the cows was not an issue: in excess of 300 collars on cows per hour was exceeded with the help of an Allflex agent. The sharemilker observed that collars were hard to remove but considered this to be a better 'problem' than losing collars.

As with other collars, Allflex supports a phone ‘app’ and computer access to information. Reports can be generated summarizing the annual results. On request, the system can compare an individual farm’s results against other farms to enable benchmarking to be carried out. The Allflex system also integrates with the Protrack self-drafting system.

While staff phones do not access the Allflex app, the farm computer at the dairy shed which is linked to the Allflex system is available to all staff, and they all take an active interest in monitoring cow records. The sharemilker observed that knowing the staff had ready access to the data, especially animal health and mating, and were proficient in understanding and interpreting this, meant there were no major concerns when, or if, the sharemilker could not be available at morning milking because of some unplanned event. The process could continue without his involvement e.g. extracting cows needing assistance or drafting off for mating etc.

6.3.2.3 Animal Health

Rumination monitoring provides enough information to identify any impending animal health issues as most issues ranging from lameness to internal ailments impacted upon rumination. While the collar itself does “not pick-up lameness” and the longest walk to shed is only about 350 metres, the sharemilker specifically noted that lame cows could still be identified through the rumination process.

In the early days of use, Allflex also monitored daily input and let the sharemilker know if there was an animal with a health issue that may have been missed. One example that occurred was a collar which was giving an odd reading. Allflex identified the cow and notified the sharemilker: this turned out to be a loose collar which had slipped too low to give accurate readings.

The replacement rate for the herd is 14.5% and the death rate is around 1% so there is little room to improve upon these by using more technical versions of the collars which may provide better animal health monitoring.

6.3.2.4 Mating

The herds dry rate is 2.5% -2.8%, which is similar to what was being achieved before the use of Allflex collars. Mated cows go straight into a twice a day milking (TAD) regime with the exception of a handful of individual cows which may remain on once a day (OAD) until deemed ready.

Animals coming into season appeared to be accurately identified and were ‘self-drafted’ off in morning ready for AI technician. This is a major labour-saving factor as without this another staff member would be needed in the milking shed two hours earlier than otherwise. Over the 6-week mating period this equates to 84 hours of shed attendance. The sharemilker generally does the early milking himself, so the 'collars' drafting and identification give the staff "more time in bed".

Throughout the milking season the sharemilker scans cows to check pregnancy status and has found there has not been a need to use tail paint to follow up. The system also generates a "suspected abortion list" which can be acted upon.

6.3.2.5 Mob Management

The herd is managed in two mobs (500 and 200 cows). The sharemilker made the comment that the collars make it easier to keep the cows in the correct mob through the automatic recording of cow mobs. This keeps the cows more settled (better animal welfare) and improves production: a decrease in production has been observed for some days when cows switch mobs.

6.3.2.6 Labour

The sharemilker explained that there is no labour cost savings as staff are on salaries rather than hourly rates, but he placed a high emphasis on keeping a happy work force and the technology contributed to this. As explained in mating, collars reduce labour requirements in the milking shed over mating. He also made the general comment that the collars enable a better night's sleep knowing there are few things that can go wrong with being noticed.

The technology, along with an automated irrigation system, are good selling points for the farm in employing and retaining staff.

6.3.3 Analysis Results (CS3)

The second and third case study farms are both located in Canterbury and as such have similarities in their make-up. Both are flat and are irrigated and use Alflex collar systems. This was the smaller of the three case study farms at 140ha. As before, where there were gaps in the financial information use was made from the Dairy NZ Canterbury budget example for 2023-24. As with the other farms this farm had been using the Alflex system for several years prior to the being analysed, but it is the differences shown that are important. Data was input into the third case study at the rates, where appropriate, as done for the previous farms with the capital cost being for the Alflex system and the Protrack drafting system. However, in this case the collars were leased, which when compared to the annualized costs of the other non-VF system meant the annual costs where slightly more although less need to find the upfront capital. This put an additional annual cost of $22,302into the farming system. This was a nearly $674 per year cost above the Case Study 2 farm for approximately 200 less cows. No VF costs were included.

Progressively, the general cells (relevant non-VF options) were completed (Cells J4 to J17). These cells acted upon animal health assumptions on milk production and cow and calf survival rates. The improvements entered into these cells were an arbitrary 1% to 2% improvement. This resulted in the financial cost to the system being eliminated and an additional $124,471 was gained by the system. and a lift in milk production of 15,489 MS (29MS per cow) or 6.2% over the year.

Farm cost changes are assumed to be greater for the VF farm than other systems due to the influence over the whole farm system. Labour savings were put in as less due to the lack of specific data, which was provided by Case Study Farm 2. These cells (J22 to J32) influence labour (4%), animal health (AH) (4%) R&M (0%) and regrassing and fertilizer costs (0% and 0%). Again, the amounts entered were arbitrary but considered realistic 'seat of the pants' numbers. As shown, considerably less adjustments to the non-VF farm due to less impact upon the overall system the technology has. This resulted in only a $7,146 lift in farm costs. The lift in costs apart from direct technology costs were also due to increased numbers of cows, although partially offset by the 4% labour reduction created by the use of the Protrack system. The cost changes along with the production increases led to a positive $124,471 on the budget.

A full breakdown of the cash benefits and a return on investment are shown in Table 8. The IRR provides a 2.13% return above the existing system or an increase of 16.7% and the NPV in Real terms (inflation taken into account) provides an addition $1,221,656 over the ten-year period of the DCF and at a 6% discount rate.

Table 8: Case Study 3 DCF analysis

Results					
Net cash benefits (yr1)			**$ 124,471**		
		Nom	Real		
IRR	Existing	15.00%	12.75%		
	with Tech	17.18%	14.88%		
NPV	Existing	5,477,382	3,785,945	**6.0%**	(discount rate)
	With Tech	6,836,833	5,007,601	**6.0%**	(discount rate)

While all aspects of the technology provided improvements to farm productivity and profitability, the increases were limited to cow production. The net per head profitability lifted by $239 per cow.

7 General Discussion and Conclusions

The expected viability and improvement in performance from cow collar technology adoption depends on the farm system, current herd performance, and the issues the business wants to address with cow collars. These factors dictate the important attributes and trade-offs in deciding whether to adopt, and which collar type, with cost or potential returns versus functionality being major considerations. While collars are often adopted to address a primary concern, these come with incidental benefits and the potential for further functionality and improvements in time.

Cow collar technologies can provide benefits to several aspects of the farm system. As this study identified, benefits can be achieved in production, cow health and profitability from relatively small incremental improvements in a number of areas. These include reducing reliance on labour, sometimes in a critical area of mating management, and animal health benefits which can lead to a lift in cow productivity and a reduction in animal health costs.

Labour is a significant industry issue and is a key driver for cow collar adoption, from both a labour quality and a labour quantity perspective. Adoption of collars for mating primarily addresses a labour skills issue (e.g. identifying cows on heat) to achieve a higher mating performance, and therefore, higher herd performance and production. Reliance on having the skilled owner or a manager in the shed over mating is reduced, or in larger operations, managers and staff are supported in heat detection to ensure cows for mating are accurately identified. More efficient milking over mating was also stated as a reason to adopt collar: reducing staff requirements or freeing up staff required in the shed for other tasks at this busy time of year is an added benefit. While these may be the main drivers for adoption, other benefits can also add to collars' attractiveness e.g. animal health, herd management planning benefits, cost reductions, and increased job attraction.

Collars with virtual fencing capability are an attractive option, with pasture management and environmental benefits, and further labour and cost savings, as well as offering the mating and animal health benefits other collars do. Nevertheless, these collars are still relatively untried and expensive compared to other collars. While farmers interested in collar technology are interested in these aspects, with some evaluating this option in comparing technologies, cheaper collars for mating and animal health benefits often with a proven track record of performing well in these functions are often chosen instead. These usually address the immediate issue can be a simpler option to try these technologies.

The production and profit benefits of VF technology extend to better pasture utilisation and growth, further labour reductions and potential reductions in vehicle costs and fence and race repairs and maintenance. Results based on these benefits suggest the benefits of VF outweigh the costs. However, environmental and compliance benefits are also likely to influence the decision, particularly if organisations such as regional councils and quality assurance schemes recognise VF as an acceptable means of meeting compliance (e.g.

fencing CSAs), and monitoring and reporting where and when cows were grazing on the farm to support this. This could significantly reduce fencing costs required for compliance. From a farmer perspective, being able to easily keep stock out of wet areas in winter, and using stock grazing data to inform cow feeding and fertiliser decisions is also attractive. Collar technologies are more common in the dairy industry to support management where cows are seen daily, than in the beef industry. However, the development of technology such as VF which can be used on beef farms, has considerable potential for improving pasture utilisation and production, and potentially compliance where the savings from having to fence off CSAs could be significant if VF fences were an acceptable alternative. Whether the costs outweigh benefits is still to be seen.

In effect, these technologies shift human risk to technological risk. As some papers pointed out, there can be a risk of technological failure, requiring competence in managing and monitoring the technology and ready access to service providers. Increasing tech capability to enable these to be used in outdoor terrains, with solar power and long-lasting batteries to ensure data is collected and VF remains functional 24/7 has made these systems more viable. No-one interviewed indicated serious technology failure as an issue and most were positive about service provision. Reliability is important with VF technology, particularly if this is to be used to fence off CSAs. This technology is relatively new, and it may require time for farmers or councils to have confidence in reliability. Another risk, that farmers are aware of, is a reliance on the technology. This exposes farmers to the risk of increasing technology price rises, particularly where competition is limited and the technology is embedded in the farm system. However, increased uptake, more competition, and reduction in technology production costs as the develop, may help counter this.

Staff need to be committed to the decision to use cow collars for effective adoption, however, results suggest these technologies are readily adopted and liked by most people using them. This might be expected with a technology that makes their life easier and more interesting, and as has been reported, makes the job more attractive. Technologies result in changing skill requirements with more technology-savvy management and staff. Staff with good skills in pasture and animal management (e.g. heat detection, pasture management) are getting harder to find which is a driver for collar technology adoption. Technologies, such as collar technologies, will replace the need for these skills over time. Whether this is a concern for the industry, or a solution in an industry with problems attracting labour and finding skilled labour, can be debated. There is a natural trade-off between technology and skills loss as industries evolve: for example, skills in managing working horse teams are now almost lost, but most farmers own a tractor which all staff can operate. No one challenges this. Some technologies are game changers. Potentially, collar technologies could be.

Cow collar technologies provide multiple benefits which may encourage their adoption. While these may be adopted primarily for a specific purpose, they offer multiple benefits, all of which farmers use. Collar technologies carry a range of sensors which capture multipurpose data (e.g. rumination and activity data can be used for health, mating and feeding purposes). Ongoing data analysis for improved algorithms and machine learning will improve prediction of parameters over time. As technology evolves, adding other sensors to 'collars' is likely to be relatively straightforward. Similarly, sensor and data capture technologies are evolving relatively rapidly.

Consequently, there is potential for these technologies to become increasingly used in the industry and integrated across the farm system. Integration with other precision ag technologies (e.g. pasture measurement via satellite) will expand their potential. These technologies produce massive amounts of data, which then needs to be converted to information to inform farmer decisions, although to some extent these technologies are going beyond this as well: a list of cows ready for mating can be provided, superseding human intervention in these decisions. Access to data and information provides opportunities for a range of providers to be involved in advisory roles, perhaps in a different context to that normally provided, as demonstrated by the monitoring and advisory role vets were using the data for to work with their clients.

The interviews and case studies captured qualitative feedback from a range of dairy farm types and sizes. However, the financial modelling analysis was more limited, although the technology was beneficial for all three case farms. Further study of perceived benefits versus actual benefits would be necessary to fully gauge how well the technologies compare between systems and technology types. This would require a more comprehensive study than this one.

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To others in the industry who shared ideas and information with us and demonstrated how these cow collar technologies worked. Your contribution was invaluable.

9 References

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10Appendix I: Research Outputs, Extension Activities and Measures of Success

The research outputs include the following.

1. A report and project summary containing the following information.
    a. A description of the cow collar technologies available in New Zealand.
    b. Information on complementary technologies that integrate with cow collar technology.
    c. Information on the advantages and disadvantages (tangible and intangible) of cow collar technology, and considerations in investing in cow collar technologies
    d. A cow collar technology investment analysis for the case study farms.
2. An investment analysis template to enable farmers and rural professionals to assess the return on investment in cow collar technology and identify other benefits.
3. A Grasslands Conference presentation and journal paper on this project in 2024 (if accepted).

Extension activities targeted to farmers and those supporting farmer decisions (rural professionals, vets, DairyNZ) will include the following approaches.

1. On-farm discussion groups and farmer field days using both DairyNZ and PGG services. Rural Professionals in Wairarapa (Baker Ag) and Manawatu have confirmed interest.
2. An investment analysis template made available via the Science Challenge and possibly DairyNZ and Beef and Lamb NZ.
3. Project findings discussed with DairyNZ during, and on completion of, research. In particular, we will liaise with Callum Eastwood.
4. Research findings, with offer to discuss, provided to OLW, Beef & Lamb NZ.
5. Research findings presented at a peer-reviewed conference such as the NZ Grassland Association conference 2024.
6. Offer to present findings at NZIPIM conference and/or an NZIPIM online seminar.
7. Article in the NZIPIM journal prepared by April 2024 (depending on publisher and if no conflict with Grasslands article).
8. Articles in rural press to generate farmer interest in cow collar technologies.
9. Social Media – Podcast, Facebook, industry blogs, Twitter. Hamish Hammond, who is experienced in social media extension activities for farmers, will contribute.

Anticipated measures of success for this research include the following.

1. Greater farmer confidence in making decisions related to cow collar technology adoption, potentially resulting in faster and greater uptake assuming benefits can be realised.
2. Improved implementation of cow collar technologies for more effective use.
3. Potential for greater on-farm integration of cow collar technology with other technologies.
4. Informed and independent advice on the costs and benefits of cow collar technologies.
5. Access to quantitative data on the costs and benefits of cow collar technology.
6. Access to qualitative information on the advantages and disadvantages of cow collar technologies.
7. More informed and relevant product development of cow collar and integrating technologies by technology providers contributing to higher uptake.

11 Appendix II: Phone Interview Questions

The semi-structured phone interviews included some or all the following questions. Questions were adapted based on interviewee's answers to the questionnaire.

General

Why did you adopt collars?

Why did you choose the brand you have adopted?

What other technologies would enhance the functionality of your collars?

How well does your collar integrate with additional technologies used at the dairy shed and on the farm?

What additional collar features would be useful for your farm system?

Mating

How have collars aided your heat detection?

How are you notified of cows on heat and how regularly are you notified?

What other heat detection aids are you using and how do they compare for accuracy of heat detection? If any.

What other benefits have your collars provided to your mating system/management?

What mating reports are generated by your collar provider and how are these used?

Animal health & Welfare

How have the collars aided you with detecting animal health issues (incl. mastitis, sick cows, metabolic issues)?

How are you alerted about cows with possible animal health issues, and are these timely?

How did the cows react to the virtual fencing training?

How are you using the rumination data provided by your collar to make management decisions?

Feed management

What reports is your collar provider producing and how are you using these for feed management and allocation?

How do you use the feed management app?

What other benefits has your collar provided for feed management?

How do you use the virtual fencing feature of your collar and how does this aid your feed management?

How has the way you manage pasture and feed allocation changed since you have adopted a collar brand with virtual fencing capabilities?

Labour

What extra/or different skills would you be looking for when hiring staff after adopting collars?

What additional management skills have you learnt since adopting collars?

How have you labour requirements changed since adopting a collar technology?

Environment

How and what information gathered by your collar is used for meeting compliance?

How do you use the collars during adverse whether events to minimise environmental damage (e.g. exclusion from CSA, reducing pugging, surface runoff etc.)?

How are you using the information provided by the heat maps?

What other benefits can your collar provide for environmental management?

How has your management of fodder crops in adverse weather conditions changed since you have adopted a collar with virtual fencing capabilities?

Financial implications, costs and savings

What areas of the farm business have had cost savings or increased returns because of using this technology?

Implementation and farm systems changes

What farm system changes did you need to make when introducing the collars? If any

Were there any unforeseen implications of using the technology that required you to make farm system adaptions?

How have you experienced the support from your collar provider?