

# **Farm Crime and Security: Evaluating Smart Tag Technology for Preventing, Tracking and Recovering Stolen Livestock**

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### Abstract

This research study evaluates the efficacy of Ceres Tag, a livestock information platform that utilises a unique smart tag, in improving farm security by preventing, interrupting, and reducing livestock theft – a prevalent issue among farmers and landholders in countries like Australia. The Ceres Tag is equipped with an accelerometer and global navigation satellite system (GNSS) technology to collect data on animal health, welfare, movement, and traceability. It was hypothesised that the Ceres Tag could combat livestock theft by enabling interventions at three key stages: rapid prevention, tracking of stolen livestock, and recovery of stolen livestock. To assess this, a mock theft of livestock was staged, accompanied by a coordinated law enforcement response. Key findings include: (1) the Ceres Tag issued a ‘high activity alert’ to farmers, indicating significant livestock agitation, within 12 minutes of the mock theft initiation; (2) utilising the data, the New South Wales (NSW) Police were able to track and interrupt the livestock theft within 25 minutes; (3) the data enabled the NSW Police to repeatedly track and interrupt the theft on three separate occasions over a 110 kilometre distance and 90-minute period; and (4) following the thieves' arrival at their destination, the NSW Police, aided by the data, recovered the stolen livestock within 20 minutes. The Ceres Tag system increases the risk of criminal behaviour in often riskless rural settings, effectively ‘hardening’ livestock as targets through technological innovation. Furthermore, the platform provides farmers with tangible evidence of a crime, substantially expediting the crime reporting process. This timely reporting, coupled with the data provided by Ceres Tag, positions police for rapid and effective intervention, thereby enhancing their capacity to investigate and resolve incidents of livestock theft. Overall, the results suggest that the Ceres Tag offers a promising technological tool for farmers and law enforcement officers alike, aimed at fortifying farm security and minimizing livestock theft.

**Keywords:** Ceres Tag; Livestock Theft; Farm Security; Livestock Tracking; Theft Prevention

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We would also like to recognise the contributions of Dr David Philpot, founder and developer of the Mapipedia software used in this trial. The Mapipedia software was not only user-friendly and insightful for our purposes, but David took the time to train the research team in the use and application of Mapipedia in the field. Finally, we would like to recognise the contributions of the UNE Smart Farms and Project Team colleagues Jamie Barwick, Huw Nolan and Derek Schneider. Without their support, the trial would not have been a reality.

## Introduction

Farm crime victimisation in Australia, as elsewhere, is problematic and has wide-reaching social and economic impacts on individual farmers, wider communities and the national economy (Mulrooney & Harkness, 2022; Harkness, Mulrooney & Box, 2022). Advances in agricultural technology are becoming more prominent, and this research considers one such innovation and its application to the theft of live-stock. Ceres Tag is an electronic tag which transmits movement and locational data, providing valuable information about the livestock. This ‘note from the field’ reports on a mock trial of the technology, conducted in New South Wales, Australia, in 2022, to assess the efficacy of the product from a crime prevention and law enforcement perspective. The results of this trial suggest that Ceres Tag is a promising technological innovation that can aid farmers and landholders in preventing livestock theft, while also significantly enhancing law enforcement's capability to intervene in livestock theft and recover stolen livestock.

## Farm Crime Victimisation

Crime victimisation among Australian farmers is a pervasive problem, particularly regarding property and acquisitive crimes (Barclay, 2015; 2016). The New South Wales (NSW) Farm Crime Survey conducted in 2020 found that 80 percent of farmers have experienced farm crime at some point in their lives and this victimisation is often repeated (Mulrooney, 2021). For example, 77 percent of farmers reported being a victim of crime on two or more occasions, with 23 percent experiencing crime more than seven times. One of the most common crimes experienced by farmers and landholders is the theft of livestock. The survey found that 39 percent of respondents reported experiencing livestock theft (Mulrooney et al., 2022). The Victorian Farm Crime Survey conducted in 2018 found that 32 percent of respondents had experienced stock theft (Harkness, 2021). Notably, these percentages are likely much higher if we consider that not all respondents to these surveys farm livestock.

## Financial Impacts

The impact of crime on individual farmers and rural property owners is significant, both psychologically and financially, and has broader social and economic implications that can affect entire rural communities and the agricultural industry as a whole (Anderson & McCall, 2005). For example, figures from the NSW Police Force indicate that between 2015 and 2020, an average of 1,800 cattle and 16,700 sheep were stolen in the state each year, costing farmers nearly AUD \$4 million annually. When accounting for the value of stud livestock, the loss of animal by-products such as wool or milk, and the loss of future breeding potential, the annual monetary impact on NSW primary producers could realistically be over AUD \$60 million per year. Nationally, it is estimated that an average of 31,000 cattle are stolen each year in Australia at an estimated cost of AUD \$50 million (PwC, 2022). Notably, these figures are highly conservative as they are based on reported crime while farm crime (particularly stock theft) is notoriously under-reported. Moreover, crimes such as livestock

theft can have additional effects, including impacts on pricing, distribution and the availability of produce, as well as issues of biosecurity and, by extension, food security.

### **Emotional impacts**

In addition to financial losses, the intrusion of an offender on private land and the theft of property can have a significant impact on an individual's emotional state and sense of safety and security, particularly in isolated rural areas where a police response may not be immediate. Research suggests that farmers have high levels of worry about crime and that this can impact their quality of life through stress, physiological effects and negative psychological well-being (Smith, 2019; Mulrooney, 2021). Furthermore, the personal stress and anxiety associated with victimisation, as well as the loss of valuable livestock bloodlines that may have been developed over many years or generations, can lead productive farmers to leave the sector altogether. These costs are particularly burdensome for farmers already facing challenges such as droughts, floods, bushfires, climate change and mental health issues.

### **Under-reporting**

Livestock theft is often not reported, meaning that estimates of its incidence are likely to be conservative due to the 'dark figure' of farm crime. For example, only 42 percent of farmers in NSW indicated they would report crime all of the time and, of those who experienced stock theft, only 66 percent had reported the crime at least once in their lifetime. Research suggests that farmers do not report crime for a variety of reasons, including discovering the theft too late, perceiving barriers to investigating crime in rural areas, such as a lack of evidence or proof, and a lack of confidence in the police's ability to solve the crime (Mulrooney, 2021; Harkness, 2021). These issues are particularly relevant in the case of stock theft where stock is often stolen from remote paddocks which are not formally or informally guarded or are done so infrequently. For instance, the distance, remoteness and large size of rural properties can limit the frequency with which farmers check their livestock, meaning that they may not be aware that a theft has occurred until much later. As a result, the time lag between the theft of livestock and the reporting of the theft can be lengthy, if it is reported at all, reducing the ability of the police to intervene.

### **Use of Technology for Livestock Theft Prevention**

The advancement of technology, in particular agricultural-specific technology, offers new tools and techniques with which farm crime and stock theft can potentially be prevented. An example of such technology, smart animal ear tags, can provide farmers with important information related to animal movement and location. While such tags may be used for a variety of farming needs, including herd and land management, pasture feed-intake and animal health and welfare, this technology may also be used for the prevention of and policing response to stock theft and, in particular, address those spatial factors which make combatting this crime so difficult. Flowing from this, the objective of this study was to assess

the effectiveness of a particular smart ear tag known as Ceres Tag in enhancing farm security, with a focus on determining its efficacy in preventing and disrupting the theft of livestock.

Ceres Tag is a livestock information platform that utilises a unique smart tag equipped with an accelerometer and global navigation satellite system (GNSS) technology to collect data on animal health, welfare, movement and traceability. As such, these ear tags empower producers with advanced grazing management control, enabling remote livestock location tracking and timely alerts for stock theft, health issues, or birthing events. Additionally, the tags incorporate behavioural data, allowing for the estimation of daily pasture intake values for cattle. The accelerometer continuously monitors an animal's activity level over a rolling six-day period, updating a baseline measurement on a scale of 1-7 (1 representing low activity and 7 representing extremely high activity) through machine learning. Unusual changes in activity relative to the baseline are identified and alert the producer of potential problems with the animal.

The GNSS technology provides the animal's location approximately every six hours through the Globalstar satellite network, with a margin of error of plus or minus 10 metres. Ceres Tag establishes a direct connection between animals and satellites, bypassing the need for on-farm towers. The data collected by the ear tag is transmitted via low earth orbit satellites to a secure cloud-based platform, which can be accessed and analysed through farm management software such as Mapipedia. The software platform allows users to set custom alerts, such as notifications of perimeter breaches or animals in distress, and to visualise and analyse historical data to gain insights into animal behaviour, land usage, and, in this case, theft events.

Drawing on this technology and its associated movement and location data, it was hypothesised that Ceres Tag may combat livestock theft by offering opportunities for intervention at three key stages: rapid intervention/prevention of livestock theft; tracking stolen livestock; and recovering stolen livestock (see Table 1).

To test this hypothesis, a proof-of-concept mock theft trial, coordinated by the authors, simulated the theft of sheep from a university research farm in rural NSW.

The purpose of this study was to evaluate the application of the Ceres Tag smart animal ear tag for improving farm security, and specifically to determine the efficacy of this technology for the purpose of preventing, interrupting, and reducing the theft of livestock.

**Table 1***Key Stage of Experiment*

<b>Stage</b>	<b>Opportunity</b>
<b>1: Rapid Intervention /Prevention</b>	Thieves commence theft of livestock near the town of Armidale. Ceres Tag is evaluated on the data it may provide the farmer/landholder to enable a quick response to the theft event.
<b>2: Tracking Stolen Livestock</b>	Thieves proceed to drive stolen livestock from the site of theft in Armidale to the Tamworth Regional Livestock Exchange. Ceres Tag is evaluated on the data it may provide and enable police to track and stop the thieves on route to their destination.
<b>3: Recovering Stolen Livestock</b>	Thieves arrive at the Tamworth Regional Livestock Exchange. Ceres Tag is evaluated on the data it may provide and enable police to recover the stolen livestock.

For this trial, the following research questions were addressed:

1. Does Ceres Tag provide near real-time data that may indicate that livestock are being disturbed or stressed, and if so, what is this data and how does it differ from normal conditions?
2. Does Ceres Tag alert or notify of a breach of boundary by livestock, and if so, what factors determine the time it takes to receive this notification?
3. Does Ceres Tag provide data on livestock movement and location once a boundary has been breached, and if so, can this data be used to track livestock in near real-time while in transit?
4. Can data from Ceres Tag be used to track livestock to their destination and facilitate recovery?
5. Based on the results of this trial, can Ceres Tag improve the capacity of the police to prevent and respond to livestock theft, and if so, how?

### Methodology and Description of the Trial

Twenty sheep were fitted with Ceres Tags attached to collars around their necks (see Figures 1 and 2). Collars were used as it was deemed unnecessary to tag the sheep for short trial and, as the intention of the trial to evaluate the use of the data as opposed to whether the tags could be removed, the use of collars had no negative bearing on the study. Prior to the theft event, using the Mapipedia software a virtual perimeter, or geofence, was set up around the paddock boundary, and alerts were programmed for a paddock escape (PEA) if the sheep were to breach this. Alerts were also created for high accelerometer activity, which would notify if unusual changes in activity occurred relative to the baseline and high distance movement (HDMA), when animals travelled a distance greater 1000 metres away from the previous recorded GNSS position.

#### Figure 1

*Ceres Tags (Trace) on collars*



Actors in the mock trial were divided into three groups: the thieves; the farmer/landholder; and the police. The thieves stole the sheep using a tandem trailer, the farmer monitored Ceres Tag data and alerts in Mapipedia, and the police followed standard protocols to intercept and recover the stolen sheep using the data from the tags. The actors operated in isolation and were unaware of the actions or information of each other. There were only two contact points between the actors: first when the farmer called the police to report the theft of their stock, as indicated by the Mapipedia alerts; and second when the police, acting on this data and information, intercepted the thieves. The roles of the thieves and farmer were occupied by members of the research team, while the role of the police was

undertaken by the NSW Police Force (NSWPF) Rural Crime Prevention Team (RCPT). The officers working in the RCPT are specialists from the NSW Police Force, specifically trained to probe rural crimes. They possess extensive knowledge of the laws relevant to offences against rural industries and are dedicated to protecting these sectors (see Whiteside et al, 2022; Whiteside et al, 2023). While the NSWPF was participating in the mock theft, they acted and intervened as if it were a 'live' scenario and without interjection from the research team.

## Figure 2

*Sheep fitted with Ceres Tag on collars*



During the first stage of the trial, which focused on the rapid intervention and prevention of stolen livestock, the thieves entered the paddock and began moving the sheep into the loading yards and on to a trailer. In order to artificially skew the conditions in favour of the thief for the purposes of the trial, the paddock and accompanying geofence were located near the roadside, the thieves had access to an all-terrain vehicle (ATV) to muster the sheep, and there were loading yards present. Once the sheep were loaded, the theft vehicle and trailer breached the geofence and drove 200 metres from the loading yards before beginning the second stage of the trial, which focused on tracking the stolen livestock. The thieves waited for the first PEA before embarking on a journey to Tamworth Regional Livestock Exchange, approximately 110 kilometres away (90 minutes by road). Upon arriving at their destination, the third stage of the trial which focused on recovering stolen

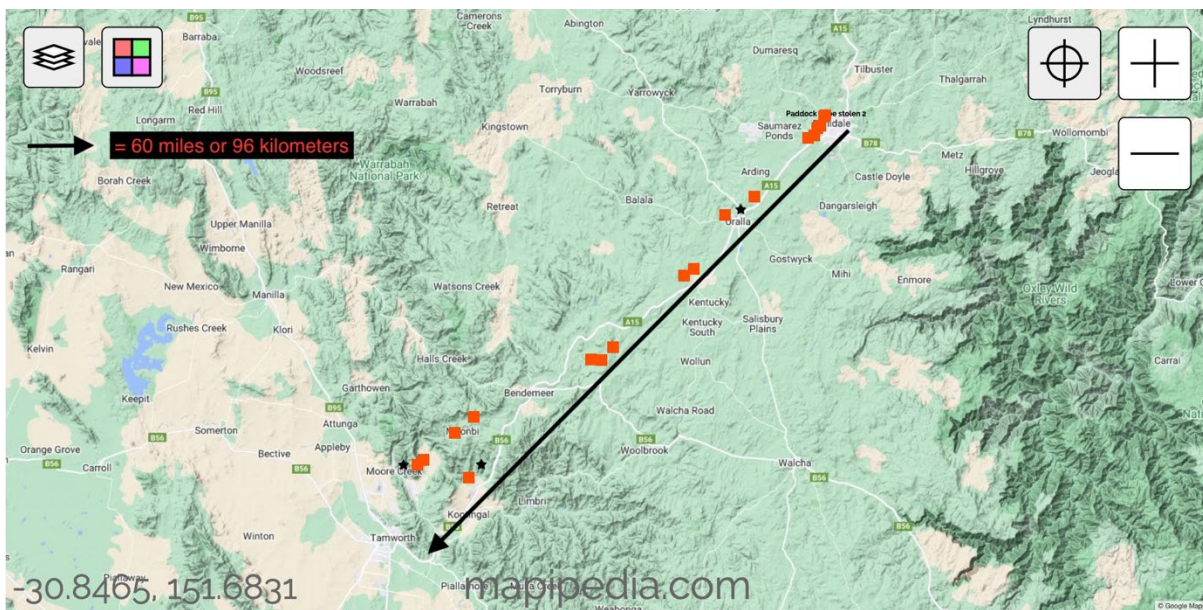


livestock began, and the experimenters timed and waited for the police to recover the livestock.

During the trial, the farmer’s role was to act upon the information provided by the Ceres Tag smart animal ear tags through the Mapipedia software. The tags generated data on the animals through activity monitoring and location monitoring and were able to send alerts to the farmer via SMS messaging and email in the event of unusual activity. In the event of the mock theft, the farmer received a notification of high activity across multiple tags 12 minutes after the theft began, and a notification of a boundary breach (PEA) 33 minutes after the boundary had been breached. The farmer then called the police dispatch and provided them with access to the data on the Mapipedia platform via a publicly accessible link, allowing them to track and recover the stolen livestock without an intermediary. Figure 3 illustrates the location of data packets and intercept locations.

**Figure 3**

*Data packets* ■ sent by Ceres Tag as seen in Mapipedia software, and three intercept locations ★



The NSWPF Rural Crime investigators (RCIs) worked in conjunction with local law enforcement to respond to the simulated theft of livestock. Following standard operating procedures, the police relied on information provided by the farmer and data from Ceres Tags accessed through Mapipedia software to make decisions with the goal of intercepting the thieves and recovering the livestock. At 11:05am on the day of the trial, the NSWPF RCPT received the report of the stock theft and dispatched RCIs to the area to search for persons, vehicles and animals of interest. At 11:14am, police noted that the last GNSS data from the Ceres Tags indicated a vehicle of interest was heading for a nearby highway, and that it was unlikely the thieves would travel through town. At 11:18am, one of the 20 Ceres Tags sent a

high distance movement alert, and accompanying GNSS information indicated that the livestock were moving south along the New England Highway from the farm. As the RCIs entered a nearby town of Uralla, they observed the vehicle of interest travelling west and pulled it over for inspection. The stolen livestock was successfully tracked, and the thieves were intercepted at 11:30am, 25 minutes after the police received the initial report of the crime.

The RCIs then disengaged from the interaction and reset the scenario until receiving further data from the Ceres Tags. At 11:48am, the RCIs received GNSS location data indicating the thieves were travelling south of the village of Kentucky and likely still on the New England Highway. The RCIs radioed ahead to officers in the town of Kootingal and at 12:13pm, the vehicle of interest was sighted at the top of Moonbi Range. On the highway, the RCIs intercepted the vehicle towing the stolen livestock for a second time at 12:21pm. The RCIs then disengaged from the interaction and reset the scenario until receiving further data from the Ceres Tag. A subsequent high-distance movement alert (HDMA) was received at 12:22pm, indicating that the thieves were still in motion.

Using the GNSS location data, the RCI estimated the vehicle's probable location and alerted the Tamworth RCI to be on high alert. The Tamworth RCI sighted the vehicle at 12:48pm and intercepted it for the third time. The RCIs then disengaged from the interaction and reset the scenario until receiving further data from the Ceres Tag. The thieves arrived at the Tamworth Livestock Exchange at 1:04pm, and the livestock was successfully recovered by the RCPT 20 minutes later.

## Results

### Rapid Intervention/Prevention of Livestock Theft

Ceres Tag is designed to provide near real-time data on the movement and location of livestock, along with associated alerts. Regarding animal movement, the system uses accelerometer data which is sent every 10 minutes, to detect when livestock may be experiencing disturbance or stress, such as if they are being mustered or loaded by a thief. As the accelerometer records movement patterns over a rolling six-day period to establish a baseline activity level for each animal, these alerts can be considered reliable indicators that, at the very least, warrant further investigation. In the mock trial, for instance, the receipt of six HAA alerts in the 12th minute of the theft commencing prompted the farmer to check on the livestock. Table 2 provides a summary of key 'time' results for Stages 1, 2 and 3 of the trial. This timely information may allow for quick intervention or prevention of the theft, such as calling the police, as well as the collection of evidence to pass on to the police, such as details about the thief's vehicle or video footage of the incident.

**Table 2***Summary of Key 'Time' Results by Stage*

<b>Scenario</b>	<b>Data</b>	<b>Alert</b>	<b>Time</b>
<b>Stage 1: Rapid intervention/prevention</b>	Accelerometer	High activity alert	12 minutes
<b>Stage 2: Tracking stolen livestock</b>	GNSS location data	Paddock escape alert/ high distance movement alert	25 minutes
<b>Stage 3: Recovering stolen livestock</b>	GNSS location data	Paddock escape alert/ high distance movement alert	20 minutes
<b>Total trial</b>	Accelerometer/ GNSS location data	High activity alert/Paddock escape alert/high distance movement alert	175 minutes

Likewise, the locating data and associated alerts notifying a breach of boundary (PEA) may also indicate livestock are being stolen. With these timely notifications, farmers are provided an opportunity to respond to theft with significantly reduced delay and inform the police who can react in a timely manner, allowing for intervention/prevention of the criminal event and/or the preservation of evidence. Where intervention/prevention is not possible, the notification of boundary breach, especially in combination with any HAA, should prompt farmers to check on their livestock thereby greatly reducing the time to reporting. This provides the police with a much greater ability to track and recover the livestock as well as gather evidence which may otherwise be destroyed or rendered useless over time (for example, tyre tracks washed away from rain).

In the case of this trial, prompted by the HAA at the 12th minute, the farmer checked the GNSS data in Mapipedia and was able to see two tags were slightly outside the geofence. While this did not trigger a PEA, given the +/- 10 metres margin of error with the geofence, the discovery of the location of these two tags in combination with the HAA already received should further encourage the farmer that something may be wrong and to check on the stock. Ultimately, upon breach of the geofence, a PEA was received by the farmer in 33 minutes, prompting the farmer to phone the police.

### **Tracking and Interrupting Stolen Stock**

When livestock theft takes place, GNSS positional data and related alerts can serve as powerful tools to both track stolen animals and facilitate police investigations. The information supplied by Ceres Tag can also enable law enforcement to trace the movement of stolen animals, possibly intervening mid-journey. In the mock exercise, the RCIs successfully traced and disrupted the theft on three distinct instances within a 90-minute timeframe, with the first intervention occurring merely 25 minutes post-theft notification (refer to Table 2). Should police intervention prove unfeasible, the location data could still prove instrumental in evidence gathering. Knowing the path taken by thieves, along with any stops they make, can aid in procuring CCTV footage from various points of interest or vehicles of interest, like service stations, residences, dashcams, and so on. Such evidence could significantly aid with the prosecution of such offenders.

### **Recovering Stolen Livestock**

The GNSS positional data and corresponding alerts can prove effective in determining when the stolen livestock have ceased movement, subsequently enabling the orchestration of a recovery operation at the destination. In this trial, as the GNSS location data began to cluster, this information equipped the RCIs with the knowledge that the thieves had stopped and where they had stopped, leading to the recovery of the stolen livestock just 20 minutes following the thieves' arrival at their destination (refer to Table 2).

### **Policing Livestock-Theft**

The RCIs reported that their response and investigative decisions during this trial were exclusively based on the data supplied by Ceres Tag through the Mapipedia Software, combined with local and sector-specific policing knowledge (for example, probable points of interest, major highways used, and so on). Importantly, the immediate reporting of the theft by the farmer enabled the police to rapidly react to the theft, representing a significant departure from the existing real-world norm. Further, the data granted the officers the ability to determine the thieves' direction and disrupt the theft on multiple occasions. This information provided the RCIs insight into the fact that the vehicle had come to a halt at a certain location, enabling them to intercede and retrieve the stolen livestock.

In a debriefing session following the trial, the RCIs underscored several specific investigative advantages. For instance, they pointed out how the data facilitated the deployment of a strategic police response by radioing ahead to set up checkpoints. A retrospective analysis of the data was helpful in identifying the thieves' travel route and any points where they had been stationary. Consequently, the police could gather evidence like CCTV footage of the route and/or of the persons of interest, as well as financial records if payment cards had been used.

The RCIs also noted that the early alert to the theft could allow them to use additional resources such as stationary speed cameras set to real-time triggers if the vehicle registration is known, and automatic number plate recognition (ANPR) technology installed in Highway Patrol police vehicles. They also indicated that, in the unlikely event that the tags are removed, evidence of possession would enable the application of crime scene/search warrants at the location and, if tags are discovered onsite, DNA/fingerprint examination due to the timeliness of recovery.

### Study Limitations

The Ceres Tag was effective in facilitating rapid intervention/prevention, tracking and interrupting stolen livestock and recovering stolen livestock in this trial. However, there are some limitations to consider. One potential limitation is the possibility of thieves removing the tag. However, the specific Ceres Tags used in this trial, known as Ceres Trace, have tag pins that are made of polymer-coated stainless steel, which makes removal difficult and time-consuming. Additionally, the removal of the tag may cause damage to an animal's ear, which may raise suspicion and make it more difficult for the thieves to move the livestock to market. Another limitation is that the amount of data received is dependent on the number of tags. Fewer tags would mean less data and therefore greater limitations on law enforcement's ability to track and intervene in the theft.

In this trial, upon receiving the HAA the farmer noted two tags pinged outside the geofence. However, as the livestock had yet to move beyond the +/- 10 metres geofence buffer, a formal SMS/email PEA was not sent. In a real-world scenario, the combination of this location data with the HAA should prompt the farmer to check on the stock, at the very least. In terms of receiving a PEA, as GNSS data was sent and received just prior to the paddock geo-fence buffer being breached, a formal PEA took 33 minutes to be received by the farmer.

The time it takes to report a PEA (or the GNSS data more broadly) depends on the total number of tags. Each tag should send data every 4-6 hours, but they do not all send data at the same time. In this mock theft trial, 20 tags were used. When the data sent by each tag over a two-week period is reviewed, the timeliness of information flowing from the tags can be estimated. Over the 14 days in question, the highest number of times GNSS data was transmitted over a day was 111 times with the lowest number being 89 times. This provides an average of 101 data transmissions per day. While the times of these transmissions may vary, users should expect to receive data 4.21 times per hour or every 14.25 minutes if using 20 tags. This number will increase or decrease depending on the total number of tags and how close to each other each tag reports.

A final limitation is the controlled nature of this mock-theft trial. Variables present in a real-world scenario, such as theft occurring at night or a response from police officers without industry knowledge, may impact the results.

## Discussion

Livestock theft is a high-reward and low-risk crime for motivated offenders, particularly those with cultural and industry-based knowledge (knowing, for instance, how to muster and load cattle). Cattle are economically valuable. Yet, the vast, open expanses combined with a lack of both formal (police) and informal (local community) guardianship mean there is a low likelihood of being apprehended and brought before the courts. When it comes to formal guardianship, the large distances between rural settlements and properties present a unique challenge compared with urban areas where policing presence is more concentrated and regular. As for informal guardianship, one way to increase the risk for offenders is through natural surveillance. For instance, a busy city street tends to be safer because there are always people around to witness and possibly intervene in any criminal activity, thereby discouraging such actions. Yet, in the rural environment, the risk/reward calculation made by a potential offender is often skewed to them favourably as there are a myriad of valuable assets on farms yet eyes and ears in the paddock are few and far between.

The tyranny of distance and geographic isolation of many farmers pose similar constraints to target hardening and the implementation of physical security measures. For example, while there have been innovations in the use of CCTV in rural locations, in practice it is nearly impossible to fully secure and monitor such vast wide-open spaces, and technological limitations (such as internet access) and the cost of such systems may prohibit their use by farmers. Cultural attitudes, along with working practices, may also restrict the use of such measures. For example, there may be more relaxed attitudes towards security in rural farming communities and it may be impractical to lock a gate which is passed through multiple times per day or to remove the keys from vehicles which are used with significant frequency. In terms of social density in rural communities, while strong social bonds have been shown to mitigate crime, for example through increased informal social controls, others have highlighted that these same tight-knit acquaintanceship networks may facilitate crime and criminal networks (Barclay et al, 2004). This is particularly relevant when considering that undertaking these offences tends to require some level of industry and socio-cultural knowledge.

These components come together to create a crime-prone environment, heavily reliant on local characteristics (like the presence of livestock), but vastly divergent from urban settings in terms of the types of offending, possibilities for crime, and strategies for prevention and response. This is not to say that crime prevention theories, tools and techniques are inapplicable on farms. Rather, we must factor in the unique attributes of rural spaces and, more precisely, how the geographical context and cultural landscape influence the types and frequency of crime, and the capacity for prevention, intervention and response (Harkness & Mulrooney, 2020). Ceres Tag is one such tailored intervention which offers the opportunity to increase the risk of criminal behaviour, in an often-riskless space. However, in addition to a general contribution to guardianship and target hardening through the monitoring of livestock, Ceres Tag offers a solution to many of the problems associated with preventing and responding to livestock theft identified above.

Research on farm crime consistently reveals a significant ‘dark figure’ of rural crime (Mulrooney, 2021). It has been observed that many farmers fall victim to crime repeatedly, but they often refrain from reporting these incidents to the police. This under-reporting poses a fundamental challenge in tackling livestock theft. Clearly, the police cannot respond to crimes they are not aware of, and insufficient reporting hampers the intelligence that police can utilise for decision-making. For instance, if four farmers within a specific area fall victim to theft within a month, the police might not solve each individual crime, but with this information, they could identify potential opportunities for proactive intervention. The absence of such details keeps the police in the dark.

Farmers provide various reasons for their reluctance to report, including lack of trust in the police’s ability to resolve the crime, absence of evidence, inability to prove property has been stolen, and uncertainty about whether a crime has actually taken place. Ceres Tag addresses these concerns and the broader issue of under-reporting. Indeed, the foremost benefit of this technology is that the time taken for farmers to detect stolen livestock can be drastically reduced from potentially months to almost immediately because of HAA and PEA notifications from Ceres Tag. This near real-time alerting system also provides farmers with evidence and more confidence about the occurrence of a crime, thereby significantly reducing the reporting time to the police. With prompt reports, police are in a much better position to respond to livestock theft.

Studies have indicated that the relationship between farmers and the police is often tense (Mulrooney, 2021; Harkness, 2021). Partly, this tension is a result of the rural environment where these crimes occur. This environment often leaves the police grappling to solve crimes such as livestock theft due to the scarcity of evidence. Concurrently, farmers grapple with frustration owing to the bleak likelihood of achieving a satisfactory outcome, a situation they often encounter repetitively. Therefore, it is hardly surprising that farmers generally express low satisfaction with the police, particularly regarding their confidence in the police's ability to solve livestock theft. This, of course, feeds into and discourages the reporting of crime.

This sentiment has seen some improvement in NSW following the introduction of the RCPT (Mulrooney et al., 2022). Nonetheless, the police themselves acknowledge the challenges of responding to crimes that may have been committed well before they were notified and/or those with scant evidence to initiate an investigation. Ceres Tag has the potential to offer farmers a heightened sense of security and peace of mind and can also enhance the police’s ability to prevent and intervene in livestock theft. Consequently, this might foster increased confidence in the police’s ability to respond to livestock theft and, in turn, could motivate a higher likelihood of farmers reporting crimes to the police.

### Conclusion

In the mock trial conducted, the Ceres Tags demonstrated positive outcomes in all three tested intervention stages. provides the opportunity for rapid intervention/prevention into the theft of livestock, thanks in large part to accelerometer data and subsequent HAA. Additionally, PEA informs the farmers of any paddock breaches. Evidently, prompt intervention is feasible and, at the bare minimum, the duration from awareness of theft to reporting has significantly shrunk from potentially days, weeks, or even months, to mere minutes. The trial was also able to confirm the capacity of the Ceres Tag to track stolen livestock and interrupt on route. The GNSS location data, accompanied by related alerts provided by Ceres Tag, empowered the RCPT to orchestrate a law enforcement response that tracked and thwarted the theft of the livestock on three distinct occasions. Lastly, GNSS location data and corresponding alerts assisted law enforcement in discerning whether the stolen livestock were on the move or had stopped, subsequently allowing them to arrange an intervention for recovery at the identified location.

Collectively, these results suggest that Ceres Tag is a promising technological innovation that can equip farmers and landholders to prevent livestock theft, while also significantly enhancing law enforcement's capability to intervene in livestock theft and recover stolen livestock. This technology greatly shifts the risk of rural offending, making the act much more difficult to complete, while also significantly improving our capacity to prevent and rapidly intervene in livestock theft, track and interrupt the theft of stolen livestock, recover stolen livestock, and the ability of the police to solve such crimes more broadly.

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## Erratum

9/29/2023: Added disclosure statement to article.