European Innovation Partnership (EIP) Wales

Early adoption of on-farm 'Internet of Things' (IoT) sensor networks to alert and notify farmers to improve farm security

Year 2 Report

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1.Background

The Internet of Things (IoT) for Farm Security project is running on five farms in North Wales with the aim of evaluating the capabilities of a range of LoRaWAN sensors to alert and notify farmers to improve farm security. The sensors are monitoring the location of valuable farm assets that are a common target for thieves. The real-time information gathered by the sensors will alert farmers to an incident involving these assets, enabling them to inform the police sooner with higher quality information. These monitoring systems provide logged evidence to show when the sensor was triggered. This information is intended to help police to focus their resources to a specific time helping to trace stolen property quickly. Positive results could encourage the uptake of a new type of security sensors that reduce the risk of threats such as the theft of fuel, livestock, and vehicles.

Each farm has had a LoRaWAN gateway installed on them, which made this project possible. Details on each farm and their location can be found below. This information has been gathered from the Farming Connect website which details activity on Demonstration Farms (Farming Connect, 2023).

1

Glynllifon Farm

Glynllifon agricultural college, including the woodland, extends to 300 hectares. It is the first Digital Playground in North Wales, which offers opportunities to experiment with the Internet of Things (IOT) in a rural setting.

2

Erw Fawr Farm

Erw Fawr and the remaining farms below are Farming Connect Demonstration Farms. It is a 192-hectare holding farmed by Ceredig and Sara Evans in partnership with Ceredig's parents, Ifan, and Ann. The family produces milk from a high yielding pedigree Holstein herd, run on an all-year around calving system. The Branwen herd was established in 1980 when the farm converted from beef and sheep to dairy.

3

Wern Farm

Wern Demonstration Farm is a 486-hectare mixed holding farmed by Osian Williams and his parents, Dafydd and Eleri, and his partner, Nikki. Osian is the fourth generation of the Williams family to farm Wern, an upland farm rising from 700 to 1400 feet. The farm specialises in beef, lamb, and free-range laying hens.

4

Bodwi Farm

Bodwi Demonstration Farm is a lowland beef and sheep holding which has been run by the Griffith family for four generations. Edward and Jackie Griffith farm with Edward's parents, William, and Helen. They have now been joined in the business by their son, Ellis. The total area farmed is 247 hectares which includes 113 hectares of rented land on a holding 18 miles from Bodwi.

5

Moelogan Fawr

Moelogan Fawr Demonstration Farm is a 304-hectare upland holding farmed by Llion and Sian Jones. The couple had been tenant farmers on a National Trust farm before they returned to the farm which has been in Sian's family for three generations. Moelogan Fawr rises from 1,000 feet to 1,500 and supports a beef herd of 100 suckler cows and 36 heifers and a flock of 1,200 ewes.

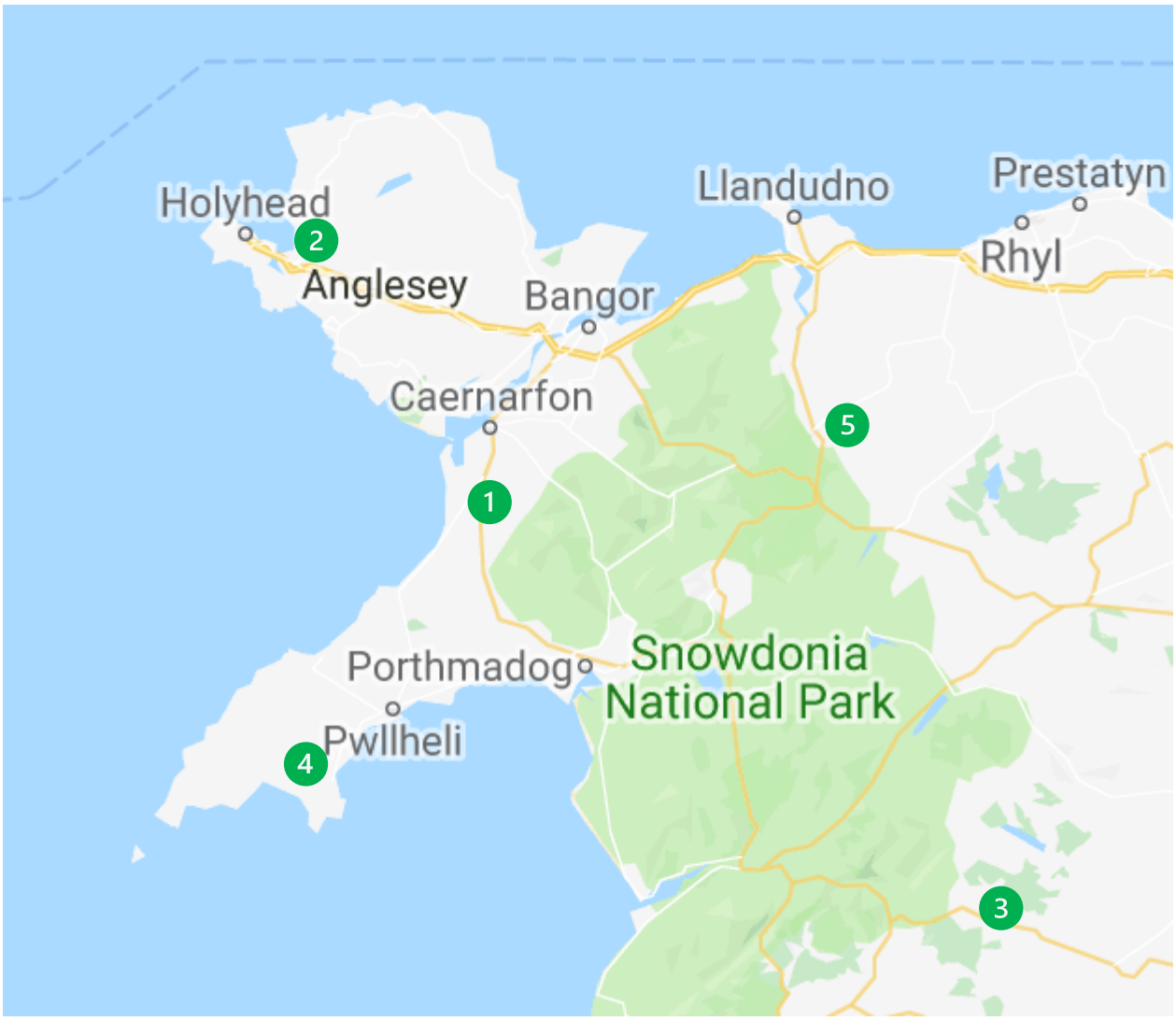

Figure 1: Map showing farm locations. Farms are numbered above the map.

The project aims to further build on the cooperation between the farming community, North Wales Police (NWP), and technology experts to solve common problems and bring about a smarter way of working.

The project is trialling sensors across five farms to tackle the following areas of priority as identified by the Rural Crime Team of North Wales Police.

1. **Quadbike theft.**
2. **Monitoring the open/close status of various on-farm infrastructure.**
3. **Tracking valuable farm equipment.**

The project has commissioned relevant expertise to merge the sensor data into an easy-to-use alerting system for the farmer to use on their tablet or smart phone.

Project Design:
The design of the project followed the five phases below. They are:

PHASE 1. Continuous Participatory Evaluation.

- Establish an evaluation process including farmers, police, and insurers to gather opinions regarding the application or LoRaWAN technology.

PHASE 2. Sensor configuration & Alerting system programming.

- Lease sensors for all five farms for the duration of the project.
- Install, configure sensors and programme to communicate with the LoRaWAN gateway.
- Create a bespoke alerting system that notifies the farmers when the sensor is activated.
- OG training in how to use and interpret the security alerting system and sensor maintenance.

PHASE 3. Sensor & System Assessment.

- Sensor Testing
- Farmers attitude analysis

PHASE 4. Mock Emergency Scenario

- A Mock emergency scenario has been simulated on each farm to evaluate sensors and systems.
- Mock emergency scenario analysis
- Film and edit mock emergency scenarios for promotional material.
- Conduct feedback assessments from the users on the effectiveness of the alerting system.

PHASE 5. Review & dissemination.

- Evaluation of the data gathered over the course of this proposed EIP project.
- Report on project conclusions and recommendations
- Attitude and opinions to be measured using Likert Scales.
- Use the end user and focus group feedback to continuously make improvements to the alerting system tool.

Delays and changes from the Original Plan

The original plan was to install fifteen sensors, three on each farm. Fortunately, twenty sensors were installed on the five farms, with Erw Fawr and Glynllifon having five each, and Moelogan having four installed. This provided a better range of results, feedback, and spreads the risk in case some of the sensors fail to work.

The project has uncovered new sensors on the market that were not available at the time of application and has gone ahead to research them - this is a sign of how quickly this sector is changing. In particular, the prototype vehicle detector by EvoMetric that is being trialled at Glynllifon.

2. Sensor Specific Information

Below are the details of types of sensors that are being trialled on each of the farms.

Erw Fawr

1. **Sensor**: Gate Open Close – Dewin Agor:Cae *Compact*
   Location: Side Gate to Farm Livestock Buildings
   Details: Please see pictures

Figure 2: Open close sensor on gate post

Figure 3: Open close sensor on gate post

2. **Sensor**: EvoMetric – Prototype vehicle detector
   Location: Farm track from main road
   Details: Buried alongside the track with the transmitter in the hedgerow. Only alerts between 22:00 and 04:00

3. **Sensor:** Digital Matter Oyster GPS Tracker
   Location: Mounted on Forklift/Handler
   Details: Alerts on movement out of hours 18:00-06:00 and if outside of geofence at any time

4. **Sensor**: Digital Matter Guppy Movement Sensor
   Location: Tractor or Quad bike
   Details: Alerts on movement out of hours 18:00-06:00

5. **Sensor:** Tabs TBMS100 – Passive Infra-Red Movement Sensor
   Location: Medicine Store

Details: Alerts on detecting movement of people in the medicine store out of hours 18:00-06:00

Glynllifon

1. **Sensor:** Tabs TBMS100 – Passive Infra-Red Movement Sensor
   Location: Dairy Store & Medicine Storage
   Details: Alerts on detecting movement of people in the medicine store out of hours 19:00-05:00

Figure 5: Passive Infra-Red Movement Sensor in Dairy/medicine store

Figure 6: External view of Dairy Store & Medicine Storage

Figure 4: Internal view of Dairy Store & Medicine Storage

2. **Sensor**: Digital Matter Guppy Movement Sensor
   Location: Telehandler
   Details: Alerts on movement out of hours 18:00-06:00

Figure 7: Digital Matter Guppy Movement Sensor in telehandler

Figure 8: Telehandler Cabin with movement sensor at top

Figure 9: Telehandler containing movement sensor.

3. **Sensor:** Digital Matter Oyster GPS Tracker
   Location: Mounted on Kubota ATV
   Details: Alerts on movement out of hours 18:00-06:00 and if outside of geofence at any time

Figure 10: Digital Matter Oyster GPS Tracker Mounted on Kubota ATV

4. **Sensor**: Gate Open Close – Dewin Agor:Cae
   Location: Side Gate to Farm Livestock Buildings
   Details: Please see pictures below

Figure 11: Gate open close sensor on gate

Figure 12: Open close sensor on gate post

5. **Sensor**: EvoMetric – Prototype vehicle detector
   Location: Farm track to forestry and further farm fields

Details: Buried alongside the track with the transmitter in the hedgerow. Only alerts at weekends, 00:00-23:59

Figure 13: Prototype vehicle detector buried alongside farm track.

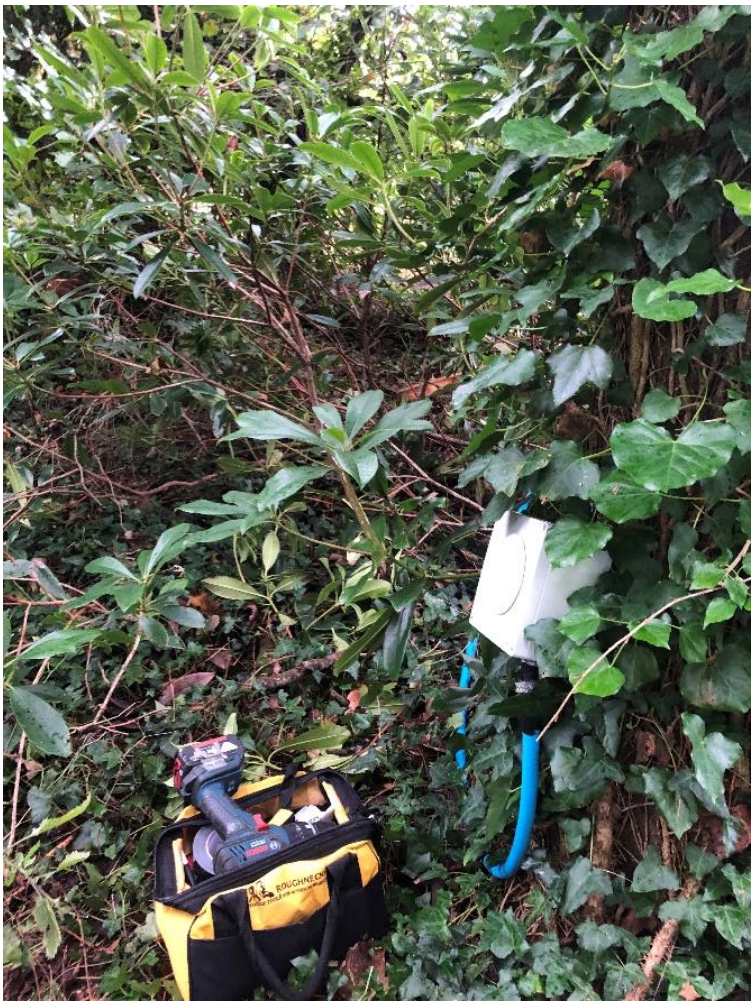

Figure 14: Prototype vehicle detector transmitter in hedgerow

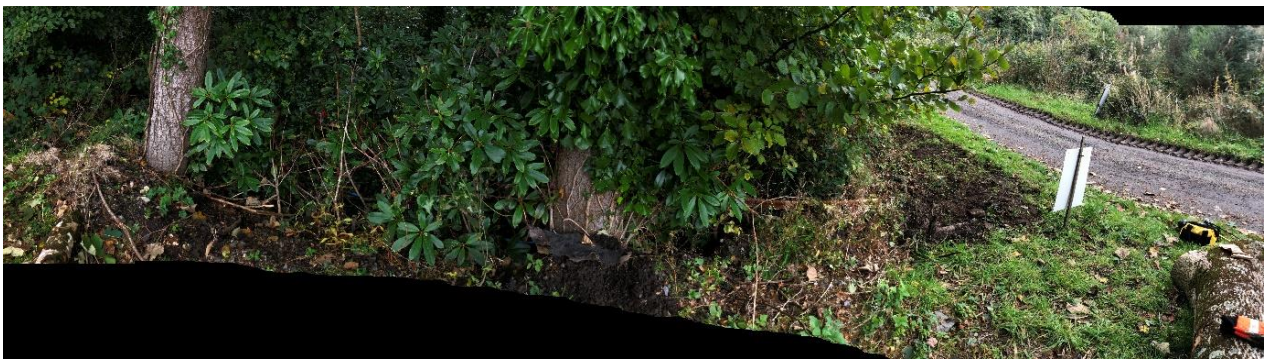

Figure 15: Prototype vehicle detector and transmitter alongside farm track

Bodwi

1. **Sensor**: Hatch Open Close – Elsys EMS Mini
   Location: Fuel Tank
   Details: Alerts 24/7

2. **Sensor:** Digital Matter Oyster GPS Tracker.
   Location: Land Rover
   Details: Alerts on movement out of hours 18:00-06:00 and if outside of geofence at any time

3. **Sensor**: Digital Matter Guppy Movement Sensor
   Location: Quad
   Details: Alerts on movement out of hours 18:00-06:00

Wern

1. **Sensor:** Digital Matter Oyster GPS Tracker
   Location: Tractor
   Details: Alerts on movement out of hours 18:00-06:00 and if outside of geofence at any time

2. **Sensor**: Digital Matter Guppy Movement Sensor
   Location: Quad
   Details: Alerts on movement out of hours 18:00-06:00

3. **Sensor:** Tabs TBMS100 – Passive Infra-Red Movement Sensor
   Location: Roadside "Honesty Box" Egg Shop
   Details: Alerts on detecting movement of people in the Egg Shop out of hours 18:00-06:00

Figure 16: Passive Infra-Red Movement Sensor in Roadside "Honesty Box" Egg Shop

Moelogan Fawr

1. **Sensor:** Digital Matter Oyster GPS Tracker
   Location: Quad
   Details: Alerts on movement out of hours 18:00-06:00 and if outside of geofence at any time

Figure 17: Digital Matter Oyster GPS Tracker mounted on quad bike.

2. **Sensor**: Digital Matter Guppy Movement Sensor
   Location: Trailer
   Details: Alerts on movement out of hours 18:00-06:00

3. **Sensor:** Tabs TBMS100 – Passive Infra-Red Movement Sensor
   Location: Open Barn Storage Area
   Details: Alerts on detecting movement of people in the medicine store out of hours 18:00-06:00

4. **Sensor:** Milesight EM300-MCS – Door Open/Close Sensor
   Location: Outbuilding store
   Details: Alerts on door being opened out of hours 18:00-06:00

Figure 18: Door Open/Close Sensor in outbuilding store

New Types of Sensors

Artificial Intelligence (AI) is becoming increasingly important and standard in all applications. Manually watching and evaluating each process in any business is a time-consuming and costly task. Monitoring and evaluating systems and processes are essential and AI provides a useful solution to this problem. AI will not only automate the monitoring and evaluation of these processes but also review past data and predict future outcomes, adding value to data interpretation with sensor networks. Machine learning can also be used to teach the software how to detect flaws in systems and allow corrections to be made to improve them. AI and machine learning will advance and would be worth investigating in the future.

New AI applications have been developed based on computer vision. The OpenCV AI Kit (Oak-D) offers a fast route to market for Vehicle Detection. It provides depth from two stereo cameras and colour information from a single 4K camera in the centre. This allows the camera to recognise the make, model, and number plate of a car meaning it could identify vehicles not belonging to the farm and alert the farmer if they enter the property. This type of sensor could detect both known and unknown vehicles on site which could offer huge benefits to farm security.

Figure 19: Image credit: (OpenCV.AI, 2023)

Oak-D is also capable of facial recognition. This potentially could be active outside of farm working hours, such as from the evening until the morning to detect if they are employees. Although, the camera may struggle with this in low light.

3. The research of the project

Erw Fawr

Sensor 2 - The vehicle on track was originally set to produce alerts at the default period of 6PM through to 6AM. At Erw Fawr, the dairy staff arrive at around 4AM and other farm work occurs later in the evening, so the alerting period has been changed to 10PM through to 4AM.

All other sensors have had no feedback.

During a maintenance visit by Rob Shepherd on the 28th of November 2022, all sensors had at least 90% battery power remaining. This included 1 vehicle detector, 1 gate detector, 1 GPS & 1 quad motion detector.

Sensor 1 - The Infra-Red person detector works well but needed the out of hours shrinking to 1900-0500 to prevent many alarms being generated between 5AM and 6AM.

Sensor 2 - The movement sensor on the Telehandler is working fine but has generated no alarms. It has not been moved (stored indoors) at all between 6PM and 6AM

Sensor 3 - The GPS sensor on the Kubota ATV is currently off site and only occasionally able to transmit to a LoRaWAN gateway. It is being repaired and did not trigger the "Virtual Fence" alarm until it was a long way off site. It would be worth shrinking the virtual fence to allow an early warning alarm.

Sensor 4 - The Gate sensor on the track to the lambing sheds was not working for a lengthy period. The gate had been left open for a few months and it needed a stronger antenna.

Sensor 5 - The vehicle detector was used to pin-point the timing of a potential theft of timber from the forestry site. The plan is to double check those details with Rhodri Owen, the farm manager at Glynllifon to see if the information was received and used by North Wales Police, and if so, how they dealt with the matter. This would be a good example of a discrete and anonymous sensor being used to support the investigation of rural crime.

During a maintenance visit by Rob Shepherd on the 1st of December 2022, both the motion detector on the telehandler and the motion sensor on the dairy store had 95% battery power remaining. The battery was replaced in the sheep yard open/close sensor and there was an ongoing issue with the gateway at Glynllifon which Rob was looking into with Rhodri.

Bodwi

Sensor 1 - The door sensor on the Fuel Tank works well and Ellis Griffiths, the farmer at Bodwi, requested that this be set to alert at any time of day (not just "out of hours") - so he can keep track of fuel being used by staff and contractors.

There have been some errors from the Text Message service which caused a slew of messages – this was a problem at the SMS provider not Pethau and seems to have been a one-off event. Switching to "Telegram" means it is easier to control "mute" high frequency periods of alarms. Telegram is a free software, cloud-based instant messaging service which can be accessed through apps for mobile and desktop platforms.

A new gateway was installed to provide coverage at Bodwi. This allows the land rover and Quad to be used between the two farm sites.

During a maintenance visit by Rob Shepherd on the 29th of November 2022, the gateway was unplugged, plugged in, and re-commissioned with new SIM card. The battery in the Land Rover GPS and the battery in the fuel tank hatch open/close sensor were both replaced and working fine.

Wern

A suitable place for the gate sensor was not found and the device that was selected did not work on site. There is still a question on the configuration of the gateway at Wern. This has since been upgraded by Farming Connect. The plan is to revisit this site and try the sensor again if there is interest.

Moelogan
A suitable site for the vehicle detector was not found, however there is still one sensor available to be used and can be deployed here or at another site. The are some concerns surrounding the gateway coverage at the top of the farm.

During a maintenance visit by Rob Shepherd on the 30th of November 2022, the barn motion sensor, and the GPS on the Quad bike both needed a clean but were working fine and the batteries were replaced in both. The battery in the trailer motion detector was also replaced and working fine. The battery in the Open/Close sensor in the storeroom was still at 95% power and was not replaced.

Attitude Analysis

The first and second attitude assessments have been conducted over Zoom with the focus group attempting to identify behavioural characteristics and attitude of the farmers in relation to the application of LoRaWAN technology. The results from these assessments have been compared with further analysis at the end of the project where all OG members have been asked to re-evaluate their thoughts on the technology. The specialist has been contracted to use methods that allow qualitative data to be measured and analysed via mixed measure and or ANOVA analysis. Attitude and opinions have been measured at the start, middle and end of the project using Likert scales.

It was important to do this as it was possible there would be resistance to using the technology in areas of agriculture. Another important part of the project was to form an operational group (OG) who are naturally interested in using the technology.

This type of analysis is very innovative as it could add a lot of value to the project. It enables the constant flow of feedback throughout the project ensuring that all opinions can be voiced and heard. It also provides valuable insight to how the technology may be received when trialled in other communities and geographical areas.

The results and outcomes from the attitude analysis have been shared in the final project report, and summarised below.

- Participants' attitude to the technology and its potential is extremely supportive, which is positive in terms of adoption of this technology (other factors such as availability and cost effectiveness allowing) (Owen, 2022).

- Review of previous work in this field suggests that positive early attitudes as recorded here, are likely to encourage adoption of the technology (Chuang, 2020) (Bhattacherjee, 2004) as is early farmer involvement in the trialling of the equipment (Kaler, 2019).

- Considering the findings of Smith and Byrne (2017), the rapid development of cost effective and reliable technology to combat the rise in rural crime is extremely important in terms of both farm profitability and the well-being of rural communities (Smith, 2017).

- Some useful initial findings emanate from this small study despite its limitation in terms of budget, timescale and being disrupted by a global pandemic. Future similar studies might

consider how to better measure attitude change, by ensuring more longitudinal evaluation of the same group of participants across the life of the study (Owen, 2022).

4. Strategic relevance

Relevance of the research project for farmers and the farming community

The project aims to further build on the cooperation between the farming community, North Wales Police, and technology experts to solve common problems and bring about a smarter way of working.

At the start of this project the operational group had engaged with PC Dewi Evans who has many years of operational experience within North Wales Police's Rural Crime Team. Based upon his detailed knowledge of rural crime incidents he has identified the areas that LoRaWAN technology could assist in preventing and solving and this was incorporated in the project design following the agreement from the OG.

This trial is already helping the farming community learn more about the capabilities of LoRaWAN technology, and if it is successful as a security solution, it could detect and eventually prevent rural crime. Additionally, linking this technology with agriculture and law enforcement has the potential to help both stakeholders successfully work together for the benefit of their local communities.

If the project is successfully implemented, then the door has been opened for other farmers and family members to diversify by incorporating more technology on farms. The knowledge that is gathered from this project is being shared with the farming community in Wales and will develop a skills base in agriculture that is fit for purpose for the future world. This could increase the number of jobs available within agricultural technology sectors encouraging those with an entrepreneurial flair to venture into this market to create further solutions for current agricultural challenges.

Latest trends in rural crime and farm security

The cost of rural crime dropped by 9.3% in 2021, the second annual fall since the start of the pandemic. Security measures, rural crime initiatives, quieter roads and community vigilance have all played their part in suppressing countryside crime. The first quarter of 2022 shows costs up by over 40% from the same period the previous year. As prices rise, supply chains strain and crime gangs can travel more freely, there is a concern that thieves are already looking to make up for lost time. According to NFU Mutual's recent poll, this concern is also shared by the rural community as 89% of respondents are worried that inflation and the increased cost of living will lead to an increase in rural crime (NFU, 2022).

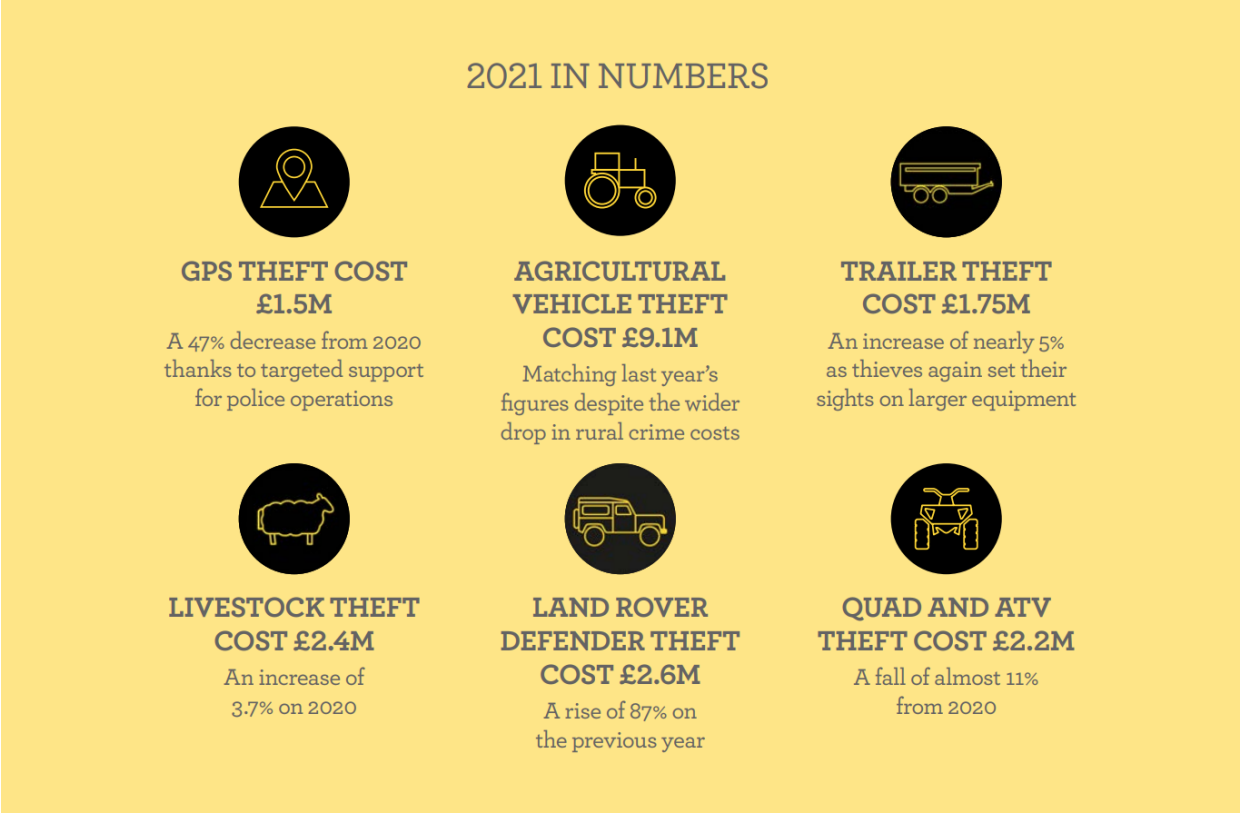

Figure 20: NFU summary of rural crime in 2021

NFU Mutual's rural security expert Bob Henderson and DC Chris Piggott from the National Vehicle Crime Intelligence Service highlight the following smart ways in which farmers can protect themselves against rural crime.

- CESAR mark, etch or indelibly mark farm name and post code onto kit so it's harder to sell on.
- Install CCTV, security lighting and an alarm.
- Fit vehicles with a tracking device and immobiliser. NFU Mutual offers premium discounts when approved security measures are used.
- PIN protect GPS systems and apply manufacturer stickers.
- Fit a fuel tank lock or sensor.
- Join a rural watch or farm watch scheme.
- Use mechanical immobilisers like steering wheel or pedal locks on vehicles.
- Animals are still effective early warning systems. Noise can scare criminals off (NFU, 2022).

After fulfilling and exceeding its primary objectives over an initial 12-month trial, the new post of 'Wales Rural and Wildlife Police Crime Coordinator', Rob Taylor QPM, has received a further three-year commitment from the Welsh Government. The new post has seen several exciting projects and engagement with our rural communities throughout Wales, including a Welsh strategy to tackle farm crime and livestock attacks. The four policing areas of Wales now work together even closer to tackle farm issues, with a crossover of ideas and a training programme at a local farming college to help rural officers fully understand the farming environment and associated problems (NFU, 2022).

5. Collaborations

This trial is bringing people from a variety of backgrounds to collaboratively trial a solution which could help shape the way rural crime is solved in the future. These stakeholders have been collaborating with each other during the project forging lasting relationships between agriculture, technology, and governance to solve common agricultural challenges beyond security. This collaboration of knowledge and combined skills of the Operational Group actors benefit the project.

Dewi Rhys Evans has almost 10 years' service with North Wales Police and is currently on secondment with the Police's 'Future Farm Project' which aims to increase the use of technology on farms to detect and prevent crime. Dewi is committed to reducing crime within agriculture and believes collaboration between North Wales Police, farmers and technical specialists should help to achieve this.

The appointed police, technological, and behavioural specialists have been working with and facilitating the farmers and non-farming OG members to determine what the evaluation process includes and how to define success. The OG believe this approach is best as it is a collaboration of multiple stakeholders using this technology who are best placed to understand and determine if LoRaWAN technology can be usefully applied in a real-world setting.

6. External information and other activities

The strong OG bought together for this project means that the outcomes have been disseminated to many different stakeholders interested in improving farm security. Having four farms that are part of the Farming Connect Demonstration Farm Network means that the project is very well positioned to benefit from the programme's various communication outlets.

For this reason, locating this project on an agricultural college and four current 'Farming Connect' demonstration farms opens the opportunity for demonstration and dissemination.

Other activities

End of Project Attitude Analysis

As at the start and midpoint of the project, Farmers attending the events have been asked to participate in the attitude analysis commissioned by the appointed project specialist. This has been replicated at the end of the project.

Open event at Glynllifon, including mock emergency scenario

The open event held at Glynllifon, which invited OG members and others interested, provided the opportunity for demonstration and dissemination. Mock emergency scenarios were delivered at the event in partnership with North Wales Police. This provided an opportunity for interested parties to visit the farms and receive a demonstration of the technology. This raised the awareness of LoRaWAN technology, helping to break down one of the traditional barriers to LoRaWAN uptake which is a lack of knowledge and familiarity with the technology.

Video content has been recorded from the mock emergency scenarios to create a short video of the event. The video highlights the work that has been achieved during the project to jointly promote LoRaWAN and EIP Wales by being shared on social media and the EIP Wales website. North Wales Police conducted a short farm walk at the event to see how the technology works and give feedback.

Websites & social media
All OG members are active on social media either through professional or personal accounts. They have been posting regular content on these platforms throughout the project which has been raising awareness of the work being done.

Findings Dissemination
It is recommended that sufficient resources are allocated to share the learnings from this project. This could be done by creating videos whilst the sensors in place on farms to show them being used and provide articles for access to information gathered by this project.

7. Summary

- This technology provides an evidence trail which is especially important going forward regarding working with the police for tackling crimes that have taken place.

- The farmer participants' attitude to the technology in this project increased from being neutral to more positive than negative across the life of the project.

- Once a security sensor network has being set up on the farm it takes time to test and refine the system to enable the best performance.

- At the end of year 2, the battery life in most sensors was still at least 90% and any issues found with the technology were minor. It was possible to overcome any issues that arose with the technology.

- Having an IoT security system in place on a farm is likely to be a significant deterrent for any prospective criminals.

- Technology is evolving rapidly and very few farm businesses have any capacity to conduct R&D work despite many being ready to invest time on it.

8. Conclusions

- There is scope for this project to evolve as it has uncovered many new avenues to be explored and is important it does not stop here. It has laid the foundations for LoRaWAN technology to provide better information to improve farming security.

- The technology trialled in this project does work for monitoring and tracking valuable farm assets. Overall, we can conclude that this technology does improve farm security.

- The approach and methodology have worked well overall. The phases of the methodology have enabled each stage of the trial to be assessed, giving success, and learning points from valuable failures. Each stage is important for the subsequent phase to have the best chance of success.

The methodology has enabled lots of questions to be answered but also has raised some new questions for further developing this project.

- It is imperative to give as much time as possible to outdoor based trials of the technology. Due to the short timescale of the project, allowing as much time as possible for the cycle of gathering data, feeding back, and applying changes, will have a greater outcome and impact of any similar project using the same approach.
- Monitoring the attitude towards the use of the technology has proved to be a valuable approach in this project. Participants' attitude to the technology and its potential is extremely supportive, which is positive in terms of adoption of this technology.
- The current trend in rural crime gives further importance to this project. Even if better farm managements solutions are not completely developed from this project, a better understanding of the technology and closer collaboration between farmers and IT technical expertise to further develop the emerging Agri-tech sector in Wales, is a big step forward. The OG should look to benefit from government funding provided for tackling rural crime in the future.

9. Recommendations

- This EIP project has little artificial intelligence or machine learning elements. As an evolution of this system, it would be an improvement if the sensors could also include AI and learning. For example, person detection and number plate recognition.

- The evidence trail provided by this technology could be further bolstered by blockchain or enforcement authority having an independent network to function as verification.

- Ongoing investigation into the cost of the technology after the project needs to be done. The technology must be viable going forward and this can be done by assessing whether it meets the farmer needs for this cost. Once the project has determined the functionality and usefulness of the IOT for Farm Security, the ongoing cost would need to be analysed to see if it is outweighed by the benefits.

- This system could be commercialised and rolled out to the wider industry. The step-by-step approach of trialling the technology, developing the application, and monitoring the attitude of the users, makes sense and one that can be replicated for other technologies in farming benefiting the wider industry.

- If this project is developed further, it is recommended that monitoring users' attitude towards the technology is included as part of the methodology as this is a valuable part of the approach. Attitude analysis would provide learning outcomes that could help steer the project to improve the probability of technology adoption by users.

- There could be an opportunity for developing an approved status for farms adopting this technology which may also lead to these farms having discounts on their insurance premiums from the like of NFU Mutual.

Acknowledgements

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- Dewi Rhys Evans Police Constable, North Wales Police
- Geraint Hughes - Lafan Consultancy (project Innovation Broker)
- EIP Wales

References

Bhattacherjee, A. &. (2004). Understanding changes in belief and attitude toward information technology usage: A theoretical model and longitudinal test. *MIS quarterly*, 229-254.

Chuang, J. H. (2020). Farmers' knowledge, attitude, and adoption of smart agriculture technology in Taiwan. *International Journal of Environmental Research and Public Health*, 17-19.

Farming Connect. (2023). *Demonstration Network Site Locations*. Retrieved from Business Wales: https://businesswales.gov.wales/farmingconnect/our-farms/projects

Kaler, J. &. (2019). Technology adoption on farms: Using Normalisation Process Theory to understand sheep farmers' attitudes and behaviours in relation to using precision technology in flock management. *Preventive Veterinary Medicine*, 170.

NFU. (2022). *Rural Crime Report 2022*. Retrieved from NFU Mutual: https://www.nfumutual.co.uk/globalassets/farming/rural-crime/nfu-mutual-rural-crime-report-202222.pdf

OpenCV.AI. (2023). *OAK—D.* Retrieved from OpenCV.AI Web Site: https://www.opencv.ai/

Owen, W. (2022). *Using IOT technology to improve security on farms.* Organisational Development Consultants.

Smith, K. &. (2017). Farm crime in England and Wales: A preliminary scoping study examining farmer attitudes. *International Journal of Rural Criminology, v3*, 191-223.