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 1 Report
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1

Contents

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 assets 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.

1

Glynllyfon 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.
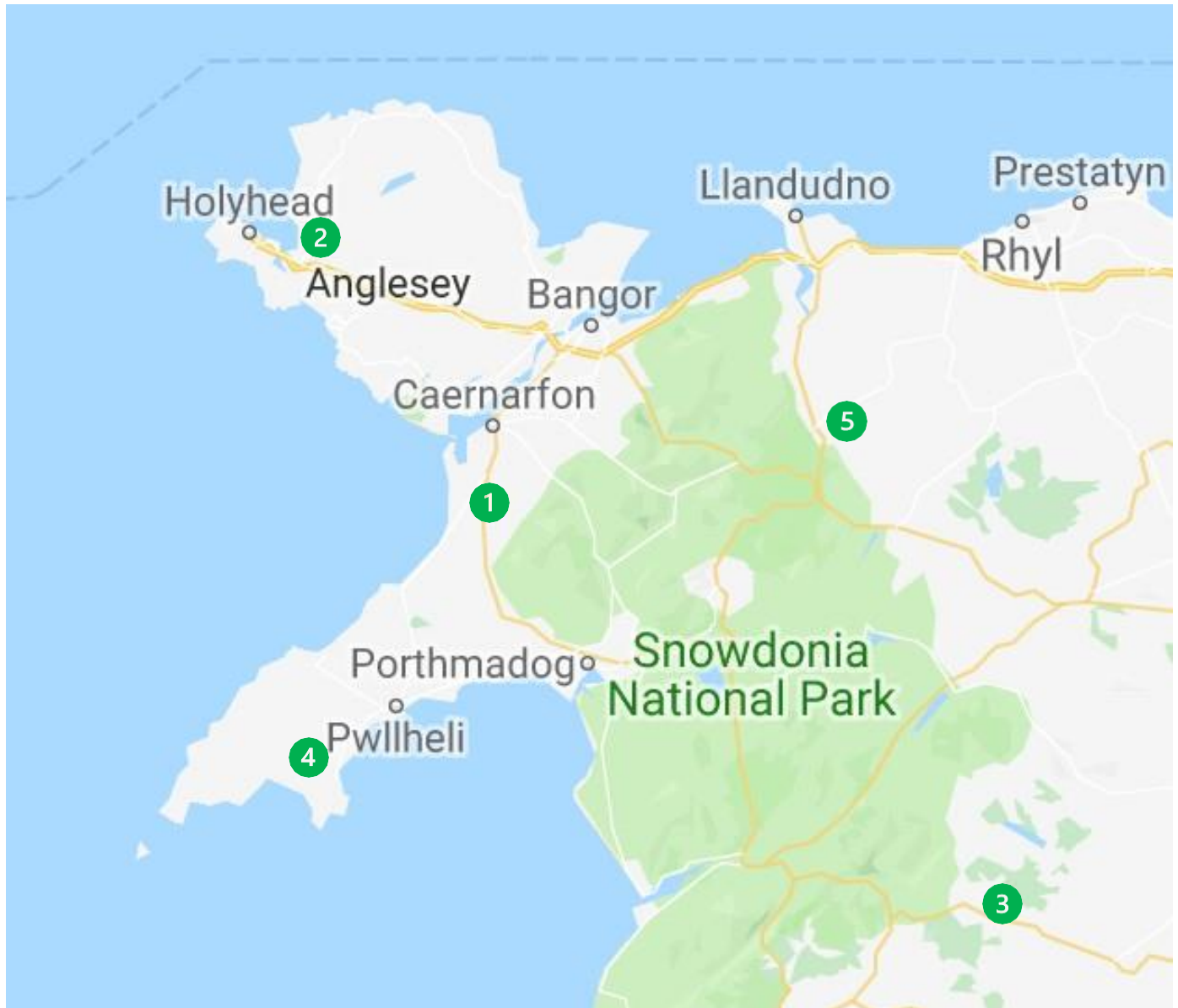
Map showing farm locations. Farms are numbered above the map.

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 trailing 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.

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Project Design:
The design of the project proposes to follow five phases. 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
- Mock emergency scenario will be simulated on each farm to evaluate sensors and systems.
- Mock emergency scenario analysis
- Film and edited 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 Original Plan

The project currently is in Phase 3 with the sensor testing and attitude analysis. This is a little bit behind schedule as this was in the project design to be at the end of 2021. There is a risk that the project might not finish by May 2022, unless an extension is possible. Further details can be found in the 'Research Findings' section.

The original plan was to install fifteen sensors, three on each farm. Fortunately, twenty sensors have now been installed on the five farms, with Erw Fawr and Glynllifon having five each, and Moelogan having four installed. This should provide 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 time of application and has gone ahead to research them - this is a sign ow how quickly this sector is changing. In particular, the prototype vehicle detector by EvoMetric that is being trialled at Glynllifon.

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

Open close sensor on gate post

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

External view of Dairy Store & Medicine Storage

Passive Infra-Red Movement Sensor in Dairy and medicine store

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

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Digital Matter Guppy Movement Sensor in telehandler

Telehandler Cabin with movement sensor at top

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

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

Gate open close sensor on gate

Open close sensor on gate post

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5. **Sensor**: EvoMetric – Prototype vehicle detector
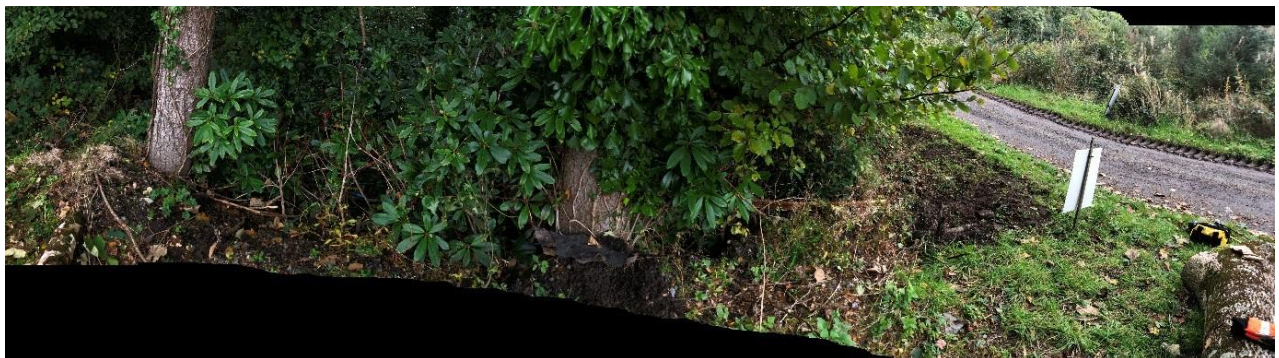   **Location:** Farm track to forestry and further farm fields
   Details: Buried alongside the track with the transmitter in the hedgerow. Only alerts at weekends, 00:00-23:59

Prototype vehicle detector buried alongside farm track

Prototype vehicle detector transmitter in hedgerow

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

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

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

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 further 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.

Image credit: OpenCV.ai

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.

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 – There has been no feedback.

Glynllifon
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.

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" for 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.

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 use and can be deployed here or at another site. The are some concerns surrounding the gateway coverage at the top of the farm.

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 will be compared with further analysis at the end of the project where all OG members will be 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 of the start and mid points of the project using Likert scales.

It was important do this as it is 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 will need to be shared in the final project report.

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 will be 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 latest trends in rural crime show an overall fall in rural theft during lockdown, the downside was that when crime did occur, incidents happened on a larger scale, using new tactics to overcome security.

NFU Mutual research found that gangs were operating in rural areas and that theft of Global Positioning Systems (GPS) increased across the globe. Tractor GPS have become the rural thieves' top target, as well as high value quad bikes and ATVs. Gangs have commonly been found using silent electric scooters to steal farmers' systems and escape the farm site along country lanes at high speed. GPS systems are an essential part ofmodern farming, and without these, farmers are left unable to work, delaying such time sensitive activities such as harvesting.

From its claim's statistics, NFU Mutual estimates that rural theft cost the UK £43.3m in 2020, a 20% decrease on the previous year. While the number of theft claims went down, the average cost rose to

£4,425, up from £4,128 in 2019. Lockdown movement restrictions, police rural crime teams, and improved farm security helped to curb crime over the pandemic, with most parts of the UK seeing an overall decrease in cost. The cost of agricultural vehicle theft claims reported to NFU Mutual remained high at £9.1m. Agricultural vehicle theft saw only a 2% drop in cost from 2019, still well above 2018's total of £7.4m. While livestock theft decreased by 25% to an estimated £2.3m, the Southwest region saw the cost of rustling rise by over a third. (NFU Rural Crime Report, 2021)

2020 IN NUMBERS

GPS THEFT COST £2.9M
almost twice last year's figure

AGRICULTURAL VEHICLE THEFT COST £9.1M
a 2% reduction in cost, and an 8% reduction in claims

QUAD AND ATV THEFT COST £2.5M
a decrease of nearly 18%, returning to 2018 levels

LIVESTOCK THEFT COST £2.3M
a reduction of 25%, but up by over a third in the South West

The cost of rural theft around the UK

Region or country	Cost in 2019	Cost in 2020	% Change from 2019
East	£8.1m	£6.4m	−20.5%
Midlands	£10.6m	£7.9m	−25.3%
North East	£8.6m	£7.8m	−9.7%
North West	£3.5m	£3.7m	3.3%
Northern Ireland	£3.3m	£2.1m	−36.9%
Scotland	£2.3m	£1.7m	−25.0%
South East	£8.7m	£7.1m	−18.6%
South West	£6.6m	£5.1m	−23.7%
Wales	£2.6m	£1.6m	−39.4%
Grand Total	£54.3m	£43.3m	−20.3%

* Estimates based on NFU Mutual claims statistics, costs rounded to the nearest £100,000.

Collaborations

This trial is bringing people from a variety of backgrounds to collaboratively trial a solution which could help shape the way future rural crime is solved. These stakeholders have been collaborating with each other during project so far 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

External information and other activities

The strong OG bought together for this application means that the outcomes will be 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 will need to be replicated at the end of the project.

Mock emergency scenario
To further evaluate the effectiveness of the sensors it would be good to have a mock scenario on farms. If this is not possible then and alternative would be to ask North Wales Police to do a farm walk through to see how it works and give feedback. However, NWP resources are maybe too stretched as it is. The mock emergency scenario will be filmed, edited, and translated to create a short video of the event. The video will be used to highlight the work that has been achieved during the project and will jointly promote LoRaWAN and EIP Wales being shared on social media and the EIP Wales website.

Open event at Glynllifon
An open event inviting OG members and others interested would give the opportunity for demonstration and dissemination. During the proposed project, the OG plan to hold open days at each of the five farms that participate in the trial. These will be delivered by Farming Connect and EIP Wales and run in conjunction with North Wales Police and provide an opportunity for interested parties to visit the farms and receive a demonstration of the technology. This will raise awareness of LoRaWAN technology and EIP Wales, helping to break down one of the traditional barriers to LoRaWAN uptake which is a lack of knowledge and familiarity with the technology.

Websites & social media
All OG members are active on social media either through professional or personal accounts. They are posting regular content on these platforms throughout the project which will consistently raise 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 making the Glynllifon event open to all who are interested, 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.

References

Farming Connect Demonstration Sites. https://businesswales.gov.wales/farmingconnect/our-farms/projects

NFU Rural Crime Report 2021. https://www.nfumutual.co.uk/globalassets/farming/rural-crime/2021/rural-crime-report-2021.pdf