SmartRural Use Cases

June 2021

Improving environmental outcomes using Smart Sensor Technology

Like many sectors, agriculture is coming under increasing pressure to modify its practices and contribute to tackling the Climate Emergency – all the while guaranteeing sustainable food production. Targeted use of sensors and internet of things (IoT) technologies has the potential to support this transition, both in providing data to inform and quantify the impact of best practice and to develop new ways of working.

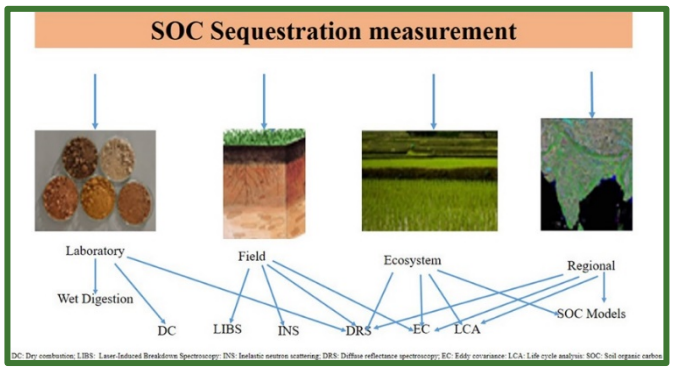
The Climate Emergency requires that our food and farming systems must rapidly adapt to new methods of working that are leaner, greener and data driven. Critically, there is a requirement that Scottish agriculture positively steps up to the climate challenge and contributes towards our nation's ambitious targets of reducing GHG emissions by 75% by 2030 and become net-zero by 2045.

Without the adoption of digital tools and smart use of data, Scottish agriculture will not be able to act as quickly or as effectively in modifying systems to become more efficient and climate friendly. Scotland is already lagging other nations in exploring the potential of LoRaWAN sensor systems for improving farming enterprises. Potential areas where sensor technologies can be used to support environmental outcomes include:

Livestock Health – Reduction in GHG through demonstrable improvements in livestock health as directed by sensor data points. Examples include – monitoring of vaccine fridges to ensure efficacy; monitoring of housing conditions to alert to conditions that might lead to negative health outcomes; monitoring of water usage to alert to health conditions; and monitoring of movement via GPS to provide mobility insights.

Nutrient Management – Significant GHG abatement opportunities are available through better, more targeted use of nitrogenous fertilisers. Data farm soil temperature and moisture sensors can be used to inform application timings, which offer a clear and substantive opportunity for improvements in nutrient uptake and a reduction in losses to the environment.

Reducing Food Losses – Limiting food losses within primary agriculture, associated with poor management practices, offers a significant opportunity to reduce emissions attributable to each unit of output. LoRaWAN sensors monitoring building and product parameters are currently active in grain and potato stores, enabling early alerts to temperature anomalies and the elevated risk of spoilage.



Improvement in Grazing Management – There is a significant and realisable opportunity to use technology to improve grassland management in livestock systems – improving the ability of soils to sequestrate and store carbon as well as improving cattle performance.

Monitoring & Management of Farm Woodland – Agroforestry is identified in the Scottish Government's Climate Change Plan as an area where expansion and an improvement in the management of this resource could lead to substantially improved environmental outcomes. Sensor technologies offer opportunities for improved data quality and the unlocking of better management insight, and decision making with respect to productivity, efficiency, and the carbon sequestration potential of farm woodland.

Monitoring and managing your watercourses is an increasingly important part of farming's role in land stewardship – flood management plays a major part

Flooding is an issue affecting not just farming, but the wider economy as a whole and is estimated to cost the UK £1.4bn per annum. Understanding how the rivers and streams around you behave by monitoring their levels in response to rainfall, can help you put in place mitigating measures, help avoid losses, and avoid putting people and livestock at risk. It can also underpin your Natural Capital management plan.

Because water courses link us to those upstream and downstream of where we farm it is important to understand our part in their management and how that can affect others. Avoiding a problem for ourselves often passes it on and magnifies this for others. Not forgetting that the data most useful to you and to get as much warning as possible, might come from land upstream of yours – so working with your neighbours is key.

Where you have infrastructure such as road, rail or canals crossing your land, you may also have the liability for ensuring that gulleys and culverts are functioning as they should. Monitoring them and being able to spot "abnormal" behaviour is a key part of delivering that responsibility.

With the removal of the existing subsidy schemes and the move towards Natural Capital, it will pay to understand how your land and rivers affect the wider catchment area, as part of your duty to manage the land for the Public Good. As prevention of flooding is obviously the best policy, there may even be opportunities to use the data you gather to justify putting in place Natural Flood Management measures on your land that will earn credits within any Natural Capital schemes. It will also feed into how you manage water quality, another important aspect of Natural Capital.

Whilst SEPA has a network of over 500 gauging stations across Scotland, they are placed well down stream where the flow is greater and normally close to the asset/town at risk. There is considerable lag between the rain falling on your land and the impact being seen on these gauges. To give communities as much warning as possible, your data will again be invaluable.

All the above mean that it is not just a passing interest to monitor the level of rivers and streams as they cross your land. It is important financially, for safety and for the environment. A simple way of doing this is to automate the data gathering by installing a sensor, which is connected to the internet and delivers data and alarms to your phone and PC. Link this to rainfall data and you start to build a picture of how your land responds and what you can do to improve matters for yourself and your neighbours.

Woodland monitoring using LoRaWAN Sensors

As Scotland looks to increase its forest inventory to meet climate change ambitions, an opportunity exists to use LoRaWAN technology and smart sensors to capture data that will support management decisions and allow a better understanding of this resource for policy makers.

As we head towards Net Zero, the Scottish Government's Climate Change Plan outlines the need for more woodland, with £150 million in incentives being provided to support landowners in forestry creation. This will underpin the ambition to reduce emissions and sequester carbon with 18,000ha of new woodlands being created annually by 2024. Furthermore, The Woodland Carbon Code will establish a standard for the verification of carbon credits through the planting of new woodland.

Internet of Things (IoT) devices communicating over LoRaWAN have the potential to help farmers, landowners and forestry operators benefit from improved woodland monitoring, collecting much needed data to support decision making. Insights derived from sensors located within forests will help support policy makers by understanding how climate change is impacting on tree growth as well as facilitating a better understanding about our forest resources as a store of carbon.

At present, many of the measurement parameters required by forest owners and managers need to be undertaken manually. Field visits are costly, demanding significant manual effort which means that obtaining regular measurements is difficult. Using sensor technology there is an opportunity to automate a number of recording tasks, saving time, money and providing more timely and accurate data that can be used to support management efforts.

Once such innovation is LoRaWAN enabled, dendrometers can allow forest managers to monitor growth rates in their plantations without manual intervention. The principal use of dendrometers is to capture measurement attributes that can be used to derive wood volume.

Coupled with weather data from wireless weather stations and data from soil temperature and moisture sensors, valuable insights into growth response to local climatic conditions can be gleaned. Beyond capturing tree and environmental data, LoRaWAN sensors can be used to deliver other use cases within the forestry sector, including site security, lone worker safety and the tracking of machinery and other valuable assets.

Monitoring soil temp to optimise spring fertiliser application

To make best use of nutrients on farm and reduce harmful emissions, fertilisers needs to be better targeted to improve crop uptake, reduce waste, and improve profits. A range of benefits come from using soil temperature sensors to gather data on your farm. Measuring soil temperature using a sensor is the most accurate way of deciding when to apply spring nitrogen. As a guide, the optimum time for the first fertiliser application is when the soil temperature at 10cm deep reaches 4- 5°C for at least four-days.

It is widely recognised that significant opportunities exist for emissions abatement and environmental protection through improved utilisation of fertilisers in Scottish agriculture. Research shows that a significant proportion of the nitrogen applied as synthetic or organic fertiliser is wasted through leaching, denitrification and volatilisation.

A report by N. Lampkin et al. (2019) states that almost 50% of Scottish nitrogen applications taking place during 2017 (equivalent to an average of 92kg of nitrogen per hectare) were not taken up by the target crop and as a result were lost to the environment. In addition to contributing to greenhouse gasses, there is the serious issue of nitrate losses to watercourses; elevated nitrate levels contribute to eutrophication of waterbodies and pose a risk to human health.

T Sum 200. Using T-sum 200 (when cumulative positive air temperatures from 1st January reach 200) to assess the right time to apply nitrogen is a useful guide but it is more accurate to measure soil temp at root depth on your own farm. The T-sum can be out of sync with what is happening in the soil, especially with mild winters. It is important to recognise each season varies so regular soil temp monitoring is important.

The focus should be on getting nitrogen into the soil at the time when crop roots are able to respond. If the application is too early, there's a risk of run off or leaching, and if it's too late, the opportunity to optimise crop growth is lost. Therefore, nitrogen should be first applied when crop growth starts, and ground conditions allow spreading without soil damage – best determined by soil temperature.

The addition of a very small number of soil temp sensors across the major farm soil types or in different aspects (especially South and South West compared with North and North East laying fields) can further refine decision making.

Why is soil temperature important?
Temperature affects several processes in soil and soil ecosystem, namely:

- It directly affects plant growth and seed germination.
- Soil temp influences aeration, soil moisture content, and the availability of plant nutrients.
- Vegetative cover. A bare soil quickly absorbs heat, becomes hot during the summer, and becomes cold during winter.
- Organisms within the soil thrive at different temperatures.
- Understanding and monitoring soil temp allows you to quantify early and late seasons.

Monitoring your silage effluent tank levels regularly is not just common sense it is a legal requirement

Under the Control of Pollution Regulations farmers must keep all effluent collection channels and drains clear of blockages and check effluent tank levels on a frequent basis when effluent is being produced, and regularly throughout the year. This is because the effluent can have an extremely negative impact on water courses and water supply quality.

Failing to comply with the regulations can result in costly fines and have an impact on business. Additionally, as Natural Capital comes to dominate the way that farm subsidies are calculated, the importance of protecting the environment and being able to evidence what you are doing becomes even more important, as it will directly affect your income.

Effluent and slurry systems can produce noxious gases, so meeting the regulatory requirement of checking levels "on a frequent basis" carries a health hazard for personnel, which must be managed.

Whilst effluent systems are designed to be separate from any rainwater runoff, torrential rain can get past even well-designed systems. In these circumstances your attention will likely be focused on the highly visible effects of the rain, rather than the effect it is having on effluent levels.

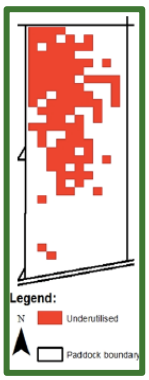
All the above, mean that monitoring the level of your silage effluent tanks is not just desirable, nor is it simply Regulatory Compliance but is important financially, for safety and for the environment. A simple way of doing this is to automate the data gathering by installing a sensor, which is connected to the internet and delivers data and alarms to your phone and PC.

Here's an example installed in a tank to monitor the level. In this case it did pick up an unexpected rise during torrential rain, helping prevent a loss of containment and prompting work to identify and prevent future rainwater ingress.

Monitoring your livestock's location, behaviour and state reduces costs, increases revenue, and gives peace of mind

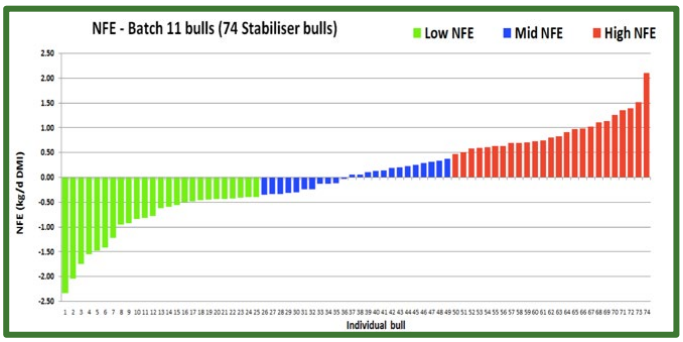
A range of benefits come from using sensors to gather data on your individual livestock. These include management and timing of grazing rotations, understanding grazing utilisation, detection of drinking times/frequency, stock theft, and stressors affecting welfare and performance. There is advantage in gathering, otherwise hard to obtain, management information and comfort from knowing that there is no adverse event(s) occurring. These sensors can support applications around market compliance and assurance, biosecurity, (increasingly important) social license outcomes, and enable on-farm management insight and research.

Good animal husbandry and stockmanship revolve around valuing and acting on certain information about livestock. The critical information that producers are most interested in is the location (where is my animal?), the behaviour (what is it doing?) and its state (is it in a "normal" biological state or is there a problem?). By tradition this would have been done by dedicating time to observing the animals and using years of experience to spot when things are wrong. That time and those skills are an increasingly rare commodity. However, automating the gathering of appropriate data and simple interpretation can make up for this and make your farming operations more profitable, sustainable, environmentally friendly and can promote animal welfare.



Data can be gathered several ways, but the most common is such that the data and the information generated answers one or more of the three critical questions above, in such a way that action can be taken, where required. An example – if you want to know whether your cattle are uniformly grazing your pasture, to know if areas need improvement, it is no use if all you see is where they are now; what you need to know is where they spend their time and what they are doing in each location during that time that way you can identify underutilised areas for further investigation. For this GPS trackers and accelerometers (integrated within, in a single unit) can be used to gather the data and feed the software.

A critical area for livestock is to be able to manage the individual rather than the average. Identifying the best and the worst performers through objective data gathering is immensely powerful and has been demonstrated to great effect on dairy farms. There is no reason why this cannot be achieved on more extensive livestock units, even whilst grazing. Using EID, tracker/accelerometers allow you to build a picture of the individual animal to identify abnormal behavior and the impact of management decisions, and critically, provide an early indication of health problems before they become clinically significant.



Animal health and monitoring livestock buildings

The continued health and well-being of livestock is at the forefront of any livestock farmer's mind, and smart LoRaWAN sensors are one of the best ways to help ensure housed animals are performing at their full potential.

Scottish livestock farmers have much to gain from the application of smart digital sensors – these IoT (Internet of Things) devices are a great tool to ensure optimal performance of livestock during housing. Time is limited on a busy farm so relying on people to observe changes in the housed environment and in animal welfare and performance, beyond the obvious or clinical, is increasingly difficult. Having access to smart sensors can help monitor a range of parameters of housed livestock in real time, allowing the early detection of any potential problem. Notification can also be sent to more than one person to ensure prompt action. It is also a reliable route to gather vital information to help the farm's vet in assessing any potential livestock health issue.

Sensors for monitoring livestock buildings

There is a range of simple cost-effective smart sensors which help farmers monitor their livestock buildings in real time, all equipped to send alerts to a mobile phone or dashboard if something is happening beyond the normal range.

- Temperature and humidity monitoring
- Light (Lux) monitoring
- Air quality – monitoring ammonia (NH_3) and carbon dioxide (CO_2) levels
- Water trough monitoring
- Gates /doors closure and security monitoring

Benefits of monitoring livestock buildings

- Early warning of potential animal health risks
- Improved animal welfare; performance and productivity
- Reduced use of medication, particularly antibiotics
- Reduced production costs – leading to improved margins
- Alerts to warn if water troughs are either overflowing or blocked
- Improved animal efficiency leading to less waste, all contributing to lower GHG emissions
- Importantly, saving valuable time for farmers.

Early identification of the risk of pneumonia at housing

Calf pneumonia is one of the major causes of health problems in beef and dairy youngstock. Early intervention is critical to prevent permanent lung damage which has lifelong effects on health and performance. Research has shown infected calves lose an estimated £43-£84 per head, through increased vet and medical costs, feed, extra labour and reduced weight gains. Monitoring the temperature and humidity in livestock sheds, particularly in autumn / early winter, is a useful indicator of the environmental risk associated with pneumonia infection. Good ventilation and building design are critical for removing pathogens, ammonia, and excess humidity.

Contribution to Climate Challenge

The use of a range of sensors in livestock buildings help farmers better manage the housed environment which in turn contributes to more efficient livestock production. Efficient production demands that animals remain healthy, which supports reproductive performance, lowers veterinary costs and antibiotic usage, and ensures livestock are able to exploit their genetic potential – this is good for the farm, the supply chain and helps mitigate against harmful GHG emissions.

Measuring light levels

The quality and duration of natural light varies throughout the year. Research has shown that light influences reproduction efficiency, feed intake, behaviour, and performance. Dependent on building design, there can be benefit in automatically monitoring light levels and adjusting timing and brightness of artificial lighting, via robust farm sensors.

Low Cost Sensors Keeping Farm Vaccines Effective

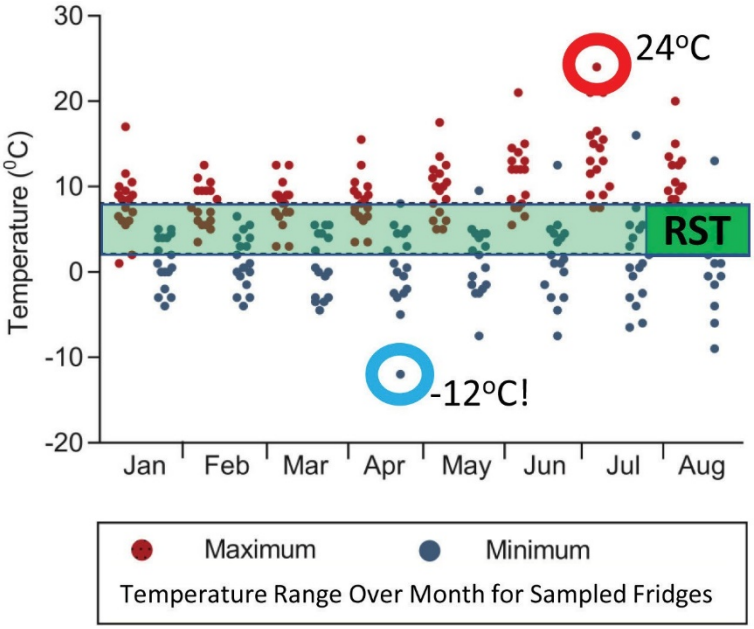
The economic impact of sub-optimal health and welfare in livestock is huge and costs the industry millions of pounds each year. With the drive to reduce the use of antibiotics on livestock of all types, vaccines are increasingly being used on farm. Storing these vaccines correctly is essential to maintaining their effectiveness.

Vaccines vary, but they generally require a storage facility that maintains temperature in the range of 2-8°C, the Recommended Storage Temperature (RST). Storage at temperatures outside this range can markedly impact the effectiveness of the vaccine, meaning that both the value of the vaccine is wasted but, more importantly, the animal to which it is administered is at risk because the vaccine may have no positive effect.

Given the above, it is important to understand both the efficiency of the farm's on-site storage at maintaining the required temperature range, and that of the vaccine itself.

Whilst some vaccines are kept by the vets at their practice and deployed by them when required, a significant number of farms store their own vaccines on site.

This is commonly done in domestic specification fridges, which have no thermostatic controls, and can be highly influenced by the conditions around them.



Work by PD Williams & G Paixão (*1) found ina study of fridges on UK farms, that the majority would have failed to keep the temperature within the RST.

It's not just a problem of overheating, the study recorded a fridge with an internal temperature of -12°C, which would have had severe effects onthe vaccine.

Because domestic specification fridges do not have sophisticated temperature control systems and do not display internal temperatures, farmers can be unaware of the problem and may only suspect an issue when the animals start to suffer from the ailments that the vaccine should have protected them from.

Deploying a standard temperature and humidity sensor in the fridge would feed data back to an app that monitors the fridge's internal temperature. If temperatures recorded move outside the recommended range, an alert would be sent.

Using this simple, low-cost, sensor would give piece of mind that vaccines are kept in optimal conditions and remain effective.

Insulation material used in fridges does not affect the workings of the sensor device. The fridge sensor shown (right), successfully transmitted through the stone walls of the barn and over a hill to the base station.

(*1) Williams, P.D., Paixão, G. On-farm storage of livestock vaccines may be a risk to vaccine efficacy: a study of the performance of on-farm refrigerators to maintain the correct storage temperature. BMC Vet Res 14, 136 (2018). https://doi.org/10.1186/s12917-018-1450-z

Have confidence your livestock remains on the right side of the electric fence

Whatever livestock you own, keeping them where they should be, and knowing that they stay there is vital. Often, it's not only important to you, but also to your neighbours, and even more so if your land is adjacent to a road or railway line. Livestock owners have a duty to ensure fencing is stock-proof and maintained in this manner.

Drivers for farmers include managing livestock performance, animal health and welfare, management time and avoiding disasters:

- Ensuring that animals don't break out and damage crops, escape onto a road, neighbouring land, or indeed anywhere they shouldn't be
- Maintaining control of flock/herd, correct grazing
- Removal of need to check fencing 'just in case'

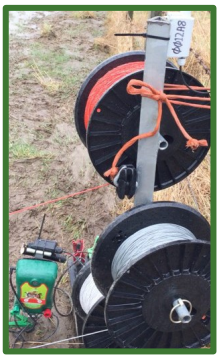
Given the above, it is important to have systems that:

- Alert farm workers to failure of the fencing due to grounding or breaking of the wire
- Show the state of the battery supplying the shock unit

When livestock is on grass or forage crops, they are often strip grazed, using movable electric fencing to keep the herd or flock in the right area of the field for optimum grazing.

Electric fencing is only effective when the battery is suitably charged and the discharge wires are not grounded, through foliage, branches resting on the wire, or the fence falling over. Similarly, a broken wire can mean that the system no longer functions.

In all cases, the malfunction is only detected when someone checks the fence or livestock is seen wandering in areas where they should not be – and this can include the public highway with all the liability ramifications this entails.



SmartRural's solution offers farmers and landowners peace of mind by deploying a combination of low-cost fence monitoring devices.

The first simply monitors the state of charge of the battery, which works whether or not a solar panel is used for topping up the charge.

The second monitors the discharge wire to monitor the 'zap' - or the lack of it.

Both tie into a simple app that alerts you when the system needs your attentionhelping keep the livestock where it is meant to be.

Avoid livestock stress from undetected water supply failure

If livestock cannot access adequate drinking water then productivity is negatively impacted, whether in daily liveweight gain, milk yield or health. Equally, when a watertrough is damaged and flooding occurs, the resulting loss in bedding and time wasted can be significant.

Quality Control and Assurance Schemes such as QMS's Livestock QA are highly valuable in the Scottish red meat sector. Schemes like these are explicit in their guidance on assuring that stock have access to water; water troughs are functional; and contingency plans are in place in the event of failure in water supply.

Given the above, it is important to have systems that:

- Alert farm workers to failure of the water trough feed system or its level control; and
- Provide automated record keeping of responding to such reduced welfare conditions.

No matter what livestock you are dealing with, and whether they are kept in or outdoors, the need for a consistent drinking water supply is a constant across all sectors. Effort invested in the optimization of dry matter intake can be completely undermined by a failure to maintain water intake. Checking that these systems are working, and that water levels are where they should be, forms an important part of the daily 'just in case' checks on a farm.

For outdoor grazing, SEPA is actively discouraging the use of natural water courses due to poaching and sediment displacement into the water. This is resulting in an increase in the numbers of remote water troughs being used and requiring checks. The time consumed by these checks is a drain on farm time and resource.

Maintaining consistent records to meet standards and market outlet requirements can be onerous. An automated system to provide evidence when required is beneficial in terms of consistency and timesaved.

The SmartRural solution is to deploy simple sensors in the water trough. For example, one sits off the bottom, but below the normal working water level. These devices detect if they are sitting in water (all is good) or if water is not present and indicating that the level has dropped, and something is wrong.

If a 'water is not present' signal is detected, the software triggers one or more alarms, identifying the trough's location and notifying the recipient(s) that intervention is required.

Records will show when the system was operating normally and the response to a 'water is not present' signal, providing evidence of good management and animal husbandry.

Manage ammonia emissions with real data

The advent of cost-effective sensor solutions to monitor levels of ammonia in near real-time means farmers can now make more informed decisions to reduce these emissions and demonstrate practical impacts to regulators and supply chains.

Ammonia (NH_3) is a significant air pollutant that can have a serious impact upon the health and performance of both humans and animals, as well as being deleterious to the environment. Excess environmental ammonia is linked to adverse health conditions in livestock which impacts productivity and GHG emissions intensity.

Agriculture dominates the ammonia emissions inventory, accounting for around 92% of all emissions in Scotland. Importantly, ammonia emissions have not reduced in line with other air pollutants and the UK is legally committed under the UNECE Gothenburg Protocol and the National Emissions Ceilings Directive to reduce ammonia emission by 16% (compared to 2005 levels) by 2030.

Most of Scotland's agricultural ammonia emissions come from livestock manures in animal housing (especially intensive pig and poultry operations) and stores, and when manures and nitrogen fertilisers are applied to land. Moving forward, it is anticipated that greater pressure will come to bear upon agriculture from government and regulators to mitigate ammonia emissions. Whilst much good work has been done in the pig and poultry sectors to mitigate ammonia emissions by introducing new technologies, improving building design and implementing new management practices, much more can be done using real data and insights to better target interventions. NH_3 levels can be linked to many variables, including building and manure storage structure, management practices, animal age, stocking density, outdoor temperature, ventilation control, time of day, weather and season.

In addition to negative environmental impacts, elevated levels of ammonia in indoor animal housing systems can have a deleterious effect on the health of livestock and workers. Whilst low levels of NH_3 will have limited impact upon animal (and human) health, higher concentrations (50ppm or more) can reduce growth rates, reduce bacterial clearance from the lungs, exacerbate nasal turbinate lesions in pigs infected with bordetella bronchiseptica and may influence the course of infectious diseases.

To ensure any effort to reduce ammonia emissions is of the right scale and targeted appropriately it is important to have access to data on emissions within buildings and to understand how these vary over time and with different regimes. To date, the collection of data on ammonia levels has been cumbersome and expensive. LoRaWAN sensors offer pig and poultry producers the opportunity to cost effectively monitor NH_3 and a host of other environmental parameters that have an impact upon health, welfare, productivity and environmental impact.

Having insights into the levels of ammonia being Generated and patterns in the data will ensure that pig and poultry producers are able to put in place mitigation measures that are appropriate in scale and cost and, importantly based on real data.

Avoiding crop waste through effective grain storage monitoring

Storing grain effectively is critical to ensuring that quality is maintained, reducing the risk of crop rejection.

Methods of storage include silos, bins, and flat stores, but in all cases the temperature of the stored grain needs to be monitored to prevent deterioration or contamination by insects and mites, sprouting or fungi growth.

Combinable crops such as wheat, barley and oilseed rape have varying storage requirements depending on their market destination. Malting barley, for example, should be stored at above 10°C to prevent secondary dormancy.

Quality assurance (QA) and food safety requirements are becoming increasingly stringent, requiring regular temperature monitoring of stored grain. Failure to comply could lead to a rejection or even a claim.

Anecdotal evidence suggests many farms store grain with no or limited grain monitoring equipment.

The onset of potential problems is detected by monitoring the grain temperature in the core of the heap and at other points, signaling the requirement for ventilation, cooling, and agitation to remove the risk.

Whilst most modern grain silos come with preinstalled systems for monitoring the stored grain and taking action, many flat stores by their very nature do not.

Grain heaps tend to be in the order of 6-7m in height, so probes are inserted into the heap once formed, to a depth of around 2.5-3m. The signal from the probes is monitored along with ambient conditions and software used to trigger alarms and notifications.

Most commercially available solutions use wired probes, which are highly prone to cable damage.

SmartRural has identified a solution that comes with a choice of probe lengths (1.5m & 3m).

As well as monitoring the temperature at probe depth, the device also reports ambient temperature and humidity, which helps support other decisions in the management of the stored crop.

The software will trigger alarms (to limits set by the farmer) and populate a report suitable for Scottish Quality Crops and other buyer QA purposes.

Water is a valuable resource and making maximum use of it and avoiding waste are high priority issues for farming

Water is a critical part of all forms of farming, but in some regions and for some crops rainfall or its timing is not sufficient to optimise yields, therefore, some form of irrigation is required. Most agricultural irrigation systems fit into one of two broad categories: sprinkler irrigation and micro-irrigation. Both forms can benefit from enhanced monitoring of equipment and growing medium to enhance efficiency and guard against damage and detrimental effects of malfunctions.

Sprinkler irrigation systems used in farming include centre pivot, linear move, traveling gun, permanent set, and solid set. Micro-irrigation systems include drip (or trickle) irrigation and micro-sprinklers. All these systems are there to deliver water to the crop (and in some cases carry feed and nutrients too) to optimise soil moisture and growth. Whilst at times water feels like an overly abundant resource when it is raining, run off, percolation, drainage and evaporation mean that it's not always available when or where we need it. Hence the value in irrigation. This starts with the water supply, which can be from the mains (usually metered), via abstraction (by permit) or rainwater harvesting. All of these have a cost and part of the return from proper management of irrigation is cost reduction.

The ongoing move to base farm payments schemes on Natural Capital, Climate Change mitigation and other Public Goods brings ever increasing focus on how farmers manage water on their land, and the impact of that use "downstream" in the water ecosystem.
Detecting irrigation equipment malfunction is an easy win. Devices can be mounted on pumping equipment to monitor that they are running when they should be and even to detect changes in pump performance indicative of the need for maintenance before a failure occurs.

Monitoring pressure in the irrigation pipework at the pump, the discharge head or at points along the way if you have a long pipe run enables detection of a burst pipe. Monitoring movement of the traveling system or rotation of the sprinkler gun head can detect a stop in the regular movement and hence over watering of an area.

Understanding the distribution of moisture in the soil is also critical to crop optimisation. Soil moisture sensors come in a variety of types and styles, but whichever you choose, offer the opportunity to monitor moisture levels at various depths, meaning that you can see not just the surface layer, but within the root zone too. Because of their ease of use and cost effectiveness if you have a variety of soil types, you can also deploy the same sensors in various areas of the same field to better understand how your crops are affected by the varying soil types and if changing irrigation practices can level up performance – something particularly effective in high value crops.

In short, such sensors and data collection offer a simple and cost-effective way to monitor water use, provide management information and an early warning alert, when required. This can save a lot of time sourcing the inevitable leaks, provide valuable agronomic information, and make best use of a hugely valuable resource. Making best use of our water resource makes good business sense, being able to demonstrate responsible use is good business, and (as the cost of water and demands of climate change increase) such advances only going to become more important.

How to avoid expensive disasters with effective monitoring of potato storage conditions

Potatoes are a high-value crop with rigorous quality standards and tight market specifications. Stringent protocols need to be met to ensure that a quality crop is safeguarded and in optimum condition for sale. The safe storage of potatoes is complexand depends on several factors, meaning that efficient store monitoring is essential.

Poor storage control and monitoring can result in significant problems, such as disease development, rots and sprouting. All lead to potato loss and additional grading requirements.

- High store temperatures and air flows are important at lifting to encourage prompt curing (wound healing).
- Store humidity is important to minimise moisture loss (potatoes continue to respire when in store).
- Quality Control and Assurance – automation of verification of compliance with applicable QA and customer audit requirements

Given the above, it is beneficial to understand if the farm's on-site storage (both ambient and cold) is effective at maintaining the required conditions.

Potato storage is a critical part of the quality chain and a specialist activity that can have a significant impact upon quality parameters, marketability, and financial return to the farmer.

Monitoring and management of storage temperature is a critical component in managing potato quality and minimising disease impacts. Incorrect in-store measures can have potentially catastrophic consequences leading to physical crop breakdown and a subsequent loss of market value.

Clearly it is important from the farmer's perspective to ensure that the value of the crop is not lost due to poor storage conditions and hence an alarm function is vitally important should equipment fail or the integrity of the store be compromised.

Maintaining consistent records to meet QA and customer audit requirements can be onerous. An automated system is beneficial in terms of consistency and time saved.

SmartRural offers potato farmers and store managers piece of mind by deploying temperature & humidity sensors in the potato store. The data from these easily deployed devices drives a monitor/alarm function, feeding data back to an app that monitors the internal potato store temperature and humidity.

The insulation material used in the store does not affect the workings of the devices, nor does the mass of the potatoes and storage boxes. Working examples on a Demonstration Farm show the solution working through the full store.

Knowing where your assets are is a vital and valuable part of managing your farm

Whether we are talking about mechanical equipment, vehicles, or livestock, knowing that they are where you expect them to be is a key part of your day-to-day farm management– the confirmation that all is "normal" is a great comfort. More importantly, however, is knowing immediately when they are somewhere, they shouldn't be – it could be an accident or it could be theft – whatever the cause, being alerted to the 'abnormal' is a vital risk management tool.

Vehicle theft alone accounts for £40-50m per annum in losses, never mind the disruption to your business of being without the vehicle or equipment until a replacement is sourced. Whilst forensic tagging plays a significant part in being able to recover the asset once found, it is much better to prevent or "catch in the act". To do that you first need to understand what is normal for the vehicle in terms of where it goes and at what time of the day it would normally be in work. This is best done through a tracker on the vehicle which uses GPS technology to monitor its location and build the picture of 'normal'. Once that picture / those parameters have been set, it is then possible to spot anything abnormal, going beyond the normal range e.g. moving in the early hours of the morning, and raise an alarm.

GPS Tracking of assets isn't just about theft prevention, it is much more than that. It gives you access to data that can give you automated insight into your farming practices and costs, allowing you to carry out meaningful benchmarking and make fact-based decisions on whether to own your own equipment or to contract out certain operations for example, see the report from the KTIF Foresight Farming Project for thoughts on this. Having a GPS tracker on plant and equipment means that the data can be recorded automatically and consistently, removing the need for filling in logbooks and transferring them to the computer.

Other examples include using the tracking data as input to a Nutrient Management Plan. Tracking the vehicle and knowing over what area it spreads each load of slurry or FYM is valuable input data to the Plan, which can be gathered automatically.

Farmers also use it to know when a job is nearing completion in a remote location and when they need to go to join the team to help with the next phase, saving time and resource.
GPS trackers come in many forms covering all types of application. Your choice will be driven by the use case to which you are applying it and how it can be configured. As most are battery powered you need to consider battery life and how often you are gathering and transmitting data. For tractors or ATVs, you would have the device set to sleep whilst the vehicle is static; wake up when movement is detected; and send data every 15 minutes until it is static again when it then goes back to sleep.

One thing to be aware of is that GPS is not pinpoint accurate. Typically, the error band is about 25m. This is the same for the SatNav in a car, but it just appears more accurate because the software forces your position to be on a road. Out in the field we do not have that good fortune. Consequently, you will sometimes see odd things, such as the tractor being shown on the other side of the wall! But that is just the GPS technology.

Monitoring soil temp to optimise spring fertiliser application

To make best use of nutrients on farm and reduce harmful emissions, fertilisers needs to be better targeted to improve crop uptake, reduce waste, and improve profits. A range of benefits come from using soil temperature sensors to gather data on your farm. Measuring soil temperature using a sensor is the most accurate way of deciding when to apply spring nitrogen. As a guide, the optimum time for the first fertiliser application is when the soil temperature at 10cm deep reaches 4- 5°C for at least four-days.

It is widely recognised that significant opportunities exist for emissions abatement and environmental protection through improved utilisation of fertilisers in Scottish agriculture. Research shows that a significant proportion of the nitrogen applied as synthetic or organic fertiliser is wasted through leaching, denitrification and volatilisation.

A report by N. Lampkin et al. (2019) states that almost 50% of Scottish nitrogen applications taking place during 2017 (equivalent to an average of 92kg of nitrogen per hectare) were not taken up by the target crop and as a result were lost to the environment. In addition to contributing to greenhouse gasses, there is the serious issue of nitrate losses to watercourses; elevated nitrate levels contribute to eutrophication of waterbodies and pose a risk to human health.

T Sum 200. Using T-sum 200 (when cumulative positive air temperatures from 1st January reach 200) to assess the right time to apply nitrogen is a useful guide but it is more accurate to measure soil temp at root depth on your own farm. The T-sum can be out of sync with what is happening in the soil, especially with mild winters. It is important to recognise each season varies so regular soil temp monitoring is important.

The focus should be on getting nitrogen into the soil at the time when crop roots are able to respond. If the application is too early, there's a risk of run off or leaching, and if it's too late, the opportunity to optimise crop growth is lost. Therefore, nitrogen should be first applied when crop growth starts, and ground conditions allow spreading without soil damage – best determined by soil temperature.

The addition of a very small number of soil temp sensors across the major farm soil types or in different aspects (especially South and South West compared with North and North East laying fields) can further refine decision making.

Why is soil temperature important?
Temperature affects several processes in soil and soil ecosystem, namely:

- It directly affects plant growth and seed germination.
- Soil temp influences aeration, soil moisture content, and the availability of plant nutrients.
- Vegetative cover. A bare soil quickly absorbs heat, becomes hot during the summer, and becomes cold during winter.
- Organisms within the soil thrive at different temperatures.
- Understanding and monitoring soil temp allows you to quantify early and late seasons.

Making assurance recording easier using LoRaWAN Sensors

Farm assurance schemes provide trade buyers and consumers with the certainty their food is being produced to high standards. Read how LoRaWAN sensors can automate some of the manual recording required through various assurance schemes saving time and enhancing accuracy.

A number of voluntary assurance schemes exist within the UK farming and food industries, the aim of which is to establish production standards covering food safety, animal welfare, traceability, and environmental protection. The aim of these schemes is to add value to the sector by providing trade buyers and consumers with the confidence that our food is grown, stored, processed, and transported to the highest standards. Some schemes operate within small niches whilst others cover several sectors and activities.

Common across almost all schemes is the requirement for data to be captured, recorded, and submitted as evidence that a farm or business is complying with the standards set out by that scheme. Often, the recording of data for assurance schemes can be time consuming, relying upon manual checks and paper-based recording.

Cost effective Internet of Things (IoT) sensors offer an opportunity for the recording of data for assurance schemes to be automated – providing benefits for the farmer or producer who can reduce or eliminate manual checks, and for the assurance scheme operator who can access a digital record of measurements that are timely, accurate and verifiable.

One such opportunity for automated recording lies in stored grain temperature monitoring for farm assurance schemes such as that for Scottish Quality Crops (SQC). SQC standards set out that the temperature of stored grain must be regularly monitored and that a level of 12°c must be achieved by the end of December. Each store of bulk grain must be checked weekly until 12°c is achieved and at a regular interval thereafter. Additionally, any rise of more than one degree between inspections must be investigated and detailed records must be kept.

These manual checks are time consuming and can be prone to error yet using battery powered LoRaWAN sensors inserted into the grain pile this process can be completely automated with the results being displayed on a web-based dashboard.

Furthermore, any identified temperature anomaly can be sent as an alert to a farmer's mobile phone, allowing remedial action to be undertaken.

Another example comes from the QMS Pigs Assurance Scheme, where the Standards (Standard 6.4) set out minimum water flow rates for various weight classes of pig to maintain welfare. Assuring a particular flow rate is maintained can be challenging, but the use of a simple LoRaWAN water flow sensor can record that data and present it via a simple dashboard interface to the farmer. This allows the farmer to have an accurate record of water flows and additionally provide an alert should the flow rates drop below the prescribed levels.

Advances in radio, battery and sensor technology now mean that it is possible to collect data from even the most remote locations

Gathering appropriate and actionable data about your farm and its operations is going to be increasingly vital in being profitable, sustainable, and environmentally responsible, driven not only by regulations, but by good business sense. The established technologies are not suited to remote locations – broadband goes to buildings and mobile coverage is inconsistent, if we want to deliver remotely, we need to include another technology in the mix - LPWAN (Low Powered Wide Area Network).

LPWAN underpins the explosion of Internet of Things and is most often seen in the press as "Smart Cities", but it is equally if not more applicable in rural settings. Whilst there are several "flavours" of LPWAN, they all have the same principal aim – to cost-effectively provide the means of gathering data and transmitting that data over long distances and then over the internet to where it can be used for alarms, analysis etc. The form of LPWAN that we are going to review here is LoRaWAN (**Lo**ng **Ra**nge **WAN**), but at the highest level they are all similar.

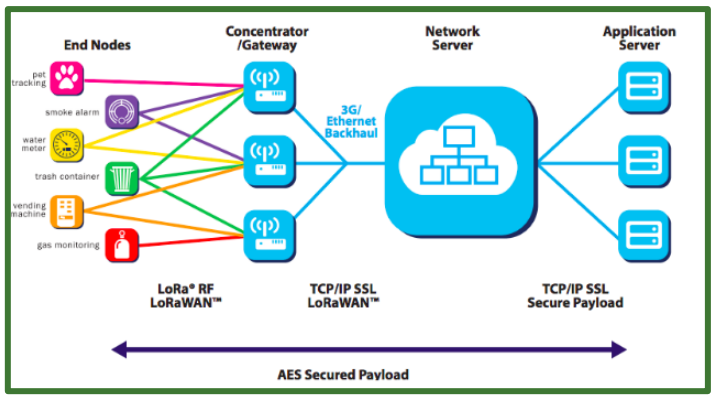
Over the last two decades the mobile phone war has led to massively improved battery and energy use technologies, shrinking size and falling prices. The "Peace Dividend" from this war means that you can now get devices (referred to as nodes) that sit out in the field for 5-10 years on their original batteries, sending data 10s of kilometres, to be picked up by a listening gateway, that helps you better manage your farm.

Underlying LoRaWAN is a very clever patented radio technology that allows small packets of data to be sent long distances using very little power and resistant to some of the problems that plague regular radio and WiFi – namely obstacles and reflections creating noise. Think of WiFi as a constant stream of conversation. If you have reflections and echoes of that conversation, they increase the background noise and reduce the amount of signal energy remaining that you receive, that is distinct, and you can listen to. In LoRaWAN the packets of data are transmitted with gaps in between, in such a way that they can also receive the echoes to remove their detrimental effect or even to reinforce the original signal. In some circumstances, this ability also allows it to be received around corners!

LoRaWAN is extremely low bandwidth, so it would take years if you were to use it to download a movie, it cannot even deal with voice traffic, but it is ideally suited in transmitting small secure data packets. The data packets are very small to save energy (think tiny SMS text) and the nodes themselves spend most of their lives asleep to further save energy, only waking up at a set time or triggered by an external event such as movement.

On top of the patented radio technology LoRaWAN defines the communication protocol and system architecture for the network, delivering reliable and secure communication for M2M – Machine to Machine systems – Node to Computer in this case.

The LoRaWAN communication protocol is defined by the LoRa Alliance, a non-profit technology alliance of more than 500 member companies. It is committed to enabling large scale deployment of Low Power Wide Area Networks (LPWAN) IoT through the development, and promotion of the LoRaWAN open standard, permitting inexpensive, long-range connectivity for IoT devices with particular attractions in rural, remote and offshore industries where long battery life devices are an advantage.



Lone working is a dangerous aspect of everyday farming life - how can we improve safety?

We have a duty to keep ourselves, our co-workers and the public safe at all times in and around our farms but serious, often tragic, accidents happen all too frequently, particularly to lone workers. Health and safety regulations bring a range of procedures and measures to bear on our industry – and lone worker rules feature in several guidelines such as INDG73 and Farmwise.

Knowing the location of lone workers, enabling them to raise the alarm if there is an accident, and being notified that a lone worker has returned safely 'to base' (or not) are key factors in ensuring their safety.

It is important to have systems that:

- Allow the alarm to be raised even when out of mobile phone coverage
- Provide the location of the worker to those who can assist
- Give assurance that workers and equipment have returned to base safely at the end of the day

In terms of risk management and health and safety, there are a number of regulations relating to agriculture that are imposed on the farmer.

LoRaWAN* and sensors are not the silver bullet for any of these, because compliance is fundamentally about human behaviour and therefore requires training and supporting procedures.

What sensors and devices do is support several of these procedures, including machine maintenance monitoring, fall monitors, pressure systems instrumentation and lone worker personnel beacons.

SmartRural is developing an innovative and cost-effective system to support a farm's lone worker procedure, that will function effectively in areas of low, or even no, phone coverage. This will be achieved through a combination of devices on various items of plant and equipment, and a wearable device for the lone worker.

Effectively, this configuration of sensors and software will deliver the following:

- When a worker takes out a vehicle at the start of a shift, the device registers and logs its movement
- On arrival at a remote work site, the worker presses a button and receives visual confirmation (a flashing light) from software that the 'check in' signal has been received
- After that, the device is 'armed' and the next call will be in the case of emergency, notifying the farm manager and any other nominated parties, of the location and person involved. (The lone worker also gets confirmation that the software has received their call)
- The system resets overnight, ready for the next day

*LoRaWAN is a radio communication system that receives data from simple, battery-powered devices, up to 15km away. The data is then fed back through the internet to where it can be used by software to help farmers make more informed decisions about a multitude of aspects of their businesses. SmartRural is working with farmers across the length and breadth of Scotland to deploy this technology, even in areas where there is no mobile or broadband coverage.

Keeping secure with LoRaWAN sensors

Rural crime is a growing issue across the UK, costing the farming sector millions each year and creating anxiety in the countryside. Cost effective sensor technology deployed over LoRaWAN networks opens new and innovative ways to keep farms secure and alert to suspicious activities.

In its 2020 Rural Crime Report, insurer NFU Mutual revealed that rural crime in the UK had jumped 9% between 2018 and 2019 and cost the industry some £54m. Scotland has been particularly hard hit, seeing a rise of 44% between 2018 and 2019. Unsurprisingly, the main target for rural crime is farm machinery, including quad bikes, tractors, and other high value items. Livestock theft also increased substantially, showing a 15% year-on-year rise. Unfortunately, much of this rise in rural crime is linked to organised criminal gangs and is causing anxiety and even fear in rural communities across the UK.

LoRaWAN GPS Tracker

Many farmers and communities are turning to technology in the fight against this rural crime wave, deploying a range of solutions that span a wide spectrum of cost, complexity, and usefulness. Sensors working over LoRaWAN networks can help in the fight against rural crime using cost-effective GPS asset tracking devices and other sensors. LoRaWAN overcomes many of the connectivity challenges associated with deploying traditional security systems by providing a reliable network over which real time alerts can be sent to a farmer in the event of a piece of machinery being moved, a gate being opened, or movement being detected out with regular working hours.

With most thefts occurring out with daylight hours it is often the case that the farmer only notices an asset is missing the following day, at which point the ability of the police to catch the perpetrators is reduced. By providing timely alerts via smartphone, the farmer can be notified of suspicious activity immediately increasing the chance of arrest and asset retrieval.

In addition to GPS trackers, other security focused devices such as movement sensors, noise triggered sensors and gate sensors can be deployed as part of a LoRaWAN based security system, allowing alerts to be triggered in the event of e.g., a gate being opened, or movement detected. This can help in situations where livestock theft is an issue as long-life, battery powered LoRaWAN sensors can be deployed in remote parts of the farm beyond the reach of traditional security systems.

Similarly, smoke detectors can be deployed for early detection of fire from accidental ignition or arson.

Using LoRaWAN as part of your security system, to supplement CCTV and conventional systems, also has the advantage that the connectivity can come from more than one location. Hence," knocking the power out" at the target property, does not automatically remove the protection.

Managing and monitoring motors, pumps, and compressors so that they don't let you down when you need them most

Motors, pumps, and compressors form a large part of the farming tool kit that we depend on to keep our operations running, our products in the right condition and to power our activities. At the heart of this equipment whether it be a cooling compressor, a biomass feed auger, or a well lift pump will be an electric motor. If that motor fails then the repercussions for your business can be significant in terms of lost product, deferring activity and costly replacement/repairs. There is a way of getting ahead of the game, preventing that catastrophic failure, and spotting changes in performance.

All electric motors and rotating equipment vibrate as they operate. You will hear this all the time when you are near the equipment. You will also know that, like any engine, when you change the load that sound changes. Some of us even do that as part of our day-to-day inspection routine and in extreme circumstances can hear when something is wrong. For the human ear to pick up these "sounds of distress" they have to be pretty far gone, but with technology today it is now possible to get devices to attach to your key motors that constantly listen and analyse the most subtle of sounds to tell you when something starts to go wrong.

The technology at the core of this has been used in many other industries for decades, especially around complex and expensive equipment like power turbines. Here they monitor a wide range of parameters around the turbine, to understand the equipment's performance and all the input factors that affect it. All this data is then used by a computer to build a picture of what is normal at various loads and operating conditions, so that when it starts to become 'abnormal' they can spot it before it becomes a problem and respond accordingly. This enables smart maintenance schedules, targeting what is needed and only when it is needed to maximise time and performance.

Whilst these industrial units are much more complex than any of us are likely to see on farm, the underlying principles are the same – monitoring our key equipment to know that it is working properly, to spot any issues before they become problematic and only to maintain when we need to. Those of us with modern combines will already know about vendor maintenance services and how they know before we do.

The big breakthrough is that this technology is now available in a hand sized, battery powered device, that attaches via a magnet, does the smart stuff on board, and sends alarms when it detects anything abnormal. The device learns about the operation of your motor and the system around it, building up a library of normal vibration pictures for the motor's performance at various loads and performance conditions. It then stores this onboard to compare with ongoing operations to spot when something is going wrong.

What can be "wrong" can be the motor itself or something in the system. Examples of the latter would be a blockage of the inlet filter in an irrigation lift pump requiring cleaning; blockage in the biomass hopper meaning that the furnace feed auger has no product to transfer; a downstream burst in an irrigation system or bulk milk transfer line removing back pressure; air filter fouling etc. All these examples are preventable before they become problems/failures meaning greater uptime and productivity and the avoidance of losses.

Monitoring your diesel tanks and other liquid stores so that you don't get caught short

Most farms have a range of liquid storage tanks – diesel, water, fertiliser etc. All need monitoring for operational preparedness and some for security and/or cost allocation. Not all tanks are conveniently placed nor have remote monitoring.

Do you keep a log of use and status, so that you always have what you need when you go to the tank? How good would it be if it was done automatically, and alarms raised if you got below certain levels?

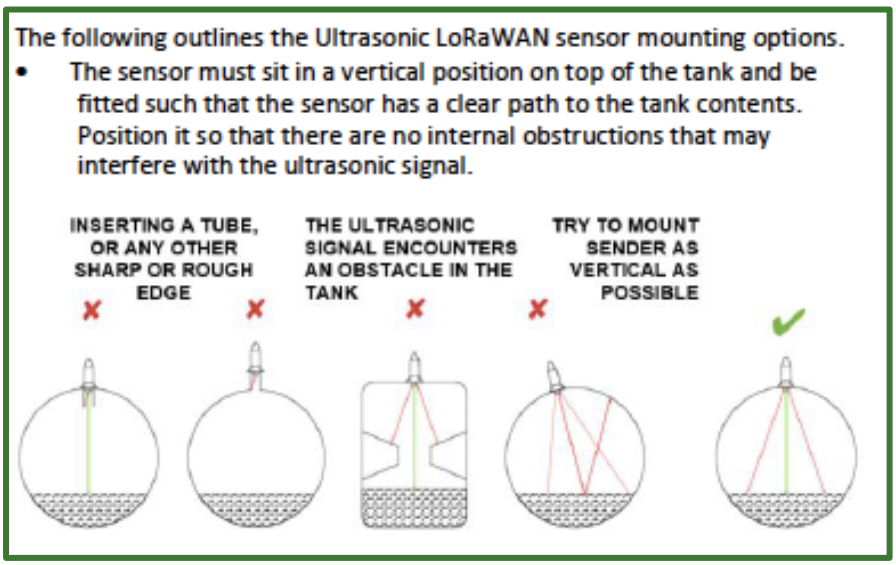
Liquid tanks are generally vertical or horizontal cylinders and, in farming, have a wide variety of uses. In each case it is important for us to know how full they are or how close to empty. There's no point in heading over to a remote site to perform a spray job if the tank is empty. Having an app on your phone where you can check your stock levels, before setting off, can save a lot of time and money.

Similarly, diesel stocks are a vital part of the farms inventory at busy times of the year. Having a monitor on the tank allows you to easily check and restock, or even have your supplier check for you when they have a tanker in your area and plan on your behalf to always keep you around an agreed level.

Remotely 'watching' the level and spotting irregular movements out with expected hours of work, for a given time of year, is a hugely important part of crime prevention and detection. Linking the monitored data to an alarm centre configured with preset rules would help a lot in deterring this aspect of rural crime.

Techniques for monitoring liquid levels in a tank fall into two main groups:

- Ultrasonic – mounted in the top of the tank – measuring the distance to the liquid-air interface
- Pressure/Head – pressure transducer suspended in the liquid at the bottom of the tank or on the tank side of the outlet valve



The ultrasonic sensors have advantages in terms of ease of installation, they aren't in contact with the liquid and they have no moving parts, but they need to be mounted correctly and there can be no obstructions in the tank.

Suspended pressure gauges don't have this problem, but are obviously exposed to the tank contents and are potentially impacted during filling etc.