Digitizing Fomite Tracing to Mitigate Livestock Disease Spread

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Executive Summary

There were two overarching goals for this project. Goal 1 was to complete a review of device technology to assess fitness for tracking of fomites (vehicles) in agriculture. Goal 2 was to develop and code the necessary software and build a robust disease spread prediction tool that can be used by industry and government to manage disease outbreaks. The results are outlined below.

Goal 1 results: Vehicle devices are not created equal for digitizing fomite movements

The field testing we conducted showed that the vehicle devices are not created equal for digitizing vehicle movements in agricultural settings. Of the technologies tested, three GPS devices (two wired or powered, and one fully battery powered) showed reliable performance in and were unaffected by harsh cold winters. They proved reliable in daily operations related to livestock production and sanitation, with no significant impact on battery life. Based on field testing, we recommend two wired device and one battery powered devices, pictured on page 20.

Testing of LoRa technology helped to demonstrate the practical application of devices in the swine industry and their potential to improve operational management and disease control measures. LoRa technology does show promise but needs more development before it can be scaled up for full industry use.

We also found that manufacturers recommendations are not always the best guide for identifying devices that are suitable for farm and livestock trailer transport use. For example, some devices with IP ratings of IP67 (no ingress of dust and full immersion in water up to 30 mins at a depth of 1 meter) will not keep water out if subjected to pressure washing. Likewise, any devices rated as “water resistant” are not sufficiently sealed to withstand normal farm vehicle operations.

Goal 2 results: Mapping tools are useful for both disease response and strengthening biosecurity

The disease mapping software developed as part of this project has proven to be useful in not only disease response but also for strengthening biosecurity in ‘peace time’. Disease mapping software needs to provide information to organizations and farmers that is useful or has practical application for them today in order to show them the benefits. It is not enough for companies and farmers to adopt technology and change their day-to-day practices for potential disease control benefit in the future. They need to see value immediately to their operations or organizations.

As a result, the software capabilities developed during the course of this project are applicable for both disease response and for boosting biosecurity, including:

- Prediction of disease spread with addition of weather factors (wind speed and direction, temperature, humidity)
- Prediction of disease spread with ability to identify route and fomite (vehicle)
- Identification of biosecurity breaches through fomite movement recording
- Ability to establish control zones, including identification of farm properties
- Ability to validate compliance of fomites with biosecurity protocols (such as truck washing)

Introduction

Tracing of fomite movements is shown to be highly effective at reducing disease transmission and minimizing economic impacts compared to other disease control strategies.[1] With the constant threat of devastating diseases such as African Swine Fever (ASF), Foot and Mouth Disease (FMD) and Avian Influenza (AI), and highly infectious production limiting diseases such as Porcine Epidemic Diarrhea virus (PEDv) and infectious bronchitis (IB) in poultry, fomite tracing as a regular management practice undertaken at a company or industry level has a vital role to play in protecting the health and welfare of farmed livestock and poultry.

Paper-based systems exist for the purpose of tracing people, (i.e., visitor logbooks), and truck logistics systems (i.e., GPS) make vehicle tracking possible. However, neither of these systems is designed for the purpose of track and trace, and as a result neither can work in real time. For a system to efficiently mitigate disease spread, the track and trace capability should work in as near real time as possible.

What is a fomite?

A fomite is an object or material that can carry pathogens and spread disease infection. Examples of fomites in agriculture include any vehicles (cab, wheels, chassis) any people (clothing, boots, hands, etc.) that enter the farm property. Equipment such as shovels and other items can also act as fomites.

Vehicle tracking logistics systems are designed to be truck centric as they are programmed to monitor driver behaviour, fuel consumption and other physical attributes related to truck performance and efficiency. The other issue with vehicle GPS logistics systems used with semi-trailers is that the trailers are not tracked. Once they are dropped off in a collection yard the trace history from the original cab GPS system is lost for that trailer. As soon as another truck picks it up the trailer becomes associated with a completely different cab and therefore its movement history is lost. The devices tested in this project enable the tracking of semi-trailers even when they are being pulled by a different cab or truck.

This latter point is very important. Livestock and poultry live-haul trucks are the highest risk fomite in the industry. This is because they carry live animals which - as demonstrated by Alban and Boklund (2008)[2] - are the highest risk carriers of pathogens. The trailers are often heavily contaminated with manure, other animal secretions, skin, hair, contaminated fodder and bedding, etc. This makes livestock trailers extremely high risk if they are not completely cleaned and disinfected between loads, a vital step that is often missed or carried out in haste and therefore ineffectively, due to time pressures of logistics management. This creates a massive risk of pathogen transfer and without full trailer traceability a huge, if not the biggest gap in the track and trace process.

For disease movement monitoring, the system needs to be specifically designed in a property centric manner which allows for temporal and spatial analysis of fomite movements relative to the index

[1] https://onlinelibrary.wiley.com/doi/10.1111/tbed.14334

[2] Qualitative ranking of disease transmission routes in relation to the risk of transfer of pathogen. (Alban and Boklund, 2008)

property and infected premises. When tracing is undertaken after the fact, a significant amount of manual work is needed to determine and analyze the connections between potentially affected premises and the subsequent epidemiological analysis that will help shed light on how to better manage future outbreaks.

Tracking trailer movements are a different problem. Because trailers are not connected permanently to a power source there is a need to have a battery back-up system for times when the trailer is parked. This may be either be when the trailer is parked awaiting its next run or it could be when the trailer is in lairage awaiting its turn to be pulled into the processing plant. It could also be that there is no easy way to connect the tractor power to a permanently fixed GPS Device on the trailer which means the trailer device must have sufficient battery power to enable it to monitor movement accurately for long periods. Two ways exist to make this work reliably:

- Recent developments in battery life have made vehicle track and trace for this purpose possible.
- Devices that seamlessly connect into the trailer system and which carry battery back-up.

Goal 1 of this project was to complete a review of the technology that is being investigated for fitness for purpose (location centric contact tracing). Farm Health Guardian conducted field testing of track and trace technologies in vehicles that do not have GPS logistics (e.g., trailers and service vehicles) making them impossible to track without a geo-location device. Field testing occurred over the course of several months, and as such we were able to evaluate performance over several seasons and extreme temperatures. Among the characteristics we evaluated were:

- Ease of installation,
- Durability,
- Accuracy,
- Performance under a variety of different conditions and,
- Open API with ability to integrate with a cloud-based tracking system (such as Farm Health Guardian).

Goal 2 of this project was to develop and code the necessary software and build a robust disease spread prediction tool that can be used by industry and government to manage disease outbreaks.

Project Goals:

Goal 1: Test vehicle and trailer tracking technologies in real agricultural environments.

Goal 2: Build a robust disease spread prediction software tool that can be used to manage disease outbreaks.

BACKGROUND - WHY TRACK AND TRACE IS SO IMPORTANT

Economic Impacts of Disease

The impacts of livestock diseases are staggering and include lost sales, lost profits, lost consumer demand and market access, as well as costs related to disease control for stamp out/euthanasia or acute treatments. For example:

- PRRS – a production-limiting pig disease is estimated to cost $184 million per year in Canada.[3]
- The cost of Porcine circovirus associated disease (PCVAD) on the Canadian swine industry was estimated to be $562 million over five years of total direct losses, composed of $150 million in lost farm revenue, and increased veterinary/recovery costs of $268 million.[3]
- The total economic impact of PCVAD in Canada was estimated at $1.4 billion.[3]
- The estimated impact of a Foot and Mouth Disease outbreak in Canada would be from $38 - $50 billion.[3]
- Economists estimate that an outbreak of African swine fever (ASF) could cost $50 billion to the US alone.[4]
- The Canadian Food Inspection Agency (CFIA) reported 1.82 million birds on farms had been culled or died from the disease, in May of last year.[5]
- The recent and on-going outbreaks of highly pathogenic avian influenza (HPAI) are estimated to have cost the US government roughly $661 million with the slaughter or more than 58 million birds to limit the spread of the virus.
- Its also estimated that farmers who raise those animals lost more than $1 billion.

[3] https://www.ahwcouncil.ca/pdfs/AHC_Gaps%20Analysis%20Report_February%2013_EN.pdf

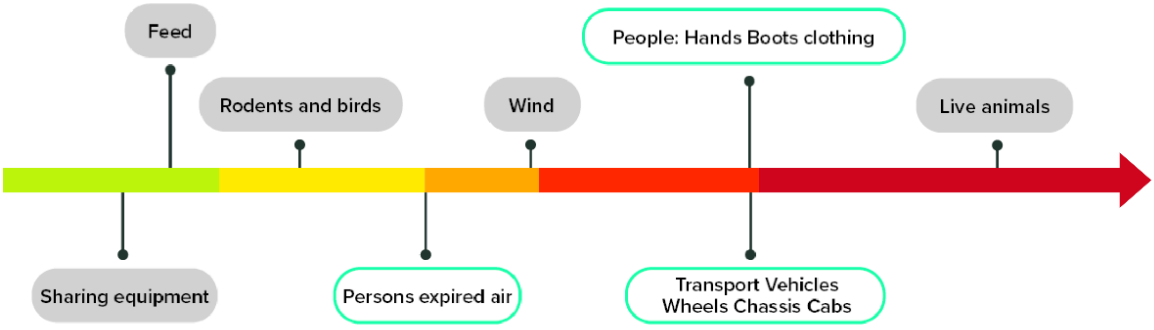
[4] https://thepigsite.com/articles/new-economic-study-african-swine-fever-outbreak-in-the-us-could-cost-50-billion#:~:text=New%20economic%20study%3A%20African%20swine,of%20ASF%20in%20the%20US.&text=The%20study%20replicates%20the%20impact,%2450%20billion%20over%2010%20years.

[5] https://www.realagriculture.com/2022/05/avian-influenzas-toll-on-canadian-poultry-farms-exceeds-1-8-million-birds/

What Does the Research Say?

1. Disease transmission occurs mainly through fomite movement (animals, people & vehicles)

The figure below shows the relative importance of the different pathways of pathogen transmission between farms[6]. As shown, the disease transmission pathways increase in importance from lowest to highest risk moving from left to right along the graphic. Feed and sharing equipment are the lowest risk and animal to animal transmission is the highest or most important pathway for disease spread.



According to tables published by Iowa State University College of Veterinary Medicine, fomites are the main mode of transmission of all the major poultry[7] and swine[8] diseases. Do we know enough about our transport and people connection networks to be able to predict spread and prevent such significant losses?

Understanding fomite movements within a network is essential to prevent and control spread. An analysis of the network between poultry farms in Korea during the Highly Pathogenic Avian Influenza (HPAI) outbreak of 2016-2017 confirms that to prevent and control disease spread, it's essential to understand fomite movements within a network of farms[9]. This will help minimize negative impacts of disease by targeting restrictions to the highest risk premises and not farms at lower risk. The researchers go further to recommend that animal health authorities should investigate the real-time vehicle movement data to assess the farms at risk and prevent further spread. Common send tells us that some farms are higher risk than others based on biosecurity practices. One common denominator that we can monitor and validate is the movement of people and vehicles between properties at risk. Most other biosecurity practices are inside the farm gate and can not be validated to the same degree of accuracy. However, fomite movements can still be accurately recorded.

While migratory bird flyways make a region vulnerable to HPAI, once it is introduced, fomite movements between premises are likely responsible for its spread. Dr. David Swayne, a leading U.S. Department of

[6] Qualitive ranking of disease transmission routes in relation to the risk of transfer of pathogen (Alban and Boklund, 2008)
[7] https://www.cfsph.iastate.edu/Assets/routes-disease-list-poultry.pdf
[8] https://www.cfsph.iastate.edu/Assets/routes-disease-list-swine.pdf
[9] https://www.nature.com/articles/s41598-021-03284-x

Agriculture veterinarian, says that "There have been multiple studies across the world that would say transmission of virus from farm to farm is through fomites in most situations, and movement by air (as being sucked in by the ventilation and distributed by wind), is a much less common occurrence".[10]

An analysis of the African Swine Fever (ASF) outbreaks in China which recently appeared in the peer reviewed journal *Viruses* identified people as the main source of disease spread. Almost half (46%) of the ASF outbreaks appear to have had the virus introduced by fomites.[11]

2. Disease transmission risk increases with frequency of visits to a farm

True risk can be expressed using the probability formula: P= 1-[1-p]n where p = risk of transmission route and n = frequency of transmission route)[12]. Assume that the risk of disease introduction into a herd or flock through feed delivery is 1 out of 1,000. For example, the feed truck may be carrying porcine epidemic diarrhea (PED) on its tires when it comes to the farm. If feed is delivered every week, what is the annual risk that the feed truck will introduce the pathogen? Repeated weekly, a single event with a 1/1,000 risk becomes a 1/20 risk. The event has a very small risk when it occurs only once but becomes a much higher risk when it occurs frequently.

In another example real time data taken from the Farm Health Guardian system truck visits to a specific farm were monitored. An analysis of the data revealed that a single truck visited the farm 3 times in 7 days (Aug 20, 24 and 26). Using the calculation and assuming three visits per week, this truck poses a 15% risk of bringing a disease pathogen onto the farm per year. In this example, frequency causes risk to increase by 150 times, from a 0.1% risk from a single visit to 15% due to multiple visits. The repetition increases this risk to a level that is important to consider when prioritizing biosecurity measures.

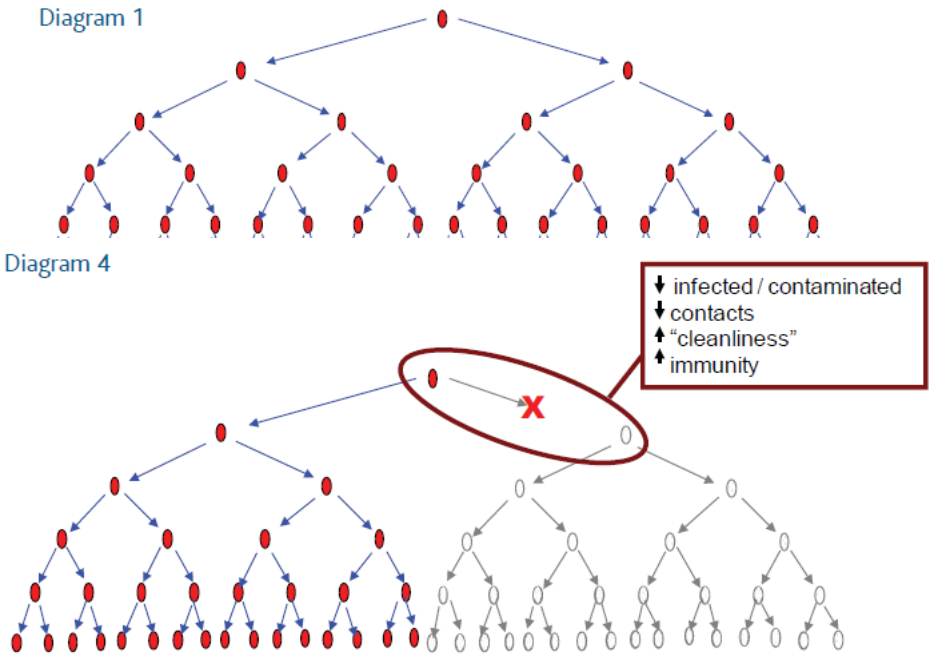
The frequency of the repetition of an action is very important. While the everyday event may be low risk, repeating it frequently results in it becoming a much higher risk over time.

3. Early disease detection significantly reduces disease spread

The ability to immediately (i.e., in real time) understand people and vehicle routes/connections and the transmission risks will help stop the spread and impact of disease. Research in Korea confirms this point: "A good monitoring system should provide fast tracking of disease outbreaks and assist decision makers in understanding and explaining disease dynamics and spreading patterns[13]."

The figures below illustrate how stopping disease at even one node of transmission will have a dramatic impact (Source: Dr. Bruce McNab, Animal Health & Welfare Branch, Ontario Ministry of Agriculture, Food & Rural Affairs):

[10] https://www.wattagnet.com/articles/35999-avian-flu-can-be-transmitted-by-air-but-focus-on-fomites?v=preview
[11] https://www.mdpi.com/1999-4915/13/12/2552/htm
[12] The formula P= 1-(1-p)n is the statistical formula to calculate cumulative proportions or probabilities based on the binomial distribution (binomial distribution derived by Jacob Bernoulli is the correct statistical distribution for 0/1 events (eg. 0 = no introduction: 1 = introduction).
[13] https://www.frontiersin.org/articles/10.3389/fvets.2021.676661/full



4. Contact tracing the best intervention for controlling swine disease spread

Mathematical modeling was used to show the effectiveness of different control strategies on African Swine Fever (ASF). The study used real animal movement data to simulate the propagation of two ASF strains among more than 13,000 pig farms[14]. The researchers showed that contact tracing was the best intervention compared to any other control strategies in the model. Contact tracing resulted in 95% disease control, outperforming radius-based quarantining. Of all the scenarios tested, contact tracing always resulted in the best control from both a disease control and an economic standpoint.

Control strategy	# infected farms quarantined	# healthy farms quarantined	% control of transmission
15 km quarantine around index farm	14	63	85%
15 km quarantine + system-wide quarantine of all farms in the same company*	16	2100	89%
15 days of contact tracing	18	12	95%
30 days of contact tracing	18	28	99%

Combining contact tracing with a 15 km quarantine zone plus system-wide quarantine, did not show any significant increase in control of transmission compared with contact tracing on its own. It did, however result in 2100 healthy farms being unnecessarily quarantined. The economic consequences of quarantine are often devastating for individual farms and companies. Movement permits are required

[14] https://onlinelibrary.wiley.com/doi/10.1111/tbed.14334

for feed deliveries and to bring animals in or out. Product can not be shipped and exporting countries may be forced to a standstill.

THE PROJECT

Devices Tested and Results

Goal 1: To test and validate vehicle and trailer tracking technologies in real agricultural environments for the purposes of disease control and mitigation in livestock.

Method:

Over a period of 8 months, we tested five different technologies, each was tested for a minimum of 6 months. The technologies tested were all bought 'off the shelf'.

The technologies tested were as follows:

- Battery powered GPS devices – some augmented by solar power
- Wired GPS devices and,
- Long-Range Local Area Network (LoRa LAN).

143 devices tested and 278 properties in Ontario were involved in the trial.

Two properties in Manitoba were involved testing LoRa LAN technology, as well as 44 properties in Quebec.

Devices were purchased from independent suppliers. Each was given a unique identifier for ease of recognition in the field based on the User, his or her company and the vehicle carrying the device. Some vehicles were equipped with multiple device types to enable comparison.

Installation instructions were provided to the user or user organization and where it was deemed necessary FHG provided field support to ensure that the devices were correctly set up and working. Some devices were mounted externally on trailers, and some were placed 'in cab'. Externally mounted devices were carefully placed to ensure they received the most extreme treatment likely to be experienced in the

Testing technologies in Saskatchewan

In Saskatchewan, four swine companies participated in the pilot project. Devices were monitored from December 2021 to May 2022, focusing on vehicle movements onto and off swine properties.

LoRa LAN was specifically tested in SK because the province is using 3G telecommunications, whereas many GPS devices require 4G. Sasktel is committed to developing LoRa WAN (Long Range Wide Area Network) in populated areas only, leaving rural Saskatchewan without devices that will work for agricultural tracking purposes. Our goal was to determine the biosecurity technology for movement recording that performed the best in Saskatchewan.

Testing of both LoRA and GPS (with both 3G and 4G capabilities) in vehicles travelling to and from swine properties was conducted in rural Saskatchewan. The project findings indicate that the GPS devices tested exhibited satisfactory performance, showcasing their viability for tracking vehicle movements in real-life agricultural conditions.

field. For example, these devices were subjected to:

- Hot and cold high pressure washing
- Thermal Assisted Drying and Decontamination (TADD) at >75°C for 15 minutes,
- Being mounted on the exterior of trailers in Northern Manitoba during winter they were also subjected to temperatures below -40°C and with the windchill factor probably lower than -50°C.

It is important to note that for accurate GPS data flow the battery devices should have a clear 'view' of the sky and therefore needed to be mounted externally on the trailer. This does not seem to be such an issue for powered devices.

The vehicle movements which were recorded in the FHG system and those recorded on the device company dashboards were compared. This comparison enabled a detailed analysis of times of entry and departure from premises recorded on both systems and the accuracy of those measurements appearing in the FHG system. Where possible these records were also compared with the participating company records of entry and exit from the properties by the vehicles. While company records of dates of movement were available it was generally only possible to get approximate entry and exit times so these data were not used in our final analysis.

General observations:

None of the devices currently on the market are designed specifically for use in a livestock trailer tracking capacity. It was therefore not easy to identify those that could withstand the rigours or requirements of use in an agricultural setting and particularly in relation to being used for pathogen tracking.

Manufacturers recommendations, while accurate, are not always the best guide for producers and agricultural transporters looking to identify devices that are suitable for farm and livestock trailer transport use. For example, some devices with IP ratings of IP67 (no ingress of dust and full immersion in water up to 30 mins at a depth of 1 meter) might sound good but will not keep water out if subjected to pressure washing. Likewise, any devices rated as being "water resistant" are not sufficiently sealed to withstand normal farm vehicle operations. If as an operator you can be sure never to have to hose down or pressure wash a vehicle, then IP67 rating might suffice but for livestock transport monitoring they are not recommended.

All of the systems tested have very good website dashboard capability. The dashboards come with good maps, ability to group and view devices within the system or individually, good historical data for retrieval. These were all attributes one would normally associate with a fleet tracking system. The devices we tested that were battery powered clearly did not have the ability to link to the vehicle operating systems and did not perform any of the vehicle monitoring systems offered by powered systems connected though OBDII ports for example. This was not the purpose of the pilot, so it was not a measurement of fitness for use that we measured.

All devices were straightforward to fit especially the battery powered devices and manufacturers instructions on fitting were clear.

Signal (ping) frequency significantly affects battery life. All devices had the ability to increase or decrease the number of times the device reported movement to the system (pings). They could also be set to only report starts and stops.

To enable the ability to utilize multiple systems within one monitoring system (FHG) all the systems we selected had an open API for external system integration. API documentation was variable and some more difficult to implement than others and in two cases had to be corrected by the device supplier before it could work.

All of the companies we trialed had a different method of charging for the systems and these need to be carefully compared before purchase as some have separate API and cellular data fees.

Results of technologies tested:

The following table summarizes the attributes of the various technologies tested during this project.

Device type	Description	Best use case for track and trace in livestock and poultry trailers
Small GPS – battery powered	Small lower end GPS devices, accuracy good but the battery-life/frequency of signal makes this device unsuitable for real-time reporting of position battery life severely compromised when set to anything other than the lowest frequency of signal to satellite. Very easy to install, readily available in Canada, serviced and maintained in Canada.	Best suited for trailer that is not frequently and aggressively washed e.g., Horse trailer.
Mid-range GPS – battery powered	Mid-range GPS devices, high accuracy, battery life severely compromised when set to anything other than the lowest frequency of signal to satellite. Very easy to install, shipped from US serviced and maintained in US. Service slow as the companies that sell these devices generally are dealing in much higher volumes of devices.	Best suited for livestock hauling and other heavy goods trailers. Look for IP rating of 69 or above to ensure no water ingress during power washing. Will withstand TADD at +75C and weather exposure as low as -50C
Higher range GPS – battery powered	Higher range robust devices. Excellent battery life as GPS positions are stored on the device and only released at intervals set by the user. These tend to have bigger battery with more powerful signal strength so can be fitted on truck chassis which can protect them from weather and water incursion and theft.	Recommended, although larger than the other devices tested due to battery size. Best suited for livestock hauling and other heavy goods trailers. Look for IP rating of 69 or above to ensure no water ingress during power washing. Will withstand TADD at +75C and weather exposure as low as -50C
Passenger vehicle - powered	OBDII devices - various makes. Easy to fit and 'splitters' available if you already use OBDII port for other purposes. All have excellent coverage - the price range and the size of the devices varies considerably but all appear to be reliable. Big drawback you do not get trailer coverage - excellent for delivery vehicles, tech vehicles etc.	Recommended in vehicle only for passenger vehicles (cars, pick-up trucks, vans).
Taillight GPS - powered	Trailer taillight device - we only found one. It is easy to fit, robust,	Recommended. Best suited for livestock hauling and other heavy goods trailers.

	very accurate and no battery required. Fits most but not all N. American trailer models and no EU ones yet.	Look for IP rating of 69 or above to ensure no water ingress during power washing. Will withstand TADD at +75C and weather exposure as low as -50C
LoRaLAN (Long Range Local Area Network)	All these systems require a reader positioned indoor or outdoor at the property and a beacon (sensor) in the vehicle. The beacons are usually small and can be carried in-cab or fixed to the truck or trailer body making vehicle installation very simple. The readers on the other hand need to be specifically positioned with good line of sight to the vehicle, need to be connected to WIFI or cellular network and hardwired to the power supply. The readers vary in price with outdoor being the most expensive.	Pros: Technology Performance: The technology successfully records feed truck visits without relying on GPS. Management Visibility: Managers can monitor the arrival of feed trucks, enhancing operational oversight. Validation of Movements: Companies that do not wish to integrate the technology can still validate vehicle movements. Cons: Visit Length Accuracy: The current system does not accurately capture visit lengths. Wi-Fi Dependency: The system requires Wi-Fi availability at barn locations. Setup Complexity: Implementing the system on a large scale necessitates intensive setup processes, including in-person setup and downtime requirements. Challenges in High-Density Areas: The potential exists for difficulties in reducing the radius and addressing issues in high-density locations. Has potential but needs more development and refinement to scale up for track and trace in agriculture.

Disease Management Tool

Goal 2: Develop and code the necessary software and build a robust disease spread prediction and mapping tool.

Method:

Extensive and in-depth consultation was done with pilot project participants testing the devices and disease mappers from commodity organizations. These consultations helped to determine disease mapping needs from an industry and government perspective, as well as desired features and capabilities of the software.

Consultation findings & observations:

Through these consultations, participants identified a number of core disease mapping needs:

- Respond to emergency situations that affect all producers within a sector (e.g. poultry)
- Quickly identify index properties
- Quickly establish quarantine zones of any size or shape and generate a list of all farm properties within the zone (Figure 1)
- Generate a buffer zone with other affected farms in the area (Figure 1)
- Create reports with contact information (Figure 4)
- Ability to notify all producers and industry personnel of urgent actions that are required
- Assist government agencies as a resource in identifying farms in the affected area
- Easily access information from each farm to support traceback efforts and prompt disease response (Figure 4)
- Model environmental factors including wind and temperature to predict disease spread (Figure 2)
- Having the ability to isolate and identify a fomite, enabling a more detailed analysis by animal health managers (Figure 3)
- Ability to verify truck movements and to identify whether a truck is clean based on whether movement was directly from a truck wash (Figure 3)

When time is of the essence

We generated a copy of a disease map showing a multi-sided polygon quarantine zone. Generated in the Farm Health Guardian system, this map took approximately 8 minutes to complete.

The disease mapper who had generated the same map through software currently being used by the organization said it had taken 25 minutes to complete, and it often takes longer because the maps don't always save properly in the program currently being used.

Additional opportunities were identified during pilot project meetings, including:

- Improve staff efficiency when determining control zones and generating contact lists
- Improve disease response time to create and share outbreak information and maps
- Improve timeliness of outbreak communication to stakeholders

Results:

Software requirements to enhance efficiency and speed of communications were completed as part of this project. These capabilities can be used by industry and government to manage disease outbreaks during 'war time' and by academics for further research during 'peacetime.'

The new biosecurity mapping features provide the ability to draw customized radius maps and polygon quarantine zones around a farm property. The system can also factor in wind speed and direction to identify surrounding properties at risk from windborne pathogen transmission. These enhancements can improve the prediction of disease spread, assist in rerouting transportation to avoid hot zones and provide a communications tool so producers and other stakeholders can take action early before a disease gets out of hand.

The following enhancements were also developed:

- Anonymizing farm location data so that maps can be shared
- Creating downloadable reports that include contact information within a control zone (radius or polygon)
- Including farm location data from multiple commodities or groups while maintaining confidentiality and data security
- Adding contact information for properties even if they aren't using the FHG app so they can be contacted by email or phone
- Adding temperature and humidity (in addition to wind) as part of the outbreak report mapping

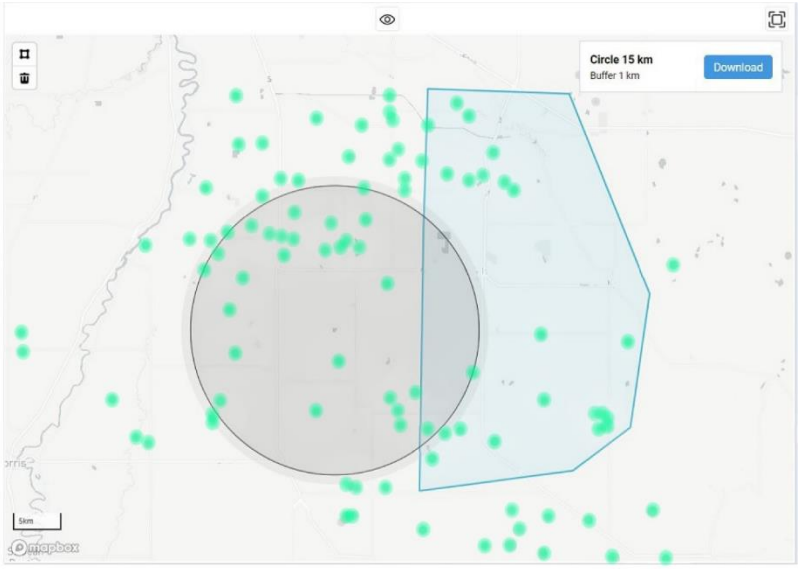


Figure 1: Mapping features developed provide the ability to draw radius and polygon quarantine zones with an optional buffer zone. The green dots show farm property locations.

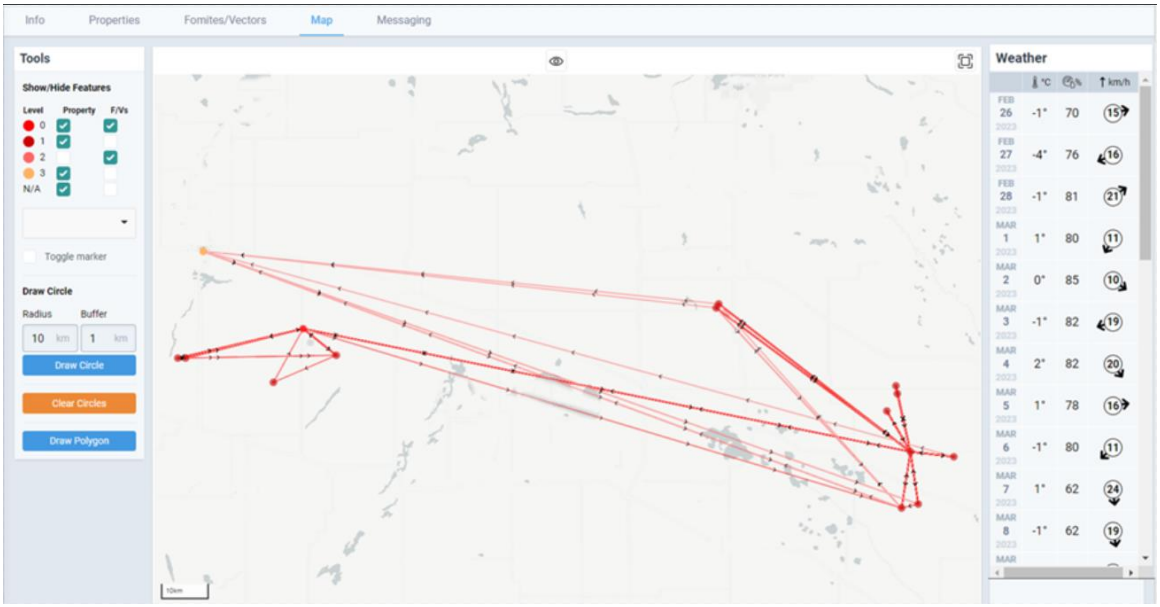


Figure 2: Example screenshot of the mapping features developed shows the addition of weather factors including temperature, wind speed and direction, and relative humidity to better predict disease spread.

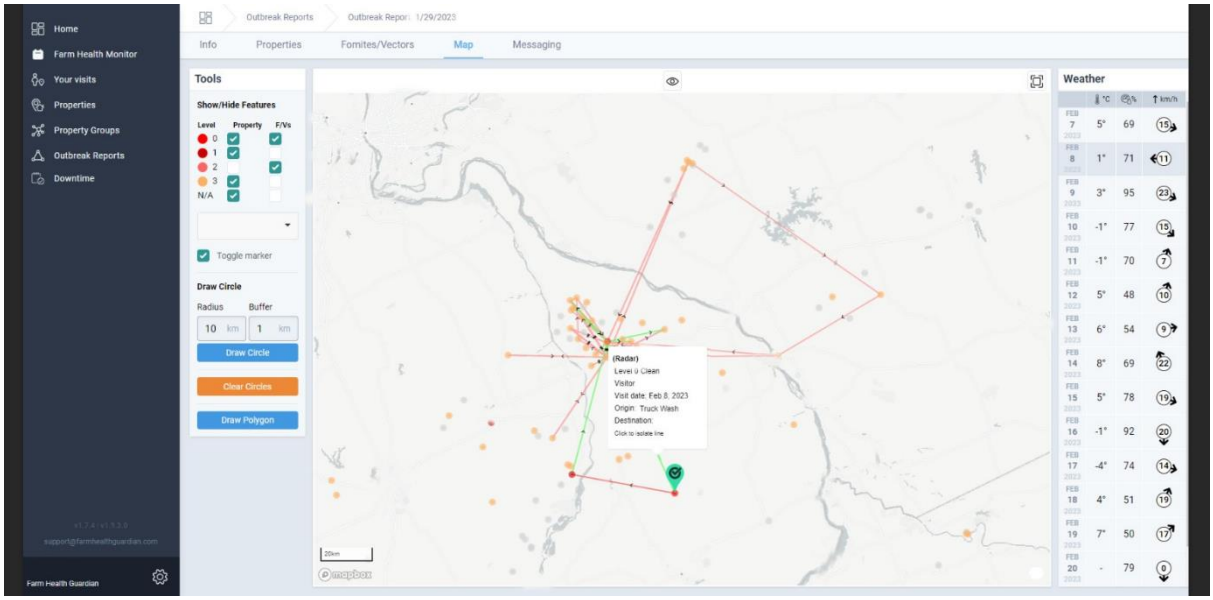


Figure 3: Additional mapping feature showing clean truck movements (green lines) after they have been to a truck wash location. The ability to isolate and identify fomites is also shown.

Contact Information

Property Name	Property Manager	Phone Number	Email Address
Farm-2765	Ted Smith	226-614-2298	tsmith@testemail.com
Farm-6571	Jane Brown	123-456-7890	jbrown@testemail.com
Farm-2680	Samuel Baker	845-365-7845	sbaker@testemail.com
Farm-6583	Rick Arnold	458-963-1254	rarnold@testemail.com
Farm-6581	Sarah Smith	843-879-4451	ssmith@testemail.com

Figure 4: Enhancements include the ability to download a report that shows contact information for farms within a control zone.

Recommendations

GPS device recommendations:

- **Device Performance**: Of the technologies tested, three GPS devices (two wired or powered, and one fully battery powered) showed reliable performance in and were unaffected by harsh cold winters. They proved reliable in daily operations related to livestock production and sanitation, with no significant impact on battery life.
    - Based on field testing, we recommend two wired device and one battery powered devices, pictured below. Passport L is a GPS powered taillight, wired into the vehicle and doesn't require a battery. Passport A plugs into the ODBII port of a vehicle so it has a direct connection to power. Radar are battery powered GPS devices.

Radar, Passport A, and Passport L devices.

- Manufacturers recommendations are not always the best guide for identifying devices that are suitable for farm and livestock trailer transport use. For example, some devices with IP ratings of IP67 (no ingress of dust and full immersion in water up to 30 mins at a depth of 1 meter) will not keep water out if subjected to pressure washing. Likewise, any devices rated as "water resistant" are not sufficiently sealed to withstand normal farm vehicle operations.
- **Pressure washing:** Devices must be able to withstand cleaning and disinfecting procedures, including hot and cold high pressure washing and resistance to cleaning and disinfecting agents.
- **Cellular Coverage**: The devices demonstrated reliable usability even in regions with limited cellular coverage, ensuring satisfactory performance in such areas.
- **LoRa**: Testing of LoRa technology provided valuable insights into the effectiveness of LoRa technology in recording feed truck visits. This capability offers enhanced visibility to managers and stakeholders, enabling them to validate movements and monitor activities more effectively. This aspect of the project demonstrates the practical application of devices in the swine industry and their potential to improve operational management and disease control measures. LoRa technology does show promise but needs more development before it can be scaled up for full industry use.
- **Battery Life**: Signal (ping) frequency significantly affects battery life. All devices had the ability to increase or decrease the number of times the device reported movement to the system (pings). They could also be set to only report starts and stops.

- If vehicles are travelling between jurisdictions e.g., USA and Canada, it is important to ensure that the system will work in both and to understand if there will be roaming charges when the device moves out of its home jurisdiction. Our recommendation is to select a system that carries a universal SIM card so that it works in any jurisdiction and the data fees remain the same regardless of where the transmission is originating.
    - This only applies to devices that are directly connected to the internet and not to devices which are based on a beacon and gateway system where the gateway is connected to the internet via a central router (e.g.LoraLAN).

Disease mapping recommendations:

- Commodity organisations/ and governments involved in disease response need software that is user friendly, fast, and meets their needs for disease mapping.
- Disease mapping software needs to provide information to organizations and farmers that is useful or has practical application for them today in order to show them the benefits. It is not enough for companies and farmers to adopt technology and change their day-to-day practices for potential disease control benefit in the future. They need to see value immediately to their operations or organizations.
- To keep transport data secure, the system must encrypt data being transmitted and the supplier must agree that the data will never be sold. The issue of data privacy cannot be ignored. Privacy is a key consideration when selecting any system that is reporting movements. Data being transferred from devices to the cloud are susceptible to 'man in the middle' attacks. For example, company 'A' seeking information about company 'B's' regular routes, or welfare activists intercepting location data and planning campaigns to disrupt transport to draw attention to their cause.
- To ensure that the data flowing from vehicle to cloud storage is secure, it must be encrypted. There are many systems that provide such encryption, but many do not. For example, in this project one system was rejected simply on that basis. Suffice to say that the unencrypted systems are generally cheaper than the other systems and often come with no guarantees that the data being transferred will be encrypted, nor that the company providing the system will not use the information itself. It is our recommendation that only systems that encrypt data being transferred and the companies that sell them will attest to this claim should be used and that the companies agree not to use the data for financial gain.
- Movements of livestock trailers should be recorded in a confidential database using tracking devices to significantly reduce track and trace time in the event of a disease outbreak. This information is kept confidential unless it is needed for a disease investigation. Having movement data readily accessible and easy to share in a database enables rapid disease response.
- We encourage governments to accelerate adoption of suitable track and trace devices by supporting investment in sensor technologies, in order to reduce costs of disease response and recovery.
- The device supplier's Application Programming Interface (API) must enable the movement data to be transferred. Most companies that manufacture and sell devices provide a dashboard and various features to help you track and trace vehicles. However as with GPS logistics systems these features are vehicle rather than property centric and in order to make sense of the data

from a disease management perspective a system needs to have specific mapping capabilities and attributes that are not usually available from off the shelf systems. It is important therefore that the company supplying the sensors will provide an Application Programming Interface (API) that will enable the movement data collected by the sensor to be transferred to a system designed to provide epidemiological information (such as the Farm Health Guardian system).

Appendix A: Acknowledgements

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- Moonfleet Poultry
- Cargill hatchery
- Maple Leaf hatchery
- Masterfeeds
- Grand Valley Fortifiers
- Hendrix Genetics
- South West Vets

Appendix B: Photos of examples of types of devices tested

Battery powered devices

Wired and OBDII port devices

LoRa device and receiver/gateway