Dingle Peninsula Farm Ambassador Program report and lessons learned.

Background:

Several technologies were deployed across 6 Dingle farms with an aim to provide spatial and temporal data to the farmers enabling prompt data driven decision making on the farms. This data in conjunction with best farming practices is expected to improve farm productivity, environmental impacts and labour hours.

Technologies implemented:

- **Pasturebase**: grass measuring is a proven method of increasing farm productivity by improving grass quality, grass management and grass budgeting. An app is installed on the farmer's phone and his paddock are entered into a map, the farmer measures his grass weekly using the cut & weigh/rising plate. This data is entered into the app during the farm walk by the farmer and the app calculates the DMkg in each field, with this the farmer can ensure his cattle get the correct DM coverage and can look forward to see which fields are next in his rotation and which to remove for silage.

- **Nutrient Management Plan (NMP):** there is a financial, legal and environmental responsibility for a farmer to ensure proper management of nutrient applications on their farm. The NMP is a tool that aids the farmer in conjunction with a Teagasc advisor to organise their nutrient inputs and outputs according to statutory and fiscal requirements. The plan requires a soil sample to be taken of the farmer's paddocks to identify the nutrients currently in the soil, next the nutrient demands are calculated on the headage/hectare. This allows the calculation of organic fertilizer produced on the farm, the nutrients removed from the soil through cultivation and the required purchase and application of lime, organic and chemical fertilizer to ensure a nutritionally balance productive farm.

- **Libellium waspmote smart agriculture pro (€601)**: this sensor array allows implementation of various sensors with one central control unit. The unit transfers data via LoRa wireless network to Netfeasa's servers via a localised gateway. The unit consists a rechargeable central control unit with 6 ports for various sensor probes.
  Probes chosen to be used on the farms are:
  - **WS-3000 weather station (€75)**: Wind speed (km/hr), Wind direction (cardinal) rain (mm)
  - **PT-1000 Soil temperature probe (€40)**
  - **Watermark (€80)** soil moisture sensor
  - **BME280 (€55):** Air temperature (°C), Relative Humidity, Atmospheric pressure (Pascal)
  - Solar panel to recharge the battery.

  This data can be used to produce a soil moisture deficit model and correlated to grass growth rates and milk production rates allowing a localised model for the farm to give predictive decision making matrix for the farmer.

- **Sensoterra soil moisture probe (€150)**: this wireless soil moisture probe communicates through the same LoRa network gateway as the Waspmote. The probe uses capacitive and frequency domain resistance to determine the volume of water in soil. The system comes with an app which allows the farmer to select the type of soil the probe is placed in and give the farmer live soil moisture levels. The selection of soil type is very important as the probe resistance reading is converted to a %Vol water using independent calibration curves for each soil. The app allows the selection of 12 different soil types.

- **Tek Agri LoRa Ultrasonic (€130)**: deployed on the milk tank and on the slurry tank. This sensor uses ultrasonic sound waves to measure the distance between the sensor and the surface in front of it. The sensor communicates through the LoRa network sending centimetre measurements at pre-determined intervals. The sensor reading of cm must then be converted into a volumetric measurement of litres and cubic meters for the milk tank and slurry tank. The slurry tank conversion is carried out using the dimensions of the rectangular slurry tank provided by the farmer. The conversion of the milk tank is approached in two ways, dimensional and polynomial. The dimensional requires the internal measurements of the milk tank to produce litres volume, the polynomial equation approach requires the sensor readings and numerous lorry collections to be plotted to develop an equation that can convert the sensor reading to litres.

- **LoRa network Gateway (€1373):** Gateways create a local network on the farm which the various assortment of sensors can connect to the gateway then communicates to the servers via mobile data facilitated by Eir. The system works best on line of site. Four out of the six farms have gateways installed, farms 1,2,3 and 4 having gateways and the gateway on farm 2 serving farm 5 and the Dingle Hub serving farm 6. The in favourable conditions the range of the gateway can be quite impressive, therefore location of the gateway is very important. The robustness of the gateways was demonstrated during this pilot project with only one short occasion of down time that was an Eir issue.

Placement of sensors.

- Sensor placement is very important as the location of the sensor must be a representative area of the farm. Sensors were placed out on the pilot farms in January 2020. Some issues observed on the placement of sensors have been noted and the following recommendations are to be implemented going forward.

    - Survey of the farmer asking the following questions:
        - What is the highest point in your farmyard/house?
        - Is there a power source near this location?
        - Which field would be representative of your farm?
        - Is there any hardpans/old drains/old structures/old passageways under the surface that may affect the soil moisture sensor?
        - Is the soil in this location representative of your farm?
        - What type of milk tank have you? (note model and connection type required for sensor)
        - What times do you milk and what is the usual milk collection time?
        - Do you provide milk to the calves of milk replacer?
        - What are the internal measurements of you slurry tank? (Note some clients may give the measurements of the shed not the internal measurements of the tank)
        - How many slurry tanks have you and which one is your main and largest tank? (note if similar size tanks or if requested by the client another slurry sensor may be implemented on the farm)
        - Are you currently grass measuring and using Pasturebase?
        - Do you graze new paddocks at night?
        - Are you recording your slurry and fertilizer applications in Pasturebase?

        - Have you an NMP in place?
        - Who is your Teagasc advisor?
        - What data is most important to you?

    - All sensors should be placed in a similar manner e.g. weather stations should be all the same height off the ground.
    - Weather stations should be as far as is practicable positioned away from ditches, trees, sheds and houses to prevent a shadow effect from the local structures. The most favourable position would in the middle of a field along a wire fence dividing two paddocks, most farms will have this.
    - Ensure a strong mounting pole for the waspmote, a standard steak will not suffice, the farmer must place a strong (corner pole) steak in the ground or a 2 inch galvanised pole in concrete, must be level. If there is any movement in the post/pole do not use it.
    - Protection of the sensors is also required, placing a small wire fence around the station is the best option to prevent animals interfering with the equipment, this does not have to be very large just enough to prevent an animal touching the equipment 1.5-2m^2. All wires should be protected.
    - It may be necessary to produce a protective covering for the waspmote to prevent weather damage, ensure this is large, white and UV resistant. The cover must not interfere with sensor such as the air temp/humidity (i.e. creating and oven effect from sunlight). (note for a few weeks a large white box may spook the cattle but they will get used to it very quickly, inform the farmer that this might happen before erecting)
    - Watermark placement is very important to ensure good contact with the soil. A wood auger bit slightly smaller (.5mm smaller) than the diameter of the watermark works best. Select the site and depth required, drill out a hole and using local water (rain water if possible) saturate the hole. Push the water mark firmly to the bottom and back fill the hole ensuring no air gaps. Make sure the wire is below the surface as it may creep water to the water mark if directly above the watermark and on the surface.
    - The milk tank sensor must be firmly attached to the tank to prevent damage to the sensor and for hygienic reasons.

Review of technology:

- Pasturebase, two farmers were already carrying out grass measurements a third farmer's walks were carried out by Teagasc. There was poor uptake of this system by farmers as it can be time consuming and farmers need to see the value in the data provided. Grass data is vital for this study as it allows the weather data, fertilizer application and milk production data to be correlated to the grass growth rates. If this data is not captured correctly the value in the weather data, soil moisture and milk tank sensor will never be realised.
    - It is recommended that a grass measurement service be provided to the farmers for the first year in the project to allow value of the data to be demonstrated to the farmers.
    - Some farms in Dingle feed new paddocks at night due to the broken paddock size of the area. This data is very difficult to capture on pasturebase, it is important when correlating the milk production rate to DM grass intake of the cows to know how much grass the cows are actually receiving. A whiteboard in the dairy may aid this system, to allow the farmer and grass measuring operator to keep track of the data. The whiteboard should have:

        - the days of the week, AM/PM
        - Paddock number.
        - The farm map should be placed next to the whiteboard.
        - Daily ration intake.
        - Number of cows
        - Amount of milk for calves
        - Fertilizer application (if not inputting into the pasturebase app)
        - To do list
    - A Grasshopper rising plate should be purchased for the operator measuring the farms to improve efficiency and accuracy.
    - The operator needs to be clearly instructed in grass measuring, should be polite and considerate to the privacy of the clients.
    - It is important to measure the residual grass in a field that has just been fed to correctly determine the amount of grass intake.
    - A survey of the grass seed used on the paddocks should be carried out to identify if different grass types improve the milk production rates. If a mixed crop is used this must be noted.
    - A sensor to capture ration inputs must be implemented on the farms, while this will only work on some farms as some use buckets a steam lining of the data will aid the project.

- **NMP**

  This technology is poorly implemented and poorly followed. There is a vast amount of valuable information in the NMP for the farmer which is not thoroughly followed. The main points used by the farmer is lime requirements which vital is only a portion of the NMP. Once implemented the pasturebase app will aid in the tracking of slurry/fertilizer application which can be checked against the NMP to identify successes and failures. The plan should be carried out with the farmer and the Teagasc advisor jointly. The application rate page and the relevant soil maps should be placed on large printouts in the dairy/office to allow the farmer to visualise the paddocks that require fertilizer/slurry.

- **Waspmote**

  This technology chosen for its cost effectiveness and system familiarity has a lot of advantages and disadvantages. The failure rate of the waspmotes over the period of February to November is shown below. These numbers reflect the number of times the waspmote sent data to the server it does not indicate the quality of the data.

Farm 1	Farm 2	Farm 3	Farm 4	Farm 5	Farm 6
66.1%	69.0%	76.3%	78.8%	93.8%	94.5%

  The robustness of the waspmote and it sensors are questionable with a significant failure rate, however the low cost of the unit and sensors would allow the purchase of a float stock to ensure low interruption time on the data flow. Troubleshooting of the sensors must be made a priority a time limit of 5 working days must be placed on the sensor downtime i.e. the data flow must be reinitialised within 5 working days of a sensor going down.

  Various iterations of the programme on the waspmote were trialled during the project these are shown below

- V1.0 – deployed Dec 19 / Jan 20
- V1.1 – March2020, changes to LoRa parameters

- V2.0 – August 2020, Changed reporting interval from 15 minutes – 1hour and fixed time issue
- V2.1 – October 2020, Synch time on and device set to report on the hour
- V2.2 – Dec 20 / Jan 21, Updated device to start reporting at 58 minutes past hour, in order to get hourly rainfall

Various issues were detected during each version update. This is a difficult process as each code change requires field trials to verify the success of the new code. One main issue noted during the project was the time difference between the internal waspmote clock and the server clock which led to poor rainfall data. It is recommended that the sensors attach a timestamp to the data that is sent to ensure this does not happen in the future. This has been implemented on the later variations of the programme ensuring accurate rainfall readings.

- Recommendations
    - Float stock of 10% should be purchased.
    - 5 working day turnaround on breakdowns

- Watermark soil moisture sensor probe.
  While this is a robust and reliable probe it will not give a soil moisture reading out of the box. There were several different approaches to convert the hertz reading from the probe to a %Vol water in soil. Soil moisture sensors are not a plug and play technology and require careful calibration to the soil it is placed in.
  The first approach was to use the Van Genuchten equation with pedotransfer soil parameters derived using a Rossetta model programme and the soil maps/soil samples to convert the hertz reading to a water volume, this was not very accurate and was abandoned. Next field calibrations were attempted but issues with variations in soil sampling and hysteresis again gave poor results (note improved soil sampling methods and accounting for sensor hysteresis may allow this to be carried out again). This final approach was laboratory based soil was collected from the farms and trail was carried out. This trial took 4-5 weeks for one soil to dry completely giving a Soil Water Retention Curve for the soil and sensor. This system has yet to be fully verified against field soil samples but it seems to be the best approach. A method statement has been prepared for this laboratory work.
  The limitation of the water mark in the saturated zone were identified during this lab trial. The watermark will only give an accurate soil moisture reading for approximately 5-30%, once above approximately 30% Vol water the readings are not accurate. As most of the field saturations points go to 45% there is approximately 15% not captured by this sensor. However as the watermark provides 5-30% approximately this will an advantage to the farmer in the dry summer months when the Soil Moisture Deficit is monitored closely by the farmer.
  Recommendations:
    - Another soil moisture sensor should be investigated to capture the full water Vol% as provided data on the saturated region of the soil could aid the farmer on closing in dates, out dates and spreading dates. This sensor should be portable if possible.
    - Work should be carried out with the SMD model in Teagasc to use the watermark reading to calibrate the SMD model for the farm. This may allow an estimate of the SMD without the purchase of another sensor.
    - The operator should be thoroughly trained in soil sampling and laboratory methods.
    - Extra waspmotes, watermarks and a gateway will need to be purchased to allow laboratory work to be carried out in Teagasc.

Sensoterra:

This technology did not perform as advertised, during the project the sensor was set to the soil type (Loamy sand and sandy loam 1) in the field. It did not produce an accurate result giving a lower soil moisture readings than the actual field moisture readings. Only when the soil type was set to peat did the sensor begin to give somewhat accurate results, this was done in the latter part of the year when soil was at field capacity or saturation. Other difficulties occurred with the transfer of data to the sensoterra servers through the Netfeasa systems, the resistance values were corrupted giving inaccurate results. This issue was resolved during the project.

While the technology is very easy to use and the sensors are robust and portable. The poor soil calibrations curves provided by the manufacturer make this sensor inaccurate and unreliable. If a calibration was to be carried out by the manufacturer on the soil it would cost approximately €1200 for one soil and take 8 weeks, this is not a tenable resolution.

- Recommendations
  - Discontinue the use of this sensor.
  - Approach the manufacturer requesting a reduced rate on soil calibrations or a joint calibration trail between the company and Teagasc to allow the sensor to be used in the Irish market as the manufacturer soil calibrations have been shown to be ineffective in Irish soils.

Tekelek

This sensor was the most successful and reliable sensor used in the trial. With a sensor costing €130 a daily milk production rate can be produced. The ability to produce a daily milk production rate so cost effectively and accurately cannot be understated. Difficulties in attaching the sensor to the tank were resolved during the trial (see method statement on such), measuring the tank accurately was an issue that was resolved by operator training, method and equipment improvements (Bosch laser measure).

On one farm the sensor could not gain a data connection inside the dairy and the sensor was not implemented on the farm. A large amount of work is required to go through the data from the sensor to identify the milking's and the collections. Accurate capture of the amount of cows is vital to provide a daily milk production rate. This should be captured using the whiteboard or a software input by the farmer. Sensor reading times were varied throughout the trail from twice a day to every hour. The hourly reading gave a better resolution of data that is still required at this stage of the project to ensure data inaccuracies are captured and ensuring the vital lorry collection is captured. Remaining at hourly will drain the sensor battery life, this amount must be determined and account for, however the changing for a battery is of little consequence. Once a polynomial has been established for a tank a reduction of the sensor readings may be allowed to once every 2-3 hrs to improve battery life.

Difficulty in accessing the milk tank collection data was found during the trial. Data was collected directly from the farmers, going forward either a direct link with the creamery should be established or more desired is the connection of pasturebase to the farmers creamery to automatically collect the data and milk quality onto the app. this data is vital to establish the more accurate polynomial regression equation for the tank.

The slurry tank sensor gave good results and allowed the calculation of slurry going into and out of the tank. A weekly slurry production rate was also established for some of the farms allowing an estimate of the date the tank will be full. Some of the sensors were placed on secondary tanks which did not capture the true volume of slurry on the farm.

- Recommendations
  - Connect each farmer's lorry collections to pasturebase.

- Begin using the dimensional equation and once a full season (or sufficient amount to model the tank) of data has been captured on the milk collection move to the more accurate polynomial method using the lorry collections.
- An automated system must be implemented to capture the daily milking's and to error check as the time involved to do this manually is time consuming.
- More sensors should be purchased to attach to extra slurry tanks.
- Sensors should be checked yearly to ensure they are still providing an accurate measurement. This should be carried out on a level test rig at different heights to ensure accuracy.
- Some external antennas or boosters should be purchased to ensure each milk tank has a sensor on it.

IoT wireless technology:

The IoT wireless technology used for the Farm Ambassador Project was LoRaWAN and proved to be very reliable during the trial with outages only observed due to power outages or cellular coverage on the farm or in the wider area. LoRaWAN Gateways were installed across four of the six farms to provide radio coverage and the performance and coverage was excellent, with minimal message loss and messages. However, LoRaWAN Gateways are expensive and involve an installation on each farm premises. For scaling this initiative to 30 farms and beyond, it is recommended to use the IoT technology NB-IoT. Net Feasa as a network service provider can provide the connectivity and device provisioning required for NB IoT.

Method statements

Soil Sampling

Soil Auger- 30mm (procure from Patrick Touhy Patrick.Tuohy@teagasc.ie)

Plastic bags

Oven (contact Michelle Liddane in the grass lab to get time to use oven)

Foil Trays

Scales (Scales owned by this project can be loaned to others in VistaMilk (e.g. Asaf Shnel)

Method:

- Take 3-4 samples between 1.5-2.5m from the sensor.
- Drive the auger into the ground using the nylon lead weight mallet provided. Once fully inserted twist the auger and pull up carefully using your legs.
- Using the curved knife provided with the auger scrape off the excess soil by scraping the knife across the flat face of the auger see instructions by the manufacturer.
- Select the 0-15cm horizon of the watermark placed at 10cmand place this in a bag, the remaining 15-30cm is used for the 20cm watermark.
- Mix the samples in the bag and weigh the wet soil.
- Dry in an oven at 105°C for 24hrs and reweigh.
- Calculate the %Vol water by
    - Wet soil weight – dry soil weight = Water weight.

      (Water/Dry soil weight)*100 = % gravimetric water content

% Gravimetric water content * soil field BD= %Volumetric water content.

Watermark placement

Two methods to place watermarks

1: attach PVC pipe to watermark to ensure correct depth of sensor and ease of movement (see attached PDF file on construction of such)

2. Direct placement of watermark into ground

Wood auger bit required for both placements, drill hole to required depth (place insulation tape on auger to mark depth) fill hole with water and gently but firmly push watermark to the bottom of the hole. Back-fill hole if method two used. Ensure wire is buried under the surface to prevent water traveling along wire to the watermark and to protect wire.

For method 1 some materials are required.

- 2.5mm drill bit
- Drill
- Soldering iron
- Solder
- Flux
- Heat shrink tubing
- uPVC tape
- wire cutters
- Wire strippers/Stanley blade
- Hacksaw/pipe cutters
- PVC pipe ½ inch
- PVC glue
- ½"Brass blank fittings and olives
- Rubber/coriboard seal

Method:

- Remove heat shrink from watermark connector and strip back wires (black and yellow used in new models, note which wires are connected)
- De-solder the connected wires
- Pass the wires through the white PVC pipe and through the 2.5mm hole at the top.
- Place heat shrink over wires
- Re-solder the wires with fresh solder and flux if required. Ensure firm connection.
- Using the soldering iron/heat gun/lighter shrink the heat shrink onto the wire. Cover with tape to ensure watertight.
- Follow the method outline in the HOW TO MAKE A WATER MARK publication.

Watermark calibration curve

The Watermark works on the same basis as other electrical resistance sensors. The water conditions inside the probe change with corresponding variations to the external soil water content. The Watermark is made of two electrodes imbedded in a granular matrix, the resistance between the probes decreases with increasing water content in the probe. As the soil water content decreases in the surrounding soil the matric potential pulls water from the granular matrix increasing the electrical resistance between the probes and Vis versa.

To accurately develop a soil water retention curve (SWRC) for the soil in question it is preferred to carry out field base calibration but due to the difficulties in controlling the external factors, collection of samples and lengthy time required to develop a full SWRC for the soil a lab based calibration is used. However if possible a field study should always be attempted at develop a SWRC.

Materials

- 105mm (internal) black ABS pipe (conduit)
- Black pipe end cap
- Silicone & silicone gun
- Fabric glue (water insoluble, acetone based)
- Drill
- Hole saw
- Grinder/hacksaw
- File
- Stanley knife
- Polyester cloth
- Scales
- Watemark (contact Elodie Ruelle Elodie.Ruelle@teagasc.ie)
- Soil temperature probe (contact Elodie Ruelle Elodie.Ruelle@teagasc.ie)
- Waspmote (contact Elodie Ruelle Elodie.Ruelle@teagasc.ie)
- Waspmote programme on laptop
- USB A to USB micro B cable
- Access to database (contact Elodie Ruelle Elodie.Ruelle@teagasc.ie)

Method

- Cut a 13cm length of the ABS pipe (ensure a straight cut)
- Drill 8 holes on the pipe at the X/Y intersection of the imaginary axis from the centre point of the circle one hole above the other.
- Clean off burr using a file/Stanley knife
- Cut approx. 330x13cm polyester cloth and glue to the inside of the pipe.
- Glue on endcap using silicone sealant ensure firmly held.
- Allow glues to dry
- Weigh the dry container.
- Collect approx. 2.5-3kg of soil from the depth of the water mark. Remove the top sod in 1m^2 box. Down to approx. 7.5cm and then remove a layer of soil from this into a container.
- Dry the soil at 105°C for 24hrs and pass through a 4mm sieve.
- Fill container with required soil to make up the bulk density of the field. (the excel sheet will automatically tell you the soil required if the field BD is known, measurements can be adjusted if required as the known volume of the container is required to calculate the soil required and the %volume of water)
- Divide soil into three and place dried sieved soil into container pack down between adding soil. Ensure soil is flush with the top of the container.
- Soak soil in irrigation water (rain water) for 3-4 days, stand container in a bucket of water do not completely submerge the container, 2/3^{rds} of the way up will do to allow capillary action to draw water into soil. Half way through the soaking remove container for a few hours and place back into water to ensure complete soaking of the soil.
- Dry watermark and weigh, then soak watermark in irrigation water
- Attach watermark to waspmote and take reading a fully dry water mark should give a Cb reading above 200Cb @24°C, closer to 200 the better if the watermark is below 200Cb allow to dry further (note a completely dry sensor will give a 0Hz reading on the waspmote which is above 200Cb, a damaged or incorrectly connected watermark will give this reading also). Soak the watermark overnight in irrigation water the watermark should give a reading of

0Cb @24°C it needs to be below 5Cb, if the watermark is still above 5Cb then repeat the drying (may take a few days in a warm place) and wetting cycle, if the water mark is still above 5Cb it is faulty and should not be used. The water mark is a basic resistor the waspmote will convert the watermark resistance into a Hertz reading that can be converted into a Cb reading using the soil moisture trial excel sheet, this converts the Hertz reading using the below equations

Cb=(-19.74*Hz+150940)/((2.8875*Hz)-137.5) Convert Hz to Cb

Cb_t =Cb-(t°F-70)*0.01(Cb) correct for soil temperature as the watermark is factory calibrated at 24°C

- Using a wood auger drill a hole in the centre of the soil, fill the hole with irrigation water and place the soaked watermark into the hole pushing firmly into position. Back-fill hole
- Place soil temperature probe into soil

There are two ways to extract the data from the waspmotes. Method 1 is to directly connect to the waspmote and run the serial monitor. This will give you the Hz and soil temp when the probes are connected.
If using the 4G waspmotes (Elodie's) the data can be extracted from the database. There is a file connection set up on the soil moisture raw data file that will extract the data. A Macro has been developed to sort the data by pressing Ctrl+Shift+T that will organise the extracted data into the correct format to allow the pivot tables in the soil moisture trial to give daily averages.

- Once the soil has soaked for 3-4 days remove and weigh the container. This will be the soil saturation point. Place the container in a larger container to allow excess water to drain (tilt container if needed) once water has stopped draining this will be the field capacity of the soil weigh again.
- Using a desk fan on low speed allow a gentle breeze to flow over the container to encourage drying. Rotate the container every few hours to allow even drying. For best results weigh the container first thing in the morning and take the sensor readings, then allow the fan to blow over the container during the day. Turn off the fan in the evening to allow the water to distribute equally in the soil and watermark overnight.
- Weigh the soil every day and take the sensor reading. The excel sheet will calculate the %Vol of water
- Plot the Cb against the %Vol water to develop the SWRC.
- This method should take 4 weeks to reduce the Cb from 0Cb to 200Cb
- Note the watermark is only accurate between 10-230Cb and will not provide an accurate reading in the very wet range of the soil.

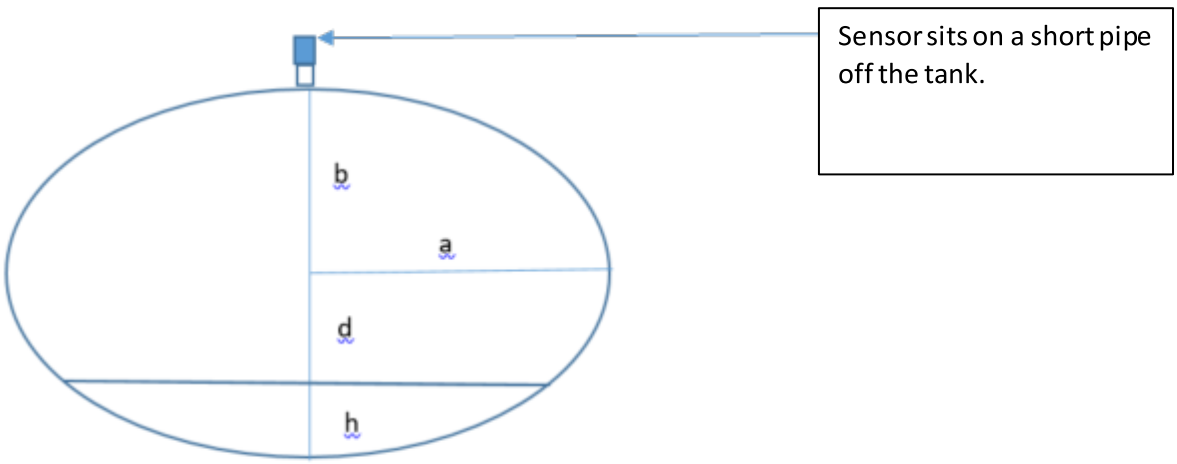
Milk Tank measurements

The Tekelec sensor is used to measure the distance between the sensor and the surface it is facing using ultrasonic sound waves. The sound wave travel path cannot be interrupted or too close to another surface as this will interfere with the measurements.

To measure the volume of milk in the milk tank two methods are being used to approach the litres in the tank, Dimensional and Polynomial regression from the milk lorry collections. The former is slightly less accurate but allows a measurement immediately once the internal dimensions of the tank are known. The Polynomial requires the milk tank collections and the sensor reading to predict the volume in the tank, as the height of milk varies over the year it requires a season of data to develop the polynomial regression model of the tank. It is therefore possible to begin with the dimensional equation and once enough data is collected on lorry collection to change over to the polynomial model.

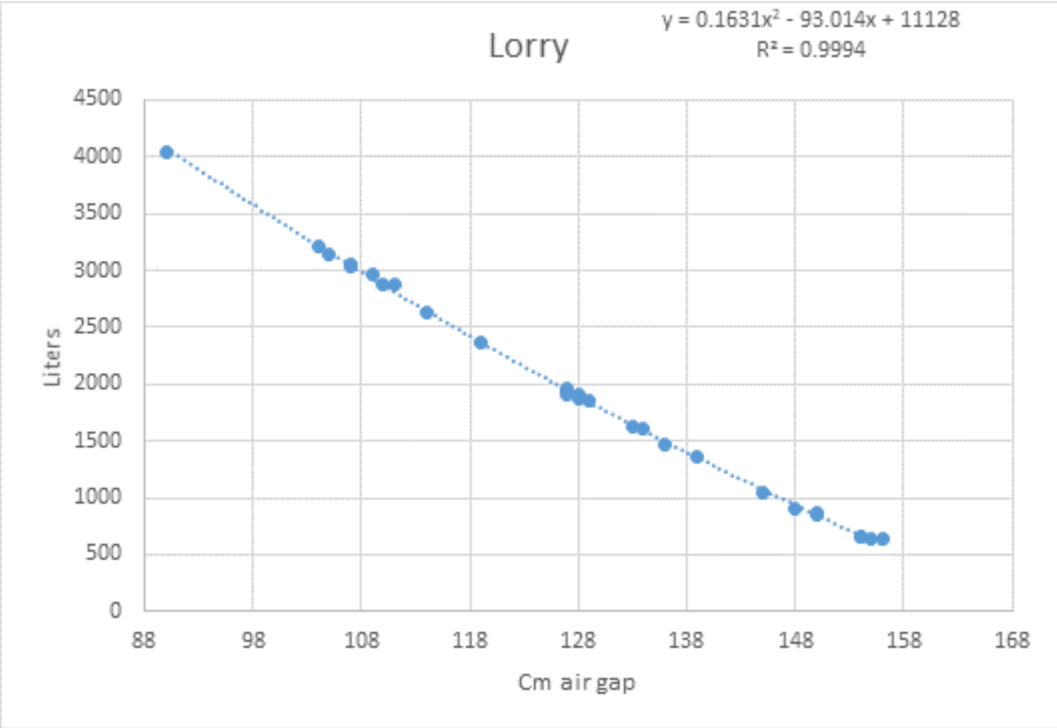
The two approaches being used to calculate the volume of milk in the tank.

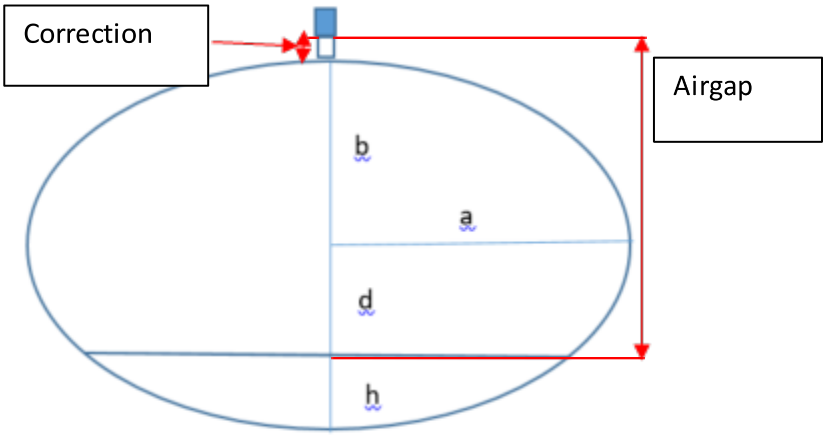
- Dimensional equation
  - Tank volume $= L(ab\cos^{-1}(d/b) - ad\sqrt{(1-d/b)^{2}})$
    - b =minor axis
    - a = major axis
    - h= height of milk
    - d= b-h
    - L= length of tank



NB: Equation assumes a perfect elliptical cylinder

- Polynomial regression of the sensor measurement cm and the lorry collection.





Air Gap is the distance between the sensor and the top of the milk.

In order to determine h (the height of milk) first correct the airgap reading by subtracting the length of the pipe it sits on and the thickness of the insulated wall of the tank. This artificially brings the sensor inside the tank where the bottom of the sensor is at the same height as the tank at brim full.

Subtract this corrected airgap value from the known measured depth of the tank to give the height of milk in the tank.

Therefore:

Airgap – correction to bring sensor to brim full = corrected airgap

Depth of tank – corrected airgap = height of milk (h)

Eg.

Farm 3 sensor sends a value of 116cm =airgap

Subtract 10cm as this is the length of pipe and the thickness of the tank wall = corrected airgap = 106cm

The depth of the tank is 177cm

177-106= 71cm = height of milk in tank

This is fed into the dimensional equation to give a value of 3077L milk

An excel sheet Milk tank trial has been set up to automatically provide the volume of milk based off the sensor reading using the dimensional and polynomial if developed for the tank (as the polynomial is individual to each tank).

How to measure the milk tank.

Measurements required (All internal measurements):

- b =minor axis (Depth/2)
- a = major axis (Width /2)
- Sensor correction distance
- L= length of tank

Equipment Required

- Laser measuring device
- Measuring tape
- Callipers
- Straight edge
- 2*1 timber
- Sanitization cloth

Using the callipers or the measuring tape and a straight edge measure the correction height (distance the sensor is away from brim full)
Using the laser measure the length of the tank take several readings and take the average.
If there is milk in the tank use a clean and sterilized measuring tape to measure the depth if the tank is empty then use the laser measure.
To measure the width attach the laser to the 2*1" timber and lower it into the tank until it reaches halfway on the depth. (a helpful way is to set the laser to read the max measurement and lower it straight into the tank 2/3rds of the way in and pulling it out this will give the max measurement which

should be (a) the major axis, repeat this for both left and right on the axis and take the average of the readings)

At all times ensure equipment is clean and sterile and the tank lid is firmly closed after.

To attach the sensor to the tank:
Requires two methods depending on the tank type, one uses the treaded fitting on the sensor; there are two different tread attachments for the sensor, the other method requires a wire cage to be built see pictures (usually used with dairymaster tanks).

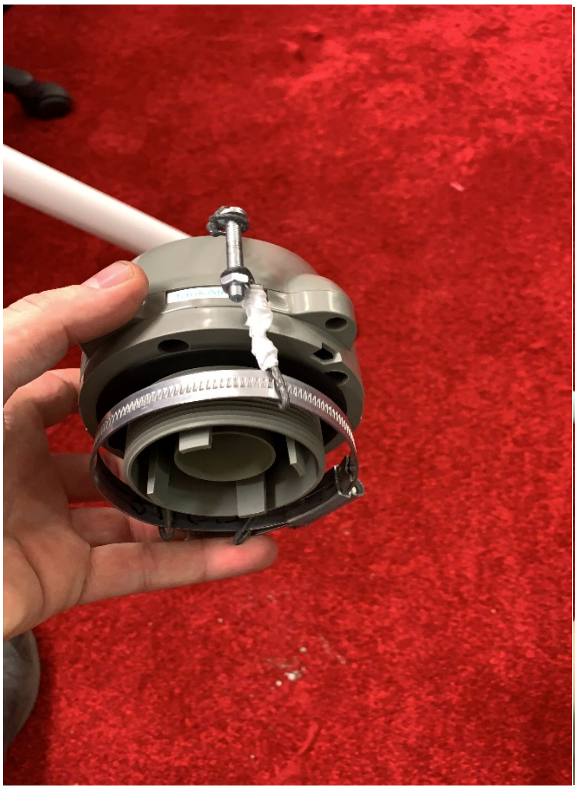
Materials:

- 2"BSP female connection Philmac (Nash plumbing supplies, Fermoy)
- Grinder/Hacksaw
- File
- Wire
- Jubilee clip
- Pliers, vice grips
- uPVC tape
- 4mm stainless steel bolt with nut

Split the 2inch BSP (British standard pipe) female connection in halve to create two plastic nuts. File off burr and clean the nut. Place the sensor on the tank door and tread on the plastic nut from underneath ensure the rubber seal of the sensor seals the tank (ensure the air inlet for the tank is free on the tank as the steam pressure during washing will damage the sensor)
Ensure all items are thoroughly clean.

To make the wire cage use soft 1-1.5mm fencing wire (any soft but strong galvanised wire will do) Form the cage as shown in the picture, tape joints and connect the galvanised jubilee clip and bolt as shown. When connecting to the tank ensure there is a tape/barrier between the stainless steel of the tank and the galvanised surfaces to prevent any galvanic corrosion of the metals on the client's tank. Attach the jubilee clip first then using the bolt tighten the sensor to the pipe of the tank. Ensure rubber seal is seated correctly.






Mounting weather stations:

Materials:

- 3*2” timber/ 2” brown-band galvanised steel pipe.
- 10mm tread bar
- Large quanity of 10mm galvanised nuts
- Galvanised washers
- 11mm HSS drill bit (have spare ones)
- 12mm wood auger bit (long 20-30cm length)
- Size 17 wrench
- Vice-grip
- Level
- Clamp
- Drill
- Philips head driver
- Long screws
- Flexible conduit
- uPVC tape
- Shovel
- Cable ties
- Zinc cold galvanizing spray
- Snips
- Grinder
- A-frame ladder
- Steel cutting discs
- File

Selecting the location of the weather station is paramount for good data. Avoid areas near trees, sheds and houses that may cause weather shadow on the device. Discuss with farmer a good location representative of the farm, also discuss if there are any underground drains/old ditches/old passageways/structures underground that may affect the soil moisture sensor and soil temperature. The best position would be mounted to a steak that divides two paddocks. The weather station should be at a minimum 2m off the ground (ensure all weather stations are the same height off the ground)

1. Once the area is selected request the farmer to place a large straining pole in the position of this steak (pole should be firmly set and as level as possible).
2. If using steel pipe cut to the desired length and make two 11mm holes through the pipe approximately 30-40cm apart, run the treaded bar through these holes and bolt onto the pipe with the washers. Using a file clean off any burr and spray any cut surface with the galvanising spray.
3. Clamp the level to the pipe and place the treaded bar against the large timber steak and level the pipe east and west (in relation to the steel pipe) so that the pipe is level east and west.
4. Mark the areas the treaded bar meets the steak and drill a 12mm hole using the wood auger bit.
5. Tread a nut onto the each tread bar along with a washer and push the tread bar through the holes drilled into the steak.
6. Tread another bolt onto the end of the tread bar. Now that the bolts are in place move the level onto the north south orientation of the pipe (relative to the pipe) using the bolts level the pipe north and south by adjusting the length of the top or bottom tread bar by moving the bolts and tighten the nuts to ensure the bolts are tight and the pipe is level.
7. Cut off excess treaded rod and file off burr. Apply galvanising spray to the cut surfaces.
8. Using the A frame ladder mount the weather station to the pipe using jubilee clips and cable tie the cable to the pole. Mount the waspmote to the pole/steak.
9. Run the sensor cables for the watermark and soil temperature probe through the flexible conduit and dig a channel (15cm) into the ground keeping the watermark and soil probe as far away as possible from the base of the steak. Place the probes into the soil following the manufactures and the above instructions. Note the conduit is to protect the exposed wires from damage the conduit does not need to run completely under the ground. Ensure the top of the conduit is turned down and secured to prevent water entering the pipe.
10. If using a 2*3” timber, clamp the level to the timber and level the timber east and west (relative to the timber) drive two screws to attach the timber to the steak.
11. Drill through the 2*3” timber and the steak with the wood auger bit
12. Follow steps 7-11 above.

See pictures below of the timber prototype construction.