Dairy Australia

SIP2 Snapshot Series
Using soil moisture monitoring to schedule irrigation

Evaluating the effectiveness of rainfall and irrigation to maintain optimal moisture

KEY POINTS

Soil moisture monitoring equipment provides real-time data on the impact of weather conditions (rainfall and evapotranspiration), plant water use and irrigation applications at-depth in the soil profile.

Technologies have advanced and become more economical, especially taking account of input savings and production gains made by irrigating to maintain optimal soil moisture within the Readily Available Water (RAW) zone.

It is recommended that dairy irrigators work closely with a suitably knowledgeable agronomist and software provider in selection and use.

Soil moisture monitors provide a range of information from a single data source to assist dairy irrigators. They give a good indication of:

- The effectiveness of irrigation or rainfall on soil moisture (depth and amount);
- Where root activity and development are occurring within the soil profile;
- Plant water demand to inform irrigation timing and rate of application (spray irrigation) and;
- Soil temperature to inform sowing and management decisions related to plant development stages.

The data generated allows you to know:

- How dry the soil is at different depths prior to irrigation or rainfall and;
- How deep the moisture has penetrated after irrigation or rainfall, and how much has been received.
- Readings in the root zone indicate whether under-watering has occurred, and below the active root zone whether there has been over-watering (drainage).
- Readings between irrigation/rainfall events help to determine the pattern of plant water use, relationship with plant development (pasture establishment/crop growth stages) and weather impacts.

Figure 1 Soil moisture monitoring equipment and rain-gauge in Paddock 6 of the Yarram Dairy Optimisation Site, installed and supported by AgLogic agronomist, Marek Matuszek (pictured).

DELIVERING *for* DAIRY

Australian Government
Department of Agriculture, Fisheries and Forestry

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Soil Moisture Monitoring technology used in the Smarter Irrigation for Profit Phase 2 project (SIP2)

Soil moisture monitoring equipment installed across the SIP2 Dairy Optimisation Sites was selected based on the performance of technologies trialled in SIP1 across dairy, cotton and sugarcane.

The following was installed:

- EnviroPro® capacitance probes (volumetric readings) with sensors at 10cm increments and a soil temperature sensor.
- Rain-gauge with automatic tipping bucket, various products used.
- Wildeye® data logger taking soil moisture status readings from each sensor every 30 minutes, and soil temperature and rainfall hourly.
- Wildeye® real-time telemetry that immediately relayed the data to a cloud-based reporting platform.
- Wildeye® reporting platform to visually present the soil moisture, rainfall and soil temperature data in a graphed format, with capability for the user to interrogate the information over time. Platform accessible via a Smartphone App and website.

Deciding on the required depth of probe

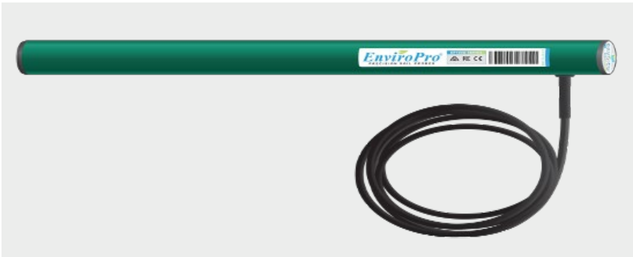
In shallow rooted perennial and annual pasture systems, 40cm probes are adequate to provide 10-30cm readings within the rooting zone, and a 40cm reading to monitor for over-watering. For deeper rooted species (lucerne, millet, wheat, maize. sorghum), 80cm- 1.2m probes are recommended allowing for root development.

Technology Options

Across dairy's SIP2 projects, capacitance probe technologies that indirectly measure volumetric soil water content (%VWC), a percentage fraction of the total volume of water contained in a volume of soil, were widely used at research and Dairy Optimisation Sites.

Volumetric readings allow the user to correlate the status of the soil moisture with the determined readily available water (RAW) of the soil type , expressed in mm (refer to ***Determining readily available water from soils texture information***). Experience has found the hardware to be durable and relatively easy to maintain, with all sensors encapsulated within a single probe casing. A limitation of this technology is that they have a small measurement volume. Examples of these sensors sold in Australia include EnviroPro®, Sentek® and Aquacheck®.

Figure 2 80cm EnviroPro® probe installed at the Mt Compass (Lucerne) and Tongala (Maize) Dairy Optimisation Sites.



Soil water potential is another way to measure soil moisture. These technologies measure how tight the water is held, and therefore how hard the plant has to work to extract the soil moisture, expressed in kilopascals (kPa). Gypsum blocks and tensiometers are two commonly used suction based tools. Whilst benefits include a wider measurement range and close correlation with plant function, it is more difficult to compare the reported measurement to RAW, and lifespan can be relatively short.

Automatic data loggers with telemetry are best adopted for ease of use and accessibility. There are many service providers in Australia who supply loggers with real-time telemetry and charge an annual fee for access to a reporting platform that converts and presents the soil moisture trace data in a convenient format. Most provide access via a smartphone app and website. The SIP2 Project found that farmers generally preferred accessing their data daily on a simple platform from their smartphone.

> "The cost of the equipment definitely pays for itself due to using less water and reduced electricity costs. Also, we have saved time by not having to check the moisture level in paddocks."
>
> *Sally Field, Yarram Dairy Optimisation Site, GippsDairy Region*

BE MINDFUL OF...

The data collected is very site specific. A certain level of user-interpretation is needed to assess the relationship of this data with other soil and plant types (variation in RAW) under the same irrigation system.

Consult with your agronomist when exploring options for your soils, pastures, crops and irrigation system/s.

Ensure the equipment supplier and software platform provider you choose are going to provide on-going technical support.

Gypsum blocks usually only last a couple of seasons before the block begins to break down, but capacitance probes can last more than six years. Manual data loggers are cheaper to purchase but require the user to visit the site periodically and are therefore labour intensive. Telemetry costs have reduced significantly over the past five years and require little human interaction.

After installation, mark the location of the probe and fence the logger and telemetry stand to protect from cows.

When it comes to automatic rain-gauges, you get what you pay for. Options within the $500 range are generally durable and reliable. Cleaning debris from the bucket frequently is required.

Sensors need time to calibrate with the soil. Re-install probes promptly after the sowing of new crops. For permanent pastures, leave the probes installed unless an issue is identified.

Calculating the Readily Available Water (RAW) zone of the soil type/ plant type in which the probe is located is important (refer to ***Determining readily available water from soils texture information***). This is the optimal soil moisture content range at which the plant can most easily extract water. It informs setting of the refill and field capacity/ full point lines on the soil moisture (trace) graphs.

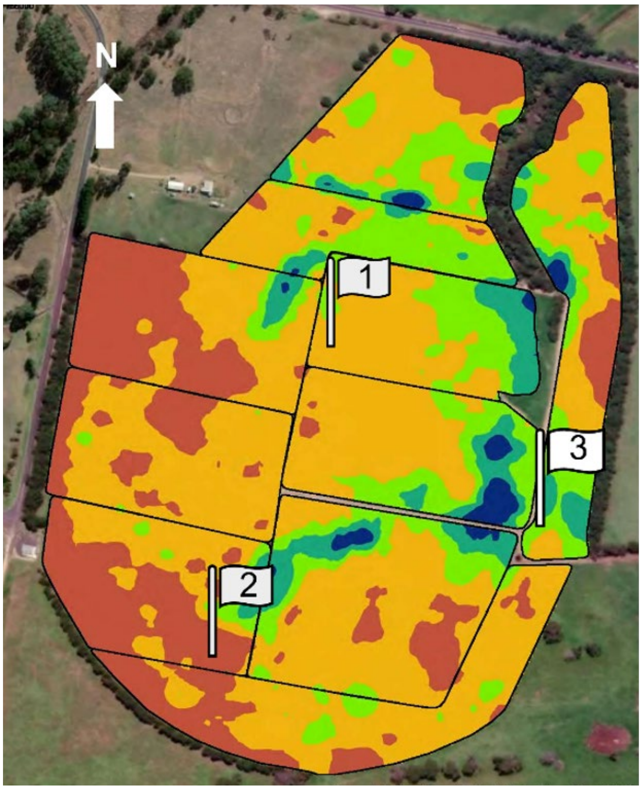
Field capacity/ full point is also determined by monitoring the sensor readings after a large rain event or through saturating the soil around the sensors. This works well when the plants are very juvenile or not actively growing. In free draining, stony soils field capacity/full point typically occurs one to two days after the event, in silt or clay loams four to five days.

Installation locations for soil probes

Principles apply across plant types and irrigation systems to assist in locating soil moisture monitors.

- Consider the soil types and characteristics of your soils under irrigation. If installing only one monitoring point, site it in the most representative soil type. Representing variation in RAW across the area is ideal (Figure 3). Electromagnetic (EM) mapping can assist in this process.
- Consider the different pasture/crop types under irrigation as this will change the RAW of a soil type.
- Avoid edges of paddocks and high traffic areas as these change the physical characteristics of a soil.
- Avoid locations that are not typical of the irrigation being applied (e.g. under end-guns, near towers or near wheel ruts).
- Avoid high spots where run-off may occur or low spots that are easily saturated.

Figure 3 EM38 Mapping showing location of soil moisture monitors at the Bega Dairy Optimisation Site. Legend: 1. Most representative soil type (middle elevation) 2. Shallow/light soil type (highest elevation) 3. Deeper/heavier soil type (lowest elevation).



Interpreting the data

Reading soil moisture trace graphs

Although soil moisture trace graphs come in various forms dependent on the software platform, they display similar information and trends. Initial training in interpreting and analysing the data is essential and should be part of the decision making when selecting an equipment and software provider. In general, the vertical axis shows the volumetric water content (converted to mm by software), and the horizontal axis shows time.

Figure 4 shows the summed soil moisture trace of the four sensors on the capacitance probe located in Paddock 2 of the Yarram Dairy Optimisation Site in the 2021-2022 irrigation season. It has the refill point and field capacity/ full point marked, manually set by the supporting agronomist by considering the determined RAW of the soil type/perennial ryegrass, as well as trend observations (refer to the section on Trend-based decisions). With the objective of maintaining the soil moisture trace in the optimal RAW zone (between these two lines) the farmer, Sally Field, successfully supplemented rainfall events with timely and adjusted rates of irrigation (red and green bars) throughout the season. Importantly, those periods when rainfall lifted soil moisture above field capacity/ full point, a number of times for prolonged periods, Sally monitored soil moisture and allowed the soil moisture to decline, applying irrigation on-time to maintain optimal conditions if rainfall did not eventuate (refer to ***Using Weather Forecasts to Schedule Irrigation***).

Figure 5 shows the individual soil moisture traces of each sensor down the 40cm probe. This is called a stacked graph. It provides precision information on how soil moisture is being used by the plant and replenished by rainfall and irrigation down the soil profile. This graph demonstrates that moisture levels declined most readily in the top 20cm, with only slight amounts of extraction by the actively growing plant roots at 30cm. This can be seen by the downward "steps" of the lines. There was very little indication of drainage losses below the roots zone at 40cm as this line remained quite consistent over the season. By not over watering, Sally saved on water and power usage.

Figure 4 Summed soil moisture trace graph of the Yarram Dairy Optimisation Site for the 2021-2022 irrigation season. A summed graph is a cumulative total of all 10cm increment sensors of the probe.

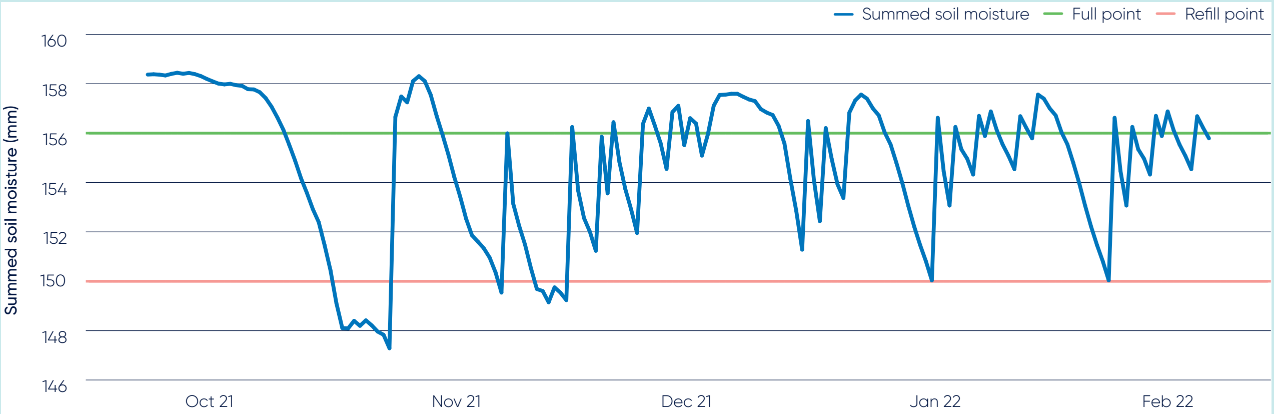
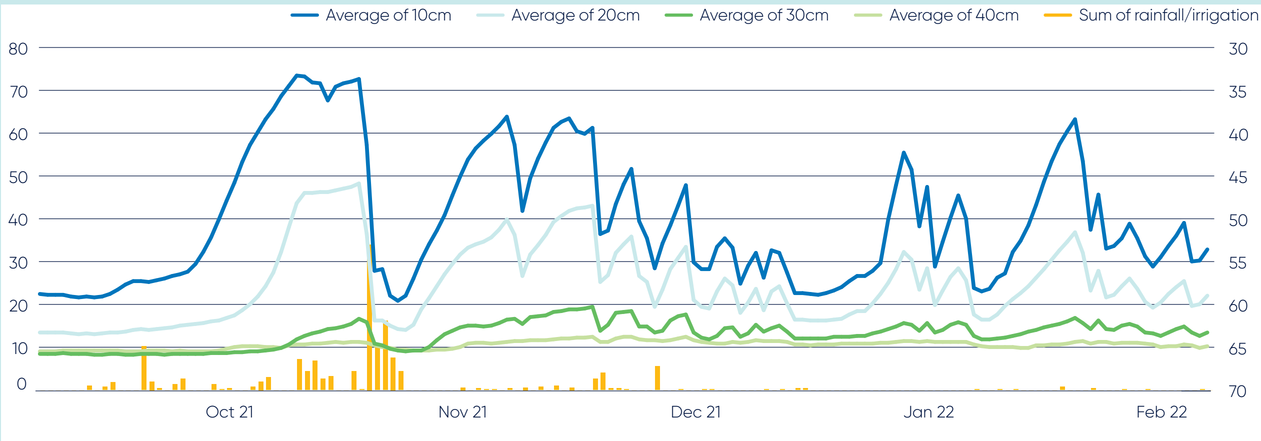


Figure 5 Stacked soil moisture trace graph of the Yarram Dairy Optimisation Site for the 2021-2022 irrigation season. A 40cm probe with sensors at 10cm (blue), 20cm (light blue), 30cm (green) and 40cm (light green) depth was used for the perennial ryegrass site.



> "I like how the probes show us at what depth the maize crop is drawing moisture from. Due to a slow start to Summer heat, our crop maintained good soil moisture throughout December. Because of this, the roots weren't forced to chase water at depth. Being able to monitor the potential impact of irrigation on plant root growth provides a bit of insight to what's going on under the ground."
>
> *Andy Tyler, Tongala Dairy Optimisation Site, Murray Dairy Region*

Four key interpretation guides:

1 As soil moisture drops below the refill point at the beginning of the season, the slope of the soil moisture trace line becomes shallower. When soil moisture drops below this point, the plant is using more of its energy to extract soil moisture as opposed to productive growth. This results in reduced yield.

2 Spikes above field capacity/full point indicate periods of saturation. This will have a direct effect on drainage and nutrient leaching. Heavier soils with limited surface drainage may remain saturated for prolong periods, decreasing production as the pasture/crop can become relatively dormant.

3 An indication of field capacity/ full point, for each sensor down the profile, is given by looking at where the first step down in the trace line occurs. All the water that is drained through gravity has gone and the step effect shows the daytime (plants transpire and water evaporates from the soil's surface) and nighttime (plants don't transpire and there is no evaporation from the soil) water use pattern. During peak hot, dry periods when evapotranspiration (ET_0) is high, the stepping becomes more pronounced (vertically longer).

4 A spike on the soil moisture trace below the root zone indicates a drainage event, either through rainfall or over-irrigation.

Trend-based decisions

Soil moisture trace graphs are mostly used for trend based irrigation start-up and stopping decisions, not to provide absolute measurements. To have confidence in these trends, sensors need time to calibrate with the physical properties and water hydrology of the soils after installation. Ideally, sensors should be "wetted-up" (field capacity/full point) by rainfall or irrigation then allowed to dry (refill point) a number of times prior to using in irrigation decisions.

For good decision making, trends over time need to be regularly monitored. Whilst the RAW for each probe should be determined, ground-truthing is needed to compare the trace graph display to the visual site conditions. A combination of this information assists to adjust the field capacity/full point and refill point on the graphs as the soil moisture trends become more consistent overtime.

Getting the most out of available data sources

Soil moisture data is best used in combination with a water balance calculation tool (refer to **irripasture.com**) and forecast information (refer to ***Using Weather Forecasts to Schedule Irrigation***). These resources help to consider the broader irrigated area and predicted rainfall inputs and ET_0 outputs to impact soil moisture in the coming period (usually seven days). Used together, decisions can be made on when and how much irrigation water to apply to maintain soil moisture in the RAW.

About Smarter Irrigation for Profit

Dairy Australia's Smarter Irrigation for Profit research, development and extension project was designed to help farmers across Australia make better irrigation decisions which improve water use efficiency and lead to greater profit. Smarter Irrigation for Profit was a partnership between the dairy, cotton, sugar, rice and grain sectors, supported by funding from the Australian Government Department of Agriculture, Fisheries and Forestry as part of its Rural R&D for Profit program and each of the industries involved.

For further information go to
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