Irrigation Scheduling Technologies

This project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural R&D for Profit program.

Australian Government
Department of Agriculture and Water Resources

Citation

White M

Acknowledgements

Thank you to the researchers and research leaders from Smarter Irrigation for Profit for their contributions to this document. J Foley, L Gall, J Hills, H Jamali, A Jaramillo, A McAllister, A McCarthy, M Morris, S North, G Roth, and J Smith.

The project is supported by funding from the Australian Government Department of Agriculture and Water Resources as part of its Rural Research and Development for Profit Program. The project, Smarter Irrigation for Profit, is a partnership between the major irrigation industries of cotton, dairy, rice and sugar, and was led by the Cotton Research and Development Corporation (CRDC) in conjunction with Dairy Australia, AgriFutures Australia, Sugar Research Australia and research partners including; CSIRO, NSW DPI, USQ, TIA, SARDI, DEDTJR Victoria, Gwydir Valley Irrigators Association and other industry organisations.

Irrigation scheduling technologies

Background

Irrigated agriculture produces 30 percent of all agricultural production in Australia, and half the profit.

Smarter Irrigation for Profit Phase 1 found irrigators could improve productivity by 10-30% through improved irrigation scheduling.

One of the key barriers to adoption of irrigation scheduling technologies is the diversity of tools available. Each irrigation scheduling tool has its own strengths and weaknesses and determining which tool is the best fit for a given farming system can be challenging.

Farmers and extension providers involved in Smarter Irrigation for Profit Phase 1 requested a simple resource that could assist them select the most appropriate irrigation scheduling tool for their needs.

Experience on the ground also found that if scheduling tools are to be adopted by industry, they need to be simple—simple to install, setup, use, interpret and respond to. Many of the tools tested required significant effort to learn how to use appropriately.

Providing a simple way to compare and consider a range of tools to enable the selection of a suitable tool is the basis for this document. This review document provides a summary of a range of irrigation scheduling tools that have been reviewed, tested or utilised by Smarter Irrigation for Profit participants.

It is envisaged that this resource will provide a starting point for others who need to review tools prior to implementing them on farm.

Smarter Irrigation for Profit is not endorsing any product. Any appropriate tool will need to be considered in the context of your own circumstances.

Irrigation Scheduling

Crops that are kept within acceptable stress limits during their growth cycle have the potential to produce optimum yields of high quality. The aim of irrigation scheduling is to keep soil moisture within a desired range, usually between field capacity (full point) and a predetermined refill point for optimal growth.

The irrigation management decision-making process involves deciding "how much" to irrigate, at "what position" in the field, and "when" to irrigate by considering:

- the current water content of the soil
- the current rate of crop water use.
- the soil's readily available water- holding (RAW) capacity and refill point
- the application rate (millimetres per hour) of the irrigation system. This allows the calculation of how many hours are needed to apply the required amount of water (in millimetres)
- the evenness of water application (uniformity) and efficiency of the irrigation equipment in your field.

Irrigation Scheduling Tools

Irrigation scheduling tools seek to assist farmers to make informed decisions with either the current water content of the soil, the rate of crop water use, or both.

As a result, the range of scheduling tools can be grouped into those that monitor the soil water content, those that use weather data to estimate how much water the plant has been consuming, and those that monitor the plant for water stress.

Experience has shown that using multiple methods to assess the amount and timing of irrigations can improve scheduling decisions. The ability to manage and interpret data has improved considerably, and some scheduling tools are now combining a range of soil and plant data into one software platform to improve the ease of making irrigation scheduling decisions.

This document provides a summary of irrigation scheduling tools used by participants in the *Smarter Irrigation for Profit* project grouped on the basis of measuring:

1. Soil water content
2. Weather based crop water use
3. Plant stress
4. Combination tools.

Combination tools include the growing number of software delivery platforms that can connect to a range of different sensors and deliver data to web connected devices for growers and advisors.

This review has not sought to be comprehensive and cover every available tool, but instead focusses on those that have been used by participants in the Smarter Irrigation for Profit project.

Irrigation scheduling technologies

Contents

The following details the list of tools that have been included in this document. The project is not endorsing any particular product. Any appropriate tool will need to be considered for your own circumstances.
The hyperlinks will direct you to the summary of the tool.

Push Probe or Dig Stick

A Push Probe or Dig Stick is a simple way of judging the depth of soil wetting after irrigation or rain. The soil moisture probe may be used in irrigated or rainfed systems to determine the depth of wet soil. This is because soils lose strength when wet so the probe easily penetrates the wetted profile but finds resistance to penetration when it reaches dry soil. Dry soil retains its structural integrity and will resist the push probes passage.

Use

Push the probe into the soil and assess the depth of the soil's resistance. Recording the position in the field and the depth of resistance will provide useful data of soil moisture in the profile and at a number of points in and across the field.

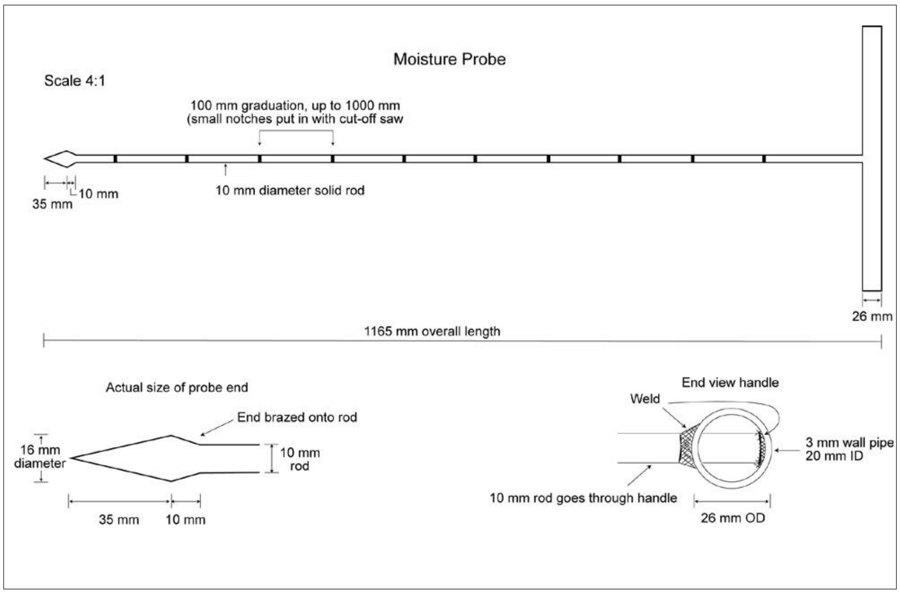
Measure the penetrated depth by reading the marks on the probe. If you repeat this procedure systematically across the paddock, you will get a good idea of water penetration across the area. In an irrigation setting, a probe can also be useful to measure sideways spread into the beds when you are looking at furrow irrigation.

With experience, the water availability in a soil sample can be estimated. To assess the need for irrigation properly a soil auger or dig stick (gouge corer) soil sampling tube should be used to test moisture content at several depths within the root zone. A number of holes must be sampled to achieve a realistic judgment of soil moisture. It is common to find some sites high in moisture while others are quite dry. This depends on the position and density of roots and the distribution pattern of the irrigation system.

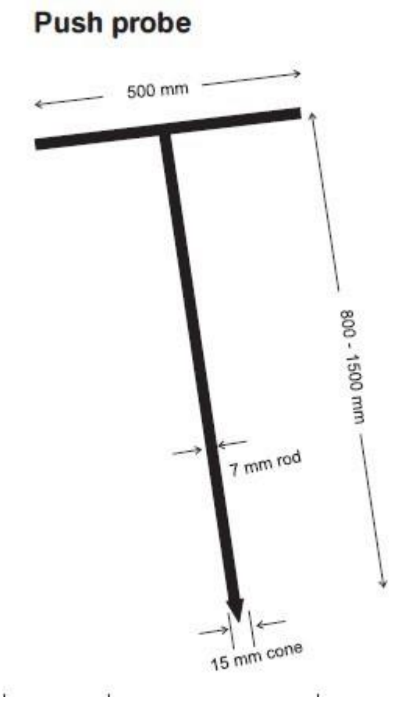
Table 1: Guide to determining soil moisture by feel.

Moisture level	Sands and Sandy loams	Loams, Clay loams and Clays
Above field capacity	On squeezing, free water oozes from the ball of soil.	Soil very sticky and sloppy. When squeezed is oozes water.
Field capacity (100% available) water	No free water appears on the soil when the ball is squeezed, but wet outline of ball is left on the hand.	Soil sticky. No free water appears on soil when ball is squeezed, but wet outline of ball is left on hand. Possible to roll long thin rods (2mm in diameter) between finger and thumb.
75% available water	Slightly coherent. Will form a weak ball under pressure but breaks easily.	Soil coherent. Soil has a slick feeling and ribbons easily. Will not roll into long thin rods 2mm in diameter.
50% available water	Appears dryish. Forms a ball under pressure, but it seldom holds together.	Soil coherent. Forms ball under pressure. Will just ribbon then pressed between finger and thumb.
25% available water	Appears dry. Will not ball under pressure.	Somewhat crumbly but will form a ball under pressure. Will not ribbon between finger and thumb.
Permanent wilting point	Soil is dry, loose, and flows through fingers.	Crumbly, powdery, Small lumps break into powder. Will not ball under pressure.

Source: NSW Ag, SOILpak™



Source: DPI NSW



Source: Apsim

Making a soil moisture probe

The probe can be made from 10–12 mm diameter stainless steel round bar, about 1.65 metres long, forming a T-handle at one end and a sharpened tip at the other. Mark 10 cm intervals along the length of the probe.

Make the handle of 26 mm outside diameter pipe cut 30 cm long so that it fits into both hands.

Make the base of the tip piece slightly wider than the rod by:

› building up some stainless steel weld and then sharpening the tip;

› hard facing welded thicker than the rod and ending in a point; or,

› by welding a sharpened stainless steel bolt to the end of the rod.

The bulbous tip means the diameter of the hole in the soil is slightly larger than the diameter of the rod. This reduces friction on the side of the rod, so that the only resistance when pushing through the soil is at the tip of the rod. Stainless steel should be used to prevent rust increasing the resistance to soil penetration.

Measurement description

Point source

Lifespan

Long lifespan

Data processing

Data visually assessed and hand recorded.

Strengths

- Low cost
- Robust
- Fast, physical measurement.

Weaknesses

- Does not work well in fine-textured or dense subsoils
- Must understand soil moisture impact on water holding capacity
- Low accuracy
- Compaction and rocks can interfere with results

References

http://www.dpi.nsw.gov.au/_data/assets/pdf_file/0003/528546/Making-a-soil-moisture-probe.pdf

Tensiometer

A **tensiometer measures soil moisture**. It is designed to measure the tension or suction that plants' roots must exert to extract water from the soil. This tension is a direct measure of the availability of water to a plant.

Tensiometers consist of a sealed tube full of water with a porous ceramic tip at the bottom and a vacuum gauge at the top. The ceramic tip is buried to a suitable depth in the soil. As the soil dries out, water moves out from the tube through the porous tip into the soil creating a vacuum in the tube. This is measured by a gauge and is a direct measure of availability of water to the plant at the depth which the tip has been buried. Gauges read either kilopascals (kPa) or centibars (cb). One centibar equals one kilopascal). Tensiometers do not need to be calibrated.

Cost of the technology

Approximately $250 for a tensiometer + a pasture cage to protect at $50

Installation

Scheduling irrigations with tensiometers requires careful installation, regular maintenance, and experience for interpretation.
At the time of installation, the tube must be completely full of water as air will affect accuracy. The tip must be completely saturated which can be achieved by standing in a bucket of water for a minimum of 24 hours. With a hand vacuum pump, pump the tensiometer gauge up to approximately 70 kPa and tap it to release any air bubbles in the instrument.

When placing in the soil ensure that all parts of the ceramic tip are in contact with the soil, otherwise a false reading will be obtained.

The bottom 10 centimetres of the installation hole should be made with a coring tool, or steel rod of the same diameter as the tensiometer so that the tip of the tensiometer fits snugly in the hole. Do not force or twist the tensiometer into position as the ceramic tip can be damaged.

Tensiometers are best installed while the soil is moist. Filling the installation hole with water and wetting the outside of the tensiometer tube with water immediately before installation will increase the ease of installation.

Positioning must ensure that tensiometer sites represent an average location. Avoid areas of poor infiltration and ensure it is in the irrigated zone. Locate the tensiometer so that it can be protected from damage from slashing, grazing or other cultural operations. Depth in the soil is also critical.

Maintenance

If air occupies the tube, then water should be added. The frequency that topping up is required depends on the condition/quality of the tensiometer and dryness of the soil. After topping up, remove air bubbles with a hand vacuum pump by applying and holding the suction at 70–80 kPa for at least 15 to 20 seconds while tapping the side of the tensiometer.

Rainwater or tap water with a minute amount of bleach should be used in tensiometers. Boil the water to remove air from it and then place in a hot water bottle to cool. An algacide should be added to the water to prevent algal growth in the tensiometers. Alternately methylated spirits at a rate of 50 millilitres per litre of water can be used.

Tensiometers do not operate properly in dry soils.

During winter, tensiometers should be covered or the gauges removed to reduce the likelihood of the water freezing and damaging the tensiometer.

Measurement description

Tensiometers measure a point location in the paddock and reflect the water content in the surrounding volume of soil, so placing it in an average area of the paddock is critical.

Accuracy/precision

Accurate to approximately 1 kPa

Data processing monitoring, interpreting and using results

Tensiometers are read visually from a gauge on the unit. Data needs to be recorded by hand.

Strengths

- Direct measurement
- Simple operation
- Inexpensive
- Measure water tension which is relevant to plant stress
- No cabling
- Not affected by salinity

Weaknesses

- Needs to be stored and used above freezing temperatures
- Maintenance required
- Manual data collection

References

https://dpipwe.tas.gov.au/agriculture/land-management-and-soils/soil-management/irrigation/tensiometers

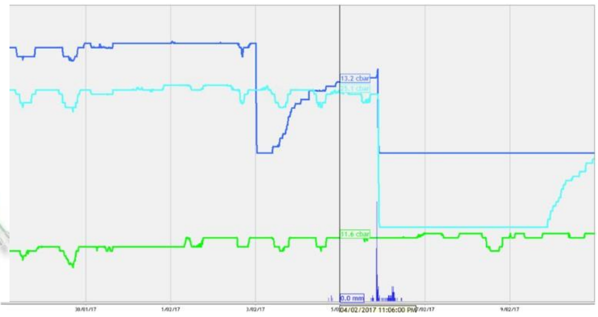
Granular matrix sensors

Watermark sensor: soil tension

The granular matrix sensor represents a low-cost alternative for farmers and primary producers seeking a solution to monitoring soil moisture across a variety of crops within irrigated agriculture. The sensor estimates soil water tension (kPa) through electrical resistance, and sensors can be installed at a range of depths.

The output can either be downloaded at the logger in the field or telemetered to a web base

for remote access.



Watermark sensor – Adcon Telemetry based interface software available from Adcon Telemetry

Cost of the technology

› Non-telemetric
3 block system ~$900

› Telemetric
3 block system ~$4,700 *plus* ongoing data hosting ~$17/month

› Additional block approximately $75

Accessibility

There are a number of equipment retailers for granular matrix sensors i.e. MEA, ICT and Adcon Telemetry, and repairs are supported by retailers. Support for farmers adopting and interpreting the data is mostly limited to industry and government extension programs, while some suppliers provide some introductory information.

Installation

It is possible to install yourself. A special sized hand auger is required. The installer must be particularly conscious about ensuring that blocks have a good seal with the soil. Sensors are generally installed dry (i.e. without slurries) into a snug auger hole. They are generally installed by hand through a slit trench to the augered hole at the desired depth. The orientation of the block at install is generally around 45 degrees in angle at the selected depth.

Where do you locate it?

These Sensors should be installed in a soil type representative of the average for the area being irrigated at one time. Soil variability should be assessed prior to site selection from grower knowledge, soil maps or EM surveys.

When installing in grazed pasture situation, it is necessary to ensure that the cable ends of the blocks can reach a fence line to ensure protection of the cable terminations the logger or telemetry unit. If the site is non-telemetric then it is best practice to locate the cable terminals inside a junction box that is attached to a fence post close to the ground where it is unlikely stock will rub against it. With telemetric systems a similar rule applies but the site will need to be bollarded to protect the solar panel and telemetry from stock. The blocks have a maximum extension cable length of around 20 metres, so it is preferable to locate in different soil types and then monitor them close to fencelines to enable the safe housing of the logging infrastructure.

Where the shallowest sensor is likely to be damaged by cultivation or sowing equipment it is recommended that this sensor's cabling is housed in electrical conduit placed at greater depth at installation, and that the sensor is disconnected from the cable and removed from the soil (when soil moisture is reasonable to avoid breakage), and then re-installed after subsequent sowing.

Installation should also consider the rooting depth of the target crop and hence the positional requirements for the blocks. In most cases a shallow sensor will be placed in the lower portion of the active root-zone to produce results of soil tension where the root cluster is present. Beyond this it is recommended that another one to two sensors be located further down the soil profile to capture soil water movement and conditions. The deeper sensors provide information on drainage potential and help the user refine the depth of irrigation applied over time.

Accuracy/precision

From new a sensor may be +/- 10 to 20%. It is essential to maintain visual assessments of paddocks to review calibration.

Measurement description

Granular Matrix sensors monitor a point location in the paddock for each sensor and reflect the water content in the surrounding volume of soil. Representative water contents and electrical resistances in the sensor can only occur if the sensor is in good contact with the surrounding soil.

Lifespan

Lifespan depends on the soil type in which the sensors are installed. In optimal conditions it should provide good information for 5 to 7 years. At the 5 year anniversary of installation, sensors should be slated for replacement. In some high pH soil types, life expectancy of is only 1 to 2 years.

Data processing monitoring, interpreting and using results

Once installed the user will either field download soil tension results onto a hand logger or review them on a web platform. Typically for hand held devices a digital display (setup at installation) will provide the soil tension results (generally in kPa) for the user's interpretation. It may be necessary in these situations to connect to each of the separate sensors.

With telemetered data accessed on a web platform the data will be provided graphically or in tabular numerical form for interpretation. Figure 1 shows a view of a web based output graph from a granular matrix sensor.

An example of using this tool is provided through Figure 1. The effectiveness of a measured 13 mm irrigation depth (green vertical bar) at a trial site can be seen on a rye grass pasture in South Australia's Fleurieu region on sandy soils in the peak of summer. As the irrigation was applied, the soil water tension fell from 20 to 0 kPa (saturated) on the blue 30 cm trace, and then following some crop extraction in the topsoil and a series of rainfall events both sensors (blue and aqua) reported tensions that fell to 0 kPa.

User interface

Users can access the data either through a hand held logger (non-telemetric), where the user needs to visit the field site and collect the data, or via telemetry, where the user downloads and views the data in graphical form using an internet connection. Soil water tension is then interpreted using soil water content/ tension relationships known as soil water retention curves. The tension values provide an indicator, and the soil water depths provide the ability to be precise about the volume applied.

Table 1 Guiding ranges of soil tension and interpretation

Reading (cbar or kPa)	Interpretation
0 to -10	Soil is very wet and is at field capacity. Conditions may be waterlogged
-10 to -25	Optimal conditions for plant growth with good levels of plant available water
-25 to -40	Dependent on crop type conditions may be suitable but tending towards dry and with higher risks in lighter textured soils. Pastures needing to be re-irrigated at ranges <-35 kpa
-40 to -60	Crop stress occurring with dry soils. For deeper rooted or perennial tree and vine crops this is the trigger point for re-irrigation
>-60	Yield decline and crop stress, outside of most irrigated scenarios except where regulated defecit irrigation style practices are being exercised

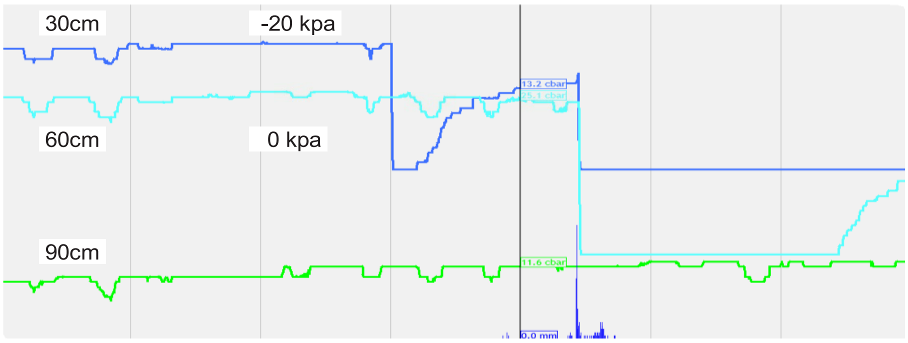


Figure 1 Typical graphed gm sensor data with a moveable cursor displaying readings at 30, 60 and 90 cm of soil depth in centi-bars of soil tension. 1 centi-bar = 1 kilopascal. Figures do not display negative notation. Rainfall displays in vertical blue bars, irrigation in vertical green bars. Adcon Telemetry.

Accessing data

Non-telemetric data is available on the hand logger and can be downloaded and processed on a desktop computer or laptop. Telemetered data is available near real-time from an internet accessible platform and is easily accessible on smartphones, tablets or equivalent devices.

Strengths

- A non-telemetric system is relatively inexpensive
- Soil tension results within an operational range, provide easy reference of soil water contents
- System is relatively simple to install and maintain, and is inexpensive to upgrade
- A telemetry system provides remote access to soil water content data

There is a sizeable repository of soil water content data in different soil types to support captured soil water tension data across varying crop types

Weaknesses

- Systems need to be field installed and protected from stock damage
- Some soils (including more saline soils) may diminish accuracy
- Sensors have a life span of around 5 to 7 years in good soil conditions and may be less than a year in high pH soils
- Cable length limitations may make it difficult to locate devices within the cropped area on the soil type of interest without the creating an isolated paddock monitoring point which becomes an obstacle to field site management activities
- Shallow sensors will need to be field re-located in new crops and removed for sowing/ cultivating activities.

References

https://cottoninfo.com.au/sites/default/files/documents/WATERpak.pdf
https://aecdatalog.com/irrigation/gms/

G-Dots

Granular matrix sensors: soil tension

The G-Dot uses a granular matrix sensor, a type of gypsum block. Electrodes embedded into gypsum blocks are used to measure the electrical resistance between them under the presence of moisture. Electrical signals are related to soil moisture tension, that is, how hard it is for the plant to extract water.

The measured soil moisture tension is represented by fluorescent yellow flip dots. The more yellow dots showing, the wetter the soil is, the fewer lit yellow dots, the drier the soil.

Cost of the technology

Approximately $315 each,
no ongoing cost

Accessibility

G-Dots can be purchased on-line from www.Gdot.com.au

Installation

G-Dots are relatively easy to install and do not require installation by a third party.

The location should be chosen based on the soil type. The location should represent the average for the area being irrigated at one time, avoiding areas that are wetter or drier than normal. Some fields have several different soil types. You should select the soil type that is the most predominant and will represent the greatest area of your field. The depth of sensor installation needs to reflect the crop or pasture root zone.

In flood or furrow irrigation, unless the bottom of the field is blocked and water can pond, there is generally more water applied to the head of the field than at the bottom due to the time required for water to advance across the field. For these systems, locate the sensors where water penetration is poorest, generally about 2/3 the way down the bay if the bottom end is blocked or the last 1/3 is the tailwater runs freely away from the paddock.

G-Dot indicating that the kPa of the soil where it is installed has reached the 60–100 kPa reading.

In pressurised irrigation systems, install the sensor 10–20 cm from a dripper, or within the wetting zone of the irrigation system.

The location for the placement should:

- have easy access
- be placed far enough into the field to avoid edge effects
- be located to avoid damage from field operations
- be representative of the predominate soil type under irrigation.

Ideally, you should have enough soil moisture monitoring sites to get representative data for your field with sensors placed at a minimum of two different depths.

The G-Dot must be protected from livestock and may need to be removed to enable paddock activities to occur.

Accuracy/precision

From new a sensor may be +/- 10 to 20%. It is essential to maintain visual assessments of paddocks to review calibration.

G-Dot indicating soil profile has reached full point or saturation as indicated by the readings of less than 10 kPa

Measurement description

Granular Matrix sensors monitor a point location in the paddock for each sensor and reflect the water content in the surrounding volume of soil. Representative water contents and electrical resistances in the sensor can only occur if the sensor is in good contact with the surrounding soil.

Lifespan

Soil type, irrigation frequency and local rainfall all influence how long the sensor will last, but you should expect between 2 and 5 years.

User interface

The G-Dot display shows a number of yellow dots relative to soil water tension. When the dots reach the soil tension at which the crop needs to be irrigated it is time to water. Timing of irrigation can be fine-tuned for your soils, season, and crop stage.

Accessing data

The G-Dot is designed to be read visually while at the site.

Strengths and weaknesses

G-Dots can be used in most soil types (although not recommended for use in light sands and heavy or cracking clays) and have an operational range of 0–100 kPa.

The cable from the G-Dot display to the sensor can be extended (up to 80 metres) allowing the sensor to be installed some distance from the monitoring point, while the display can be placed where it is easily accessible and visible and can be protected from damage. G-Dots are practical instruments but have limitations in terms of display units and ability to store data.

References

www.Gdot.com.au

Capacitance probes

Capacitance probes are a volumetric based sensor, which use a measurement of the soil 'dielectric' which reflects the capacity of a material to transmit electromagnetic waves or pulses. The dielectric of dry soil is much lower than that of water, so small changes in free soil moisture will have a large effect on the dielectric properties of the soil.

The dielectric constant of the soil is determined by a pair of cylindrical electrode plates. The electric field between the two electrodes (in Figure 1) is affected by the mixture of soil, water and air surrounding them. This mixture acts as a dielectric medium and the charge time of this capacitor is a direct linear measure of the dielectric constant.

As the dielectric constant of air is 1, is between 3 and 4 for soil, and is around 80 for water, any minor change in volumetric water content of the soil in the ground surrounding the buried probe, has a large effect on the dielectric constant. The dielectric constant of this soil mixture can then be converted into the volumetric soil water content, using a general calibration.

One capacitance sensor, consisting of a pair of electrodes, is required for every depth that will be monitored. Some capacitance probes systems have up to ten sensors per probe, while others only have one sensor per probe. An electronic logger board collects and stores the volumetric water content data, and if connected with a modem, the data can then be transmitted to a web server and displayed on various smartphone and computer devices.

Cost of the technology (capital/ongoing software)

Initial investment can be relatively high, with costs ranging from $1,000 to $3,000 for a single monitoring site. There are limited opportunities for economies of scale as one of the main drivers for cost is the number of sensors required per probe. Most systems offer data transmission via radio and the mobile phone network, which usually incurs ongoing data costs. Batteries, even when charged via solar panels, need replacing every 2 to 3 years.

Accessibility

Most major suppliers maintain a wide network of dealerships, and often local agronomists provide the aftermarket support.

Figure 1 : The inner components of a capacitance probe lifted from its buried plastic pipe sheath, showing the logger board on top, and the five pairs of cylindrical gold coloured electrode plates (sensors) used at five different depths in the soil.

Installation

Some capacitance probe systems require specific tools to complete the recommended installation method, and this must be followed very accurately to ensure good quality data is obtained. Some agronomic dealerships offer installation services, which would generate additional ongoing costs when equipment extraction and insertion is required after each crop.

Manufacturer's websites report a lot of information on the wide variety of these systems, and their necessary method of installation.

After installation, all capacitance probe type systems must be fenced off from cattle.

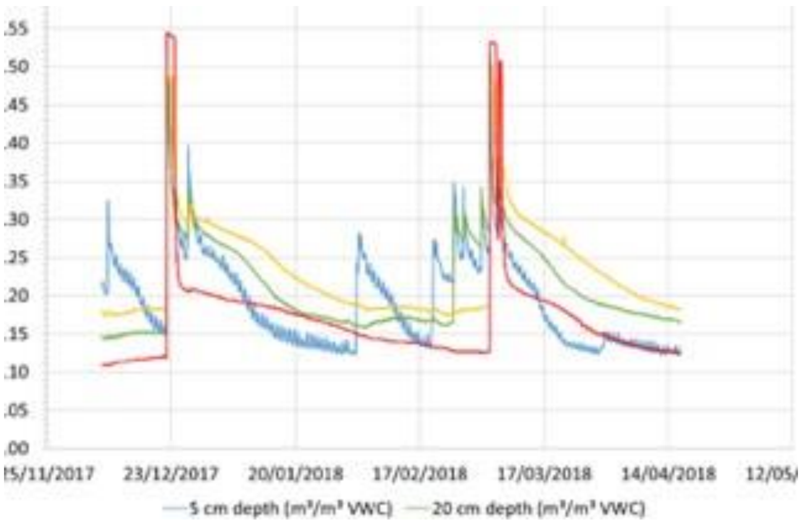


Figure 2 : Graphical output of volumetric water content change with time, over a number of irrigation cycles occurring over five months, for four different sensor depths.

Multi-probe configurations require cables to connect them to a central logging unit and are therefore vulnerable to damage by farm machinery and animals. Clear marking of the installation is therefore recommended. When using telemetry or mobile data networks to access the data, the antennas need to be above the crop canopy which affects the operation of spray rigs, and, contractors need to be made aware of any installations.

Scale

Most capacitance probes systems can be scaled up to many probes operating from one logger and modem, but the cable configurations can become challenging to handle.

Accuracy/precision

Standard soil type calibrations usually provide sufficiently accurate for most grower situations. Site specific calibration might be required if a tightly controlled deficit irrigation process is to be practiced.

Measurement Volume Point source or spatial information

All capacitance probe type systems provide a point measure of the volumetric water content of the soil at the position it is located, and clusters of single sensor probes, and multi-probe units would be required under variable rate irrigation situations, and when variable soil types and conditions occur across the irrigated field.

Lifespan

Theoretically most capacitance systems can have a lifespan of many years. Lightning is the biggest threat, followed by water/moisture ingress and damage into the electronic circuitry of the probe. Many probes are now fully sealed and therefore, fully submersible. However, damage to cable systems seems to occur more regularly.

User Interface and Data processing

Most systems these days have options to automatically transfer data via radio or mobile data networks either to some cloud storage server, or directly to the farm office. Some systems offer cloud storage and preliminary data cleaning/ checking, and this provides easier use. Most systems come with proprietary software which supports data processing and graphical presentation on most web connected devices.

Accessing Data

Several suppliers have smart phone apps that allow data access over web connected devices. It is recommended that growers ask about the capability of integrating the capacitance probe data set into irrigation equipment management software systems, to allow full automation in the future, or single user interfaces with the one.

Remarks

Availability and competence of after-market support is very important if capacitance probe systems are intended for use with intensive irrigation scheduling services.

These systems are complex electronic systems, which require sensitive handling, and only sufficiently trained, permanent staff, should be allowed to interact with them.

The relatively high labour intensity of the installation process makes these systems less popular for short term installation and use, and they are more widely used in permanent cropping systems, and intensive permanent plantings.

Strengths

The greatest strength of capacitance probes is the continuous recording of soil water content on intuitive graphical user interfaces. Multi-sensor probes allow monitoring of soil water movement down through the profile. Sensors work reliably across the entire soil water content range, which is of importance in dryland farming situations. Once properly installed, these probes require little ongoing maintenance.

Weaknesses

- All electronic systems installed in the field are sensitive to lightning.
- Relatively high initial costs, which usually only allows for one multi- sensor probe per field. With this limitation all the system provides is a single point measurement of volumetric water content.
- All capacitance probe systems are extremely sensitive to air gaps between the sensor and the soil. The volume of soil sensed is relatively small. In cracking clay soils this will lead to incorrect measurements of volumetric soil water content, with underestimation when cracks exist, and incorrect assessment of the speed of water ingress to depth.

Is it a forecasting tool?

The volumetric water content data can be used for tentative forecasting, even if the probes are not specifically calibrated to the soil site, when the application depth of the irrigation equipment at the measurement site is known, and can be well controlled between irrigation events.

References/links

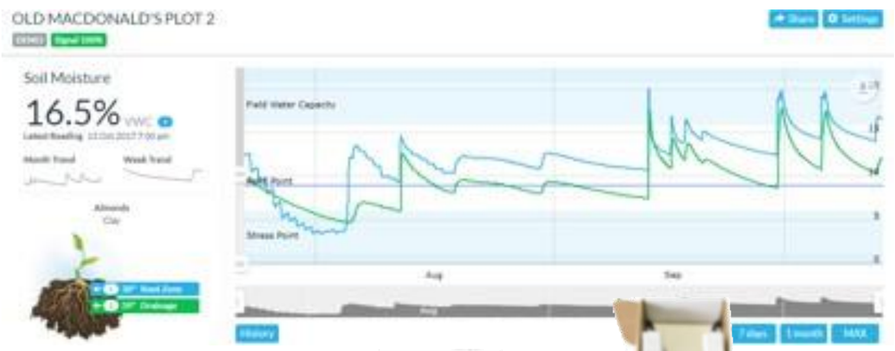
https://sentektechnologies.com/product-range/soil-data-probes/
www.enviroprosoilprobes.com
www.agric.wa.gov.au/horticulture/soil-moisture-monitoring-%E2%80%93-selection-guide

Wildeye Express:

Frequency domain sensor

Wildeye Express is a compact, rugged sensor and telemetry package. The frequency domain sensors comprise a tough epoxy body with two stainless steel needles which cut through the soil for good soil-sensor contact and easier installation.

Wildeye is available with 1, 2 or 3 individual sensors per device to allow for monitoring multiple soil depths. Web-based software is easy to use and provides visual indicators to represent key features such as Field Water Capacity, Refill Point and Stress Point.



Wildeye Express

Cost of the technology

$700 and $30/month for complete sensor/telemetry packages. Volume discounts available.

Accessibility

Purchased online via the wildeye website (www.mywildeye.com) using a credit card. Australian based support is available via online helpdesk or 1300 phone number (1300mywildeye).

Installation

The Wildeye Express has been designed to be simple enough that any user can install and commission without the need for special tools or specialist technical expertise. Because the unit is battery powered it can be installed without the need for solar panels etc.

Installations can be entirely subsurface in some situations. Some simple protection (e.g. a metal fence post and a short length of ~150mm pipe attached) from livestock and machinery may be required. It requires Telstra mobile phone coverage.

It is important to ensure sensors are installed in the correct order, although this can be adjusted in the software package, if required.

Scale

0 to 57% VWC

Accuracy/precision

Using a generic calibration: ± 0.03 m3/m3 (± 3% VWC) typical in mineral soils that have solution electrical conductivity < 10 dS/m. Using medium specific calibration, ± 0.01–0.02 m3/m3 (± 1–2% VWC) in any porous medium.

Measurement description

Wildeye Express measures a point location in the paddock and reflects the water content in the surrounding volume of soil. It captures a relatively large sample volume.

Lifespan

Unlimited battery/technology warranty while subscription remains active.
Hardware lifespan of 5–10 years.
Long life batteries last up to five years.

Data processing

Wildeye Express is designed for web based data hosting, processing and visualisation.

User interface

Web based, mobile device friendly. Accessing Data – compatibility with phone, PC, Web based, mobile device friendly.

Strengths

- Simple to self-install and configure
- No solar panels, long battery life
- Good sample volume per sensor
- Unlimited battery/technology warranty (provided subscription remains active)
- Lowest cost
- Compact form

Weaknesses

- Cable length limitations
- Shallow sensors may need to be field relocated in new crops and removed for sowing/cultivating activities
- Limited to daily updates of data to the web (although time of day that data updates occur can be user-configured)
- Battery life can be reduced where mobile phone connectivity is poor.

Type of tool

Timestep soil moisture monitoring tool that can be used for budgeting, optimisation and forecasting applications.

References/ links

www.mywildeye.com
https://vimeo.com/154161088

ECH$_2$0/Decagon Soil Probes

ECH$_2$0 soil moisture probes encompass a range of devices which utilise capacitance to infer the volumetric soil water content. These probes use a 70 MHz frequency excitation which is meant to reduce the susceptibility of the measurements to salinity and soil texture effects compared to other capacitance sensors. Each sensor measures the water content at a single location and depth, so monitoring of the root zone requires use of two or more probes at the appropriate depths.

ECH$_2$0 probes come in a range of models for different applications. Three examples from this series covering the range of capabilities are the GS1, 5TM and GS3 probes. The GS1 probe measures volumetric water content only and provides an analogue voltage output similar to other low cost soil water content sensors.

The 5TM and GS3 models operate using the SDI-12 protocol, common to most high cost soil water probes. The ECH$_2$0 5TM probe measures soil water content and temperature, while the GS3 adds the ability to measure electrical conductivity.

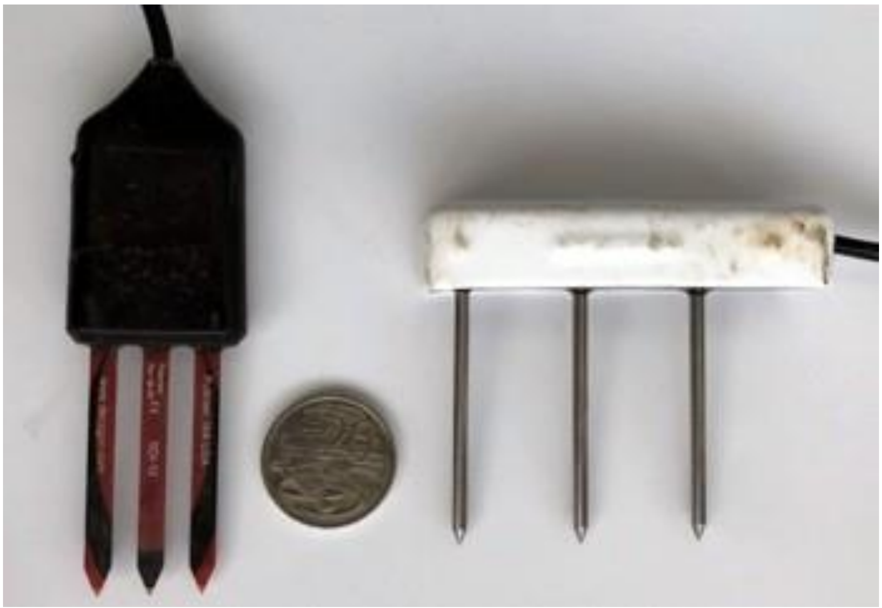


Figure 1. The ECH$_2$0 5TM and ECH20 GS3 probes for measuring soil water content.

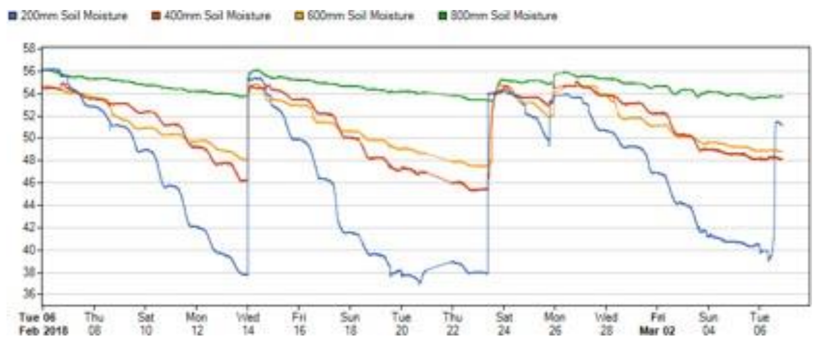


Figure 2. Plot of volumetric soil water content (%) from four GS3 probes installed in a cotton field over five weeks, as reported through a WildEye/Outpost datalogger and their free website.

Cost of the technology

The costs vary across the ECH$_2$0 range, from the analogue voltage GS1 sensor which retails at around $250, to the ECH$_2$0 5TM for around $380, up to the fully featured ECH$_2$0 GS3 for about $520. Each sensor samples the water content at a single depth, and therefore you would need to purchase of a minimum of three sensors to capture good data for root zones extent extending below 500mm depth.

These sensors can be connected to any third party logger solution that is capable of handling either SDI-12 or voltage input signals. A standalone mobile telemetry logger setup which can accommodate up to 10 sensors including solar panel and battery supply is available for approximately $1,000.

Accessibility

These probes, originally known as Decagon probes are now marketed under the name METER after the recent merger of Decagon and UMS AG. ECH$_2$0 probes can be purchased through ICT International, the official Australian METER distributer. ICT International have a long history with the use, installation, sale and distribution of these probes, and provide telephone support as required.

Installation

The best way to install the ECH$_2$0 probes is to excavate a hole with a large auger to the required depth and then push the sensor prongs by hand into the sidewall of the hole at each desired depth. The hole should then be carefully backfilled and lightly compacted to avoid preferential water flow into the hole. The GS3 and GS1 have sharp stainless steel prongs which can be pushed directly into the soil regardless of the moisture content or soil strength. The 5TM and other similar probes have silicon prongs, which would require prior insertion of a tool of the same shape to avoid breakage of the silicon sensor prongs in hard soil. Cable lengths of up to 70m can be used with the SDI- 12 capable models, meaning that a single logger could connect to many probes in multiple nearby locations.

Accuracy/precision

ECH_2O probes are a capacitance type probe, measuring the dielectric permittivity of the surrounding soil, which is directly correlated to the volumetric soil water content. METER claims that these sensors are more accurate than most other capacitance sensors. The GS3 and 5TM sensors are designed to function in a wide spectrum of media including mineral soils, peat and potting mix, and therefore can measure volumetric soil water content ranging from 0–100%. The GS1 sensor is cable of measuring soil water contents between 0–57%. These sensors have a resolution of 0.1% and an accuracy of 3% using the general factory calibration equation, or 1% accuracy with your own soil specific calibration.

Measurement Volume

The ECH_2O range overcomes one of the major problems associated with capacitance soil water content measurement. They have a greater sample volume than most of their competitors. The stated volume of influence of these probes is 160mL (GS3), 715mL (5TM) and 690mL (GS1). The ECH_2O 10HS sensor, a larger variant of the 5TM model, has a sample volume of 1320mL.

Lifespan

Providing they are protected from direct sunlight, these probes have an expected life of 5 to 7 years. The design of the 5TM probe and other similar shaped probes from METER might require extra care when being installed, to minimise the risk of damage to the sensor prongs. The GS3 and GS1 probes are marketed as the "ruggedised" version of the ECH_2O technology, with stainless steel prongs, and a better watertight sealing of the sensor head, for long term deployment.

Strengths

- Large sampling volume
- Accurate measure of volumetric soil water content
- Low power consumption
- Range of different options to measure water content, temperature and electrical conductivity.

Weaknesses

- Requires excavation of an access hole
- Requires installation of multiple individual sensors, each with its own set of wires, at each depth.

References/links

https://www.metergroup.com/environment/teros-ech20-sensors/

https://www.ictinternational.com/products/soils/moisture-sensors/

Time Domain Reflectometers

TDR (Time Domain Reflectometer) sensors are a well-proven soil measurement technology that is highly regarded as being one of the better sensing techniques for accurately capturing soil water content (IAEA, 2008).

Historically, this technology was expensive, bulky and cumbersome, and specifically built by manufacturers for use by the research community. Some researchers manufactured, assembled, and deployed TDR technology themselves for their trial work. Recently, with advances in micro-electronics, the older expensive bulky equipment has been miniaturised into a commercially viable form at an appropriate cost for use by irrigators. The sensor consists of three 150 mm long parallel metal rods that are each 3.2 mm in diameter protruding from a matchbox sized sensor head (Acclima, 2017). This fully submersible electronics head measures the dielectric permittivity, temperature, and bulk electrical conductivity of the soil, and calculates the volumetric water content and temperature corrected bulk electrical conductivity.

The TDR sensor reports these five values through a three wire cable connection to an SDI-12 capable logger. Many soil sensor manufacturers have claimed to replicate this TDR sensing technology with cheaper frequency measurement techniques, but unlike TDR, these are influenced by salinity and temperature.

Cost of the technology

Each sensor costs about $600, and a simple AA battery powered data logger capable of reading and recording ten or more of these sensors starts at approximately $600. This type of datalogger is connected with a USB cable to a computer on which the free Windows software from the Acclima website has been installed, and this allows for in-field or in-office data download and display. Mobile phone connected loggers that transmit from the field and display information on any web browser start at approximately

Figure 1: Acclima TDR sensor with 150 mm long sensing rods and ten metres of cable for connection to SDI-12 capable datalogger (Acclima, 2017)

$1000 including small solar panel, regulator and battery.

Accessibility Acclima TDR-315 units are available from Landscape Technologies, Sydney, who are the authorised reseller of this equipment in Australia. Phone and email support is available from this reseller and the manufacturer.

Installation

The three metal rods can be pushed horizontally into an undisturbed soil profile at your desired measurement depth from a vertical access hole, like a post-hole. There is no access tube used, and this vertical access hole is then back-filled to the original soil density, with the cables running to the surface or along a trench to a fence-line in grazed environments. Acclima TDR sensors can be pushed into a 60 mm diameter hole that has been augered into the soil to the required measurement depth.

Spot measures of soil water content can also be taken around any field when these TDR sensors are permanently fixed on a handle, by digging a hole to the required measurement depth, and pressing the sensor rods into undisturbed soil. Acclima has a TDR model that is round in cross-section and has 100 mm long rods for use in augered holes, or in a roving mode directly into the soil surface for spot measures.

Accuracy/precision

The TDR technology uses dielectric permittivity to accurately assess the soil water content with a proven calibration equation across a wide range of soils (Chavez & Evett, 2012; Dalgliesh & Huth, 2013). The TDR technology provides the capability to measure a higher range of soil water contents than most sensors, including slurries and humus laden potting mix.

Measurement description

TDR sensors measure a large soil volume in comparison to most other soil water content sensors. This is at least 1.5 litres depending on soil type, and is second only to the neutron moisture meter (NMM) in sensed soil volume. Buried TDR sensors are positioned at each different depth that you require, and at various positions around the irrigated block where there are different soil types.

User interface

When using the Acclima DataSnap logger with these TDR sensors, the free SnapView software downloads the data from the logger and produces plots of soil water content through time on your computer screen, for any or all the connected sensors. Timescales on the x-axis can be shortened or lengthened to provide focused examination of events, or over-view of many irrigation events.

Web interfaces for dataloggers that transmit directly through the mobile phone network to servers provide the capacity to view the soil water trace over time without the need to enter the field. A wide range of user selections allow easily configurable displays of data from single or multiple sensors, as well as the download of the data in text or csv format.

Accessing data

TDR sensors operating with dataloggers using mobile phone connections, can be read from any smartphone, tablet or computer that can operate a web browser.

Acclima DataSnap loggers only record information and must be downloaded with free software and a USB cable to laptop for direct readings in the field or viewing soil water content over time, and can swapped-out with another logger for connection to desktop computer running the SnapView software later.

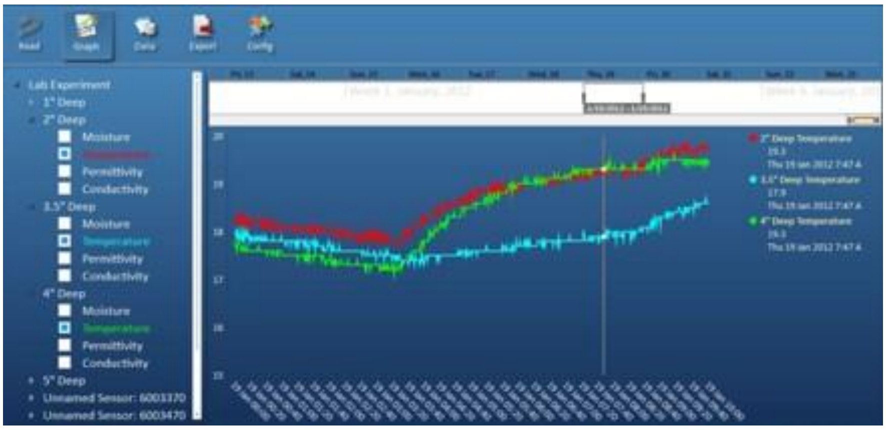


Figure 2: This is an example of the output from the Acclima SnapView software.

Strengths

- Large soil volume measured, provides accurate soil water content.
- Does not require a vertical access tube.
- Low power requirements when configured to operate at 15 min intervals or longer.
- Bent sensing rods do not affect soil water content measures.
- Measures dielectric permittivity, soil temperature, and electrical conductivity.

Weaknesses

- Rocky and gravelly soil impedes rod insertion.
- When multiple sensors are to be installed horizontally into undisturbed soil from a large
- augered post hole, there is a large volume of soil to be repacked to original density.
- Higher current draw during the quick sensing process means that some newer low power loggers that transmit to the web, have difficulty handling these TDR sensors.
- Bent sensing rods impact measures of soil electrical conductivity.

References/ links

Acclima 2017 Acclima True TDR-315 User Manual, Acclima, Inc., Meridian, Idaho

Charlesworth, P 2005 Soil Water Monitoring - Irrigation Insights No. 1, 2nd Edn, NPSI, CRC for Irrigation Futures, & NPSI, Land and Water Australia, Canberra.

Chavez, J, Evett, S 2012 “Using Soil Water Sensors to Improve Irrigation Management”, in, Proceedings of the 24th Annual Central Plains Irrigation Conference in Colby, Kansas Feb 21-22, 2012

Dalgliesh, N, & Huth, N 2013 ‘New technology for measuring and advising on soil water’, GRDC Update Papers, Grains Research and Development Corporation, Canberra.

Foley, J, Kodur, K, Whish, J, Fainges, J, Silburn, M, Bell, K, Huth, N, Peake, A 2015 ‘Measuring soil evaporation across soils of the northern cropping zone – GRDC Final Technical Report’, Grains Research and Development Corporation, Canberra.

IAEA, 2008 “Field Estimation of Soil Water Content”, IAEA Training Course Series 30, International Atomic Energy Agency, Vienna. ISSN 1018-5518

MP406 standing wave soil moisture sensor

This is a soil moisture sensor with research-grade accuracy for assisting in planting and irrigation management decisions. The sensor uses “standing wave technology” which is equivalent to Time Doman Reflectometry (TDR), the most accurate form of automated soil moisture sensing. The sensor is identical to the ThetaProbe from Delta-T Devices, but is manufactured in Australia and is completely waterproof.

Cost of the technology

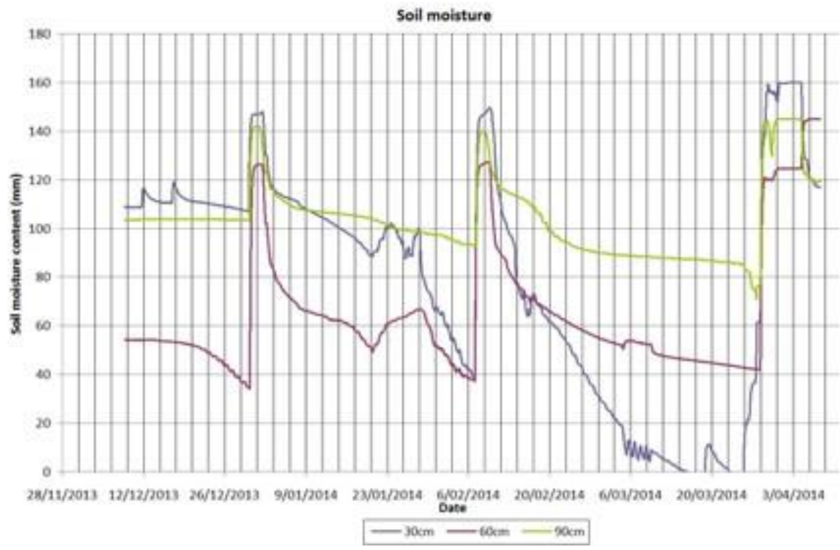
Each individual sensor costs approximately $700. An off-the-shelf handheld meter is approximately $1000 and an automated, remotely accessible logger is approximately $2000.

Installation

The sensors can be used with a handheld logger for instant measurements, but are more commonly permanently buried and attached to a logger. Sensors are installed by digging a trench and inserting the needles of the probe into the soil at the required depth/s in the soil either horizontally or vertically (as shown in photo). Horizontal installation is only recommended if the sensors will not be removed as this makes the sensors very difficult to remove without digging up the soil or breaking the cable. Vertical installation provides more flexibility in removing the probes. Probe extensions can be purchased or built using 40mm PVC pipe that extends the length of the probes to the required depths. NCEA has also used an access tube that is installed before the sensor with extension to enable easier and safer sensor removable.

Each sensor measures soil at one location, so multiple sensors are required for multi-depth sensing. For example, for crops with roots over 1m, a sensor could be installed at 30cm, 60cm and 90cm at the same location. Multiple sensors can then be attached to the same automated logger.

Vertical installation of MP406 sensors installed at three depths with access tubes.



Sample output for calibrated MP406 soil moisture sensors installed at three depths:

Measurement Volume

The sensors measure the soil within the stainless steel needles, a volume of approximately 75 cm^3. Each sensor only provides data for one point in the field, and multiple sensors are required for multiple depths.

Lifespan

The sensors can be buried for up to 20 years. NCEA has used them in cotton, grain and horticulture trials for 8 years and will be continuing to use them.

Data processing

The handheld meter and automated loggers provide the sensors with a 9–18V unregulated power supply for about 3 seconds, before the sensor takes a soil water reading. The sensor produces an output analogue voltage signal in the range 0–1.16V, depending on the soil moisture detected.

Accuracy/precision/Calibration

Calibration is required to convert the sensor's output voltage to a volumetric soil water content (%). A generic calibration equation is provided by the manufacturer for the sensor and provides accuracy to ±5%. However, site-specific calibration of the sensor will improve the accuracy to ±1%. Calibration is recommended if the quantitative soil moisture measurement will be used. However, calibration may not be required if the sensors will only be used for monitoring trends in soil water.

Calibration can be achieved in two ways:

a) collecting gravimetric soil water readings at different levels of soil moisture and comparing these with the sensor output, or

b) comparing the difference in the sensor output before and after an irrigation or rainfall event of known volume and scaling the sensor output accordingly.

User interface

A user interface is typically provided with the sensor with access through a webpage that can be viewed on a desktop computer or smartphone/tablet.

Strengths and weaknesses

The MP406 is a highly accurate and reliable soil water content sensor for a range of crops.

Weaknesses include:

› need for burying the in soil; however, adding an extension to the sensor makes the easier to remove

› need for costly logger; however $2000 is the typical cost for any standard Internet-enabled logger.

The sensors can be used to assess the "when to" irrigate. The trends in the soil moisture graphs can be assessed to compare soil moisture level before the previous irrigation and determine which measurement will be used as the trigger for the irrigation events.

Accessibility

The sensors are available from ICT International (Armidale, NSW) and can be purchased online. Support is available in selecting the number of sensors and the most suitable logger.

References/links

https://www.ictinternational.com/products/mp406/mp406-moisture-sensor/?from=/products/soils/moisture-sensors/

Neutron Probe

A neutron probe or neutron moisture meter is a reliable and robust way to measure the soil moisture and schedule irrigations. They were the preferred tool in the 1980s &1990s. They have dropped out of favour more recently due to their high cost; it is a manual process taking readings and the need to have a radiation licence. Nevertheless, they work well and are still used by people that have them, as well as soil water scientists.

The probe consists of a neutron source and detector that is connected to a cable.

The neutron probe is placed on top of the access tube and the sensor is manually lowered down the tube and a reading is taken at various depths (Usually 20, 30, 40, 60, 80, 100 and 120 cm).

The soil volume the probe measures is related to the "hydrogen" content of the soil and varies with water and clay content of the soil. The water content is the variable that changes and is what the probe can measure.

In Australia a licence from the EPA is required to own, operate and store a neutron probe.

The instruments do require calibration. This is usually done for farmers and advisors, but researchers will often do their own.

Cost of the technology

Smart 503 Hydroprobe (Neutron Probe) costs $27,398.00 plus GST

Installation

Aluminium access tubes are installed in the ground usually to a depth of 100–120 cm. Usually 2–3 tubes per paddock or irrigation unit.

Accuracy/precision

The accuracy of the readings is related to the length of measurement time with 16 seconds being the most common. A researcher might use 32 seconds especially if they only have one sample.

Measurement Volume

The area measured is usually around the size of a basketball (15 cm radius).

The large soil volume measured means air gaps and soil cracking have only a minimal effect on readings compared to capacitance probes.

Data processing

The raw count data that appears on a screen and can be manually recorded or logged for later download and is converted to water content using a calibration equation that can be incorporated into a spreadsheet or using commercial software.

User interface

The raw count data that appears on a screen and can be manually recorded or logged for later download.

Accessing Data – compatibility with phone, PC,

Strengths

- Measures a large soil volume
- Not affected by salinity and air gaps
- Measures a range of depths
- Reliable instruments.

Weaknesses

- Radiation licence
- Cost
- Manual handling and time taken to do readings
- Calibration.

References

http://ictinternational.com/products/smart503/neutron-probe-smart503/

Canopy temperature

Plant based method for irrigation scheduling

The canopy temperature method of irrigation scheduling is a low cost tool that offers growers the opportunity to continually measure their crop's water status without having to monitor soil water status and environment.

A single measurement during the day can mislead because the stress at that time may be related to the environment rather than plant's access to water. The continuous measurements allow growers to apply an irrigation before the crop has reached the point of water stress.

This method is based on fundamental understanding of plant physiology that plants close their stomata in response to water stress which results in elevated canopy temperature as plants ability to release latent heat of evaporation becomes limited.

The sensors monitor the temperature of upper canopy using infrared and can be programmed to output data at a required frequency, for example, every minute. CSIRO researchers at Narrabri have developed algorithms that enable using canopy temperature data for irrigation decision making in cotton.

Cost of the technology

The cost of canopy sensor itself is low, however, the end cost that a grower may have to pay will depend on associated costs with data access and interpretation provided by telemetry companies. The data can be transmitted to a web based portal using a telemetry system and/ or downloaded in field depending on set up. Sensors can also be incorporated into existing telemetry systems. It is not recommended to purchase sensors from overseas because of potential issues with access to data. It is anticipated that this method of irrigation scheduling will be commercially available to growers for 2018-19 cotton season and will incorporate the findings of long term research conducted by CSIRO researchers at Narrabri funded by the Cotton Research and Development Corporation (CRDC) and CSIRO. More information on the suppliers of sensors and associated services can be obtained from the authors of this article.

Installation

Canopy temperature sensors can easily be installed by growers and any required support will depend on the complexity of associated telemetry systems. Sensors are usually positioned 20 cm above the plant canopy at 45 degrees angle to horizontal using an extendable pole. Height of sensors is adjusted using an extendable pole as plants grow to keep sensors at correct position. It is important to ensure that sensor field of view is restricted to plant canopy. Inclusion of soil background in the sensor field of view may result in false signal of plant stress as soil temperature is generally higher than plants in daylight hours. It is recommended to spray sensors with insecticide to avoid insect interference within sensor field of view.

Figure 1: Infrared canopy temperature sensor installed in a cotton field

Where to locate sensors?

Concepts similar to positioning soil moisture sensors apply to canopy temperature sensors. Where EM survey data is available, it is recommended to install these sensors at a location that represents the average soil type with an irrigation unit, i.e. area being irrigated at one time. Within an irrigation unit, it is recommended to install two sensors where possible, one each at one-thirds of the distance from head ditch and tail drain. This arrangement will capture any variation caused by water distribution along the length of furrows.

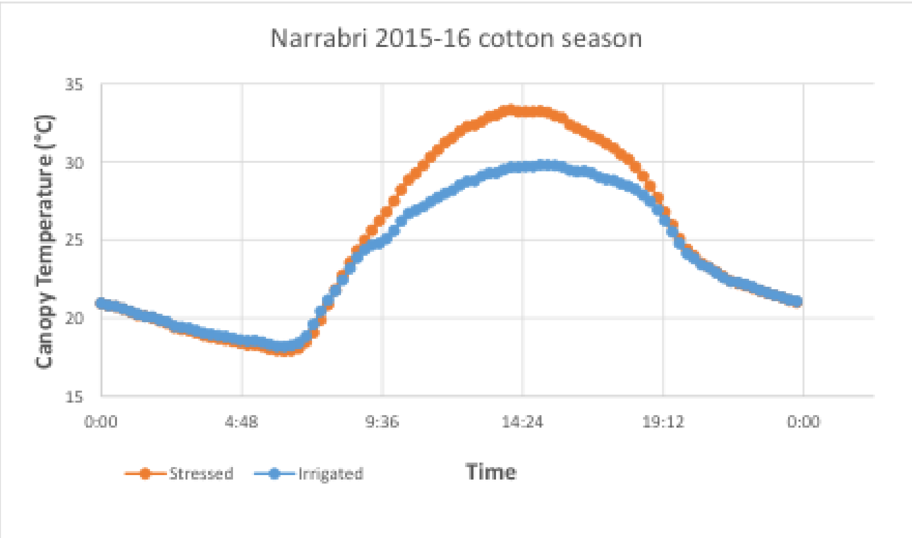


Figure 2: diurnal canopy temperature of a fully irrigated (blue) and a water stressed crop (Orange) averaged over whole cotton season

Accuracy/precision

Infrared canopy temperature sensors are generally expected to be accurate to 0.5 °C. Sensors are not expected to lose accuracy within a crop season. It is good practice to test the accuracy of sensors between seasons. Sensor accuracy is tested by pointing sensor to an object of known temperature. It is recommended to purchase sensors from suppliers which offer testing sensor accuracy as required.

Spatial information

Canopy temperature sensors monitor the temperature of the upper canopy of plants. Sensor field of view depends on height of sensor with a recommended field of view of 0.5 m^2. Any larger field of view may include bare soil especially earlier in the season when canopy is not fully closed which can result in errors. Canopy temperature of a plant is a strong indicator of its access to soil water regardless of location of water within soil profile.

Strengths

Canopy temperature is a plant-based tool and a strong indicator of crop's access to soil water. It allows monitoring plant's water status continuously which enables growers applying an irrigation before the stress has occurred thus avoiding yield loss from water stress. Sensors are weather proof and easy to install and maintain in field. This method does not require information on soil type and soil water holding capacity.

Weaknesses

Although collection of canopy temperature data is relatively simple, translating this into irrigation scheduling decision making needs technical understanding as canopy temperature through the course of the day needs translating into a response that determines whether a crop is stressed or not.

For more information contact:

Dr Hiz Jamali
CSIRO Agriculture and Food, Narrabri
email: hiz.jamali@csiro.au

Bureau of Meteorology tools

Evapotranspiration

Both gridded and point based, daily, standardised, reference evapotranspiration forecasts are available for the next 6 to 7 days from Bureau forecasts of temperature, cloud cover, wind speed and relative humidity, using the FAO Penman-Monteith equation. The resolution of the gridded product is 6km (but 3km in Victoria and Tasmania). These forecasts are available for a price of $6000–$7000 pa.

Recent Evapotranspiration

Point based estimates of daily, standardized reference, evapotranspiration derived from the Bureau's automatic weather stations and satellite data, using the same calculations as the forecasts mentioned above, and going back to 2009, are available for no charge at www.bom.gov.au/watl/eto

References/ links

For more information about the forecast evapotranspiration products, or the point-based estimates of historical evapotranspiration, contact the Bureau's agriculture team at Agriculture@bom.gov.au

Further information about the FAO Penman-Monteith equation is available at www.fao.org/docrep/X0490E/X0490E00.htm

Equations used to derive evapotranspiration in the Bureau forecast products are given in www.water.ca.gov/LegacyFiles/waterplan/docs/cwpu2009/0310final/v4c03a12_cwp2009.pdf

A user guide for the gridded evapotranspiration forecasts, and samples of these grids, are available at ftp://ftp.bom.gov.au/anon/sample/evapotranspiration

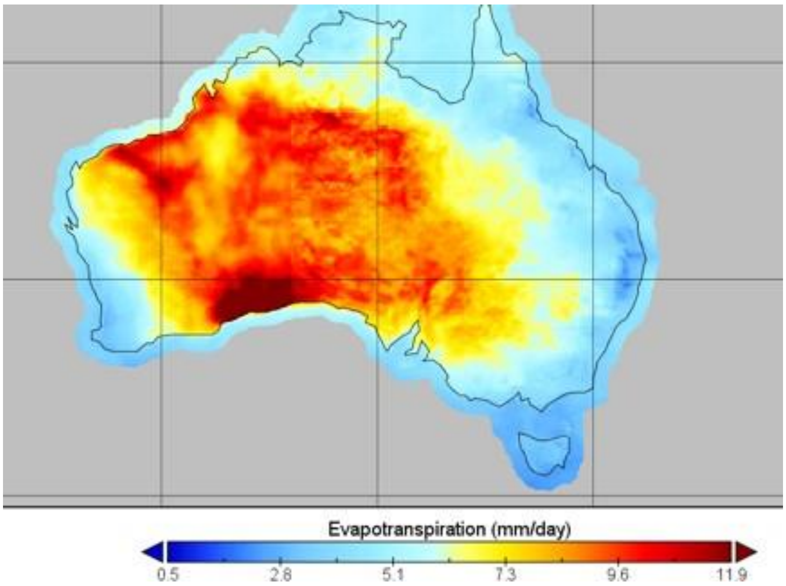


Figure 1. Graphic showing the gridded evapotranspiration forecast for day 5 (16/10/17) issued on 11/10/2017

Evapotranspiration Calculations Australia Map

Wagga Wagga Amo - February 2018 daily calculations

Date	Evapotrans-piration (mm) 0000-2400	Rain (mm) 0900-0900	Pan Evaporation (mm) 0900-0900	Max Temp	Min Temp	Max Rel Hum (%)	Min Rel Hum (%)	Average 10m Wind Speed (m/sec)	Solar Radiation (MJ/sq m)
01/02/2018	**7.0**	0.0		27.1	13.5	56	24	4.27	27.86
02/02/2018	**6.5**	0.0		28.8	14.2	70	26	3.41	26.36
03/02/2018	**6.5**	0.0		29.4	15.8	74	28	4.23	23.07
04/02/2018	**6.4**	0.6		30.5	12.6	85	22	2.84	27.24
05/02/2018	**7.4**	0.0		34.2	16.6	68	15	2.88	27.86
06/02/2018	**9.0**	0.0		35.1	19.1	52	18	4.80	26.44
07/02/2018	**9.8**	0.0		36.8	20.9	58	18	5.35	27.32
08/02/2018	**9.3**	0.0		40.4	23.7	41	11	3.74	25.12
09/02/2018	**8.1**	0.0		38.1	26.8	50	17	4.44	14.89
10/02/2018	**8.4**	0.0		38.2	16.4	67	17	4.72	16.93
11/02/2018	**8.1**	0.0		31.8	17.2	74	13	4.55	27.06
Totals:	**86.5**	0.6							

Monthly Archive

Year												
2009	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2011	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2014	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2016	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2017	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	Jan	Feb										

Product Code: IDCKWCDEA0

Figure 2. An Example Of The Point Based Estimates Of Historical Evapotranspiration

Gridded evapotranspiration

Gridded estimates of daily, modelled actual and potential evapotranspiration, (the latter using the Penman (1948) equation), at 5km resolution, back to 2005 are available at www.bom.gov.au/water/landscape

Registered users can access over 100 years of data, as well as tailored products.

All of the modelled actual and potential evapotranspiration data is available for no charge.

References/ links

For more information about the gridded estimates of historical evapotranspiration, contact the Bureau's water team at awrams@bom.gov.au

Further detail about the daily, modelled actual and potential evapotranspiration can be found in the 'More Information' sections at www.bom.gov.au/water/landscape/

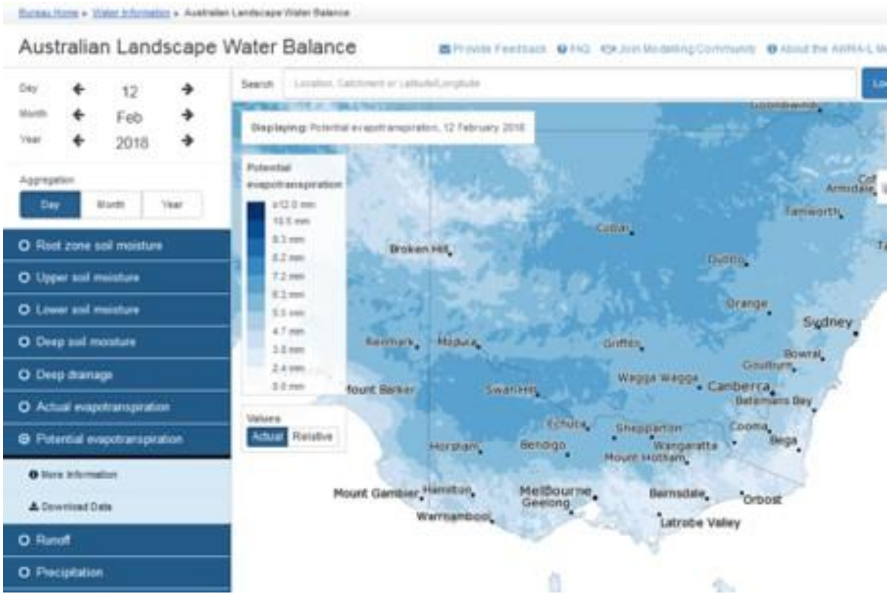


Figure 3. An Example Of Modelled Gridded Actual And Potential Evapotranspiration

Victoria: Weekly Irrigation Requirement$ Summary

Agriculture Victoria's Weekly Irrigation Requirement$ Summary is a weekly web update that is also provided by email to subscribers. It provides 'reference evapotranspiration' (ETo) data to assist with improved irrigation scheduling. It is tailored to sub regions within Victoria including the North East, Northern Victoria, the Mallee and Gippsland

The email provides *Last Week's Reference Evapotranspiration, Next Weeks Forecast Reference Evapotranspiration* and graphs of Daily ETo & rainfall for the previous week & next week. Surface ("flood') irrigators can use the "Required Surface Irrigation Interval (days)" value for their location as a guide for the timing of the next irrigation to optimise pasture productivity. Similarly, spray irrigators can use the "Spray irrigators needed to apply (mm)" value as a guide to how much water to apply to good pasture in the week.

The daily ETo data shown in the graphs can also be used to fine-tune irrigation scheduling. To optimise water productivity, the frequency of irrigation needs to be based on the water holding capacity of the soil. ETo provides a relatively objective estimate of plant water requirements and provides another handy 'tool in the irrigation scheduling toolbox.' Information in the email is a guide and can be effectively used in conjunction with other preferred methods of working out when to irrigate along with updated weather information. By regularly monitoring ETo data, the idea is that irrigators will be better informed about current irrigation requirements and will also be able to 'sharpen up' scheduling skills and tools developed over time and used regularly (eg. the use of a shovel or electric fence post).

Example email: MID ETo Update 27 August to 2 September 2020

- Flood irrigation interval for the last week was 14 days
- Spray irrigation amount was 18 mm of irrigation water for the last week.

The predicted weekly pasture water use:
Bairnsdale is 22 mm, MID 22mm, Orbost 21 mm and Yarram 21 mm.

Glenmaggie is at 85.5%

Location	ETo (mm)	Effective Rain * mm (R)	Dairy pasture coefficient	Required Irrigation mm (ETo – R)
Boisdale	19	2.2	1	16.8
Cowwarr	18	8.8	1	9.2
East Sale	18	4.2	1	13.8
Nambrok	21	1	1	20
Tinamba	16	4.6	1	11.4
Bairnsdale	20	2.6	1	17.4
Latrobe Valley Airport	19	7.2	1	11.8
Orbost	13	3.8	1	9.2
Yarram	19	2.8	1	16.2

FORECAST ETo
For Thursday 27 August to Wednesday 2 September

Location	Predicted weekly pasture water use (mm/ha)	Predicted Weekly Pasture water use (ML/ha)	Predicted daily pasture water use (mm/day)
Bairnsdale	22	0.22	3.1
MID	22	0.22	3.1
Orbost	21	0.21	3
Yarram	21	0.21	3

Cost and accessibility

The email is freely available.
You can follow on Twitter and Facebook or to receive the weekly update as an email, contact dennis.watson@ecodev.vic.gov.au (North East Victoria), robert.oconnor@ecodev.vic.gov.au (Northern Victoria), maxine.schache@ecodev.vic.gov.au (Mallee) or alexis.killoran@ecodev.vic.gov.au (Gippsland).

This email can be viewed online

https://extensionaus.com.au/irrigatingag/home

Accuracy

Typically, ETo provides a relatively accurate and reliable basis on which to determine plant water requirements. ETo values may vary slightly between the different sources. Where possible it is best to use a single and consistent source of ETo for your own situation.

In terms of accuracy for on-farm purposes, an advantage of using ETo is that it is not "point specific." ETo provides a measure that applies across a whole paddock and in most cases across a small district. Also, in terms of on-farm purposes, forecast ETo information allows you to better anticipate future plant water requirements and more accurately plan for and schedule future irrigation events.

Like any other irrigation scheduling method or tool, ETo should not be used in isolation to inform irrigation scheduling decisions.

Grower experiences

Many irrigators from different agricultural industries and locations around Australia and overseas regularly use ETo information to schedule irrigations.

Irrigators say one of the big benefits of using ETo is they save valuable time determining plant water needs and planning farm irrigations. Importantly, the ETo information assists in getting irrigation right and improving productive water use. One irrigator commented "I'm finding this info very useful. I'm following your advice on suggested irrigation interval (based on ETo data) and are growing the best pastures on this place… Milk production is up as a result (of using ETo based advice and other irrigation related changes made on farm)."

Irrigators have also indicated they use ETo information in different ways including better scheduling irrigations, minimising irrigation pumping costs and helping to calibrate other convenient scheduling methods.

Further Information

A more detailed version of this Information Sheet can be obtained from the Agriculture Victorian web site agriculture.vic.gov.au/irrigation

Alternatively further information about evapotranspiration can be obtained from The Food and Agricultural Organisation of the United Nations www.fao.org/docrep/X0490E/X0490E00.htm

Irrigate WA

The irrigate WA program is an irrigation scheduling tool for pressurised irrigation systems. The program also records seasonal water use and crop harvest results to enable crop water use efficiency indices to be calculated.

The program is aimed at simplifying the process of understanding the relationship between environmental factors driving crop water use, rootzone water holding capacity and the capacity of the irrigation system to supply water to the crop. The program uses the Department of Primary Industries and Regional Development's (DPIRD) weather stations located in all the irrigated agricultural regions in Western Australia, to calculate hourly crop water use as part of the irrigation scheduling program.

Cost of the technology

The web-based program and the smart phone apps are available free of charge. This program will only work with the DPIRD (WA) network of weather stations.

Accessibility

The main program can be accessed from the Agriculture and Food section of the Department of Primary industries and Regional Development (DPIRD) website. Smartphone apps have been developed to enable growers to access the program while out in the field. These apps can be downloaded from Apple app store and Google Play. The smart phone apps are relatively easy to install and operate, the web-based program is more comprehensive and is more suited to consultants and research officers.

Installation

There are no complicated installation requirements for the web-based program or the apps other than registering on the Agriculture and Food section of the DPIRD website. The first synchronisation of the smart phone apps with the web-based program can take some time. This is because there are several large reference files that need to be downloaded onto the smart phones before the apps become functional.

Scale

The app can be setup to represent either a paddock or a section of a paddock to represent a specific soil type.

Accuracy/precision

The accuracy of the app is largely dependent on an accurate description of the soil and irrigation system.

Measurement volume

There is no physical measurement of soil moisture, but only a calculation based on weather data and crop coefficients. It is best to reference this information against physical measurements in the paddock.

Lifespan

The irrigate WA program is currently maintained on the DPIRD website. The lifespan of the program has not been determined yet.

Data processing

Oracle database with web interface.

User interface

Data can be accessed either via the app on a phone or on the Agriculture and Food section of the DPIRD website.

Strengths and Weaknesses

Strengths

- Easy initial setup - Supports multiple irrigation systems micro sprinkler, drip, and total coverage irrigation
- Real time weather data from weather station, including evapotranspiration (ETo)
- Weather data used to calculate soil water availability to provide indicative irrigation scheduling (calculated hourly)
- Data synchronisation between mobile device and server (web-based application)

Weaknesses

- Accurate soil descriptions can only be done on the web-based application.
- Mapping function is only available on the web-based system.
- Web-based system requires basic training to operate.
- The system can only access the weather stations of the
- Agriculture and Food section of the Department of Primary industries and Regional Development in Western Australia.

Forecast tool

The IrrigateWA app can be used to forecast irrigation events.

References

For Information about the tool:
https://www.agric.wa.gov.au/spring/irrigatewa

To register for the tool:
https://www.agric.wa.gov.au/apex/eds/f?p=500:LOGIN_DESKTOP

Irriguage

The Irriguage is an evaporation based scheduling tool that has been used in the Lower Murray dairying areas In South Australia. Irriguages are inexpensive and effective scheduling tools.

Water use of pasture in the Lower Murray of South Australia was found to be closely related with the rate of water lost by evaporation from a Class A evaporation pan as used by the Bureau of Meteorology. Evaporation from the Irriguage, in turn, is related to evaporation from a Class A pan, giving farmers a simple, inexpensive measure of water lost.

Pasture water use varies according to the weather and the level in the IRRIGAUGE will also vary, subjected to the same weather changes as the pasture. When rain falls the water level rises as does the soil water level.

Soils in the region are relatively consistent highly organic black cracking clay with a RAW of around 55mm, measurements on the Irriguage are related to refilling the 55mm of RAW and the region is surface irrigated. When irrigation occurs the Irriguage is refilled to the full point, it cannot be overfilled as water will drain from the hole in the gauge. As evaporation occurs the water level will drop towards the lines drawn on the gauge 90–110mm from the full point on the gauge in summer and 110–120mm in spring. When the water in the gauge reaches the appropriate refill point the paddock is irrigated and the gauge refilled.

IRRIGAUGEs installed and numbered to match watering sections. The black lines mark the irrigation point for summer and autumn/spring.

Cost of the technology

A Nylex rain gauge will cost approximately $35. The gauges are available at most hardware stores or irrigation suppliers. You will then need to take some time to make the modifications to the gauge yourself.

How do I make an Irrigauge?

Using a Nylex rain gauge remove the top and the small inner gauge, drill a hole in the side of the larger gauge 1 cm from the top (this prevents you overfilling the gauge and makes sure you fill it to the same level each time) then measure with a ruler down the side of the gauge and mark with a texta or ear tag pen at 90mm, 110mm and 120mm—see photographs.

There is no support available for Irriguage it is strongly recommended that irrigators trial their use using other scheduling tools to confirm the refill points set on the gauge.

Installation

Install on a post or dropper 140cm above the ground. Irriguages can be grouped together in a convenient location for reading (such as by the main gate to the irrigation area) but must be exposed to the same wind, sun and rain as the paddocks. Gauges should be numbered to correspond to paddock or irrigation section numbers. One Irriguage is preferred for each watering section.

On laser levelled paddocks re-fill the Irriguage when the paddock is watered and irrigate the paddock again when the level drops to 100–110mm in summer or 110–120mm in spring and autumn. If making your own Irriguage, measure with a ruler down the side and mark with texta or ear tag pen these levels. On non-laser levelled paddocks the Irriguage can still be used as a guide, however, the gauge should not be re-filled until all the surface water on the paddock is gone. This should also be the case on lasered paddocks which may still have poor drainage or where over-watering has occurred.

Scale

Paddock scale.

Accuracy/precision

Accuracy is limited and the Irriguage should be used as an indicator only in conjunction with other indicators. Trials conducted on the Lower Murray swamps (South Australia) have compared the Irriguage to Class A pan evaporation found the Irriguage to reliably predict irrigation on established laser levelled pastures.

Lifespan

Irriguages will last for many years.

User interface

Irriguages are read visually.

Strengths

- Evaporation monitoring is cheap and easy for the following reasons:
- ease of installation
- ease of use
- low maintenance requirement
- no need to install in paddocks therefore convenient to read
- low cost.

Weaknesses

Not as accurate as tensiometers, or other tools.

John Deere Field Connect System

Moisture probe and weather monitoring unit

The field connect system is a John Deere derived soil moisture and weather station system. It can be adapted to the customer requirements, such as probe lengths from 0.5m to 1.5m with up to six sensors depending on the probe, sensors for leaf wetness, soil, air and water temperatures, solar radiation and precipitation.

The installation in Figure 1 and 2 was for a pivot system where two measuring points were set up, one within the first span and the second within the outer span. Each had a 1m probe, tipping rain gauge, temperature sensor and wireless node. Both sent data back to a central control box (shown in the Figure 2) which was located at the centre point. This unit consisted of the main box, a wireless node, aerial and a weather station picking up ambient air temperature, wind speed, direction, and humidity. All this data was then sent via a cellular link to the cloud-based field connect site which can be accessed from the customers *My John Deere* log in, on a smart phone or tablet.

Cost of technology

The Field Connect options have reduced in cost since its release. The system shown in Figures 1 and 2 with the two probes stations and the weather station at the centre point has a value in the region of $4000 for each probe station and $5500 for the weather station gateway. So, all in all $13,500 hardware costs, the subscription can be paid either in three six- or 12-month blocks at a value of approximately $1000 pa. This covers all the cellular connection and data supply portal for the gateway which can host up to eight probes within a 1.5km radius.

Figure 1. A pivot system with two measuring points.

Figure 2. Central control box.

Accessibility

The sensors and majority of hardware for the Field connect system is available through most John Deere dealers.

Installation

The system has specific installation equipment which can either be purchased or trained staff will install the system and maintain it for a fee. The installation hardware only consists of a soil auger system for the probes and a place to attach the weather station to, which can be a pole or post whichever is convenient for the crop specific installation. The time scales depend on the complexity of the system however most single probe systems can be up and running in two to three hours.

Field Connect Probe Installation

Farm operations such as harvesting, planting, spraying and cultivations all have an effect on where and how these systems are installed. The probes themselves protrude above or at best are level with the ground and do have wires attaching them to their wireless nodes, these in themselves do not make it convenient for ground engaging equipment. It is wise to remove the probes for these operations.

Figure 3. Field Connect Probe installation.

The locations of the central weather station or gateway due to their wireless options can mean that they have a more permanent place for installation, however for long season/ perennial crops they may be in the way for harvesting or spraying operations due to their location in the row or protruding above the crop.

Like most monitoring systems there is a level of management required to ensure accurate data is collected. This is particularly important in fast growing vegetative crops where rain gauges and light sensors can soon become overgrown, or wildlife tends to chew or peck at wires. For this reason it is important to look at the system once a week to ensure nature has not interfered with any of the data collection systems. If the intended installation is into a grazing system careful consideration should be taken as to how the system is installed since livestock tend to destroy anything above ground unless it is either high enough or strong enough. The field connect is suitable for grazing systems, however prior to purchasing, hardware and installation methods should be considered carefully.

Accuracy/Precision

The accuracy of any system like this is dependent on the install and maintenance of the sensing hardware. Once installed probes need time to settle before accurate data can be drawn from the sensors. Depending on the soil type and method of installation this can be from a matter of 24 hours to a week. The field connect is a wet install, requiring soil slurry to help seat the probe, this kind of system requires longer before accurate data can be drawn from the readings. The sensors for Field Connect are all capacitance. Therefore, you should review information on capacitance soil moisture sensors.

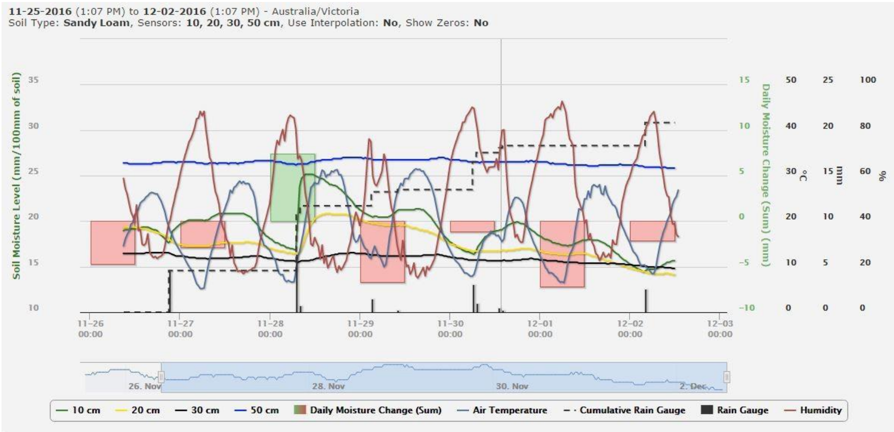


Figure 4. Field Connect user interface.

Data accessibility, formatting, Interface and compatibility

The Field Connect uses a cloud base platform for presenting the data from the field sensors. These can be accessed via PC, smartphone or Tablet with complementary apps which work via IOS or Android systems. This data is sent from the gateway at intervals which can be selected by the grower, Field Connect updates data from the wireless systems every 30 minutes to the gateway which is stored on the data logger before being sent to the cloud.

The data itself is presented in a format that can be specific to the grower requirements (Figure 4), the changeable parameters on the data are items such a units, timescales, which sensors to compare/select and many more options which needs to demonstrated to fully understand how bespoke the data delivery can be.

Field Connect platform

Figure 4 shows a snapshot of how this data can be presented on a PC or tablet, individual data points can be selected to draw down to specific times or events enabling a grower to pinpoint areas for further investigation or management. The app options for field connect allows for alerts to be set up should data points range outside grower set parameters.

Strengths

- Simple system which still gives good accurate information
- Adaptability for user requirements
- Additional development through hardware and software interface
- The user interface is easy to read, alter and understand.

Weaknesses

- Probes do not to include salinity and temperature
- The units are larger and more ‘clunky’ however this may be outweighed by their robustness.

More information

For more information on these systems please go to: https://fieldconnect.deere.com

The iMetos System

Moisture probe and weather monitoring unit

The iMetos system by Pessl instruments is a fully adaptable moisture probe and weather monitoring unit. There are several probe options with adaptable sensors. The Triscan offers soil moisture, temperature and salinity within the 'drill and drop' probe model. This is available in 30, 60, 90 or 120cm lengths with sensors every 10cms.

The climate data options are numerous with the system offering sensors to measure in crop canopy parameters such as temperatures and leaf wetness. The field climate options offer an array of sensors for wind, light, wet and dry bulb temperatures, precipitation and remote crop imagery.

Figure 1 shows a basic system installed in a melon crop and vineyard. The probe is connected remotely using an eco D3 node which sends data back to an iMetos 3.3 environmental monitoring system. This has wind speed, precipitation, air temperature, relative humidity, leaf wetness and global radiation sensors all collecting data.

Once set up the data is sent via cellular link to a cloud-based site which is fully adaptable for the grower, this can then be viewed on smartphones, tablets or any web based platform.

There is also the development of weather forecasting and disease modelling. These utilise the data sourced not only from the units in the field but other local stations and meteorology bureau data to produce forecasts and crop specific alerts to growers.

Figure 1. Example of iMetos system

Figure 2. Example of iMetos probe installation

Cost of technology

The iMetos system has a different cost structure that it is highly adaptable so in reality it is possible to simplify the system to meet growers' budgets. The wireless probe stations with Triscan drill and drop probes range from $1,000 to $2,500 depending on the probe length with a radio node costing $780 per probe. This then feeds back to the weather station as shown in Figure 1 which costs $4,700 and can handle up to sixteen probes within a 1.5km radius.

For a modest system as shown in Figure 1 the hardware costs can be in the region of $7,500. The subscription costs for the system including the disease modelling are $255 per station per user per year, however depending on the number of different crop types and stations this cost will alter slightly. In addition, a data sim card needs to be purchased from a suitable telecommunications provider to the area.

Accessibility

The sensors and majority of hardware for the iMetos system is produced by Scentec Industries in Adelaide.

Installation

This system has specific installation equipment which can either be purchased or staff will install the system and maintain it for a fee. The installation hardware consists of a soil auger system for the probes and a place to attach the weather station to, which can be a pole or post whichever is convenient for the crop specific installation. The time scales depend on the complexity of the system however most single probe systems can be up and running in two to three hours (Figure 2).

iMetos probe installation

Farm operations such as harvesting, planting, spraying and cultivations all have an effect on where and how these systems are installed. The probes themselves protrude above or at best are level with the ground and do have wires attaching them to their wireless nodes, these in themselves do not make it convenient for ground engaging equipment.

It is wise to remove the probes for these operations, which for short season crops in the horticultural industry makes sense, however in broad acre should be a consideration for system compatibility. The locations of the central weather station or gateway due to their wireless options can mean that they have a more permanent place for installation, however for long season/perennial crops they may be in the way for harvesting or spraying operations due to their location in the row or protruding above the crop.

Like most monitoring systems there is a level of management required to ensure accurate data is collected. This is particularly important in fast growing vegetative crops where rain gauges and light sensors can soon become overgrown, or wildlife tends to chew or peck at wires. For this reason, it is important to look at the system once a week to ensure nature has not interfered with any of the data collection systems.

If the intended installation is into a grazing system careful consideration should be taken as to how the system is installed since livestock have a tendency to destroy anything above ground unless it is either high enough or strong enough. The iMetos are suitable for grazing systems, however prior to purchasing, hardware and installation methods should be considered carefully.

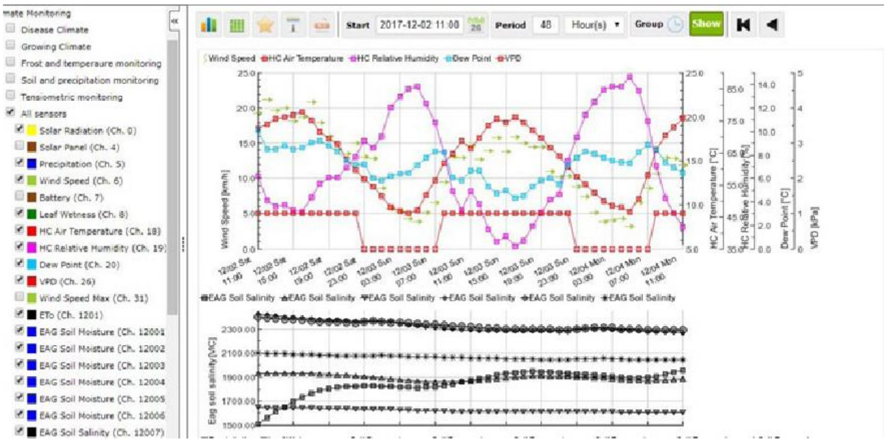


Figure 3. Example of iMetos data

Accuracy/Precision

The accuracy of any system like this is dependent on the install and maintenance of the sensing hardware. Once installed probes need time to settle before accurate data can be drawn from the sensors. Depending on the soil type and method of installation this can be from a matter of 24 hours to a week. The drill and drop system is a dry installed probe which tends to settle quicker and viable data can be gathered within 24–48 hours. The sensors themselves are all capacitance, therefore you should review all information on capacitance soil moisture sensors.

Data accessibility, formatting, Interface and compatibility

The iMetos system uses a cloud based platform for presenting the data from the field sensors. These can be accessed via PC, smartphone or Tablet with complementary apps which work via IOS or Android systems. This data is sent from the gateway at intervals which can be selected by the grower, iMetos updates data from the wireless systems every 15 minutes to the gateway which is stored on the data logger before being sent to the cloud.

The data itself is presented in a format that can be specific to the grower requirements. The changeable parameters on the data are items such a units, timescales, which sensors to compare/select and many more options which need to be demonstrated to fully understand how bespoke the data delivery can be.

iMetos Data Platform

Figure 3 shows a snapshot of how this data can be presented on a PC or tablet, individual data points can be selected to draw down to specific times or events enabling a grower to pinpoint areas for further investigation or management. The app options allow for the disease modelling and forecasting with iMetos.

Strengths

- Adaptability for user requirements
- Allow for additional development through hardware and
- software interface.
- Adaptability for the field,
- Crop specific disease modelling and forecasting.
- Great tool to optimise data for crop input and monitoring

Weaknesses

- The user interface can be confusing however once mastered becomes a simple system to use.
- May not be as robust as some systems.

More information

For more information on these systems http://metos.at/home

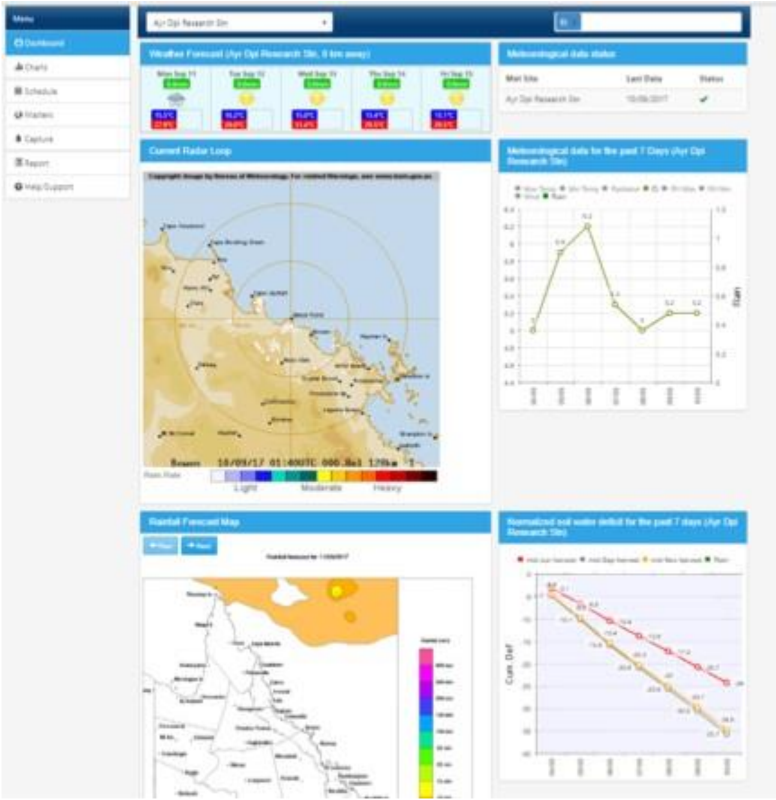
IrrigWeb

Web-based irrigation scheduling advice for sugarcane

IrrigWeb is an irrigation scheduling software system. It uses crop water use estimates from user inputs of soil type, planting date, crop area, irrigation date and irrigation volume and meteorological data from local or BOM weather stations to assist the irrigator to optimise scheduling of irrigation.

The primary aim of IrrigWeb is to provide sugarcane irrigators with current and local advice on sugarcane crop water use and development. The tool combines crop water use estimates with user-defined irrigation system constraints and crop cycle inputs to schedule future irrigation events. Developed by SQR Software, IrrigWeb uses a sugarcane crop model, CANEGRO, to calculate sugarcane crop water use and yield outputs. IrrigWeb is a cloud-based application. Users' data is saved in a secure web database, giving access to IrigWeb from any location or device connected to the internet.

Meteorological inputs are obtained daily either from government funded meteorological networks or directly from local automatic weather stations. Users select the closest meteorological site as the source of weather data inputs for the model. Variations in rainfall distribution across a farm can be captured. Fields are assigned irrigation system rules which defines the irrigation application system (surface, overhead or sub-surface drip) and the system application constraints (e.g. minimum cycle times) and a set of scheduling management rules (e.g. target soil water deficit that triggers an irrigation event).



IrrigWeb dashboard

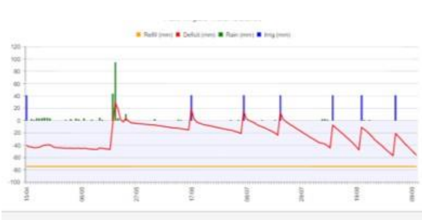
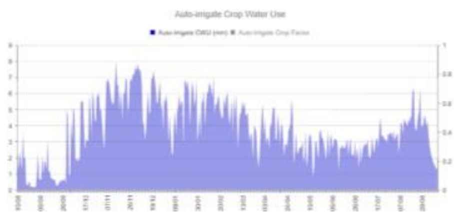
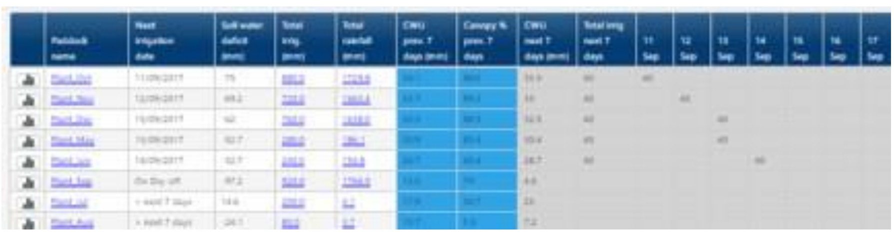


Chart showing irrigation, rain and soil water deficit

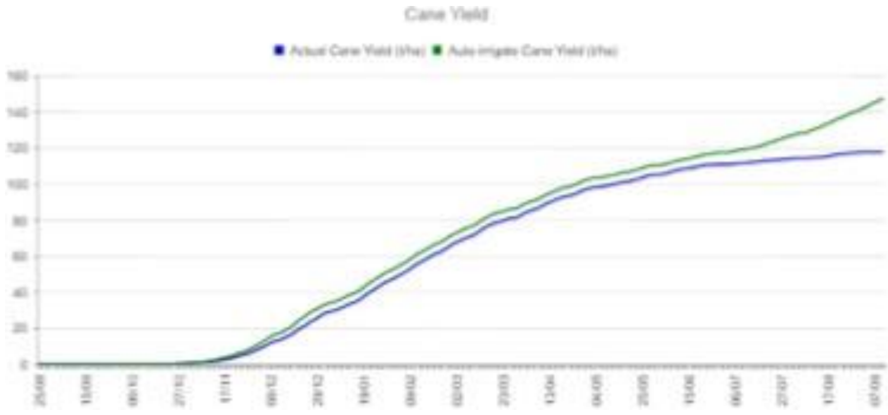


Daily crop water requirement

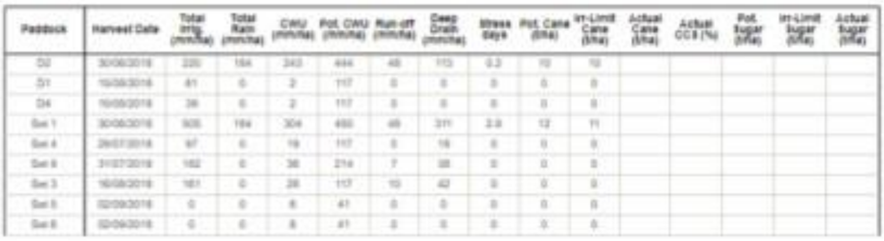


Schedule for irrigation planning

Well documented soil types are assigned to each field. Soil profile inputs define the soil's water holding capacity and concepts such as drainage rates and runoff. Irrigation inputs can either be manually captured for a field, or automatically calculated using IrrigWeb's Auto-Irrigate function. Outputs are provided by a range of graphical and tabular reports. Charts depicting the soil water balance, canopy development, water stress, crop water use and yield components are combined with tabular irrigation schedules and historical reporting.



Cane yield forecasting



Paddock	Harvest Date	Total Irrig. (mm/ha)	Total Rain (mm/ha)	CWU (mm/ha)	Pot. CWU (mm/ha)	Run-off (mm/ha)	Deep Drain (mm/ha)	Stress days	Pot. Cane (t/ha)	Irr-Limit Cane (t/ha)	Actual Cane (t/ha)	Actual CCS (%)	Pot. Sugar (t/ha)	Irr-Limit Sugar (t/ha)	Actual Sugar (t/ha)
D2	30/06/2018	220	184	243	444	48	113	0.2	10	10					
D1	10/08/2018	41	0	2	117	0	0	0	0	0					
D4	10/08/2018	38	0	2	117	0	0	0	0	0					
Set 1	30/06/2018	505	184	304	450	48	311	2.9	12	11					
Set 4	29/07/2018	97	0	19	117	0	19	0	0	0					
Set 6	31/07/2018	182	0	38	214	7	38	0	0	0					
Set 3	16/08/2018	161	0	28	117	10	42	0	0	0					
Set 5	02/09/2018	0	0	8	41	0	0	0	0	0					
Set 8	02/09/2018	0	0	8	41	0	0	0	0	0					

Reporting

Cost

Cost is based on a per hectare rate for the area scheduled.

Accessibility

Available from SQR Software www.irrigweb.com Please email irrigweb@sqrsoftware.com for further information.

User Inteface

IrrigWeb is cloud based and currently available for computers. In addition to obtaining one-on-one access to the tool, regional users or consultants can use IrrigWeb's notification functionality to provide automated SMS and or email advice to multiple end-users.

IrriSAT

IrriSAT uses crop data from the NASA Landsat and ESA Sentinel satellite platforms combined with on-ground weather station parameters to estimate crop water use. IrriSAT provides estimates of past water use and also includes a seven day forecast of crop water use for the coming seven days. IrriSAT has tools which helps users schedule upcoming irrigations by tracking crop water use deficits.

Cost of the technology

IrriSAT is freely available and is an on-line cloud-based app. There is no subscription fee associated with the product.

Installation

IrriSAT uses satellite sensors to directly measure crop performance and requires no in-field installation of equipment. The weather station network can either be an existing physical station (many are already available in IrriSAT – through Oz Forecast, Goanna, Deakin University and other providers) or users can use the SILO reference evapotranspiration gridded data which covers all of Australia and is accessible within IrriSAT. The cloud-based app requires no software installation onto devices and runs entirely online including warehousing of user entered data allowing access from any web enabled device.

A series of online YouTube tutorials are available (see references) and generally users can start getting information out of IrriSAT for their particular fields after watching the introductory tutorial and within 30 minutes of trialing IrriSAT.

Scale

IrriSAT has whole of Australia and US coverage at 10x10m pixels for both past and seven-day crop water use forecasts. It has global coverage for seven-day crop water use forecasts.

Accuracy/precision

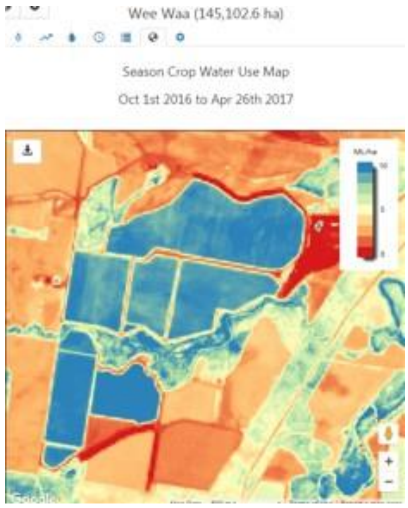
IrriSAT will provide site specific crop water use information down to a 10x10m square within a field. This water use information is updated daily and the system provides daily crop water use information. It has been compared against lysimeter and field-based probes and shows good accuracy against these methods. Like all irrigation scheduling tools it is important to compare its output with what is seen visually on the ground in the field. Accuracy can be expected to be within +/- 10% during the active crop growing period.

Measurement volume

IrriSAT estimates actual crop water use from the plant by measuring crop reflectance with satellite based sensors to determine a site specific crop coefficient and then combines this information with reference evapotranspiration data to estimate actual crop water use across entire fields at a 10x10m resolution. This allows users to see both within field variability of crop water use and compare crop water use between fields.

Lifespan

IrriSAT is used historically from the 1999/2000 irrigation season until present. However, earlier historical data is limited by lower resolution and less frequent satellite data. The current series of satellites from both NASA and ESA which sense vegetation parameters have 15–20-year lifespans and will be replaced with newer satellites. For instance, the Landsat series of satellites used in IrriSAT are currently on satellite number 8.



IrriSAT showing estimated seasonal crop water use. Variability both within and between irrigation fields can be identified.

Data processing

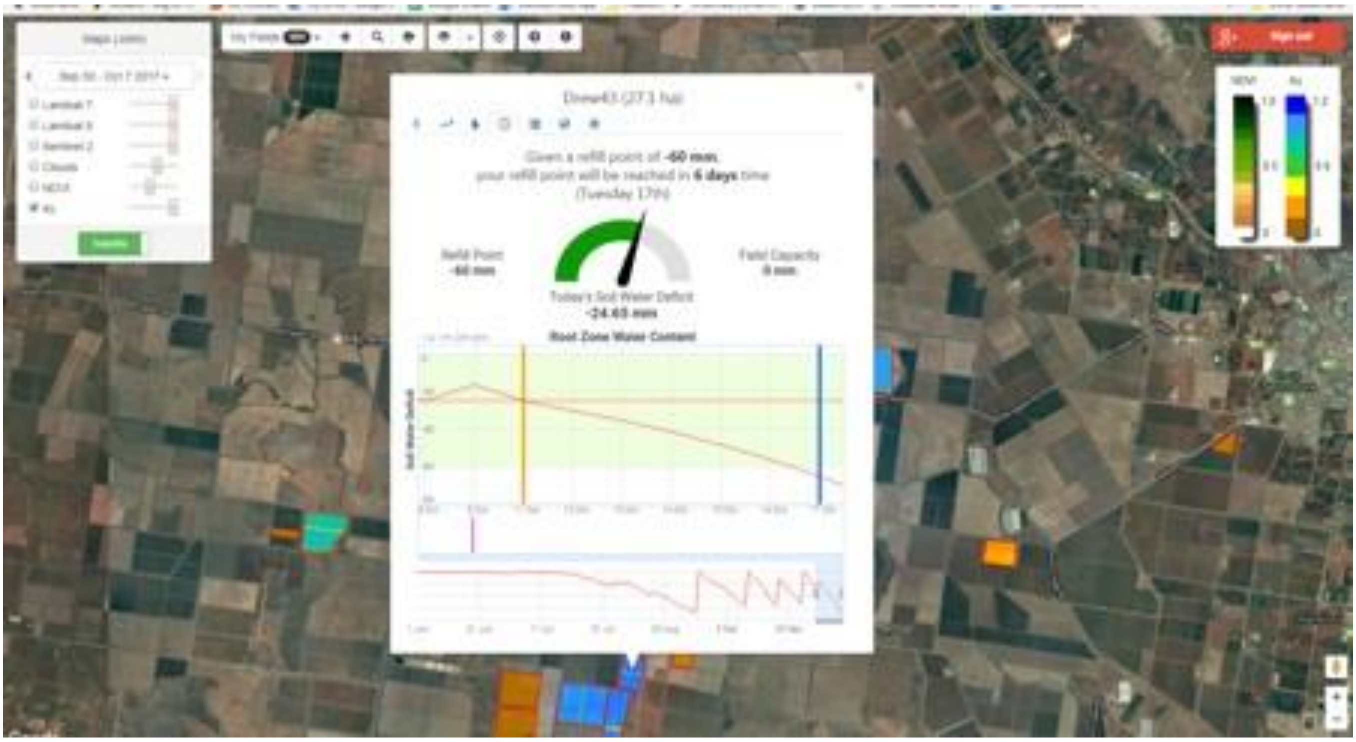
The IrriSAT cloud-based app is based on the Google Earth Engine. All satellite data and reference weather data are automatically processed within the app. As new satellite images become available, they are automatically available within the IrriSAT app and estimations are updated. The forecast weather parameters are also automatically ingested into IrriSAT. This takes away any complex processing tasks from the user who can focus on using the data for making irrigation decisions rather than having to process data.

User interface

The interface for IrriSAT is google based and is driven by a mapping interface in the Google Earth Engine. Irrigators can move around and identify fields of interest and then get site specific crop water use information for the field of interest.

Accessing data

The IrriSAT app is a cloud-based app. It can be accessed from any device that is connected to the internet. Users can therefore work across PC, phone and iPad platforms at will and all entered data is stored within the cloud.



IrriSAT screenshot showing the irrigation scheduling tool component that shows previous and forecasted crop water use and estimated time to next irrigation.

Strengths

- Provides easy access to crop water use across large areas
- High spatial resolution across large areas
- Low cost
- Easy to use
- Includes a seven-day crop water use forecast.

Weaknesses

- Relies on having good satellite data to drive crop water use estimations
- Cloud cover can prevent access to good quality satellite images
- Online tool.

Accessibility

The online cloud based IrriSAT app can be accessed from: https://irrisat-cloud.appspot.com/#

Users are required to have a freely available google account which can be created at: https://accounts.google.com/SignUp?hl+en

References/ links

IrriSAT app access https://irrisat-cloud.appspot.com/#

Quick Guide to Using IrriSAT (.pdf) https://irrisat-cloud.appspot.com/doc/IrriSAT_QuickGuide_20052016.pdf

Youtube video tutorial on getting started with IrriSAT https://www.youtube.com/watch?v=5qznIkqDsIA

Using IrriSAT in Cotton Overview https://www.youtube.com/watch?v=ccvJizT4Iw0&t=17s

CottonInfo webinar: IrriSAT use and applications for irrigation management in cotton https://www.youtube.com/watch?v=RKgc1pLtEkE&t=16s

Plexus

On-farm monitoring network

Plexus Field Stations measure attached sensors for soil moisture, flow, water level, pump pressure or rainfall, then transmit the data to a central Hub, which uploads all the farm records to the cloud. Farm records are then available in real-time through the Green Brain web application that lets users track moisture levels, water availability, irrigation status, cattle stress levels, etc. User-specific alerts can be set up so that Green Brain notifies you when something needs your attention.

Cost of the technology

Capital: For 5 monitoring sites $6,700 plus sensors

Ongoing software: $350 per year.

Accessibility

Purchase from MEA's network of agronomists and agents, who will provide professional installation, and ongoing local support.

Installation

Plexus and soil moisture probes are installed based on site conditions, irrigation type, and farming practices. They distribute through a network of trained agents who understand the myriad of factors when designing each monitoring system, and who will install everything in a robust manner. For new agents, an MEA representative will attend the installations at no additional cost to ensure the hardware is deployed in the most robust and useful manner possible. Each monitoring site takes between 15–60 minutes to install depending on the sensors at each site.

Scale

Plexus Field Stations can communicate over 1 kilometre line of sight and can re-route a signal from other Field Stations further afield. This means a Plexus networks can be deployed over areas up to 7800 hectares using a single Plexus Hub. Up to 60 monitoring sites can be linked into each Plexus Hub.

Accuracy/precision

This is dependent on the type of sensor used. Plexus is compatible with all market-leading SDI-12 soil moisture sensors and with gypsum blocks. So you can choose the sensor options to meet your budget and accuracy requirements.

Measurement Volume

Point source sensor installation, or single site weather station.

Lifespan

8–10 years

Data processing

Farm monitoring records are processed in real-time (a 30 minute upload rate is standard).

User interface

Green Brain (Demo site available at www.greenbrain.net.au – Sign in with username: demo@mea.com.au and password: demo)

Accessing data

Green Brain is a web app that is available through any internet-connected device. Phones, desktop computers and tablets.

Grower opinion example

Tom Redfern
Avocado Grower, QLD

"We have 77 MEA moisture probes over five avocado farms in Queensland. We honestly don't know how we could accurately irrigate without them. We can accurately monitor how far water goes down through the soil profile with each irrigation or rainfall event and adjust our irrigation schedule accordingly. We can see if we have underdone or overdone the water or if we are not keeping up. With the graphed information we can estimate in advance of when we will need to irrigate again, given the current water use and weather forecast. As it can take 48 hours or more to complete an irrigation program on some farms, we can juggle the orchard block priority to suit given the information from Green Brain. The ability to include notes, rainfall and irrigation records on Green Brain is a convenient historical tool also. If there is any doubt about the graph on Green Brain we can double check in the paddock with a 'Dig-stick', and so far the graph and dig-stick have always correlated."

Soil moisture monitoring with Plexus and Green Brain lets you optimise the timing and amount of irrigation, and link this into a more comprehensive farm monitoring system.

By linking a Weather Station into the mix, water requirements can be calculated and estimates of when the next irrigation will be can be made. This helps stay on top of irrigation requirements through the summer months.

Strengths

- Flexible hardware – design a system to meet your exact requirements
- Full on-farm network – once the infrastructure is in place, you can add to it without changing the annual operating costs.
- Can be expanded in future years without increasing ongoing costs
- Solar powered with fully sealed waterproof enclosure.
- Single, low annual subscription fee of only $350 per year per Hub not per monitoring site.

Weaknesses

- For 1–2 site systems, an on-farm network may not be the best solution.

References/links

www.greenbrain.net.au

www.mea.com.au/soil-plants-climate/soil-moisture-monitoring/plexus

Rubicon FarmConnect:

Soil Moisture Monitoring

Rubicon's FarmConnect is a data driven platform for irrigation management incorporating smart sensors and connected devices to automate surface irrigation outlets, monitor water levels and water flows. Rubicon FarmConnect Soil Moisture Monitoring module interprets real-time field conditions from sensors to predict the next date of irrigation to grow more crop using the correct irrigation strategies.

Rubicon's FarmConnect uses capacitance soil probes designed to measure soil moisture content at multiple depths (every 10cm) in deep rooted plants.

Cost of the technology

Rubicon will offer farmers the option to either rent the equipment for a twelve-month period (Managed Services Program) or purchase the equipment outright. Rental is arranged through your local agronomist and will include an installation and removal service along with ongoing warranty during the rental period.

Accessibility

Rubicon's FarmConnect soil moisture monitoring equipment is used by both farmers and researchers and is available through rural merchandise agribusinesses Australia wide. Comprehensive training documentation is provided online and your Agronomist can assist with crop specific data interpretation and irrigation interval recommendations.

Installation

The hardware can be installed by the farmer or by an agronomist under a Managed Services Program. Particular attention is needed in relation to site selection for soil moisture monitoring, making sure the site is representative of the field in terms of soil type, topography and has the required number of established plants around the probe. A hand auger with the appropriately sized auger bit is required along with the necessary equipment to prepare a slurry. The slurry is used to eliminate air voids around the probe tube.

If a below ground probe is installed it is advisable to lay a 10-metre cable extension in conduit in order for the telemetry unit to be situated off the field so grazing and hay making can occur without the need to remove the telemetry unit when these events occur.

Data Processing and User Interface

The raw data is uploaded every 15 minutes, processed and made available to the user on any device that has an internet connection. The advantages of the Rubicon FarmConnect software is that it is an easy to use cloud based program that is able to be run on any device. Additionally, the software can also be used to monitor water levels, rainfall and operate Rubicon's on-farm automation equipment.

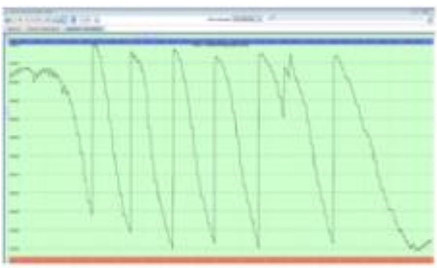
The software presents the data in three basic easy to use formats.

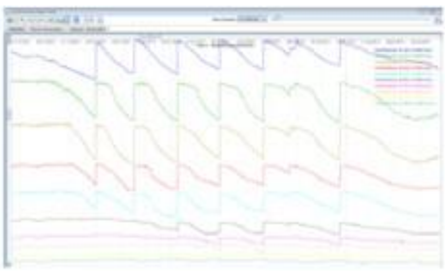
A Summed representation of the separate layers which shows daily water use, irrigation effectiveness, when to irrigate, how much to irrigate, rainfall and the full and refill points (below left).

A Separate Layer Graph shows root activity at the depth of each sensor and allows the user to assess soil moisture stress at each layer in the profile (below right).

Data provided by FarmConnect can assist farmers by informing them in real time of:

- Root zone activity and the impact of forthcoming hot and windy dry spells
- Infiltration levels as the profile builds
- The timing of duration of the irrigation to avoid overwatering
- The effectiveness of rainfall events
- Leaching
- The extent of the impact of different irrigation run times





Combination tool

In situations where farmers may have multiple soil moisture devices, a summary page shows all devices with easy to view fuel gauges showing where the current state is in relation to the full point and refill point listed in order of closest predicted irrigation date.

Life

8–10 years

Strengths

- Remote access to real time data
- Analytical tools within the software
- User defined calibration for different soil textures at depths
- Software can also be used to monitor water levels, rainfall and flow rates
- Software is also a fully featured irrigation automation solution for control

Weaknesses

- Careful installation to ensure air voids are eliminated
- Subject to livestock damage if above ground probes used

References/ links

https://www.rubiconwater.com/catalogue/software/farmconnect-software

SWAN Systems:

Scheduling Water and Nutrients

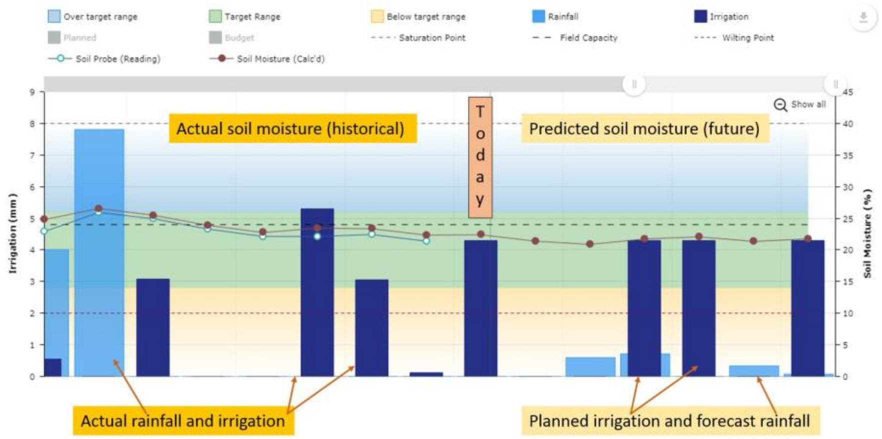
SWAN Systems is a tool for the planning, monitoring, management and reporting of water and nutrients applied to irrigated plant populations. SWAN is a web-based software solution that collects automatically logged data from irrigation controllers, flow meters, soil moisture probes, aerial imagery and weather stations for analysis. It is hardware independent, meaning it can collect data from existing on-site equipment.

SWAN analyses each weather update and irrigation event to provide a daily snapshot of soil moisture status and continuous monitoring of each site's water usage (budgeted versus actual applications). Looking forward, SWAN collects localised weather forecasts, including evapotranspiration and rainfall for each site. These are automatically updated daily and are combined with planned irrigation applications, and soil-, crop- and growth-stage specific models to predict future water use requirements and soil moisture status. In addition, SWAN has an integrated "Health Index" that provides a location-based visual check of crop health using data obtained from satellites and aerial imagery.

Cost of the technology

Single Users

- Minimum cost for a single farming operation starts at $6,200/year, plus setup costs (~$500, but depends on project size). Includes training and support. Rates are cheaper if you are not implementing the full suite of features. Rate increases with size of operation. A farm with 10 individually managed fields would cost $8,000/year.



Educational / NFPs

- As for Single Users but with 10% discount (setup costs excluded from discount).

Research

- As for Single Users but with 50% discount (setup costs excluded from discount).

Co-operatives

- As for Single Users but with a group discount of 1% per member, up to 50% total discount (setup costs excluded from discount).

Accessibility

Interested parties will need to contact SWAN Systems via the contact form and they will then be put in touch with the appropriate Partner.

Installation

If no hardware is currently installed, this may need to be installed by supplier or third party, e.g. soil moisture probes. SWAN Systems can acquire data from a wide range of equipment.

The software requires setup by SWAN Systems, or a trained representative. For initial account setup, the process takes approximately five hours. If there are many Individually Managed Units (IMU's, e.g. fields) with varying characteristics (such as different soil and crop types), then the setup may take longer.

Minimum computing requirements include:

- Google Chrome web browser
- Internet connection (minimum speed 3 MBS)
- 2 GB RAM as a minimum, however 4 GB RAM is recommended.

Scale

The software is suitable for users that wish to scale up their operations. While an individual management unit (IMU) has a maximum allowable area in SWAN (must not exceed 10,000 hectares), the number of IMUs allowable per account is unlimited.

Accuracy/precision

As with all data analysis programs, the quality of the results depends on the quality of the data going into the system. SWAN have processes to check the data automatically entering SWAN Systems, to make sure that there are no glitches in the system.

Measurement description

SWAN is a software system that can aggregate data from a range of sensors, its accuracy and measurement volume is dependent on the hardware that is connected to.

Lifespan

The software licence needs to be renewed. The licence can be renewed monthly or annually.

Data processing

SWAN Systems obtains data either through manual entry (if needed) or through data acquisition via telemetry and hardware specific scripts.

User interface

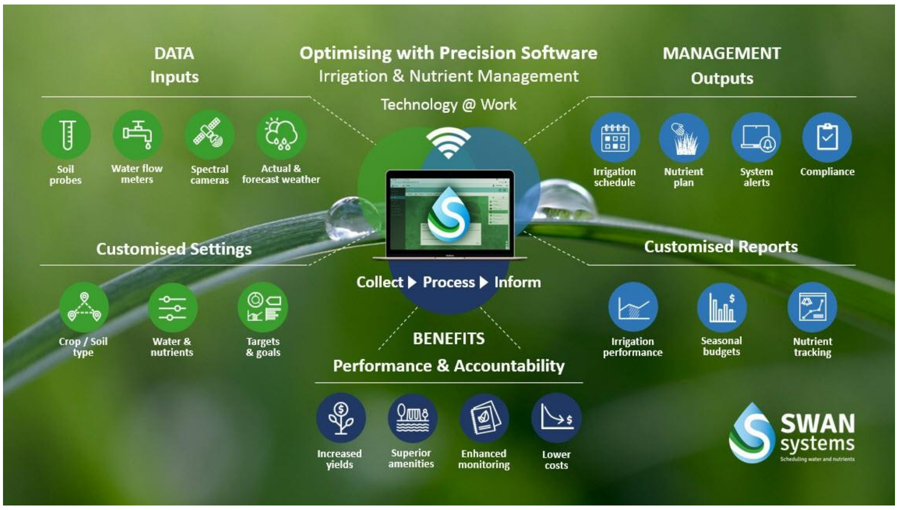
SWAN Systems uses a dashboard that provides a snapshot of the account, including information on site health, water usage summary, forecast soil moisture summary and a weather forecast.

Site navigation is via a left-hand menu, with shortcuts available via the dashboard. The mapping functionality is based on Google Maps.

Accessing data

The initial release of SWAN Systems is optimised to work on the Google Chrome desktop web browser. There is currently good functionality of the software on tablets that are 10" or greater. Future releases of SWAN Systems will include an app for mobile phones.

A popular feature of the dashboard – the weather forecast – is available via direct email subscription.



Strengths

- Web-based
- Hardware independent
- Acquires data automatically
- e.g. from flow meters, soil moisture probes, weather stations, etc.
- Scalable
- Customisable to a wide range of irrigated crops and conditions
- Incorporates both irrigation and nutrients, with NDVI used as a health-check tool

Weaknesses

- Web-based
- Currently not optimised to work on a range of web browsers
- Does not set your irrigation automatically
- Easier to use on larger/higher resolution screens.

References/ links
www.swansystems.com.au

https://twitter.com/swnsys

https://www.linkedin.com/company/swan-systems---scheduling-water-&-nutrients/

https://www.facebook.com/SWANSystems/

Wildeye Enterprise:

Wildeye Enterprise is a compact, rugged telemetry package that can be used with virtually any combination of farm sensors required. Wildeye Enterprise systems can either run from long life batteries with no solar panels, or small solar panels for near real-time data uploads.

The system uses existing mobile phone networks to send data to the cloud where it is accessed via powerful and configurable web-based software that services automated reporting, SMS/email alerts, smartphone access and online data visualisation and analysis.

Outpost Wildeye endpoint hardware, website analysis tools and smartphone installation tool.

Wildeye Enterprise works with:

- Virtually any make/model of soil moisture sensor; from relatively high-end profiling capacitance probes from manufacturers such as Enviropro, Aquacheck, Sentek etc, single point sensors frommanufacturers such as Decagon, Acclima etc, soil tensiometers, and low-cost sensors such as gypsum block and granular matrix (Watermark™) sensors.
- Weather stations and sensors, full evapotranspiration weather
- stations with derivation of reference evapotranspiration to individual weather sensors like tipping bucket rain gauges.
- On-farm sensors like tank water level sensors, irrigation pressure sensors, flow meters, flood irrigation wetting front detectors etc.
- Most existing/legacy sensors.

Cost of the technology

Typically ~$500–$850 and $5–$20 per month (excluding sensor(s)).
Volume discounts available.

Installation

Wildeye Enterprise telemetry platform is extremely simple to set up. Essentially just requiring sensors to be connected to the telemetry unit and for it to be activated via push-button. The telemetry hardware is entirely managed and configured via web portal, eliminating the need for onsite expertise and servicing. The hardware is rugged and compact, with extremely low power requirements, meaning it can be installed in ways that minimise the risk of damage/vandalism, and without requiring complex and costly site preparations and/or infrastructure (like mounting structures, hardware enclosures etc).

Scale

- Dependent on sensor type. Interfaces supported include:
- SDI12 (used by virtually all common capacitance soil moisture probes and many modern weather sensors)
- RS232/RS485 (used by some older soil moisture sensor systems and some weather sensors)
- 4-20mA and 0-5VDC (used by some soil moisture probes, water level sensors, soil tensiometers etc)
- Resistance (used by gypsum blocks and granular matrix sensors such as the Watermark™ sensor)
- Pulse (typically required for rain gauges and irrigation water meters)

Accuracy/precision

Dependant on sensor(s) used.

Measurement description

Dependant on sensor(s) used.

Lifespan

Hardware lifespan of 5–10 years. Discounted hardware upgrades are offered at any time regardless of hardware warranty status.

Data processing

Web-based graphing with powerful tools including fleet & group management, stacking of soil moisture, set-points for field capacity and stress points, calculation of Plant Available Water, determination of reference ETo (evapotranspiration) according to Penman-Montieth, automatic emailing of graphs, email and SMS alerts.

User interface

Web based; mobile device friendly.

Accessing data

Web based; mobile device friendly. API for secure third-party access and integration.

Strengths

- Simple to self-install and configure
- Free integration with many publicly accessible data sources (e.g. BoM weather station network)
- Can be operated with no solar panels in many applications with long battery life
- Rugged and compact makes installation simple.

Weaknesses

- Battery life can be reduced by poor mobile phone reception
- May require additional aerial for improved reception.

Accessibility

Purchased from Wildeye at www.mywildeye.com or via an Australia-wide network of Wildeye resellers.

References/ links

www.mywildeye.com