Smarter Irrigation for Profit PHASE II

Irrigation Tools and Technologies

Australian Government
Department of Agriculture, Fisheries and Forestry

Copyright

Citation

G. Roth, J. Hills, M. White and L. Gall

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. McAllister, G. Roth, J. Hornbuckle, A. Schultz, C. Lescun and C. Phelps.

The project is supported by funding from the Australian Government Department of Agriculture Fisheries and Forestry as part of its Rural Research and Development for Profit Program. The project, Smarter Irrigation for Profit phase 2, is a partnership between the irrigation industries of cotton, dairy, rice, grains and sugar, and was led by the Cotton Research and Development Corporation (CRDC) in conjunction with Dairy Australia, AgriFutures Australia, Sugar Research Australia, Grains Research and Development Corporation and research partners including; Deakin University, University of Southern Qld, CSIRO, NSW DPI, Tasmanian Institute of Agriculture, Agriculture Victoria, Gwydir Valley Irrigators Association, Sydney University, Melbourne University and other industry organisations.

Disclaimer

Index

Introduction

Background

Irrigated agriculture produces 30 percent of all agricultural production in Australia, and half the profit. Irrigators across Australia are constantly striving to improve the irrigation water use efficiency of their operations. Smarter Irrigation for Profit Phase 1 (SIP1) found irrigators could improve productivity by 10-30% through improved irrigation scheduling. The challenge is choosing the tools and technologies that suit individual farm needs, weather conditions, soils and crops.

This document is designed to provide farmers and extension providers a simple resource to assist the selection of the most appropriate irrigation tools and technologies for their needs.

Experience on the ground found that for irrigation tools and technologies to be adopted by industry, they need to be simple—simple to install, setup, use, interpret and respond to. There must also be service providers to quickly repair and maintain the tools and management systems that control water on farm.

This document provides a summary of a range of irrigation tools and technologies that monitor, manage, sense and automate water movement or irrigation events. The majority of commercial examples included were utilised by Smarter Irrigation for Profit participants.

This resource is an introductory guide to provide a starting point for those looking to improve or implement water monitoring and irrigation automation technologies 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 crop monitoring and 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 stage of plant growth, for example vegatative or flowering.
- the current rate of crop water use and crop stress.
- 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.

Water advancing in a surface irrigation field

Introduction

Irrigation Tools and Technologies

Irrigation tools and technologies seek to assist farmers to make informed decisions using the current water content of the soil, the rate of crop water use, water movement in field and weather conditions.

This document provides a summary of irrigation scheduling tools grouped on the basis of:

1. Soil water content
2. Weather-based crop water use
3. Water monitoring and plant stress
4. Automation and sensing technologies.

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.

There are a growing number of software platforms that can connect to a range of different sensors and deliver data to web-connected devices for growers and advisors. Some of these provide the ability for automation of irrigation, others integrate information that can be used to make irrigation scheduling decisions.

Example of automated Padman autowinch fitted to an inlet in field

Irrigation tools and technologies

Soil moisture sensors

Soil moisture probe placement

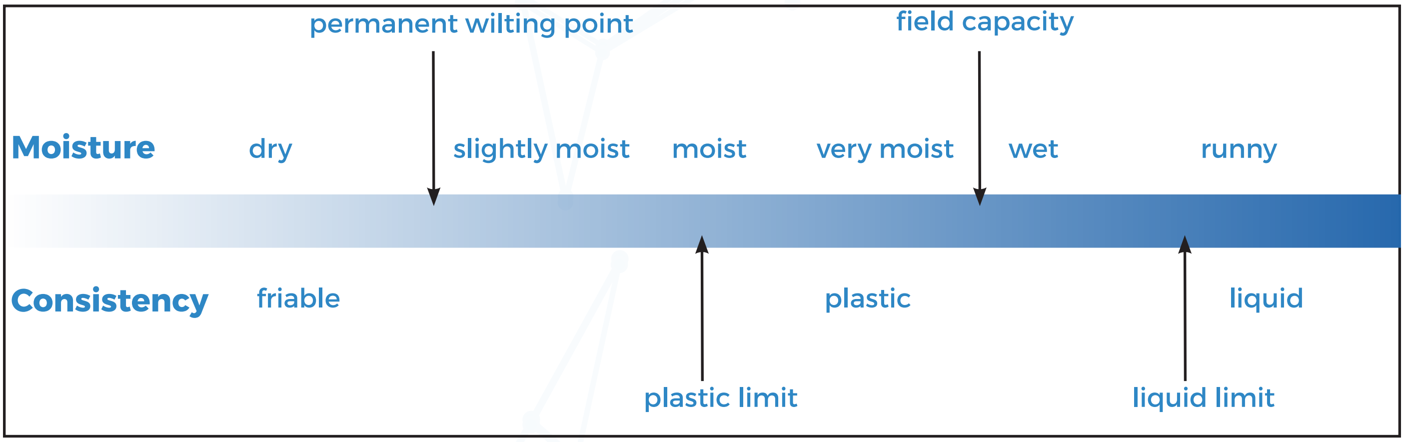
Soil variability should be assessed prior to site selection from grower knowledge, soil maps or EM surveys. There should be enough soil moisture sites to get representative data for your field.

The position of any soil moisture sensor should

- ensure plants are not damaged and soil is not compacted during installation,
- be representative of the predominate soil type under irrigation.
- avoid areas that are wetter or dryer than normal or where there is poor infiltration.
- the more depths that soil moisture content can be monitored the better.
- if only one depth can be monitored, then the depth of the sensor will be determined by the active root zone of the crop being grown, for example 30cm for wheat.
- be at two or more different depths, for example 30 and 60cm, to improve understanding of soil moisture content,
- placing five or six sensors evenly at depths down the profile will provide still more useful information.
- be far enough into the field to avoid edge effects
- be located to avoid damage from field operations (in some situations may need to be removed to enable paddock activities to occur).
- protected from livestock
- have easy access

Installing soil moisture probes, it is very important not to damage plants near the sensors

Figure 1: Soil moisture and consistency
Source: NSW Ag, SOILpak™



Push Probe or Dig Stick

A Push Probe or Dig Stick is a simple way to determine the depth of wet soil. It is in essence a metal rod that can be pushed into the soil.

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

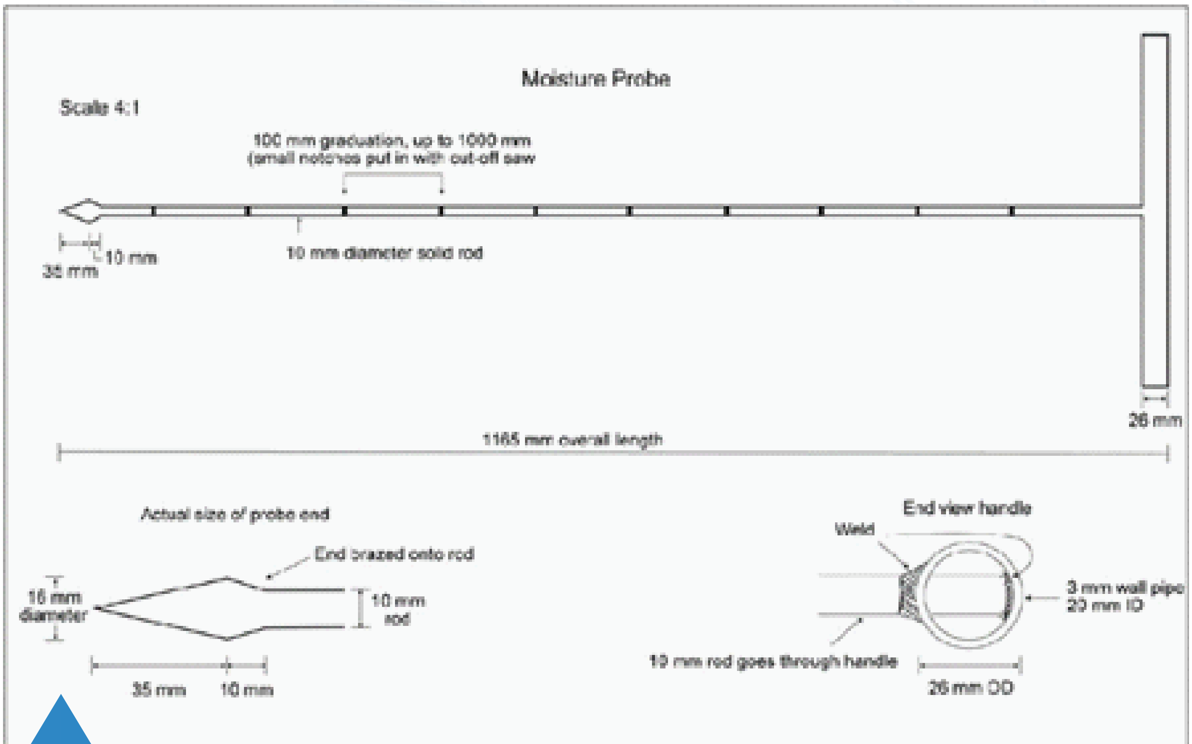
Push the probe into the soil and assess the depth of the soil's resistance. Record the position in the field and the depth of resistance to provide data on soil moisture in the profile. Measure the penetrated depth by reading the marks on the probe. Repeat this procedure systematically across the paddock, to give a good idea of water penetration across the area. In an irrigation setting, a probe can be useful to measure sideways spread into the beds. With experience, soil water availability 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 soil variability, the position and density of roots and the distribution pattern of the irrigation system.

References

- Making a soil moisture probe (nsw.gov.au)

Strengths	Weaknesses
• Low cost • Robust • Fast, physical measurement.	• Manual measure and data recording • 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



Specifications for a Push Moisture Probe.
Source DPINSW

Determining Soil Moisture by Feel

With experience it is possible to determine soil moisture content of different soils by feel.

Start by moulding freshly collected soil from the various sampling depths into a ball in your hand to estimate how close the soil water content is to the plastic limit. With loams, clay loams and clays it may be possible to roll the soil into rods with a diameter of 2-3 mm. Roll it out on a flat surface using a firm pressure, and try to shape it into a rod.

The soil's water content is classified as either dry, or at the plastic limit (PL), or wet. It gives only a rough guide to soil consistency and suitability for tillage.

Table 1: Guide to determining soil moisture by feel.
Source: NSW Ag, SOILpak™

Moisture level	Sands and Sandy Loam	Loams, Clay Loam and Clays
Above field capacity	On squeezing free water oozes from ball of soil.	Soil very wet and sloppy. When squeezed it oozes water.
Field capacity 100% available water	No free water appears on the soil when the ball is squeezed, but a wet outline of the ball is left on hand.	Soil sticky. No free water appears on soil when ball is squeezed, but wet outline of ball left on hand. 2-3mm thick rods can be rolled 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 2mm thick rods.
50% available water	Appears dryish. Forms a ball under pressure, but it seldom holds together.	Soil coherent. Forms a ball under pressure. Will just ribbon when pressed between fingers 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.
Permient wilting point	Soil is dry, loose and flows through fingers.	Crumbly, powdery, small lumps break into powder. Will not ball under pressure.

Determining Gravimetric Water Content

Gravimetric soil water content is the mass of water in the soil, measured as the difference between the moist soil and the soil dried at 105˚C, known as the oven-dry weight, expressed per unit mass of oven-dried soil.

To determin the Gravimetric Water Content of soil. Take a moist soil sample, weigh it, and oven drying it at 105˚C for 24-48 hours. Once dry reweigh the sample and calculate the mass of water lost as a percentage of the mass of the dried soil.

Calculating Gravimetric Water Content

$$\text{Volume Soil Water \%} = \frac{\text{weight of wet soil (g) - weight of dry soil (g)}}{\text{weight of dry soil (g)}} \times 100$$

When reporting the results, specify the conditions used to determine the Volume of Soil Water percentage, For example, dried at 105˚C for 48 hours.

Soil water potential sensors

Soil water potential indicates how difficult it is for a plant to remove water from the soil. It is a measure of the soil suction and closely relates to actual plant stress.

Tensiometer

A tensiometer measures the tension or suction needed for plant roots 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 (buried in the soil) at the bottom and a vacuum gauge at the top. 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 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 but do not operate properly in dry soils.

Installation

Tensiometers require careful installation, regular maintenance, and experience for interpretation. Install into moist soil. At installation, the tube must be full of water as air affects accuracy. Completely saturate the tip by emersing in water for at least 24 hours. Use a hand vacuum pump to pump the tensiometer gauge up to approximately 70 kPa and tap it to release any air bubbles.

The bottom 10 centimetres of the installation hole should be made with a coring tool so the tip of the tensiometer fits snugly in the hole.

To avoid false readings, ensure all parts of the ceramic tip are in contact with the soil at installation. Do not force or twist the tensiometer into position as the ceramic tip can be damaged.

Maintenance

If air fills the tube, add water. 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 vacuum pump by applying and holding the suction at 70–80 kPa for 15 to 20 seconds while tapping the side of the tensiometer. Water with a minute amount of bleach should be used, boil the water to remove air, then cool in a hot water bottle. An algacide (or 50 millilitres methylated spirits per litre of water) should be added to prevent algal growth in the tensiometers.

During winter, cover or remove gauges from tensiometers to reduce the likelihood of the water freezing and damaging the tensiometer.

Irrometer Soil Tensiometer MLT-RSU-V
irrometer.com

Table 2 Guiding ranges of soil tension and interpretation

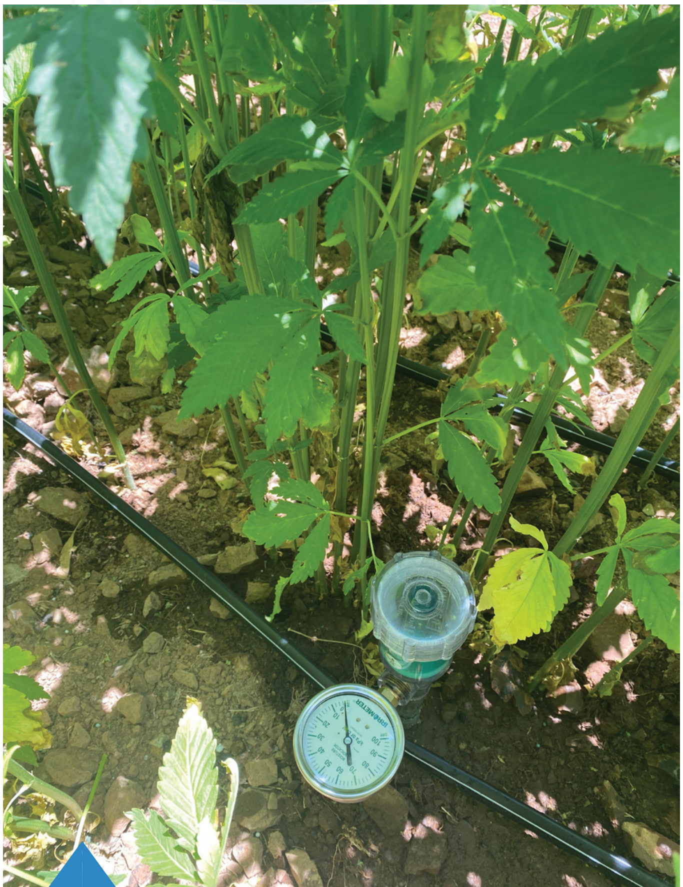
Reading (cbar or kPa)	Interpretation
0 to -10	Soil is very wet and is at field capacity. Conditions may be waterlogged
-10 to -25	Optimal conditions for plant growth with good levels of plant available water
-25 to -40	Dependent on crop type conditions may be suitable but tending towards dry and with 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 deficit irrigation style practices are being exercised

Strengths	Weaknesses
• Don't need Calibration • Measure water tension which is relevant to plant stress • Not affected by salinity	• Manual reading and recording • Need to be installed correctly • May need to be refilled with water during the season • Less accurate in dry soils

Monitoring and interpreting results

Tensiometers measure point locations, reflecting the water content in surrounding soil.

Tensiometers can be manual or digital. Gauge readings show the relative suction (and thus wetness) of the soil. A high reading means dry soil which has a high suction. Tensiometer gauges have a scale reading from 0 to 100 kilopascals (kPa). A tensiometer can operate effectively within a range of 0 to 80 kPa.



Example of tensiometer installed in field of industrial hemp

Sandy soils are irrigated at lower suction because soil water suction increases rapidly due to of their low water-holding capacity.

Cost of the technology

Approximately $250 for a tensiometer plus a cover to protect it (approx. $50)

Readings from a tensiometer at bottom of active root zone (30 cm in wheat) can be used to indicate when irrigation is necessary.

clay and clay loam soils (krasnozems)	irrigate at 50 kPa
fine sand textured and sandy duplex soils	irrigate at 30-40 kPa
coarse sand textured soils (Panshanger sand)	irrigate at 20-30 kPa

References

• https://www.ictinternational.com/casestudies/soil-water-potential-explained/
• https://dpipwe.tas.gov.au/agriculture/land-management-and-soils/soil-management/irrigation/tensiometers

Solid state sensors

Solid state sensors are the most inexpensive soil moisture measurement option, Common types are gypsum blocks and granular matrix sensors. They use two electrodes to measure the electrical resistance in the soil.

More water in the soil will reduce electrical resistance because the electrical current can pass through the water easier; less water will increase the resistance.

After the electrical resistance is measured the water tension is calculated to determine the plant-available soil moisture.

In gypsum blocks the electrodes are embedded in a porous block of gypsum that has to maintain contact with soil.

Granular matrix sensors have a granular matrix inside a metal case. The electrical sensors are embedded in the granular matrix above a gypsum wafer.

Chameleon sensor
Image from CSIRO

Strengths	Weaknesses
• Inexpensive, costing about $35–60 per sensor unit. • Do not require calibration	• Needs correct installation • Gypsum disintegrates. • Slower measure • Less accurate in sandy and high salinity soils • Not useful in cracking clays


Example of Granular Matrix sensor (top) and Gypsum Block (bottom)

Examples

The three most common commercial examples of solid state sensors are the:

1. G Dot
2. Chameleon and
3. Watermark Matrix sensors.

G-Dots and Chameleon sensors

The G-Dot and Chameleon sensors are commercial products that use a granular matrix sensor.

Electrodes embedded into gypsum blocks measure the electrical resistance between them under the presence of moisture. Electrical signals are related to soil moisture tension, or how hard it is for the plant to extract water.

Lifespan

Soil type, irrigation frequency and rainfall influence lifespan, expect 2 and 5 years.

Installation

Auger a hole, bury sensor in the active root zone of the crop, position the display on a post.

Monitoring and interpreting results

The G-Dot is designed to be read visually on site. The display shows a number of yellow dots relative to soil water tension.

When all the yellow flip dots are showing the soil is wet. As the yellow dots disappear, plants are working harder to get water from the soil.

Irrigation timing can be fine-tuned to soil, season, and crop stage.

G-Dot sensor
Image from Instrament choice.com.au

The Chameleon has three colours,

- Blue means the soil is wet (0 to 20 kPa),
- Green means the soil is moist (20 to 50 kPa) and
- Red means the soil is dry (greater than 50 kPa)

The Chameleon can be read by either:

1. The Chameleon Card: Reads a single sensor and displays the moisture values in colours.
2. The Chameleon Wi-Fi Reader: Reads an array of three sensors, displaying moisture values in colours. It stores the data for upload to farm website when WiFi Internet is available.

Measurement description

The point location measure of soil moisture tension reflects the water content in the surrounding volume of soil, represented by fluorescent yellow flip dots (G-Dot) or blue, green or red indicators (Chameleon).

Accessibility and Cost

Approximately $315 each, no ongoing cost

G-Dots can be purchased at www.Gdot.com.au

Chameleon can be purchased https://shop.via.farm/index.php/product-category/chameleon-card-system/

Strengths	Weaknesses
• Relatively easy to install and do not require installation by a third party • No need for calibration • Accuracy +/- 10 to 20%.	• Need good soil contact. • limitations in terms of display units and ability to store data. • not recommended in light sands and heavy or cracking clays

References

- https://www.gdot.com.au/
- https://via.farm/chameleon-soil-water-sensor/ CSIRO
- https://www.farmstyle.com.au/news/gdot-soil-moisture-display

Watermark granular matrix sensor

The Watermark Soil Moisture Sensor estimates soil water tension (kPa) through electrical resistance. It contains a wafer of gypsum embedded in a granular matrix to minimize salinity effects.

Installation

Use an appropriately sized hand auger. Blocks must have a good seal with the soil. Sensors are generally installed dry (i.e. without slurries) into a snug auger hole by hand through a slit trench to the augured hole at 45 degrees angle at the selected depth.

The sensor can be installed at a range of depths, depending on the rooting depth of the crop. Sensor should be placed in the lower portion of the active root-zone. Additional sensors can be located further down the soil profile. Deeper sensors provide information on drainage potential and help refine the depth of irrigation applied over time.

Ensure cable ends, logger and telemetry unit is protected from livestock and equipment.

Measurement description

Point location for each sensor reflects the water content in the surrounding volume of soil.

Lifespan

Lifespan depends on soil type. In optimal conditions expect 5 to 7 years. In high pH soils, life expectancy may be only 1 to 2 years.

Watermark sensor and the handheld reader option.

Monitoring and interpreting results

Non-telemetric data collected on site is available on a hand logger (see image),

Data can be downloaded and processed on a computer. Typically a digital display will provide the soil tension results (generally in kPa). It may be necessary to connect to each sensor separately.

Telemetered data is available near real-time, either graphically or in tabular numerical form when a cellular enabled monitor is installed. Data is accessible on smartphones, tablets or equivalent internet accessible devices.

The soil water Retention curves use a soil water content/trension relationship to interpret soil water tension. The tension values provide an indicator, and the soil water depths provide the ability to be precise about the volume applied.

Strengths	Weaknesses
• Relatively easy to install and do not require installation by a third party	• Need good soil contact.
• No need for calibration	• limitations in terms of display units and ability to store data.
• Accuracy +/- 10 to 20%.	• not recommended in light sands and heavy or cracking clays
• Can be connected to 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 many commercial equipment retailers.

References

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

Soil Water Content Sensors

Volumetric sensors

Volumetric soil moisture sensors directly measure the amount of water in the soil. This category includes:

- neutron moisture probes,
- heat dissipation sensors, and
- di-electric sensors. The di-electric sensors measure the di-electric constant of the soil, an electrical property dependent on soil moisture content, and can be purchased in 3 variations:
  - Time Domain Refractometry (TDR) sensors,
  - Time Domain Transmissiometry (TDT) sensors, and
  - Capacitance or Frequency Domain Refractometry (FDR) sensors.

Example of a volumetric water content sensor

Example of the sensors inside a capacitance probe access tube. (image Sentek)

Neutron Probe

A neutron probe or neutron moisture meter is a reliable and robust way to measure the soil moisture and schedule irrigations. The probe consists of a neutron source and detector that is connected to a cable. The neutron probe is placed over an infield access tube and the sensor is manually lowered down the tube, a reading is taken at specified depths (Usually 20, 30, 40, 60, 80, 100 and 120 cm).

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

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.

Strengths	Weaknesses
• Reliable and accurate	• In Australia a radiation licence from the EPA is required to own, operate and store a neutron probe
• Measures a larger area reducing the impact of air gaps or soil cracks.	• Require Calibration (usually done for farmers and advisors).
• Not affected by salinity or air gaps	• Expensive
• Measures a range of depths	• Manual system requiring access to sites
	• Bulky to move around irrigated fields

User interface and Data processing

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

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.

References

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

Neutron Probe Smart 503.
Image source: ICT International

Capacitance probes

Capacitance probes are a volumetric sensor, which use a measurement of the di-electric constant of the soil. It uses a pair of cylindrical electrode plates (image page 13), The electric field between the two electrodes is affected by the mixture of soil, water and air surrounding them. This mixture acts as a di-electric medium and the charge time of this capacitor is a direct linear measure of the dielectric constant. The di-electric constant of air is 1, for soil it is 3 to 4, and for water it is around 80, any minor change in volumetric water content of the soil surrounding the probe has a large effect on the di-electric constant. The di-electric constant of this soil can then be converted into the volumetric soil water content using a general calibration.

Installation

Some capacitance probe systems require specific tools to complete the recommended installation method, which must be followed accurately to ensure good quality data. Some agronomic dealerships offer installation and removal services,

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

Multi-probe configurations can be cabled to a central logging unit so are vulnerable to damage by farm machinery and animals. Telemetry or mobile data networks need antennas above the crop canopy further affecting operation of machinery. Clear marking of the installation, notifications to contractors and fencing from livestock is recommended.

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 sufficient accuracy for most grower situations. Site specific calibration might be required if a tightly controlled deficit irrigation process is to be practiced.

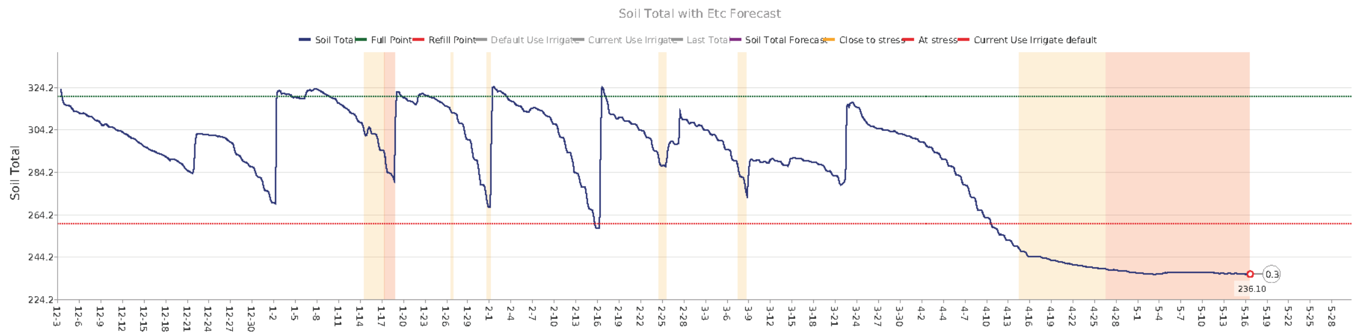
User Interface and Data processing

Most systems have options to automatically transfer data via radio or mobile data networks either to a 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 or via Apps.

Data from capacitance probes can be integrated into irrigation equipment management software systems, to allow automation.

Availability and competence of after market support is very important if capacitance probe systems are intended for use with intensive irrigation scheduling. These systems are complex electronic systems, requiring sensitive handling, and only sufficiently trained staff, should interact with them.

The relatively high labour intensity of the installation process makes these systems less popular for short term installation and use.



Capacitance soil moisture probe data plot

Cost of the technology

Initial investment can be high, at around $3,000 for a single monitoring site. Cost is influenced by the number of sensors per probe. A 120cm probe is approximately $2,100, 80cm probes will be cheaper. A telemetry unit will cost approximately $2,000 plus monthly hosting charges of approximately $20/month. This can be connected to several probes and to other digital technologies. Batteries, even when charged via solar panels, need replacing every 2 to 3 years. Leasing options are available.

Lifespan

Lifespan is influenced by lightning, cable damage and by moisture damage to the electronic circuitry of the probe. Many probes are fully sealed and therefore, fully submersible.

References

- 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

Strengths	Weaknesses
• 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. • Once properly installed, Capacitance probes require little maintenance • There are many commercial suppliers • Many can measure soil temperature.	• All electronic systems installed in the field are sensitive to lightning. • High initial costs, limit the number of multi-sensor probe per field, Often resulting in a single point measurement. • 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.

Capacitance Soil moisture probe with telemetry and data logger

Frequency Domain Refractometry (FDR) sensors

The di-electric constant or capacitance of the soil can be measured from the change in frequency of a reflected radio wave or resonance frequency.

This method of measurement uses an oscillator to propagate an electromagnetic signal through a metal tine or other wave guide. The difference between the output wave and the return wave frequency is measured to determine soil moisture. These sensors are often referred to as frequency domain reflectometers (FDR).

The FDR probes usually consist of two or more electrodes (e.g. plates, rods, or metal rings around a cylinder) that are inserted into the soil.

With ring configurations, the probe is placed in an access tube installed in the field allowing multiple sensors to measure soil moisture at different depths.

The sensors can be connected to data loggers giving continuous soil moisture content readings.

FDR probes tend to have a larger sensitivity to temperature, bulk density and clay content. Soil-specific calibration is necessary.

FDR probes can be used in soils with high salinity. They offer better resolution and faster response time compared to Time Domain Reflectometer (TDR) probes.

These sensors are very versatile and are suitable for almost every kind of crop. In addition, there are a lot of device options; prices, designs, configurations and facilities,

Frequency Domain Refractometry soil sensor
Soilsensor.com

Measurement description

The volume of measurement is dependent on sensor size, Most sensors are 5cm to 10cm in length.

Installation

Reliable measurements require good contact between the sensor (or access tube) and soil, careful installation is necessary to avoid air gaps.

Reference

- Frequency Domain Reflectometry (FDR) / Capacitance (Frequency) | SoilSensor.com
- https://www.fertinnowa.com/technologies/using-fdr-frequency-domain-reflectometry-enviroscan-sensors-precise-soil-measuring-humidity-salinity-improve-irrigation-adjustments-soil-bound-crops/

Single point sensor
https://www.mywildeye.com/soil-moisture-monitoring/

Wildeye Express:

Wildeye Express is an example of a commercial FDR sensor and telemetry package available with 1, 2 or 3 individual sensors per device for multiple depths measurement. Web-based software provides visual indicators of key features such as field capacity and refill point.

Cost of the technology

Cost will vary depending on numer of sensors, depth and data package. Sensor and telemetry packages are available from $700 and $30/month.

Accessibility

Purchased online via the wildeye website (www.mywildeye.com).

Strengths	Weaknesses
• Simple to self install, configure and relocate • No solar panels, long battery life • Good sample volume per sensor • Unlimited battery/ technology warranty (for active subscriptions) • Low cost • Compact form	• Cable length limitations • Sensors may need to be relocated in new crops and removed for machinery activities • Daily data updates to the web (time of day for updates can be user-configured) • Battery life reduced if phone coverage is poor.

Accuracy/precision

The sensor is capable of measuring soil water contents between 0–57%.

User Interface and Data processing

Wildeye Express is designed for web based data hosting and processing. Accessing Data – compatibility with phone, PC, Web based, mobile device friendly.

References

- www.mywildeye.com

Environode IoT:

Environode has a commercial example of a FDR sensor and telemetry package including an ultra-low power Water Content, Electrical Conductivity and Temperature (W.E.T.) beacon with integrated solar recharging. It can be standalone or included in a wireless network for real-time data reporting of levels and device details.

Example of EnviroNode sensor and beacon with solar panel

ECH20/Decagon soil probes

ECH20 soil moisture probes include a range of devices which use 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 depth, so monitoring the root zone requires two or more probes at the appropriate depths.

ECH20 EC-5 sensor
https://www.metergroup.com/en/meter-environment/products/ech20-ec-5-soil-moisture-sensor

ECH20 probes come in a range of models for different applications. Examples include 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
  - The ECH20 5TM probe measures soil water content and soil temperature,
  - The GS3 adds the ability to measure electrical conductivity.

Installation

The best way to install the ECH20 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. This means that a single logger could connect to many probes in multiple nearby locations.

Measurement Volume

The ECH20 range have a greater sample volume than most capacitance soil water sensors. The stated volume of influence of these probes is 160mL (GS3), 715mL (5TM) and 690mL (GS1). The ECH20 10HS sensor, a larger variant of the 5TM model, has a sample volume of 1320mL.

Accuracy/precision

ECH20 probes are a capacitance type probe, measuring the di-electric permittivity of the surrounding soil, which is directly correlated to the volumetric soil water content. 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 capable 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.

Each sensor samples the water content at a single depth. Three sensors would be needed to capture good data for root zones for example at 30, 60 and 80cm..

Example of Decagon datalogger

Strengths	Weaknesses
• Accurate measure of volumetric soil water content • Low power consumption • Range of different options to measure water content, temperature and electrical conductivity.	• Requires excavation of an access hole • Requires installation of multiple individual sensors, each with its own set of wires, at each depth.

Cost of the technology

The costs vary across the ECH20 range, from the analogue voltage GS1 sensor which retails at around $250, to the ECH20 5TM for around $380, up to the fully featured ECH20 GS3 for about $520.

Sensors can be connected to third party logger solutions that are 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.

Lifespan

Providing they are protected from direct sunlight; these probes have an expected life of 5 to 7 years.

Accessibility

Originally known as Decagon probes they are now marketed under the name METER. ECH20 probes can be purchased through ICT International, the official Australian METER distributer. ICT International offer installation and provide telephone support as required.

References

- https://www.metergroup.com/environment/teros-ech20-sensors/
- https://www.ictinternational.com/products/soils/moisture-sensors/
- https://www.ffi.nz/product/em50b-analog-data-logger/
- Purchased online via https://environode.com.au/store/product/water-content-ec-temp-beacon/
- https://edaphic.com.au/products/soils/teros-12-moisture-temperature-ec-sensor/

Decagon TEROS-12 soil probe and ZL6 data logger in field
Image: https://edaphic.com.au

Time Domain Refractometry (TDR) sensors

TDR (Time Domain Reflectometer) sensors consists of three 150 mm long parallel metal rods that are each 3.2 mm in diameter protruding from a small sensor head. This fully submersible electronics head measures the di-electric 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.

Installation

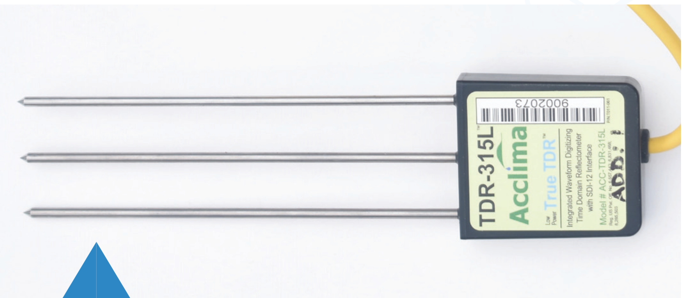
The three metal rods can be pushed horizontally into an undisturbed soil profile at the desired measurement depth from a vertical access hole. There is no access tube used, and the vertical access hole is then back-filled to the original soil density, with the cables running to the surface.

Acclima TDR sensors can be pushed into a 60 mm diameter hole that has been augured into the soil to the required measurement depth and then back filled.

Spot measures of soil water content can be taken around any field when a TDR sensor is fixed on a handle, by digging a hole to the required measurement depth, and pressing the sensor rods into undisturbed soil.

Accuracy/precision

The TDR technology can accurately assess the soil water content across a wide range of soils using a proven calibration equation The speed or velocity of the voltage pulse along the rod is related to the apparent permittivity of the substrate. In relatively wet soil the velocity of the pulse is slower than in drier soil.



Acclima- tDR315L sensor

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 and Accessing data

Acclima DataSnap loggers 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 be swapped-out with another logger for connection to desktop computer running the SnapView software later.

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.

Strengths	Weaknesses
• Large soil volume measured, provides accurate soil water content. • Does not require a vertical access tube. • Low power requirements when set to operate at 15 min intervals or longer. • Bent sensing rods do not affect soil water content measures. • Measures di-electric permittivity, soil temperature, and electrical conductivity.	• Rocky and gravelly soil impedes rod insertion. • With Multiple sensors installed horizontally into undisturbed soil from a large augered 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.

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.

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. The datalogger is connected with a USB cable to a computer installed with the Acclima free Windows software, which allows 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 $1000 including small solar panel, regulator and battery.

Reference

- Time Domain Reflectometry (TDR) | SoilSensor.com
- 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 soil moisture sensor has research grade accuracy. 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 (Delta-T Devices) but is manufactured in Australia and is waterproof.

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. Horizontal installation is only recommended if the sensors will not be removed. Vertical installation provides more flexibility in removing the probes. Probe extensions required depths can be purchased or built using 40mm PVC pipe extending the length of the probes. It is possible to use an access tube that is installed before the sensor with extension to enable easier and safer sensor removable.

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

ML3-ThetaProbe-soil-moisture-and-temperature-sensor
www.enviropro.co.uk

Measurement Volume

The sensors measure the soil within the stainless steel needles, a volume of approximately 75 cm^3. They are single point sensors, multiple sensors are required for multiple depths.

Lifespan

The sensors can be buried for up to 20 years.

User interface and data processing

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.

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%. Site-specific calibration of the sensor will improve the accuracy to ±1%. Calibration is recommended if the quantitative soil moisture measurement will be used. 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

Strengths	Weaknesses
• highly accurate and reliable soil water content sensor for a range of crops	• needs to be buried the in soil (adding an extension to the sensor makes the easier to remove) • needs a costly logger ($2000 is the typical cost for any standard Internet-enabled logger.)

MP406 Moisture Sensor
ICT international

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.

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.

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.

Accessibility

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

References

• https://www.ictinternational.com/products/mp406/mp406-moisture-sensor/?from=/products/soils/moisture-sensors/
• https://www.enviropro.co.uk/entry/48617/DeltaT-Devices/ML3-ThetaProbe-soil-moisture-and-temperature-sensor/

Plant based monitoring

Canopy Temperature

Plant-based irrigation scheduling can help improve irrigation decision making as plants integrate the effect of both water availability and evaporative demand.

Not all water stored in soil is available to plants as soil constraints such as compaction alter the soil-plant-water dynamics. Monitoring plants directly helps understand crop's response to water availability, or lack thereof. When water stressed, plants close stomata to conserve water, this results in reduced evaporative cooling and an increase in canopy temperature. Due to its strong relationship with stomatal conductance, canopy temperature is considered a good plant-based indicator of water stress (Figure 1).

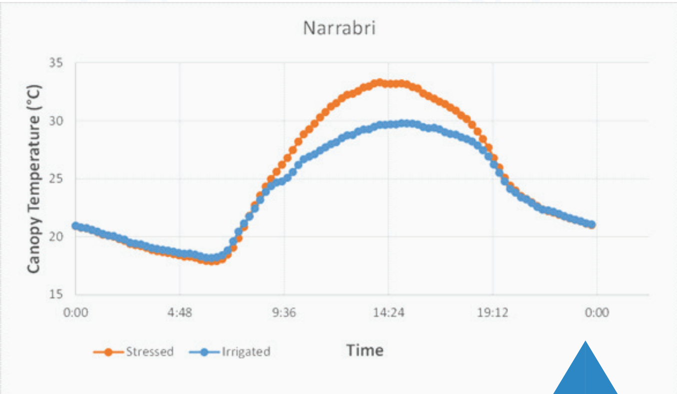


Figure 1: Diurnal pattern of canopy temperature in a well-watered (blue) and a water-stressed (orange) cotton crop CSIRO

CSIRO has developed an irrigation scheduling tool based on continuous monitoring of canopy temperature in fully irrigated cotton systems. The non-contact sensors monitor the temperature of upper canopy using infrared technology. The continuous measurements allow growers to apply an irrigation before the crop has reached the point of water stress.

Plants grow optimally within a narrow range of canopy temperatures known as thermal kinetic window which is species specific. Cotton grows optimally at a canopy temperature of 28˚C. The time a crop spends with its canopy temperature above this biological threshold is referred to as the stress time.

Accumulative stress time since the last irrigation or within a specified number of previous days (five days for cotton) helps the understanding of a crop's water stress level, and identifies when an irrigation can avoid heat-related damage. This method accounts for solar radiation and relative humidity which can affect the relationship between canopy temperature and plant water stress.

Plant-based sensing tools can complement existing tools such as soil water sensors.

Installation

Sensors are usually positioned 20 cm above the plant canopy at 45 degrees angle to horizontal using a telescopic 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 will result in false signal of plant stress as soil temperature is generally higher than plants in daylight hours.

Canopy Temperature sensor in field

Accuracy/precision

Infrared canopy temperature sensors are accurate to 0.5˚C. Sensors are not expected to lose accuracy within a crop season, however accuracy of sensors should be tested between seasons. To test accuracy point sensor to an object of known temperature. Sensores should be purchased from suppliers who will test sensor accuracy as required.

Accessibility and User Interface

GoannaAg has integrated the CSIRO irrigation scheduling algorithms into their GoApp platform. This product is commercially available to cotton growers on desktop and as mobile app and provides soil water and crop stress data in real-time.

Cost of the technology

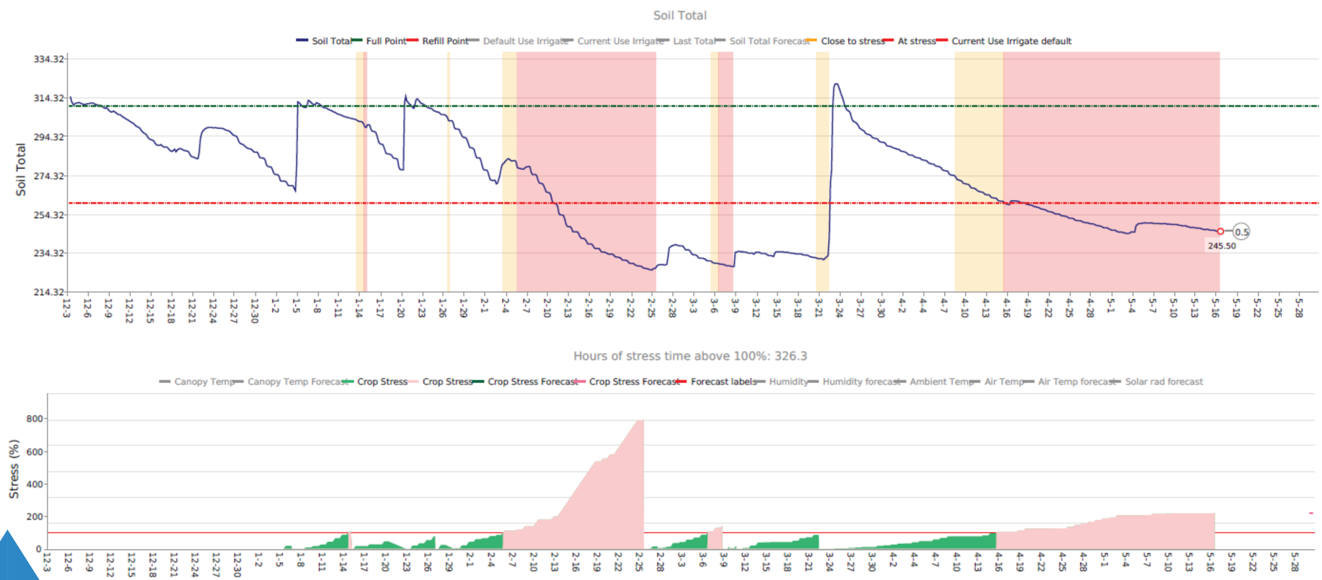
The GoannaAg GoField Plus is approximately $2,000 per unit including capacitance probe, canopy temperature sensor, and access to interpreted data on a continuous scale. Integrated local weather data to inform historic, current and forecast conditions is available. The data can be transmitted to a web-based portal or downloaded in field. Sensors can be incorporated into existing telemetry systems.

Strengths	Weaknesses
• A crop's canopy temperature is a strong indicator of access to soil water. • Continuous monitoring of plant water status enables irrigation before stress impacts yield. • Weather proof and easy to install and maintain in field.	• Need to adjust height of sensor during the season. • Can be sensitive to soil background • Cloudy or windy weather can effect data

Alternative canopy temperature sensors are available. The cost of the basic canopy sensor itself is low, however, the full cost will depend on the quality, data access and interpretation provided by telemetry companies. It is not recommended to purchase sensors from overseas because of potential issues with access to data.

References

- https://www.goannaag.com.au/gofieldnew
- https://publications.csiro.au/rpr/pub?pid=csiro:EP176242&expert=false&sb=RECENT&%20hizbullah&q=



GoField Plus data plot showing soil moisture and plant stress

Weather based tools and technologies

Bureau of Meteorology tools

Evapotranspiration

The Penman–Monteith equation approximates net evapotranspiration (ET) from meteorological data, as a replacement for direct measurement of evapotranspiration. The resulting estimate is reference evapotranspiration (ETo).

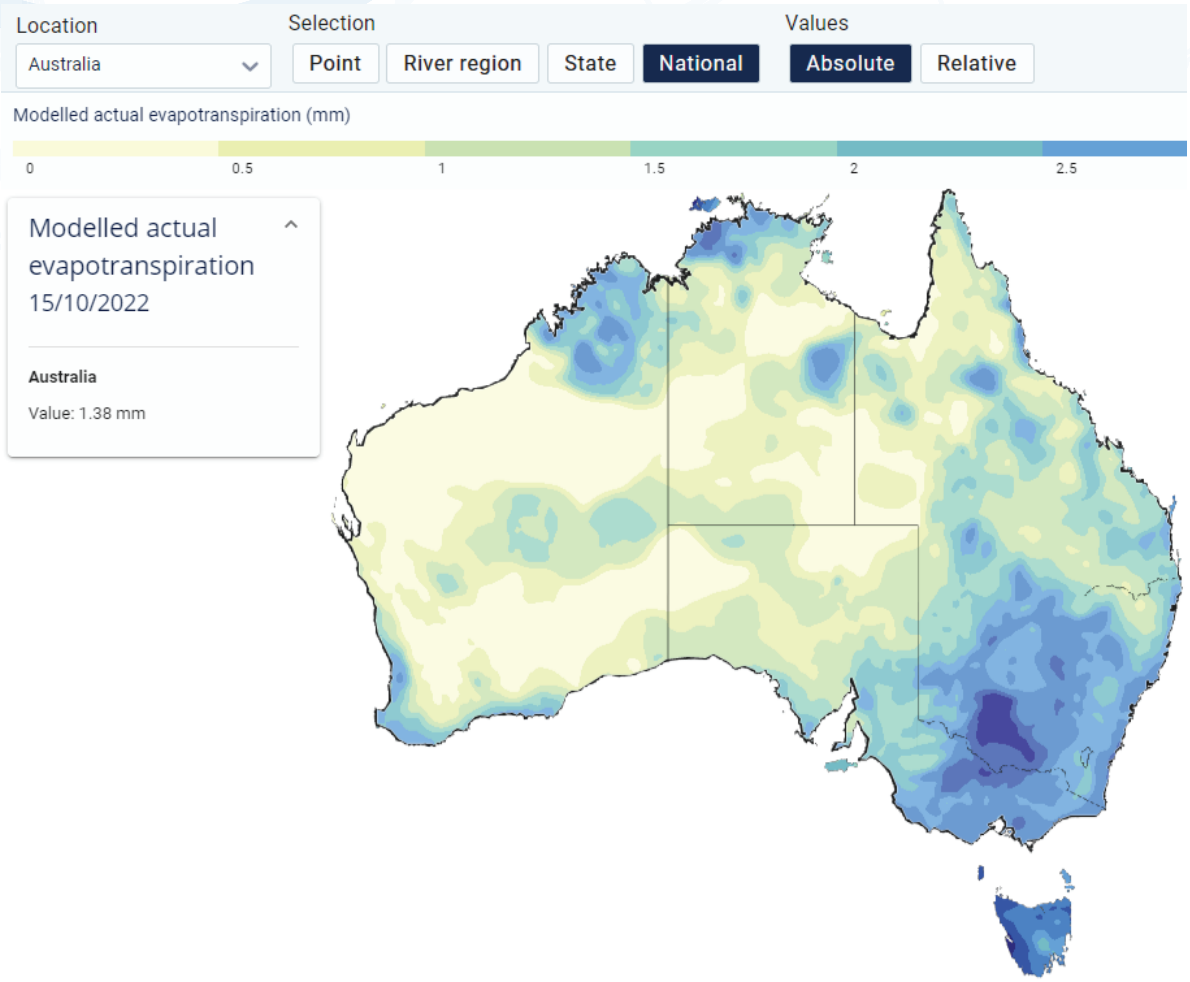
Accuracy

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.

The Australian Water Outlook (awo.bom.gov.au) site provides detailed information on rainfall, soil moisture, runoff, evaporation and evapotrasnpiration. Data includes historical, forcast and projected information across Australia.

ETo is not "point specific." ETo provides a measure that applies across a whole paddock and in most cases across a small district.



Modelled Actual evapotranspiration from Australian Water Outlook
www.awo.bom.gov.au

Forecast ETo information allows you to better anticipate future plant water requirements and more accurately plan and schedule future irrigation events, however ETo should not be used in isolation to inform irrigation scheduling decisions.

Recent Evapotranspiration

Point based estimates of daily, standardized reference, evapotranspiration back to 2009 are freely available from www.bom.gov.au/watl/eto/

The Australian Water Balance site provides evaportranspiration details for point locations, river regions, states or nationally. The data can be sourced as area potential, modelled potential, modelled actual and for either a short or tall crop free of charge.

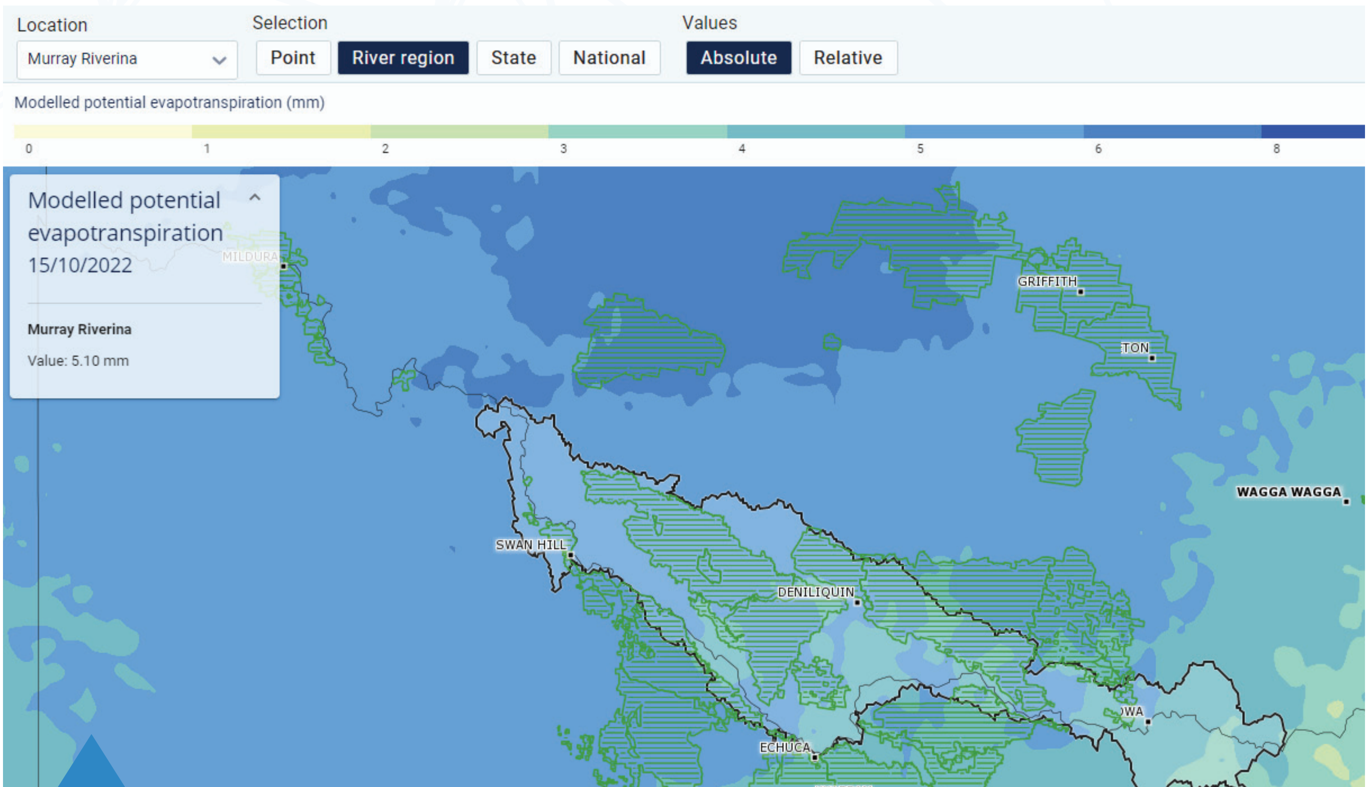
Gridded evapotranspiration

Gridded estimates of daily, modelled actual and potential evapotranspiration at 5km resolution, back to 2005 are available at Australian Landscape Water Balance (bom.gov.au). All of the modelled actual and potential evapotranspiration data is available for no charge. Registered users can access over 100 years of data, as well as tailored products.

Both gridded and point based, daily, standardised, reference evapotranspiration forecasts are available for the next 6 to 7 days from Bureau forecasts. The resolution of the gridded product is between 3 and 6km. These forecasts are available for a price of approximately $7000 pa.

References

- awo.bom.gov.au
- Forecast evapotranspiration products, or point-based historical evapotranspiration estimates, contact Agriculture@bom.gov.au
- FAO Penman-Monteith equation https://www.fao.org/3/X0490E/x0490e06.htm
- Gridded_Evapotranspiration_User_Guide (bom.gov.au)
- Catalogue and Charges for Registered User Services http://reg.bom.gov.au/other/charges.shtml
- Gridded estimates of historical evapotranspiration, contact awrams@bom.gov.au



Modelled potential evapotranspiration for Murrary Riverina October 2022
www.awo.bom.gov.au

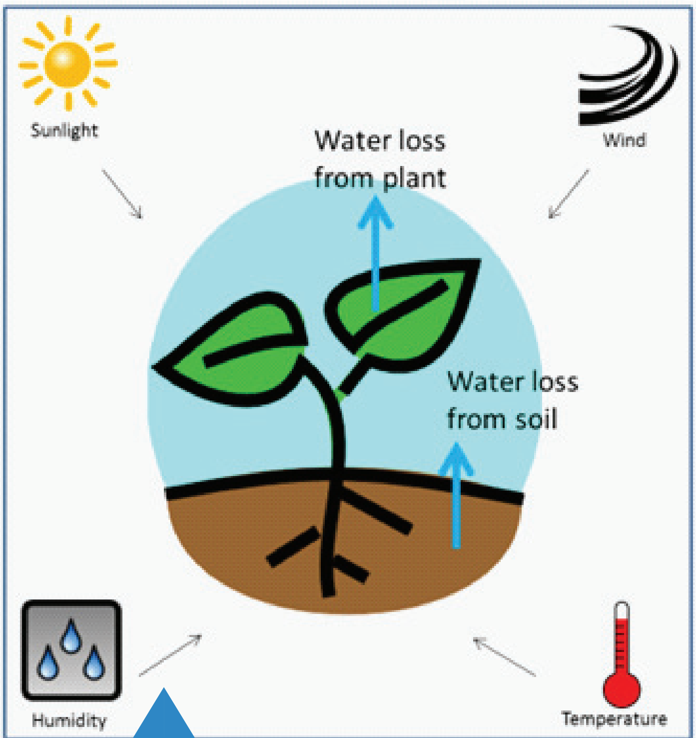
Victoria: Weekly Irrigation Requirement Summary

Agriculture Victoria's Weekly Irrigation Requirement Summary is a web update that is also emailed 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 and rainfall for the previous week and next week.

Irrigators can use either the "Required Surface Irrigation Interval (days)" value or the "Spray irrigators needed to apply (mm)" for their location as a guide for the timing or volume of irrigations.

To optimise water productivity, the frequency of irrigation needs to be based on the water holding capacity of the soil.



Evapotranspiration concept: the process of evapotranspiration and main drivers of evapotranspiration (Agriculture Victoria)

A well located weather station, protected from livestock.

The daily ETo data can be used to fine-tune irrigation scheduling. ETo provides a relatively objective estimate of plant water requirements. By regularly monitoring ETo data, irrigators will be better informed about current irrigation requirements and will be able to improve scheduling skills.

Information in the email is a guide and can be effectively used in conjunction with other methods of working out when to irrigate along with updated weather information.

Accessibility

Many other regions and industries offer similar services. Often available through an app or social media.

References

- A detailed version of this Information Sheet can be obtained from the Agriculture Victorian web site https://agriculture.vic.gov.au/farm-management/water/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

WaterSched Professional

Developed by the Queensland Department of Agriculture and Fisheries, WaterSched Pro provides Irrigation Management tools (Apps) for Irrigation Scheduling and Crop Water Use Estimation.

WaterSched is a real-time irrigation decision tool requiring minimal user input. It has been developed for irrigators and consultants to assist in making good irrigation decisions. Crop WaterSched is designed to manage irrigation scheduling decisions in individual fields, and Crop WaterUse assesses total water demand of an irrigated crop.

Crop WaterSched

The FAO56 dual-crop coefficient methodology is used to model root zone water depletion based on real time Australian SILO weather station network. data. SILO Reference evapotranspiration data is combined with on-farm rainfall records, crop information and soil moisture to calculate daily soil water deficits. Users can manage multiple fields with differing soils and multiple crops with different planting dates in any one season.

It incorporates economic analysis that generates gross margins for individual fields. Where irrigation water is limited, users can use WaterSched to make the most profitable decision on water allocation.

WaterSched produces both field and farm summary reports with information for:

- benchmarking
- irrigation event forecasting
- yield projections
- gross margin irrigation benefit

References

- Crop WaterSched and Crop WaterUse are available at https://waterschedpro.net.au/
- Food and Agriculture Organisation (FAO) Irrigation and Drainage Paper 56 Crop evapotranspiration - https://www.fao.org/3/X0490E/X0490E00.htm
- SILO | LongPaddock | Queensland Government

Crop WaterUse App

The Crop WaterUse App developed through the Queensland Department of Agriculture and Fisheries can assess the total water demand of an irrigated crop anywhere in Australia. Users can modify inputs that affect the total water demand of irrigated crops. These include:

- location
- crop choice
- planting and maturity date
- crop coefficient
- irrigation system efficiency
- irrigation deficit trigger
- the time period for analysis.

The Crop WaterUse App then compares different crops and planting dates across different locations within Australia. Reports and graphs available are:

- crop life-cycle daily water use,
- total cumulative crop water use,
- total cumulative rainfall,
- irrigation frequency.

The estimates of crop water requirements are based on the crop coefficients defined by Food and Agriculture Organisation (FAO) Irrigation and Drainage Paper 56 Crop evapotranspiration guidelines for computing crop water requirements, and independent DAF scientific research and validation.

The crop coefficient (kc) is the ratio of crop evapotransipiration (ETc) to a reference crop evapotranspiration (ETo), and dependent on factors such as evaporative demand, crop growth stage, ground cover, water availability, soil type and fertility and other growth parameters.

With these crop coefficients, Crop WaterUse calculates the water use of the specified crop growth patterns using historical ETo SILO data for the location/s specified

SWAN Systems weatherwise forecast

SWAN is an example of a commercial company that uses industry and tailored crop models based on the specific crop, variety, soil type, climate, season, and irrigation system to determine how much water is needed at any given time.

Set up involves site identification (Google Maps or KML file) and linkages to equipment, such as weather stations, flow meters and soil moisture probes. Characteristics specific to each site, including soil, crop, water budgets, irrigation system, and weather data are configured. Data analysis provides information on future irrigation needs to keep predicted soil moisture in defined optimal zones. Upcoming irrigation schedules can be made available to third party irrigation control systems to semi-automate irrigation scheduling.

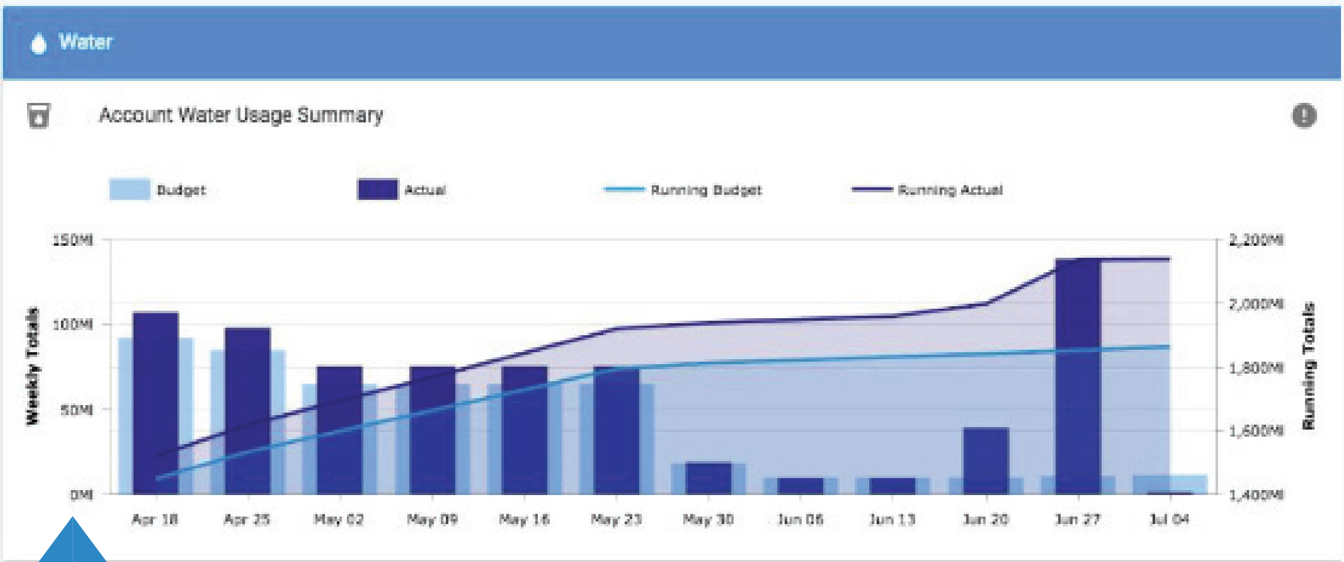
User Interface

SWAN is a web-based software collecting automatically logged data for analysis. The dashboard provides planned irrigations, soil, crop and growth-stage models and predicts future water use requirements and soil moisture status. Reports on soil moisture. budget to actual water usage are available.

Strengths	Weaknesses
• Web based • Hardware independant • Acquires data automatically • Scalable • Customisable • Includes weather data, • Incorporates irrigation and nutrition with NDVI.	• 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/



Example of the Swan Systems dashboard

IrriSAT - Weather based irrigation scheduling

IrriSAT developed by CSIRO in partnership with the CRC for Irrigation Futures, is a weather based irrigation management and benchmarking technology using remote sensing to provide site specific crop water management information across large spatial scales.

The delivery platform provides easy access to the IrriSAT crop water use data, which coupled with weather and crop water use (ETc) forecasts enables irrigators to track their soil moisture deficit and better manage irrigation schedules. Spatial crop water use information determined by IrriSAT is available through the IrriSat app, allowing users to investigate water use difference within and between fields. This information can be used for changing management decisions and investigate the impacts of these decisions.

IrriSAT's web services are used by third-party service providers such as GoannaAg and Murrumbidgee Irrigation.

Installation

There is no in-field equipment, as IrriSAT uses satellite sensors to directly measure crop performance. 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.

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

IrriSAT will provide daily site specific crop water use information down to a 10x10m square within a field. It has good accuracy against lysimeter and field-based probes. 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 uses satellite imagery to estimate site specific crop coefficients (Kc). Kc is calculated using a linear relationship with satellite derived Normalised Difference Vegetation Index (NDVI) across entire fields at a 10x10m resolution. Daily crop water use is determined by multiplying Kc and daily reference evapotranspiration (ETo) observations from a nearby weather station. A seven day forecast of ETo is also produced. It is possible to see both within and between field variability of crop water use.

Strengths	Weaknesses
• 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.	• Relies on having good satellite data to drive crop water use estimations • Cloud cover can prevent access to good quality satellite images • On-line tool

Lifespan

IrriSAT is used historically from the 1999/2000 irrigation season, earlier data is limited by lower resolution and less frequent satellite data. Current satellites from NASA and ESA which sense vegetation parameters have 15–20-year lifespans and will be replaced with newer satellites.

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.

User interface

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

Accessibility

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

References

- https://research.csiro.au/ei/impact-stories/irrisat/
- IrriSAT - Weather based irrigation scheduling (irrisat-cloud.appspot.com)
- IrriSAT app access https://irrisat-cloud.appspot.com/#
- Quick Guide to Using IrriSAT (.pdf) https://irrisat-cloud.appspot.com/ doc/IrriSAT_QuickGuide_20052016. pdf

Example of IrriSAT NDVI image
https://irrisat-cloud.appspot.com/

Infield water monitoring

Water Advance Sensors

Water advance sensors can be used to determine the water advance in the field. Traditional advance sensors are based on a wet/dry sensor enabling them to detect the arrival of water. Typically these sensors use impedance or ultrasound methods.

It is also possible to use pressure transducer advance sensors, which indicate when water reaches the location, record water depth over time and monitor the recession of water leaving the site.

Water advance sensor in-field

Types of sensors

Impedance or AC resistance meters apply an alternating current to two electrodes and the phase shift between current and voltage is detected. Impedance is measured as ohms(Ω).

Ultrasonic level sensors emit high frequency (20 kHz to 200 kHz) acoustic waves that are reflected back to and detected by the emitting transducer. The time between the emission and reception of the acoustic wave is used to calculate a measure of the distance to the liquid surface.

The ultrasonic sensors are low-cost and accurate while their installation and maintenance are easy and cost efficient.

A pressure sensor usually acts as a transducer; it generates a signal as a function of the pressure imposed. For most practical purposes, fluid level is directly proportional to pressure. Pressure is an expression of the force required to stop a fluid from expanding, referred to as of force per unit area.

Pressure sensors can be used to indirectly measure flow, speed and water level. Pressure sensors are often referred to as pressure transducers, pressure transmitters, pressure senders, pressure indicators, and manometers.

Pressure sensors can vary drastically in technology, design, performance, application suitability and cost.

Commercial water advance sensor examples include:

- EnvironNode IoT
- Padman Automation – Sensor PRO, ChatterBOX Pro and TnT Talking Topwer
- Rubicon – SmartFrontTM Sensor
- Taggle
- Unidata

Costs vary from $500 to $1,500

Water Level Sensors

Water level sensors monitor the height of a water surface in a channel. The most common options are ultrasonic and pressure transducer sensors. There are a large number of commercial providers of water level sensors for a broad range of applications including storages, tanks or troughs.

Commercial water level sensor examples include:

- Matbotix
- Rubicon
- Padman
- EnviroNode IoT
- GoannaAg

Cost vary from $100 to $1,500.

Flow meters

Flow meters measure the volume of water that flows through a particular site. They are calibrated in cubic metres (m3) or litres. Most meters record flow rate and total volume.

Types of flow meters

Displacement or Positive Displacement meters are typically oscillating piston meters or rotating disk meters. Both rely on the water to physically displace the moving components in the meter in direct proportion to the amount of water that passes through the meter. The piston or disk moves a magnet that drives the flow register.

A velocity meter measures the velocity of flow through a meter of known internal capacity. The speed of the flow is converted into a volume of flow. Examples include single-jet and multi-jet meters, turbine meters, propeller meters and magnetic meters. Most velocity meters can be calibrated to the accuracy needed.

Magnetic flow meters use electromagnetic properties to determine the water flow velocity. They have no mechanical measuring element, so can measure flow in either direction, and use electronics for measuring the flow.

Ultrasonic water meters use one or more ultrasonic transducers to send ultrasonic sound waves through the fluid to determine the velocity of the water. Water density changes with temperature. Most ultrasonic water meters measure the water temperature as a component of the volume calculation.

There are two primary ultrasonic measurement technologies used in water metering:

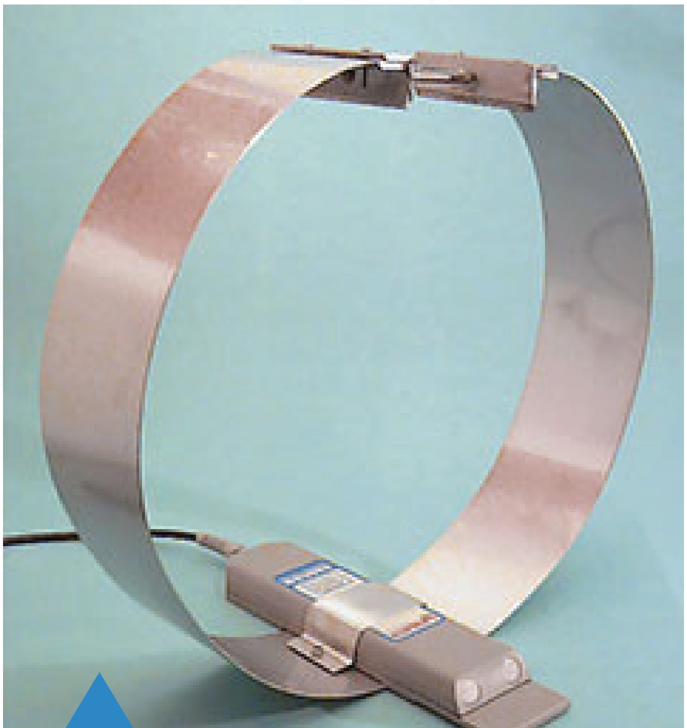
- Doppler effect meters transmit ultrasonic energy into the water. Suspended sediment particles or small gas bubbles in the water reflect some of the transmitted ultrasonic energy back to the ultrasonic receiver that calculates the water velocity.
- Transit Time meters measure the amount of time required for the ultrasonic signal to pass between two or more fixed points inside the meter.

Ultrasonic meters are either “flow-through” or “clamp-on” design. Flow-through designs are those where the water passes directly through the meter. Clamp-on designs are generally used for larger diameters where the sensors are mounted to the exterior of pipes.

Commercial examples include

- MACE - Agricultural | Flowmeters | Flow Metering Technology (macemeters.com)
- Unidata Starflow dopplers - Starflow QSD Ultrasonic Doppler SDI-12/MODBUS Instruments | Unidata
- Panametrics AT600 Ultrasonic Flow Meter
- Orcas portable flow meter

Costs vary greatly depending of the level of accuracy and the size of the site. Installiation will vary depending on the flow meter being used and whether it is in a pipe or an open channel.



Example of a flow meter for installation into a pipe. (https://www.unidata.com.au/)

Integrated irrigation automation

SISCOweb

SISCOweb (Surface Irrigation Simulation, Calibration and Optimisation) is a server based system to optimise furrow irrigation events. (SISCOweb is fully operational, running on commercial servers through the USQ API).

SISCOweb uses advance sensors down the field and channel level sensors in the head ditch. The channel level sensor monitors the water level in the channel which is used to determine the flow rates into the field during irrigation events.

Water advance sensors monitor the rate at which water is progressing down the field, which is used to estimate the soil infiltration characteristics. When infiltration rates change throughout the season, SISCOweb accounts for this, and alters the time-to-cutoff to match the target application depth required.

SISCOweb uses live data from the field and analyses data in real time to provide optimised irrigation management decisions. It can determine how much water was applied, how much infiltrated the soil, where it infiltrated and how much left the field as runoff. It also provides information on deep drainage for each irrigation.


Water advance sensor in-field

This information can tell growers when to shut off an irrigation event to meet specified targets (eg reach the end of the field to a minimum irrigation depth). This information can be sent as an SMS to growers or directly to automation infrastructure to activate an opening or closing of gates. The technology can be applied to manual siphons and automated siphons. SIP2 research has begun the assessment of its application to bankless channel systems such as a tailwater backup system.

Strengths	Weaknesses
• Suitable for manual or automated siphons • Enables irrigation optimisation of each irrigation • It adjusts run times to match the target application depth requirements.	• Requires three sensors down the furrow for best results. • Flow rates need to be monitored using a flowmeter or level sensor.

References:

- SISCOweb: Cruise Control for Surface Irrigation Part 1: Tools and Technologies (smarterirrigation.com.au)
- https://smarterirrigation.com.au/improving-water-productivity-through-automated-bankless-irrigation-systems-in-cotton-weewaa/
- https://smarterirrigation.com.au/siscoweb-cruise-control-for-surface-irrigation-part-2-optimising-the-irrigation-event/
- https://smarterirrigation.com.au/siscoweb-cruise-control-for-surface-irrigation-part-3-practical-applications-and-cost/

Padman Automation Management System

The Padman Automation ManagementSystem (PAMS) includes automated water control infrastructure, in-field water advance and flow monitoring available in permanent or portable options. The portable actuation systems are designed to be easily relocated and can be operated using an on-site time scheduling program or be integrated with soil or water sensors and subsequently operated from mobile devices using the PAMS app.

The Padman Automation Management System is designed to be suitable to fit to existing infrastructure, including bay outlets, open channel stops, or through the bank outlets.

Installation

The sensor monitoring equipment such as the Sensor Pro or ChatterBOX Pro are easily installed in-field and are fully portable between sites around the farm.

The AutoWinch is also portable and can easily be moved around the farm. Both the AutoWinch and the Pipe and Riser Winch can be opperated manually as well as being able to be remotely managed via the PAMS App.

Padman automarion fitted to infield infrastructure

User Interface

The Padman Automation system provides a range of solutions to allow flexibility where connectivity is difficult, including Cat-M1 and LoRaWAN.

Padman Automation can be integrated into existing irrigation systems.

Components

Devices available as part of the Padman automation suite include;

Sensor Pro is a standalone portable variable water height/depth sensor

ChatterBOX Pro is a portable water position sensor that integrates with the Padman Automation Management System (PAMS) web or mobile App.

AutoWinch Pro an actuation system designed to open or close outletrs fitted with a Padman winch. The winch can be fitted to most irrigation infrastructure. The winch is portable and incorporates a battery, electric actuator and communication electronics.

Pipe and Riser Winch which enables riser to be automated can be paired with AutoWinch Pro reducing manual changes.

References

- https://www.padmanautomation.com.au/

IRRISENS

IRRISENS is a Google cloud-based management platform that undertakes data analytics and control of irrigation system hardware. A range of sensors measuring soil, weather and plant performance are used to parameterize irrigation scheduling and irrigation management events. These sensing networks are connected to irrigation control hardware capable of remotely controlling irrigation outlets across irrigation bays.

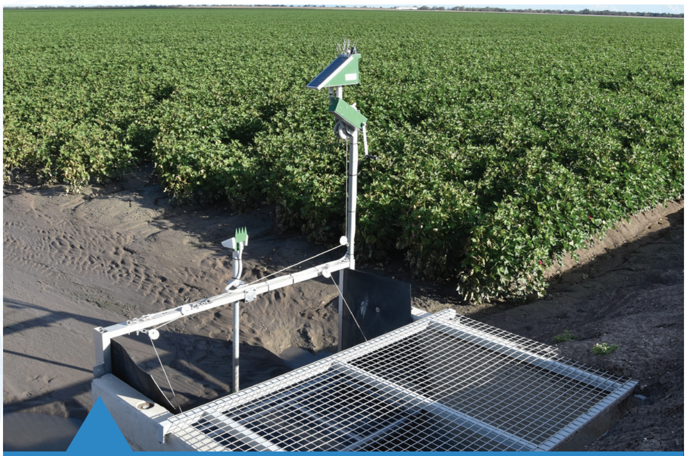
The IRRISENS core module is composed of the "crop digital model" and "crop parameter" microservices.

All the microservices in the platform refer to the "crop digital model" microservice which is based on the evapotranspiration model and is specific for each crop. The "crop digital model" describes the physical crop under monitoring. The model not only provides the parameters to be collected by the sensors, but as it is related to a specific type of crop, it also determines what data means and how to interpret sensor readings thus, giving support to deal with data heterogeneity.

The "crop parameter" microservice is responsible for collecting data from available sources including soil moisture sensors, weather stations and remote sensing services such as IrriSAT, to fulfil the model. It also must deal with data heterogeneity.

IRRISENS has a planning and irrigation control option that enables farmers/agronomists to monitor the soil moisture status or water heights at each bay as well as the status of the irrigation control actuators. This means that the platform has the capability to monitor the percentage that a specific gate is open (0 to 100%) and open or close the gates to start or stop irrigation, depending on the parameters monitored (soil moisture and water height).

The services related directly to agriculture are called Application Specific Services (ASS). which



Automated Gate

receives the irrigation planning information from the user and sends it to the cloud to enable control of the devices.

User Interface

The sensing and hardware use a range of Wi-Fi, LoRA and CatM1 communication protocols established across farms and linked to the IRRISENS Google cloud-based management platform that undertook data analytics and control of irrigation system hardware.

References

- Sensors | Free Full-Text | IRRISENS: An IoT Platform Based on Microservices Applied in Commercial-Scale Crops Working in a Multi-Cloud Environment | HTML (mdpi.com)
- https://smarterirrigation.com.au/smart-automation-in-rice/
- https://smarterirrigation.com.au/smart-irrigation-control-in-rice-growing-systems-economic-case-study/
- (https://www.mdpi.com/1424-8220/20/24/7163)

Rubicon FarmConnect

The FarmConnect Surface Irrigation management solution incorporates flow control and measurement, in-field soil and water sensors connected to solar-powered radio units, automation of infrastructure and irrigation scheduling. The weather station monitors local weather and rainfall. Can determine Reference Evaporation (ETo), and applied irrigation through the AgPod on-farm IoT gateway, FarmConnect can integrate third-party devices and process inputs to inform data-driven decisions.

Installation

The hardware can be installed by the farmer or by an agronomist under a Managed Services Program. An appropriately sized hand auger is required along with the necessary equipment to prepare a slurry (used to eliminate air voids around probe).

User Interface

FarmConnect is web-based so there is no need to download or install software., Irrigations can be managed online with any device that has web access. Data is recorded every 15 minutes, 24 hours a day and incorporates a graphing tool.

FarmConnect enables the monitoring of crops and the management of irrigations with data derived from integrated sensors and automated in-field devices. Farm and irrigation layout is displayed on a Google satellite map to enable navigation to a field device such as a soil moisture sensor or bay gate to check its status or open or close it.

The scheduling software lets users program and save multiple irrigation sequences. Users can choose irrigation sequences to suit the crop, soil conditions and grazing activity at that point in time. Sequences can commence manually or be scheduled in advance to begin automatically.

The software includes alarms to notify users if there are any problems as an irrigation progresses.

Components

FarmConnect can incorporate devices including AgPod™ (on farm IoT gateway) BladeValve™ (for pipe and riser systems) or BayDrive™ bay gate actuators (for open channel systems), weather Stations, FerIT™ nodes, SmartFroint™ sensors or Thurd-party equipment.

Strengths	Weaknesses
• Remote access to real time data • Includes analytical tools • User defined calibration for different soil textures at depths • Monitors water levels, rainfall and flow rates • Software is a fully featured irrigation automation solution for control	• Careful installation to ensure air voids are eliminated • Subject to livestock damage if above ground probes used

Gate actuator Infrastructure in-field

References

- https://farmconnect.com/
- https://rubiconwater.com/au/farmconnect-software/

Integrated sensing

Pasture.io

Pasture.io was designed in Australia to measure pasture growth rates and support irrigation decision making. Pasture.io is a decision support tool which can help match soil moisture (Readily Available Water) to pasture requirements by improved scheduling of irrigation. There are a range of sensors that can be used to measure pasture biomass, but an automated process, such as satellites integrated into the platform enables collection of growth rate data autonomously.

Pasture.io utilises a combination of key parameters; farm records (i.e.stock numbers, grazing activities and irrigation) daily hi-res satellite images and weather readings to determine pasture cover and growth rate. Machine learning integrates the information collected from the input parameters. It is dynamic developing a model for each paddock, which is improved over time. As more data is collated, there is constant calibration and the machine learning process improves the accuracy of information. The farm records are entered by users and constantly updated, The more detail inputted improves outputs and accuracy.

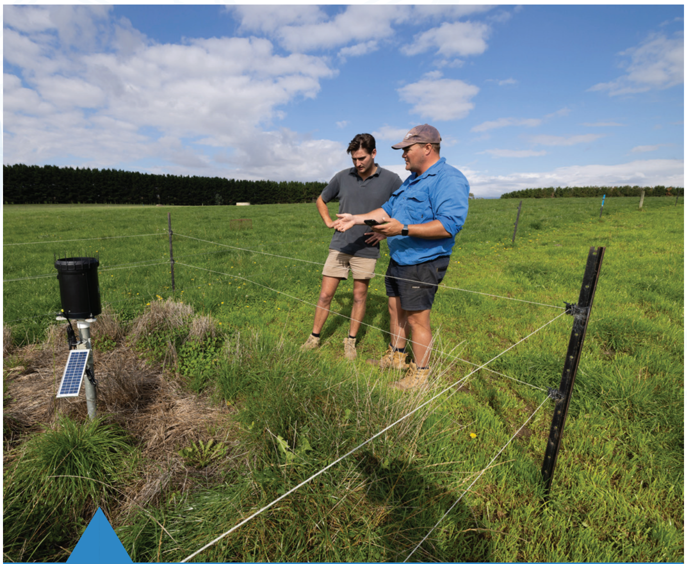
Pasture.io includes a grazing planner to help guide pasture utilisation and optimise stocking rates. This is based on pasture production, nutritional content and growth rates. Available on line or via an App.

Cost

Costs for 200ha range from $309-$722. Customised options are available.

References

- Pasture.io - More Effective Pasture Management for Your Farm
- Using Pasture.io on your farm (smarterirrigation.com.au)



Weather station in irrigated pasture in Tasmania

IrriPasture

IrriPasture is an online, smartphone accessible, water budget and irrigation scheduling tool specially developed for the irrigated dairy systems of Australia. The tool is FREE to access and use.

IrriPasture uses predetermined soil characteristic and pasture/crop data, together with daily weather data from the Bureau of Meteorology (BOM) and appropriate local weather stations (where available) to determine a water balance for your selected irrigated site/s. The graphs and tables of IrriPasture are presented in an easy-to-read dashboard to assist you in your irrigation scheduling decisions. Using IrriPasture in conjunction with soil moisture monitoring and field observations can increase precision application of irrigation at the right time and right rate for optimal pasture and crop growth.

References

- IrriPasture | Australian Dairy Pasture Irrigation Optimisation
- IrriPasture-Fieldday-story.pdf (smarterirrigation.com.au)

PESSL:

Metos is the Australian and New Zealand provider of PESSL Instruments, a commercial example of integrated sensing. The iMetos system is a fully adaptable moisture probe and weather monitoring unit. It can handle more than 400 sensor combinations to collect weather information and soil moisture. Weather stations have dataloggers with two month storage capacity, solar panels, batteries and GPS locators.

There are probe options with adaptable sensors available for soil moisture, temperature and salinity.

The climate options include sensors to measure crop canopy parameters (temperatures and leaf wetness), wind, light, wet and dry bulb temperatures, rainfall and remote crop imagery.

Weather forecasting and disease modelling uses in field data, other local stations and meteorology bureau data to produce forecasts and crop specific alerts.

Accessibility

Scentec Industries in Adelaide produce sensors and majority of hardware for iMetos systems.

Cost of technology

Cost vary depending on the number of different crop types and stations,

Installation

Specific installation equipment can either be purchased or staff will install the system and maintain it for a fee. The installation hardware consists of a soil auger and a place to attach the weather station to.

Accuracy

Accuracy is dependent on installation and maintenance of sensors. Regular inspections are necessary to check for wire damage or crop interferance.

Data Interface and compatibility

The iMetos system is cloud based, accessessable via PC, smartphone or Tablet with apps for IOS or Android systems. Data is updated every 15 minutes to the gateway and stored on the data logger before being sent to the cloud. Data is sent from the gateway at user selected intervals, and can be formatted to specific users requirements. The ability to change parameters on items such a units and timescales provides flexibility in data delivery.

Strengths	Weaknesses
• Adaptable to user requirements • Allows additional development through hardware and software interface • Adaptable for the field • Crop specific disease modeling • Tool to optimise data for crop input and monitoring.	• User interface can be confusing • May not be as robust as some systems • Requires careful installation to avoid damage from machinery or livestock.

iMetos Data Platform

Individual data points can be analysed at specific times or events enabling further investigation or management.

References

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

IrrigWeb

IrrigWeb is an irrigation scheduling software system designed for the Sugar industry. It uses a sugarcane crop model, CANEGRO, to calculate sugarcane crop water use and yield outputs, providing irrigators with current and local advice. The tool combines crop water use estimates with user-defined irrigation system constraints and crop cycle inputs to schedule future irrigation events.

Daily meteorological inputs are sourced from the closest meteorological site, such as Queensland Government's SILO application, or from local Automatic Weather Stations. A suitable soil type is selected from a list of well documented soil profiles found locally in each region. Soil profile inputs define the soil's water holding capacity and concepts such as drainage rates and runoff.

IrrigWeb can be customised to multiple fields to either represent actual blocks on the farm, or generic fields representing a range of cropping cycles throughout the season. Fields are assigned irrigation system rules which define both the system application constraints and a set of scheduling management rules. Irrigation inputs can either be manually captured for a field, or automatically calculated using IrrigWeb's Auto-Irrigate function.

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.

Output is 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.

Cost

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

IrrigWeb uses soil and weather data for sugarcane irrigation scheduling

Accessibility

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

User Inteface

IrrigWeb is cloud based. Regional users or consultants can use IrrigWeb's notification functionality to provide automated SMS and or email advice to multiple end-users.

Wildeye Enterprise

Wildeye is a commercial example of irrigation scheduling technology dashboard. Sensors are available with telemetry in a range of categories to continuously monitor soil moisture, flow rates, storage levels, climate and irrigation. Information is gathered from field sensors and sent to either a mobile phone, tablet or desktop.
New sensors and monitoring equipment can be utilised, but it is also possible to retrofit existing meters from most major manufacturers.

Wildeye® devices run on the global IoT standard of CatM1 (or LTE-M) for maximum coverage and communicate directly with the cloud - there is no need to provide a SIM card. It automatically updates device firmware and controls software upgrades.

Soil moisture sensors are available for a wide variety of crops and soil types, while water level sensors available for a range of water storage scenarios. Weather stations can be selected to provide the data you need: temperature, humidity, wind and sunlight. Weather station features may include:

- Temperature Monitoring with Alert
- Evapotranspiration (ETO)
- Delta-T and Growing Degree Days
- Chill Portions and Chill Hours
- Humidity and Leaf Wetness
- Fire Danger Index

Irrigation Scheduling can include Pump or valve control, line pressure monitoring, remote scheduling and information on water applied vs ET_o.

Installation

The telemetry platform is simple to set up. Sensors need to be connected to the telemetry unit and for it to be activated. 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, offering flexibility in site preparations and/or infrastructure.

Cost of the technology

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

Interface

Strengths	Weaknesses
• Simple to self-install and configure • Free integration with publicly accessible data sources (e.g. BoM weather network) • Battery or Solar options • Rugged and compact.	• Battery life can be reduced by poor mobile phone reception • May require additional aerial for improved reception

Dependent on sensor type. Interfaces supported include:

- SDI12 (used by common capacitance soil moisture probes and weather sensors)
- RS232/RS485 (used by older soil moisture sensor systems and weather sensors)
- 4-20mA and 0-5VDC (used by some soil moisture probes, water level sensors, soil tensiometers)
- Resistance (used by gypsum blocks and granular matrix sensors such as Watermark™)
- Pulse (typically in rain gauges and irrigation water meters)

References

• Farm & Irrigation monitoring. Soil Moisture, Flow, Climate - Wildeye® (mywildeye.com)

Plexus Network

Plexus Field Stations measure attached sensors for soil moisture, flow, water level, pump pressure or rainfall, transmiting data to a central Hub, which uploads all the farm records to the cloud. Farm records are available in real-time through the Green Brain web application that lets users track field data. User-specific alerts can be set up to notify users when something needs attention.

Each Plexus Hub can communicate with up to 60 Plexus Field Stations, enabling crop monitoring across farms on a single network. A mobile signal is required for the Hub, with a private mesh-network over the rest of the property, making it ideal for remote sites where cellular coverage is poor. Crop-specific mounting options ensure the hardware is unobtrusive, robust and optimised for agricultural conditions. There are a wide-array of sensors available, to monitor soil moisture, in-canopy climate conditions, local weather conditions, irrigation or water level.

Basic System components include; Plexus Hub – one per property, Field Station – one per site, Soil moisture probe with multiple depth options, Air temperature and relative humidity sensor, Rain Gauge and Water level.

Field Station – one per site connected to up to four of the following sensors: Gypsum Block (Lite, 5 – 300 kPa), Gypsum Block (Heavy, 50 – 500 kPa), Irrigation Switch (record on/off status), Air or Soil Temperature Sensor.

Cost of the technology

The Green Brain access fee is charged per Hub, not per site, additional sites don't add to costs. Estimated capital for 5 monitoring sites $6,700 plus sensors. Ongoing software: $350 per year.

Installation

Plexus and soil moisture probes are installed based on site conditions, irrigation type, and farming practices. When purchased from MEA's network of agronomists and agents, they provide professional installantion and ongoing support. Each site takes between 15–60 minutes to install depending on the sensors used.

Scale

Field Stations can communicate over one kilometre line of sight and can re-route a signal from other Field Stations. A Plexus network can be deployed over areas up to 7800 hectares using a single Hub. Up to 60 sites can be linked into each Plexus Hub.

Strengths	Weaknesses
• Flexible hardware (design system to meet requirements) • Full on-farm network • Site additions without increasing annual costs. • Waterproof Solar powered. • Annual subscription fee per Hub not per monitoring site.	• For 1–2 site systems, an on-farm network may not be the best solution

Accuracy

Accuracy depends on sensors. Plexus is compatible with SDI-12 soil sensors and gypsum blocks giving flexibility for budget and accuracy requirements.

Measurement Volume

Point source sensor installation, or single site weather station.

Lifespan

8–10 years

References

- plexus-network-brochure.pdf (greenbrain.ag)
- Welcome to Green Brain
- www.greenbrain.net.au
- www.mea.com.au/soil-plants- climate/soil-moisture-monitoring/ plexus

Satellites

Satellite (Low Earth Orbit Satellites)

A low earth orbit (LEO) satellites circle around the earth at lower altitudes than other satellites. They orbit between 200 and 2,000 kilometers.,so rotate around the earler faster than satelites further away. Being closer to the earth enables smaller subjects to be seen with greater detail, but they have a much smaller field of communication. To enhance coverage a constellation or group of LEO satellites working in concert will be necessary.

Examples include

- Starlink Hubs: As of July 2022, Starlink consists of over 2,700 mass-produced small satellites in low earth orbit which communicate with designated ground transceivers.
- Myriota: Modules transfer data to the cloud via a constellation of nanosatellites at an altitude of 600 kilometers.

  Messages are received by a network of satellite ground stations and processed in the cloud. Data is available via the cloud with any internet connection.

NBN Satellite access network

The business nbn™ Satellite Service leverages nbn's, high-throughput satellites and ground infrastructure to provide wholesale broadband capacity to users using the existing network architecture.

The high frequency Ka-band service can provide higher wholesale bandwidth compared with lower frequency C-band and Ku-band satellite services. Spot beam architecture means high capacity and extensive coverage.

The business nbn™ Satellite Service uses the nbn™ Sky Muster™ Satellites which are two Ka-band satellites, first launched in 2015 - currently in geostationary orbit 36,000km above the earth.

Installation

NBN offers different Network Termination Devices (NTD) to suit each product category. Each NTD includes an outdoor unit (transceiver and antenna) and an indoor unit (modem).

NBN Sky Muster

- Two geostationary (GEO) communications satellites operated by NBN Co Limited and built by SSL provide fast broadband, with download speeds of up to 25 Mbit/s, and upload speeds of 5 Mbit/s in a best-case scenario. Each satellite offers 80 gigabits per second bandwidth. and were designed to provide service for 15 years.

NBN Satellite service providers include;

- Activ8me NBN, ANT communications, Aurora, Bordernet, CDM, Clear Broadband, Field Solutions Group, Harbour ISP, iiNet NBN, IPStar, Pivotel, Sky Mesh, Southern Phone, Speedcast, Telstra, TPG Telecom, Vocus and Westnet.

References

- https://www.starlink.com/
- https://myriota.com/https://www.nbnco.com.au/business/product-and-technical-information/business-satellite-service/nbn-satellite-access-network
- https://www.nbnco.com.au/business/product-and-technical-information/business-satellite-service/business-satellite-provider-list

Telemetry

Wireless Networks

WLANs based on the IEEE 802.11 standards are the most widely used computer networks in the world, commonly called Wi-Fi, a trademark belonging to the Wi-Fi Alliance.

A wireless network is a computer network that uses wireless data connections between network nodes. Examples of wireless networks include mobile phone networks, wireless local area networks (WLANs), wireless sensor networks, satellite communication networks, and terrestrial microwave networks.

WLAN is a wireless computer network that links two or more devices using wireless communication to form a local area network (LAN) within a limited area. Through a gateway, a WLAN can also provide a connection to the wider Internet.

References

- https://en.wikipedia.org/wiki/Wireless_network#Wireless_network_elements
- https://en.wikipedia.org/wiki/Wireless_LAN
- https://ubiquitistore.com.au/about-ubiquiti/ https://ui.com/

Communication options in field

Wireless wide area networks

Wireless wide area networks (WAN) are wireless networks which generally cover large areas. The wireless connections between access points are usually point to point microwave links using parabolic dishes on the 2.4 GHz and 5.8 GHz band, rather than omnidirectional antennas used with smaller networks. A typical system contains base station gateways, access points and wireless bridging relays. Other configurations are mesh systems where each access point acts as a relay as well. When combined with renewable energy systems such as solar panels they can be stand alone systems.

Low Power Wide Area Network

Low-power wide-area networks (LPWAN) were designed to connect devices which require wide-ranging transmission and a long battery life, with minimal power consumption.

LPWANs operate at a lower cost than traditional mobile networks. License-free or licensed bands reduce network costs. LPWAN transceivers are designed to minimise power consumption, so can run on batteries for up to 20 years. The range can be upto 10 kilometers with data rate ranges from 0.3 kbit/s to 50 kbit/s per channel.

LPWAN can support a large number of devices over a large area, making them a great network choice for IoT and Machine Learning applications that utilise a lot of connected devices and sensors.

A LPWAN is oftern used as a private wireless sensor network, but may also be a service or infrastructure offered by a third party, allowing sensor deployment without the need for gateway technology.

There are three main networks; SIGFOX, LoRaWAN, and Cellular Long-Term Evolution (LTE) Cat M1/ NB-IoT:

1. The SIGFOX network in Australia and NZ is managed by Thinxtra. It's affordable, power-efficient, and the most mature of all LPWAN technologies on the market.
2. LoRaWan enables secure, bi-directional communication between wireless devices. The network can be public (e.g. Spark's NZ IoT Network) or owned by the customer (private LoRaWAN).
3. Cellular LTE Cat M1/NB-IoT network is bi-directional, power-efficient & provides extended coverage via existing cellular networks. It's managed by major telecommunications carriers such as Telstra, Spark, Optus & Vodafone. Long-Term Evolution (LTE) is a standard for wireless broadband communication for mobile devices and data terminals,

Examples Include

- Taggle: Taggle is the developer of the Australian based and owned Taggle Byron Low Power Wide Area (LPWA) radio technology, offering low-cost, low-power, long range communications for many types of sensors and devices. Data can be collected from sources including level sensors, pressure sensors, weather and rain, air and water quality and humidity sensors.
- NNN Co LoRaWAN (National Narrowband Network) NNNCo is an Australian LoRaWAN network operator with a carrier licence, providing a scalable IoT network service and platform. The Enterprise Internet of Things (IoT) service is deployed using LoRaWAN™ technology,
- CAT-M1 Long Term Evolution Machine Type Communication (LTE-M) is a cellular technology specifically designed for applications targeting the Internet of Things (IoT) or machine-to-machine (M2M) communications. The capabilities of each device that connects to an LTE network is differentiated using "categories" in LTE radio technology. Cat 1 devices offer download speeds of up to 10 Mbps, Cat M1 refers to a group of devices that operate on a narrow 1.4 MHz channel, with download rates of 589 Kbps and uplink speeds of 1.1 Mbps (3GPP release 14).
- LTE Cat-M2 is the second category of Long Term Evolution Machine Type Communication (LTE-M) standards specially adapted for the Internet of Things (IoT). Defined in 3GPP Release 14, Cat-M2 offers more than three times the bandwidth and several times the download and upload speed of Cat-M1.

Wireless gate automation infrastructure in field

References

- https://www.koombea.com/blog/what-is-lpwan/
- https://www.m2mconnectivity.com.au/technologies/lpwan/
- https://taggle.com/
- https://www.nnnco.com.au/
- https://etmpacific.com.au/iot-technologies/lte-cat-m1/
- https://www.emnify.com/iot-glossary/lte-cat-m2
- https://www.telstra.com.au/business-enterprise/about-enterprise/our-network/iot-coverage-map

Australian Government
Department of Agriculture, Fisheries and Forestry