CottonInfo Information *when you need it*

2015 cotton irrigation technology tour

2015 cotton **irrigation technology tour**

PREAMBLE:

Enabling growers to optimise the inputs for cotton production, break new ground in cotton yields and increase their productivity is a key goal for the Cotton Research and Development Corporation (CRDC). Over $1.5 million is invested annually by CRDC in irrigation research and development (R&D), specifically aiming to increase the productivity of cotton farms per megalitre of water.

Today, a deficit approach to scheduling is a commonly used technique on irrigated cotton farms. 70 percent of cotton growers use soil moisture probes (the highest of all agricultural industries in Australia) to understand how much water their soil holds and how much is available for crops.

More recently, R&D has led to advances in sensing and satellite imagery to assess crop stress and spatial variability, as well as the optimisation and automation of irrigation applications. From sensing to automation, all the components are there for a smart irrigation system to help growers make more precise irrigation decisions.

The aim of the **2015 cotton irrigation technology tour** is to bring irrigation researchers onto cotton farms across three cotton growing valleys to demonstrate new and emerging scheduling and irrigation management technologies. The tour also aims to highlight the advantages and practical benefits of each technology for optimising yield and water use efficiency in each environment.

TOUR DATES:

CENTRAL QLD (EMERALD) - TUES 10 FEB
Wills Rd, Emerald
8:30am–1:30pm

GWYDIR (MOREE) - WED 11 FEB
Joint field day with CottonInfo & Gwydir Valley Irrigators Association
'Auscott' & 'Red Mill', Moree
7:45am–2:30pm

MACQUARIE (NEVERTIRE) - THURS 12 FEB
'The Wilgas', Nevertire
8:30am–1:30pm

The 2015 Cotton Irrigation Technology Tour is delivered by the industry's joint extension program, CottonInfo, with funding from CottonInfo partner CRDC, researchers and research organisations.

All of the research presented on the tour has been funded by CRDC in partnership with NSW DPI, QDAFF, QDNRM, CSIRO and NCEA.

Australian Government
Cotton Research and Development Corporation

FOR MORE INFORMATION:

CRDC R&D Manager Jane Trindall manages CRDC's irrigation R&D portfolio to achieve the cotton industry's strategic goals. For further information, please contact Jane: 02 6792 4088, 0447 261 014, jane.trindall@crdc.com.au.

The cotton industry has many resources to assist with irrigation on-farm, including the WATERpak irrigation management guide. To access this and other resources, please visit **www.cottoninfo.net.au** or **www.mybmp.com.au**.

Best Practice

IrriSAT: Weather-based irrigation scheduling

What is the research/technology?
IrriSAT is a weather based irrigation scheduling tool that uses remote sensing to provide site specific crop management information across large scales at relatively low cost.

Why do I want to adopt this technology?
To assist with your irrigation scheduling decisions and to examine variation in crop productivity within a field or across your farm.

How will it benefit me?
IrriSAT is a weather based scheduling technology that can provide daily crop water use and a 7 day crop water use forecast at low cost, but across a large spatial area.

IrriSAT can be used for benchmarking. When seasonal crop water use is combined with yield data it provides a measure of crop productivity (Crop water use index = total production (bales)/ Crop Evapotranspiration (ML)). Variation in crop productivity can be examined within and between fields, farms and regions.

Why is it important?
Irrigators aim to maximise returns per ML. IrriSAT will help irrigators apply the right amount of water at the right time, provide benchmarks and examine performance drivers to enable continuous improvement in crop productivity.

How do I set it up on my farm?
Very easily! Regional IrriSAT weather stations will provide evapotranspiration data. Satellite imagery and accompanying software is freely available to download and apply irriSAT methodology to calculate daily crop water use.

Come along to an IrriSAT Workshop in your region and learn how to apply the IrriSAT technology to obtain daily crop water use and develop crop productivity maps.

Who do I ask for more information?
- Dr Janelle Montgomery, Project Leader NSW DPI, Technical Specialist CottonInfo - 0428 640 990
- Dr John Hornbuckle, Project Leader CSIRO - 02 6960 1583
- Ed Joshua, NSW DPI Macquarie Valley - 0428 285 987
- Rob Hoogers, NSW DPI Southern NSW - 0427 208 613

Canopy temperature sensors: plant based scheduling

What is the research/technology?
Our present research is mainly focused on infrared thermometry i.e canopy temperature sensors, investigating the feasibility of using canopy temperature as a tool for scheduling irrigation in limited water scenarios.

We are also investigating the use of some other plant based scheduling technologies:

- Daily stem shrinkage (Phytech Limited, Israel)
- Canopy conductance (CSIRO Canberra, Australia)
- Infrared thermomgraphy (USDA, Texas, USA)
- Sap flow meters and stem psychrometers (ICT, Armidale, Australia)

Why do I want to adopt this technology?

- For experienced and high yield producing growers: To eliminate guesses and provide confidence when making irrigation decisions during times of unusual weather conditions.
- For inexperienced and low to average yield producing growers: It provides for better water stress management and improved water use efficiency which might potentially improve yield.

How will it benefit me?

- Better and more confident irrigation decision making process
- Improved crop water stress management
- Potential for water saving and its accompanying economic gains

Why is it important?
Plant based scheduling techniques eg canopy temperature sensors, can minimize the agronomic (yield and quality losses) and economic (cost of excess water application, profit margins) risks of irrigation decisions.

Our research tools place Australian cotton growers and the industry at the forefront of worldwide practical on-farm application of canopy temperature in furrow irrigation scheduling.

How do I set it up on my farm?
On farm set up is not yet available but when it is it will require on-farm installation of:

- Canopy temperature sensors and
- Weather station radiation sensor (if not already available)

A youtube video showing the installation process is available here: http://bit.ly/1yKpF1T.

In addition an online web tool for data analysis and decision support will be provided. This would use data provided by the farmers to calculate daily stress time and suggest when next a crop is due for irrigation

Who do I ask for more information?

- Dr Onoriode Coast, CSIRO (ACRI Narrabri) - 0477 386 110, onoriode.coast@csiro.au
- Dr Rose Brodrick, CSIRO (ACRI Narrabri) - 0428 819 163, rose.brodrick@csiro.au

Dynamic deficit scheduling

What is the research/technology?
Investigating the implementation of a flexible or 'dynamic' soil water deficit in furrow irrigation scheduling to more effectively match irrigations with potential crop stress and short-term forecasted climatic conditions.

Currently testing dynamic deficits in different regions in commercial fields in Emerald and Moree and looking in detail at the stress response to refine the implementation of the dynamic deficits approach so that it is integrated into current grower practices for scheduling irrigations.

Why do I want to adopt this technology?
This tool can help all categories of growers:

- For experienced and high yield producing growers: to eliminate guesses and provide confidence when making irrigation decisions during times of unusual weather conditions
- For inexperienced and low to average yield producing growers: Increase the likelihood of capturing rainfall if it occurs when delaying irrigations "safely" when rain is forecast.

How will it benefit me?

- Better and more confident irrigation decision making process
- Improved crop water stress management
- Potential for water saving and its accompanying economic gains

Why is it important?
Current irrigation strategies for furrow-irrigated cotton in Australia use schedules that are aligned to fixed irrigation points (a soil-water deficit) based on measurements or previous experiences for particular fields. In many instances the irrigation point is based on average climatic conditions and soil water status to prevent plant stress and does not take into account the actual or future level of plant stress in response to these variables.

Many growers respond to weather forecasts of high temperatures or chances of rainfall but this relies mostly on experience and intuition.

How do I set it up on my farm?
If successfully tested on farm, the approach is to apply a simple rule that looks at the short-term forecast and if the forecasted evaporative demand is for lower than average conditions this indicates the irrigation can be delayed past the normal irrigation trigger.

Who do I ask for more information?

- Dr Rose Brodrick, CSIRO (ACRI Narrabri) - 0428 819 163, rose.brodrick@csiro.au

EM38: Soil moisture monitoring

What is the research/technology?
EM38's (Geonics Ltd., Ontario, Canada) are electromagnetic induction instruments used by researchers, agronomists and growers to provide rapid and reliable information on soil water within the root zone.

Why do I want to adopt this technology?
They are an efficient way of monitoring crop water use and plant available water (PAW) in the soil profile throughout the growing season so that informed management decisions can be made e.g. the application, timing and conservation of irrigation water and fertiliser.

How will it benefit me?
EM38's can be used to determine how much and how often to irrigate. They can also be used post-irrigation to assess application efficiency and uniformity e.g. total change in water stored in the root zone at various depths, uniformity of wetting across the paddock and potential problem areas due to waterlogging or under watering.

Why is it important?
EM38's are commonly used in precision agriculture to provide rapid and reliable information on soil salinity and soil management zones. Increasingly they are being used in agronomic and environmental applications to measure and monitor soil water within the root zone (e.g. during a growing season).

EM38 datasets are also valuable when testing and validating decision support tools and water balance models, which are used to extrapolate to other seasons, management scenarios and locations.

How do I set it up on my farm?
They are portable hand held instruments, giving instantaneous readings which can be viewed on-screen. They have none of the wiring, electronic logging or access tube requirements of other monitoring technologies. Growers can rapidly gather information on paddock water content and variability for a large number of sites.

EM38's measure the soil's electrical conductivity (EC), which is mainly a function of clay, water and salt content. A simple soil calibration (paddock or whole farm) can be used to convert EM38 readings to mm of water stored at various depths in the soil.

Repeated measures at the same locations within a paddock (with clay and salt remaining constant) allow for any changes in EC to be attributed to changes in soil water content. If an absolute value of PAW (mm) is not required, then a 'qualitative' approach is often sufficient and useful estimates can be made about the PAW and how full the 'bucket' is from experienced observations.

Who do I ask for more information?

- Jenny Foley, QDNRM - 0428 113 502, jenny.foley@dnrm.qld.gov.au

VARIwise: Site-specific surface irrigation and fertigation using adaptive control

What is the research/technology?
Adaptive control strategies have been developed whereby irrigation and liquid fertiliser application are adjusted according to a combination of soil and plant measurements, hydraulic modelling and calibrated crop model outputs. This is packaged in the form of 'VARIwise' software which enables site-specific irrigation and fertiliser requirements to be determined.

Why do I want to adopt this technology?
This control system will automatically determine and deliver irrigation and fertiliser. This precise application of water and fertiliser will increase water and nitrogen use efficiency and reduce labour costs giving significant benefits to a farming business.

How will it benefit me?
Field trials have demonstrated 5-12 percent water savings and 10-11 percent yield improvements using adaptive irrigation control. This also enables some automation of irrigation and fertigation management which could be used either directly to control the application, or presented to the grower to check before controlling the irrigation.

Why is it important?
Automated irrigation and fertiliser application systems can increase water use efficiency and crop productivity by automatically analysing spatial soil and plant measurements to identify site specific water and nutrient requirements, and only applying irrigation and fertiliser when and where they are needed.

There are also a number of environmental benefits associated with site-specific water and nutrient management.

How do I set it up on my farm?
This system would involve the following components:

- Soil sensors and camera-based plant sensors.
- Flow control hardware on irrigation outlets to apply water and/or nutrients where and when they are required.
- Adaptive control algorithms that automatically analyse the sensor data and prescribe irrigation and fertiliser requirements.

Who do I ask for more information?

- Dr Alison McCarthy, NCEA - 0458 845 858 alison.mccarthy@usq.edu.au
- Dr Diogenes Antille, NCEA - 07 4631 2948, dio.antille@usq.edu.au

Smart automation in furrow irrigation

What is the research/technology?
The technology is the hardware and software that together constitute 'smart' automation of furrow irrigation.

It provides:
- precise, automated control of flows throughout the farm from the source (channel or ring tank) to the field,
- sequencing the irrigation of fields and sets according to a pre-programmed schedule,
- precise, automated control of flows into the furrows, and
- real-time selection of time to cut-off for individual furrow sets to maximise application efficiency.

The field sites are demonstrating the real-time control and two alternative in-field hardware configurations, both of which use a Rubicon automated BayDrive attached to a standard box culvert which lowers and raises a rubber flapgate:
- The Moree site supplies the irrigated furrows via 80mm PVC pipes inserted through the bank of the head-ditch and spaced every 2 metres.
- The Emerald site uses a smaller box culvert and BayDrive and delivers the water directly into a 24m wide level rotabuck area.

Why do I want to adopt this technology?
It converts traditional manual furrow irrigation to an efficient modern system.

It preserves the advantages of furrow irrigation that growers are accustomed to but provides labour savings and irrigation performance equivalent to centre pivot and lateral move machines at much lower capital cost and without the energy cost of pressurised systems.

How will it benefit me?
The automation delivers substantial labour savings and labour efficiency, and precise control of flows and water levels throughout the farm.

The in-field real-time optimisation 'smarts' gives:
- water savings and increased water use efficiency through increased application efficiency, and
- reduced pumping costs through reduced recycling volumes.

Why is it important?
It deals with two issues crucial to cotton growers, namely, water scarcity and labour cost and availability. Together the labour savings and improved irrigation management result in improved productivity and profitability.

Smart automation in furrow irrigation (cont)

How do I set it up on my farm?
Furrow automation hardware and software is currently available from a Victorian company Rubicon Water under its FarmConnect system.

The Rubicon system uses a gateway located at a central location on the farm and communicates with each radio node attached to the culvert using ZigBee radio technology. The gateway houses a NextG SIM card to communicate to Rubicon servers and the farmer uses any internet connection to remotely control and monitor the outlets.

It can be installed progressively if required, e.g. by installing the farm channel control and at a later stage the in-field automation or vice-versa. The real-time optimisation involves a software add-on plus some in-field sensing, both of which can be retrofitted to any automation system (or applied to existing manually operated siphon systems).

Who do I ask for more information?
For information on the system performance and the real-time optimisation:

- Dr Jasim Uddin, NCEA - 07 4687 3966, mdjasimu@usq.edu.au
- Dr Malcolm Gillies, NCEA - 07 4631 1715, gilliesm@usq.edu.au

For information on the Rubicon FarmConnect automation system:

- David Robson, System Sales, Rubicon FarmConnect - 0418 740 306, David.Robson@rubiconwater.com

Meet our team

Led by CottonInfo Program Manager Warwick Waters (0437 937 074, warwick.waters@crdc.com.au), the CottonInfo team of Regional Development Officers, Technical Specialists & *my*BMP experts are all here to help!

Regional Development Officers

Regional Development Officers provide cotton research outcomes and information directly to growers, agronomists, consultants and agribusinesses in each region. Contact your local Regional Development Officer for the latest research, trials and events in your area.

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Technical Specialists

Technical specialists are experts in their fields and provide in-depth analysis, information and research to the industry, for the benefit of all growers. Contact the technial specialists to learn more about water use efficiency, nutrition, soil health and much, much more.

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*my*BMP team

The *my*BMP team run the industry's best management practice program, *my*BMP. Contact the *my*BMP team to learn more about - or to participate in - *my*BMP.

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Overview of IrriSAT

Satellite Measurements

Satellite images used to determine plant performance of an irrigators crop

Incorporates management/soil/water/salinity constraints

Determination of a crop coefficient (Kc) from satellite image

Representing Individual Paddocks

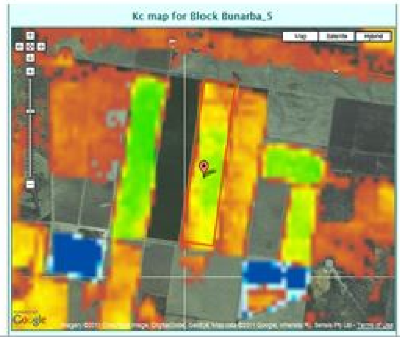
On Ground

ETo from Weather Station and ETo forecast

Potential Evaporation based on Atmospheric Demand

ETc = ETo X Kc

Crop water use determined and irrigation requirement



Crop water use information delivered to irrigators for benchmarking crop productivity and refining irrigation schedules

ETo http://www.irrigateway.net/weatherstations

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Weatherstations

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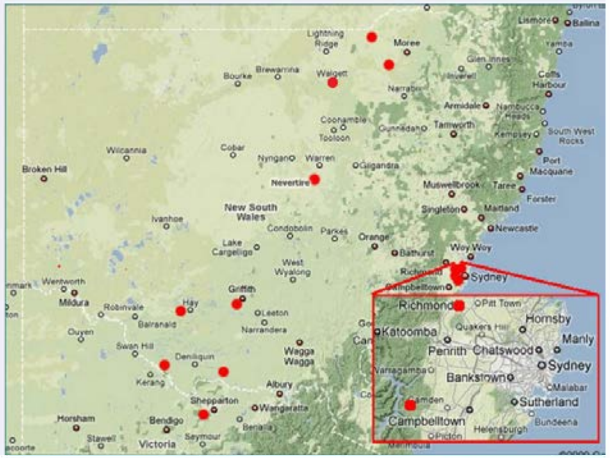
  - Griffith
  - Hay
  - Finley
  - Tullakool
  - Whitton
- Hawkesbury-Nepean
  - Richmond
  - Oakdale
- Gwydir
  - Keytah
  - Weemelah
- Macquarie Valley
  - Nevertire
- Namoi
  - Walgett
- Murray
  - Tatura

Select a weatherstation from the map or menu for detailed information



Lastest Hour's Average readings from all weatherstations

Time format: AEST

Station Name	Latest reading	Air Temp (°C)	Rel. Humidity (%)	Wind Speed (km/hr)	Rain (mm)	Solar Rad (MJ/m²)
Dural	22:00	9.83	92.8	2.05	0	0
Finley	22:00	14.72	58.3	13.51	0	0
Griffith	22:00	14.11	57.28	8.37	0	0
Hay	22:00	16.52	48.16	13.99	0	0
Keytah	22:00	16.03	48.2	8.73	0	0
Leppington	22:00	7.54	92.8	1.78	0	0
Oakdale	22:00	8.56	95.7	1.6	0	0
Richmond	22:00	8.24	95.2	1.6	0	0
Tatura	22:00	15.27	63.21	16.51	0	0
Tullakool	22:00	16.63	51.38	13.79	0	0
Weemalah	22:00	15.93	55.27	7.23	0	0

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irriGATEWAY Weatherstations

Weatherstations

- Riverina
- Hawkesbury-Nepean
- Gwydir
- Murray

Weemalah

Summary | Today | Yesterday | 7 Days | 14 Days | 7 Day forecast | Data Download

7 Day's data for Weemalah

Date	Air T Avg °C	Air T Max °C	Air T Min °C	RH Avg %	RH Max %	RH Min %	Wind Avg km/hr	Wind Max km/hr	Sol Rad MJ/m²	Dew Point °C	Rain mm	$ET_{ref,s}$ mm	$ET_{ref,t}$ mm
21/2	27.2	33.5	23	52.3	85.4	18.6	11.8	26.2	24.11	16.6	0	6.6	8.9
22/2	25.5	34	16.5	45.5	77.7	28.6	8.8	21.1	25.37	12.9	0	6.3	8.3
23/2	23.5	30.3	16.2	48.7	77.7	25.3	7.8	21.7	27.94	12.1	0	6	7.6
24/2	24.3	32.5	16.6	49.7	82.5	21.1	5.7	15.3	25.84	13.1	0	5.4	6.7
25/2	25.3	33.7	18.5	50.2	78.6	21.1	8.5	24.4	23.4	14.2	0	5.8	7.5
26/2	26.6	38	18	47.3	78.2	19	7.4	19.1	22.98	14.5	0	5.8	7.5
27/2	28	37.1	20.2	44.5	67	19.1	10.2	20.8	24.64	14.8	0	6.9	9.3

Download this table as a CSV file: download

Figure 5: Last 7 day's air temperatures for Weemalah (deg C per day)

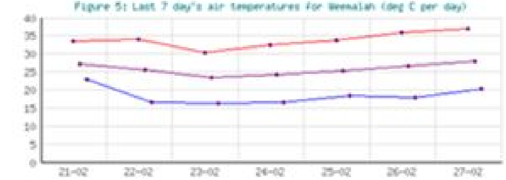

Figure 6: Last 7 day's rain for Weemalah (mm per day)

Figure 7: Last 7 day's ET for Weemalah (mm per day)

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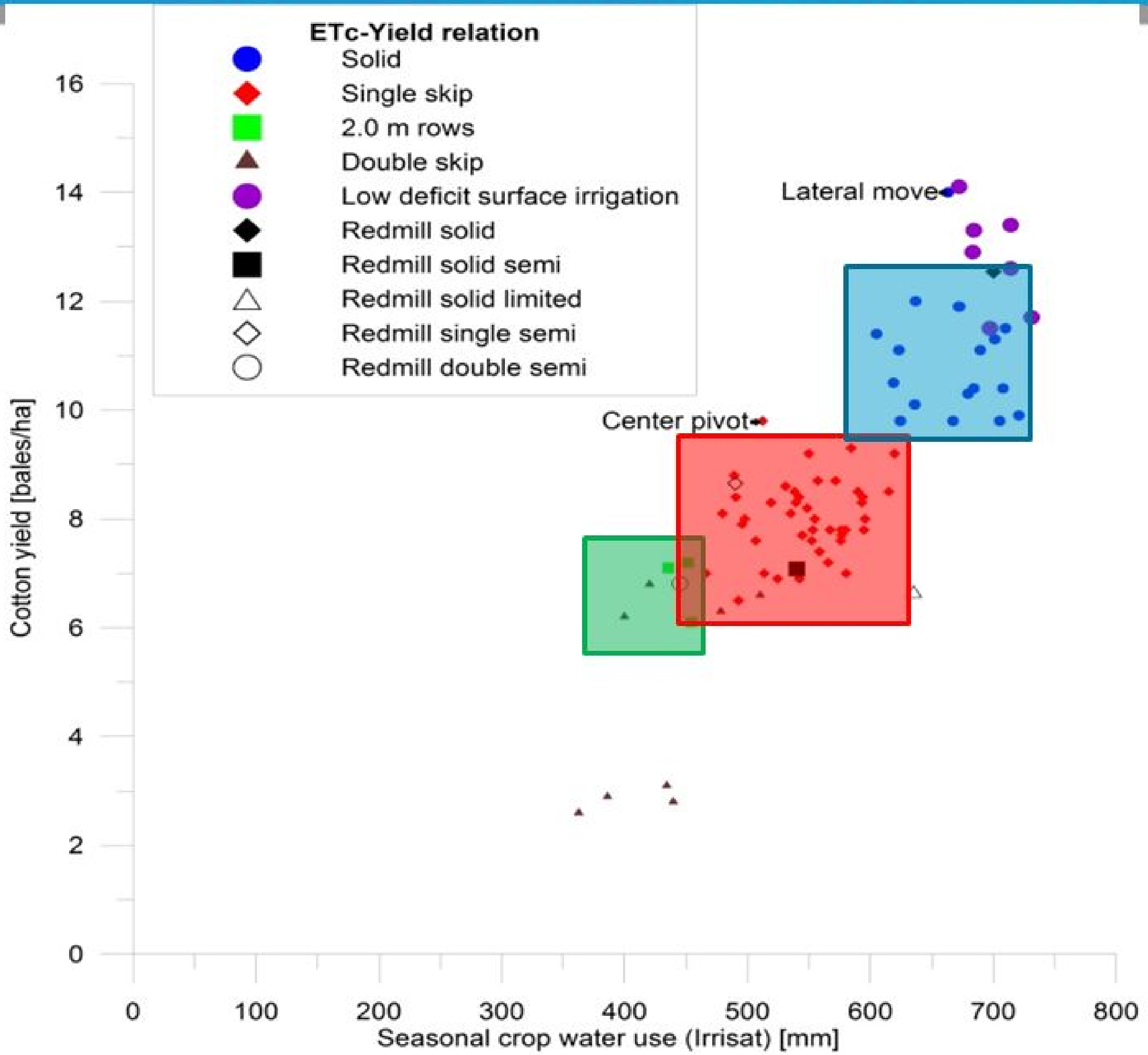
Spatial Irrigation scheduling / water management information

Yield/production/water use relationships



Measuring soil water using an EM38

Jenny Foley, Department of Natural Resources and Mine, Qld.

EM38's are easy to use geophysical surveying instruments that provide a rapid measure of soil electrical conductivity (EC). Soil calibrations or qualitative assessments can be used to convert this to estimates of soil water in the root zone. This valuable information can be used to make farm management decisions that are based on accurate knowledge of soil PAW.

Introduction

Despite an extensive range of monitoring instruments now available to us, measuring paddock soil moisture is still a considerable challenge. Among the suite of instruments currently available, one that stands out and is increasingly being used by researchers and agronomists is the EM38 (Geonics Ltd., Ontario, Canada). This electromagnetic induction instrument is proving to have significant application potential for determining soil properties useful in precision agriculture and environmental monitoring. It is now commonly used to provide rapid and reliable information on properties such as soil salinity and soil management zones, both of which relate well to crop yield. It is also used in a wide number of agronomic and environmental applications to monitor soil water within the root zone. It provides an efficient means to monitor crop water use and plant available water (PAW) in the soil profile throughout the growing season so that informed management decisions can be made e.g. the application, timing and conservation of irrigation water and fertiliser.

EM38's are easy to use, lightweight, and provide rapid, numerous measurements over large areas without the need for ground installations or destructive sampling. New advances in EM38 technology now allow a direct connection to computer based data acquisition systems to record survey and GPS receiver information.

What do they actually measure?

EM38's measure the apparent electrical conductivity (EC_a) in the root zone, i.e. the ability of the soil to conduct a current. The EM38 sends a current into the soil and the 'sensing depth' (the depth range measured) is determined by the machine orientation and coil offsets. This produces a set of EC_a readings that are a weighted average across various depth ranges.

There are two EM38 models available, the newer EM38-MK2 which has two coil sets incorporated into the unit (1 m and 0.5 m spacing), and the EM38 which has a single coil set (I m spacing). The EM38-MK2 takes four readings to various depths in the soil profile using both sets of coils, while the EM38 takes readings to only two depths using the single coil set. When the EM38 is placed upright on the ground surface (vertical dipole position) the top 1.5 m of soil is measured, with readings weighted most strongly towards soil attributes in the 0.3-0.6 m depth. When the device is placed in the horizontal dipole mode (EM38 sideways on ground surface) the top 0.75 m of soil is measured, with readings weighted strongly towards soil attributes in the surface 0-0.3 m. The EM38-MK2 can also measure EC_a to half these depths using the smaller 0.5 m coil set i.e. the current travels only half the distance into the soil.

Targeted readings can be taken for tracking soil water movement and redistribution at depths of most interest to the operator by simple choice of dipole, coil spacing or height above ground.

What affects the measurements?

The strength of the induced current is determined by the EC_a of the soil which is mainly a function of the soil's water, clay and salt content. These soil attributes influence EC_a in a complex and interrelated way. As the percent of clay increases in a soil, the water holding capacity and the ability to hold salts in solution also increases. This is particularly so for the swelling clay Vertosols found extensively in the irrigated cotton growing regions of northern Australia. A site/soil specific calibration may be necessary to differentiate between these variables.

For the purpose of tracking water movement and re-distribution throughout the growing season, repeated measures at the same locations within the paddock (with salt and clay remaining constant) allow for any changes in EC_a to be attributed to changes in soil water content.

How do I get a paddock calibration for estimating soil water?

Calibrations allow us to convert EM38 readings to cumulative mm of soil water in the profile. These calibrations are simple linear regressions (Figure 1) that describe how soil water changes as EM38 readings change. To get a soil/paddock calibration, EM38 readings are taken at the same time soil cores are collected (to measure the volumetric water content). Sampling at a range of wet to dry paddock conditions provides the best calibration e.g. sampling during fallow, after irrigation and after harvest. A single calibration can be used for each paddock or the whole farm if the soil is reasonably uniform. As few as 6 sampling points gathered across a range of soil moistures may be sufficient to develop a calibration that provides a very good estimate of soil water.

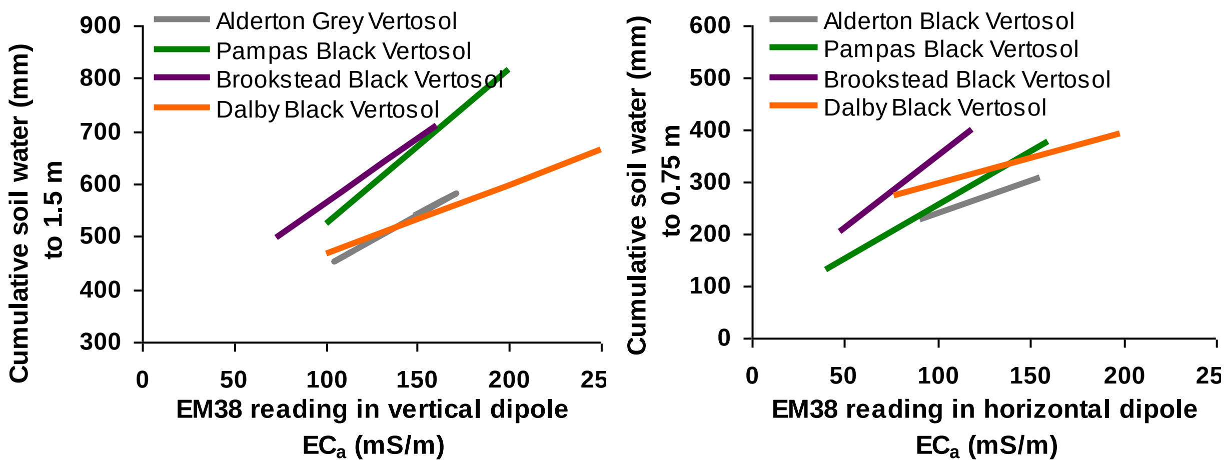


Figure 1. EM38 readings calibrated against soil water for southern QLD Vertosols - showing variation between sites and soil types for both vertical (1.5 m) and horizontal (0.75 m) dipoles

A case study – estimating crop water use throughout an irrigated cotton growing season

In this study we used the EM38 to track soil water under an irrigated cotton crop for part of the growing season. EC_a readings were calibrated against cumulative soil water for a range of wet and dry field conditions (Figure 2a). Soil cores were taken with a soil coring rig to 1.5 m depth and bulk density and gravimetric water content sampled in 0.2 m increments. Several adjacent paddocks were sampled to get a good range of moistures, including post harvest in zero till sorghum (at crop lower limit, CLL); our experimental PAWC plots (at drained upper limit, DUL); bare fallow (filling); the cotton crop after an irrigation (wet to saturated); and native vegetation (very dry).

EM38 readings were taken in rows and furrows at head, mid and tail positions before and after irrigations and throughout the growing season. Sampling was rapid, taking less than 2 hours to take

600 readings. This included loading and unloading the vehicle between sampling positions (head, mid and tail) and temporarily laying a string sampling framework in each position so that repeated measures occurred on the same spot each time. Results in Figure 2b clearly show us the variability in total infiltration after irrigations (head gets more water than mid or tail), the degree of over watering (at head of paddock and this was accompanied by visible plant water logging), and the crop water use over the growing season.

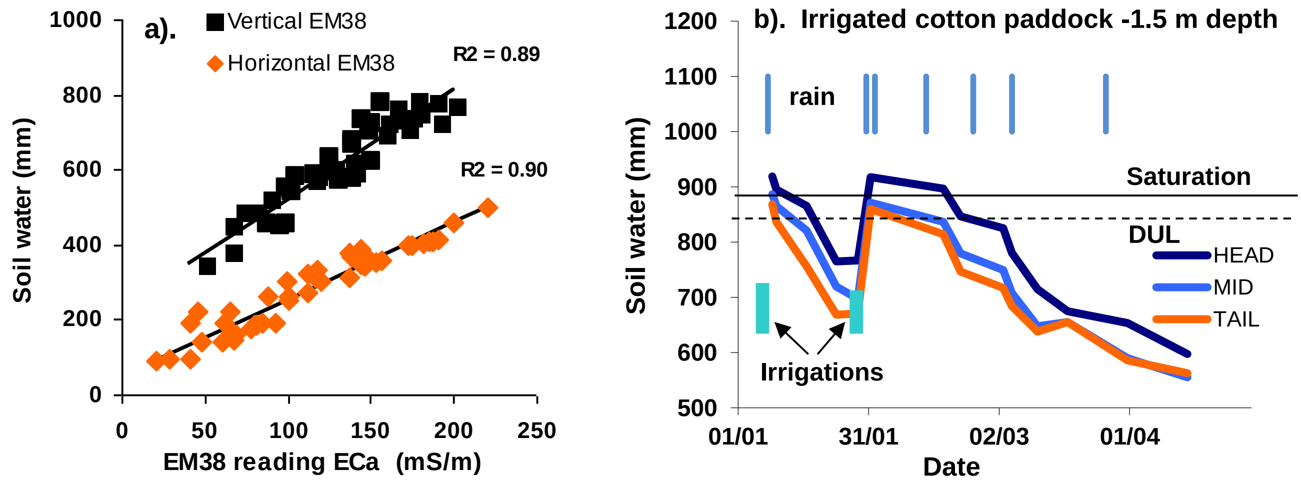


Figure 2. Detailed EM38 measurements of soil water, distribution of irrigation water and changes to the water balance of an irrigated cotton crop, during a summer growing season on a Black Vertosol at Pampas, a) calibration used to estimate soil water, and b) change in soil water to 1.5 m at head, mid and tail positions in the paddock

What about soil texture variability in my paddock?

When we measure EC_a across a paddock with variable soil texture, differentiating soil water content from other attributes becomes increasingly difficult. An increase in EC_a may be due to an increase in water content, or salinity or it may be due to an increase in clay (which is often accompanied by increased water and salt). Some care must be taken when interpreting readings in these conditions. Applying a paddock calibration to derive soil water becomes hazardous unless detailed mapping of soil zones, verified by soil surveying, is undertaken and separate calibrations developed for the different soil zones. This requirement, however, is similar for other methods of soil water measurement.

How does temperature affect the EM38 readings?

Soil temperature is dependent on time of the year, local climate and paddock conditions. Due to the temperature dependency of EC_a, a soil correction factor needs to be used to adjust readings for soil temperature variations. This is only required if measurements occur throughout the year. Tables of representative temperature correction factors have been published for a range of eastern Australian sites by Huth and Poulton (2007, Table 2).

What if I don't have a paddock calibration (qualitative versus quantitative use)

The EM38 can be used to enhance and support our instinct, experience and knowledge. By simply walking in the paddock during fallow and cropped conditions with the EM38, changes in soil water and EC_a can be observed (readings are instantaneous and can be viewed continuously on screen). Over time the operator comes to know both the degree of paddock variability, and the expected EC_a for a range of moisture conditions for a particular paddock or whole farm. This range will encompass typical readings when the soil is drier e.g. harvest and potentially at CLL, and typical readings when the soil is wetter e.g. after irrigation when the soil is around DUL. If an absolute value of PAW (mm) is not required, then this 'qualitative' approach is often sufficient. From this type of application, a very useful qualitative estimate can be made about the PAW and how full the 'bucket' is.

For example, let us use the soil and calibration from Figure 2 (Black Vertosol from Pampas). We already know from our studies the DUL, theoretical CLL (1500 kPa) and corresponding EC_a readings (given in Table 1). However for a qualitative assessment we need only know that the typical range of EC_a values we have observed over a range of soil moisture conditions ranges from ~100-190 mS/m. If we then, for instance, go out into the paddock and find the readings are around ~145 mS/m (half way between the wet and the dry valus), we know the paddock 'bucket' is half full, i.e. at 50% of PAWC. We don't need a calibration, simply a range of EC_a values across wet to dry soil moistures, to then estimate the percent of PAWC available at any time.

Table 1. Soil water estimated from the vertical EM38 calibration on a Black Vertosol at Pampas

Soil moisture	Cumulative mm to 1.5 m	EC_a reading mS/m
DUL	770	188
CLL	525	100
50% PAWC	648	143

References

Huth NI, Poulton PL (2007) An electromagnetic induction method for monitoring variation in soil moisture in agroforestry systems. *Australian Journal of Soil Research* **45**, 63-72.

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Variable-rate irrigation and fertigation

Site-specific application of irrigation and fertiliser can better target inputs which is essential to reduce costs. Precision agriculture technologies have enabled: (i) measurement of high resolution spatial data through GPS and sensing technologies; and (ii) control of water and nitrogen application through variable-rate hardware. Productivity improvements are expected with an automated control system that links these measurements and variable-rate hardware.

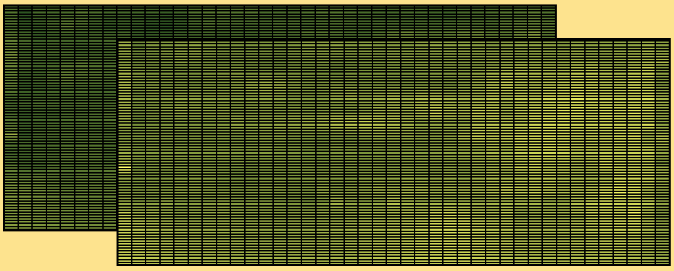
1. Sensors for infield variability sensing

Spatial variability in soil-water estimated using electrical conductivity and infield sensors

On-ground sensing platform estimates spatial variability in flowering and bolls using multi-spectral camera images (red for flowers and near-infrared for bolls)

2. 'VARIwise' control framework

Maps of spatial variability in soil-water and plant fruiting are created using sensed data

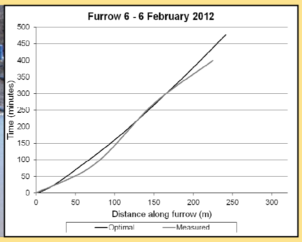


Control strategies are implemented to determine irrigation and fertiliser application and/or timing:
- **Iterative Learning Control** (ILC) that varies the irrigation and fertiliser application based on the error between the measured and desired process output
- **Model Predictive Control** (MPC) that uses a calibrated crop production model to determine the irrigation and fertiliser application that achieves desired crop/soil response

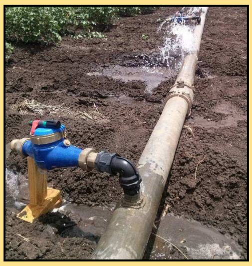
The optimal volumes in each cell and system hydraulics are analysed to determine the hardware adjustment.

3. Real-time irrigation and fertiliser adjustment

The flow rate through each outlet is automatically controlled during the irrigation event to apply the required water at different points along the furrow



Liquid fertiliser application is also controlled with valves on the irrigation outlets. A fertiliser injection unit has been developed for a gated pipe irrigation trial.



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Smart Automation in Furrow Irrigation

The Project

To develop, test and demonstrate a commercial prototype smart automation system for furrow irrigation of cotton.

Background

Automation has been available in pressurised sprinkler and drip systems for some time and provides the ability to irrigate when required and with reduced labour. Recently several commercial providers (e.g. Rubicon) have developed systems for automation of border check (bay) irrigation for pasture in the dairy industry.

However existing automation systems are:

a) Not suited for infrastructure on cotton farms
b) Not smart enough (adaptive) to cope with changing soil/crop/weather

Why Automate:

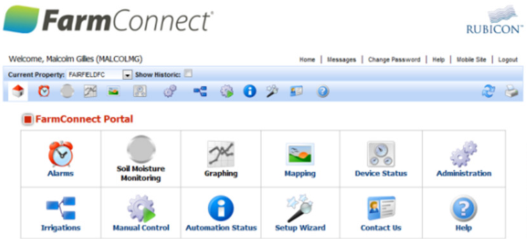
- **Reduced labour** – *there are better things than chasing water all day and night!*
- **Reduced energy costs** – *Only pump what you need to.*
- **Improved productivity** – *reducing stress by irrigating when the crop requires it.*
- **Water use** – *In many cases automation will result in reduced water use & reduced loss of nutrients with drainage water.*
- **Checks & Alarms** – *Grower can be notified immediately via phone if channel level changes unexpectedly or gate fails to open.*
- **Record Keeping** – *maintain records of water applied to aid in future decision making.*

Project Outcomes and Results:

1. New systems for delivering water to furrows have been designed and tested
2. Working automation systems have been successfully installed at several sites
3. All components of the system are functional
4. It has been possible to predict time to shutoff remotely using a single in-field sensor.

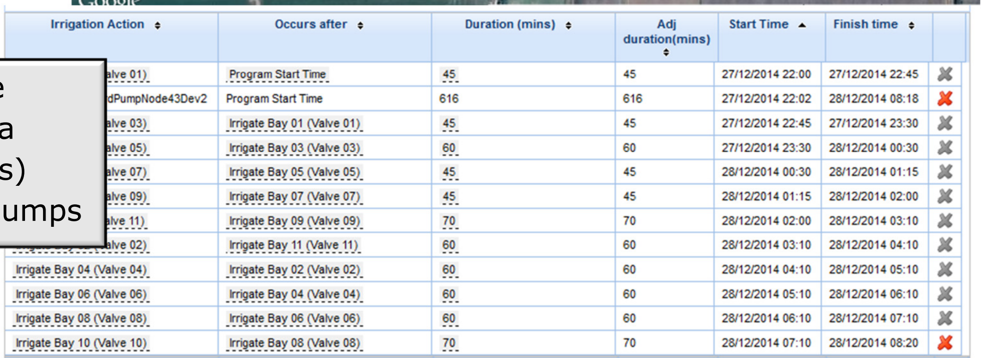
An Example of on-farm automation:

The Rubicon FarmConnect system for border check irrigated pasture



Each rectangle is a separate bay and each triangle is a control structure

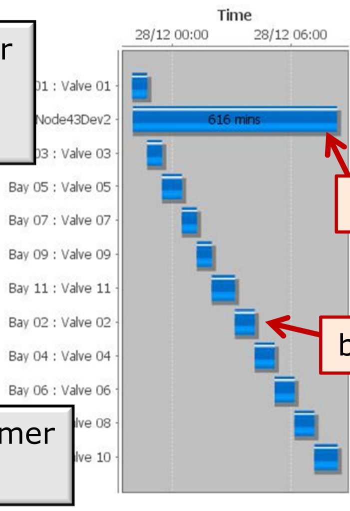
The system can be setup to schedule a series of bays (sets) and the required pumps

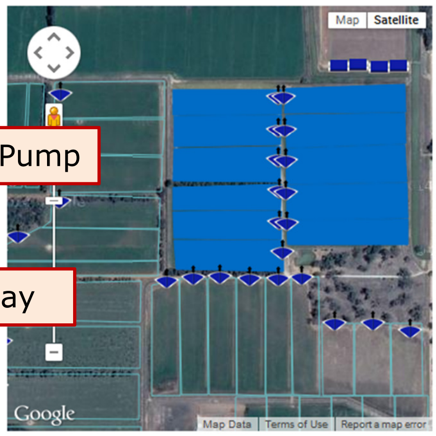


Irrigation Action	Occurs after	Duration (mins)	Adj duration(mins)	Start Time	Finish time
alve 01)	Program Start Time	45	45	27/12/2014 22:00	27/12/2014 22:45
dPumpNode43Dev2	Program Start Time	616	616	27/12/2014 22:02	28/12/2014 08:18
alve 03)	Irrigate Bay 01 (Valve 01)	45	45	27/12/2014 22:45	27/12/2014 23:30
alve 05)	Irrigate Bay 03 (Valve 03)	60	60	27/12/2014 23:30	28/12/2014 00:30
alve 07)	Irrigate Bay 05 (Valve 05)	45	45	28/12/2014 00:30	28/12/2014 01:15
alve 09)	Irrigate Bay 07 (Valve 07)	45	45	28/12/2014 01:15	28/12/2014 02:00
alve 11)	Irrigate Bay 09 (Valve 09)	70	70	28/12/2014 02:00	28/12/2014 03:10
alve 02)	Irrigate Bay 11 (Valve 11)	60	60	28/12/2014 03:10	28/12/2014 04:10
Irrigate Bay 04 (Valve 04)	Irrigate Bay 02 (Valve 02)	60	60	28/12/2014 04:10	28/12/2014 05:10
Irrigate Bay 06 (Valve 06)	Irrigate Bay 04 (Valve 04)	60	60	28/12/2014 05:10	28/12/2014 06:10
Irrigate Bay 08 (Valve 08)	Irrigate Bay 06 (Valve 06)	60	60	28/12/2014 06:10	28/12/2014 07:10
Irrigate Bay 10 (Valve 10)	Irrigate Bay 08 (Valve 08)	70	70	28/12/2014 07:10	28/12/2014 08:20

The farmer can easily alter the schedule if run times need to change.

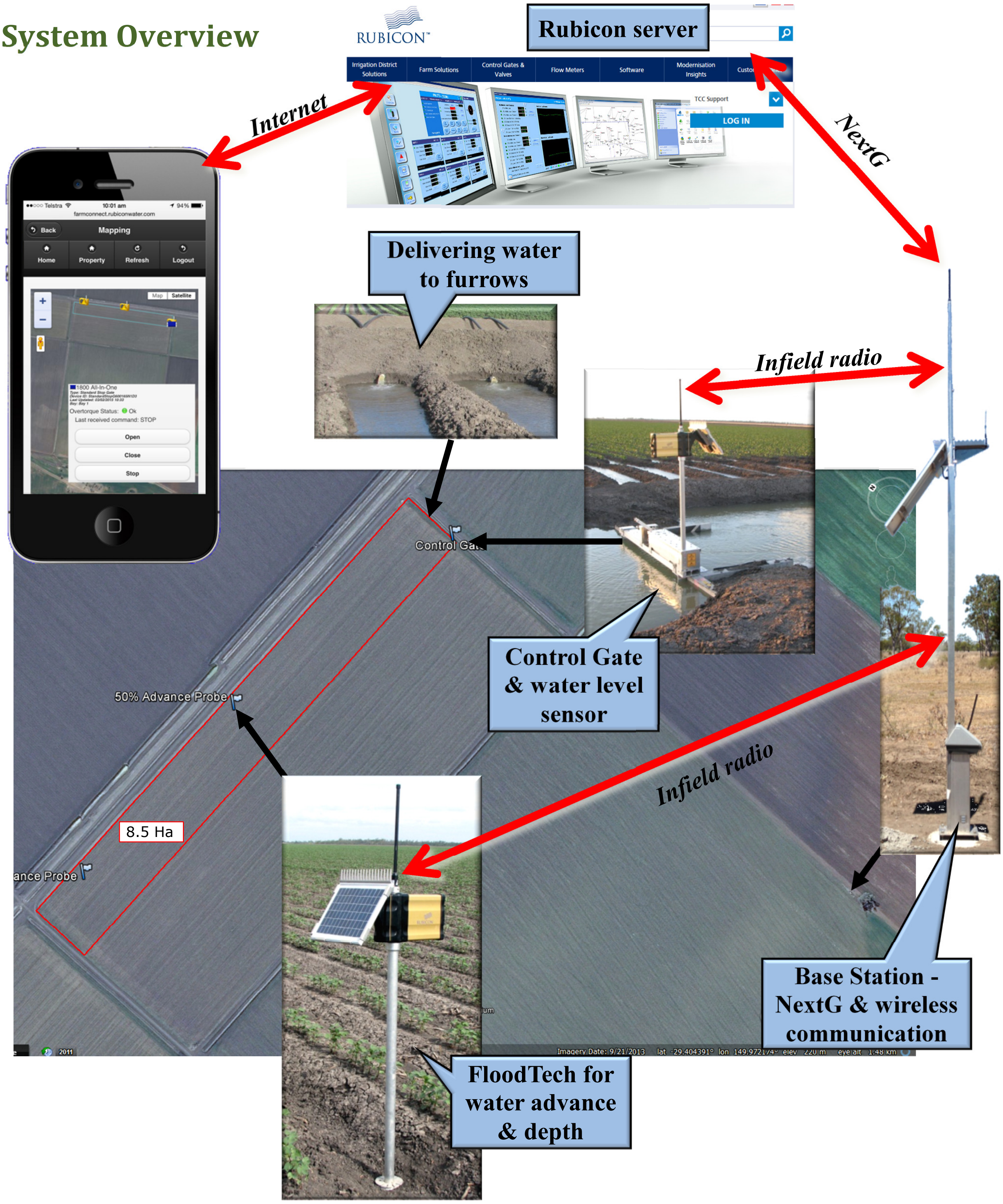
But we need this to be automatic!



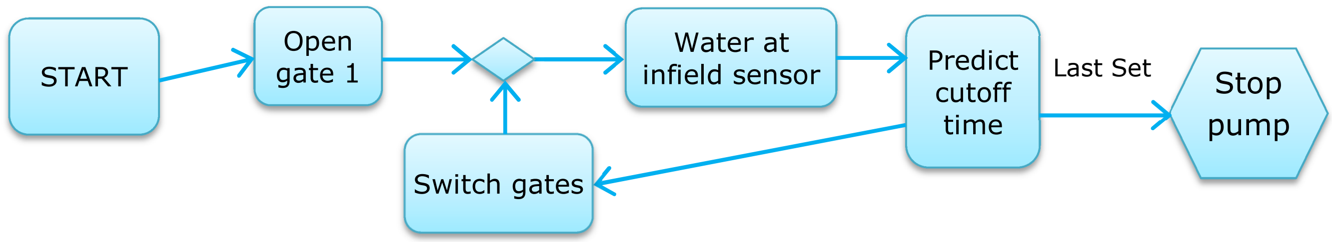


Alarms are sent to the farmer if something goes wrong

System Overview



Process:



Finding a replacement for siphons

Large PTB with T-Valve & fluming  	*Moree and Goondiwindi (2013-2014)* • Distributes water evenly • Pipe may be rolled up if required • Flow is controlled by orifice size • Potential risk of valve or pipe blocking with trash • Requires more head than other options
Drop Gate with T-piece  	*Emerald (2014-2015)* • Higher flows than T-valve • Can be connected to fluming for even flows • Care must be taken to size pipe appropriately if fluming is not used
Drop Gate with small PTB's  	*Moree (2014-2015)* • Uniform water distribution • Large number of furrows for each control point • Size of PTB's governs flow • PTB's must be installed level • Requires either a secondary head ditch OR significant slope in channel

Next Steps?

- Refining the rules to decide when to stop the irrigation set.
- Improving the robustness of the in-field sensor.
- Ensuring the system is commercially viable for grower and supplier.

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